Green Energy Corridors

Detailed Project Report for Establishment of Renewable Energy Management Centres (REMC)

Report on Assessment of existing SCADA/EMS Control Centres, Telecommunication Infrastructure and Conceptual Design of new REMCs

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Executive Summary

India has one of the largest power generation portfolios worldwide. The country has been rapidly adding capacity over last few years, with the total installed capacity growing to over 258.7 GW in January 2015 from 105 GW in 2002. Economic growth and increasing prosperity, coupled with factors like rapid urbanization, rising per capita energy consumption and widening energy access to energy are likely to push energy demand further in the country.

Renewable energy has shown a steady growth during this period. The Ministry of New and Renewable Energy has set a target of capacity addition of 29,800 MW from various renewable energy sources during 12th Plan period. The target comprises of 15,000 MW from wind, 10,000 MW from solar, 2,100 MW from small hydro and 2,700 MW from bio-power.

As of January 2015, India's **renewable power installed portfolio** stands at **31.69 GW** out of the total **258.7 GW** installed capacity in the country. India aims to add **175 GW of renewable power capacity by 2022**, with 100 GW of solar and 60 GW contribution from wind.

Renewable generation from wind and solar has increased substantially during the past few years and forms a significant proportion of the total Renewable generation portfolio in the Indian grid. This is concentrated in a few states, to the extent that it cannot be called marginal generation and serious thought needs to be given to manage the uncertainty and balance variability of such generation. In a few states, on some days, generation from such sources becomes nearly 50% of the total energy generated. The ambitious target of more than doubling generation from wind and solar implies that this form of generation will form more than 30% of total generation capacity.

Therefore, it is imperative to work out a way forward for facilitating large scale integration of such variable Renewable Energy Sources (RES) in the grid, keeping in view the security of the grid[1]. This requires an enabling framework of policies, processes, tools, training and skill building amongst the current grid operators and managers.

Establishment of Dedicated Renewable Energy Management Centres, to facilitate large scale integration of renewables into the grid, is a global best practice. Renewable Energy Management Centre (REMC), equipped with advanced Forecasting Tools, Smart Dispatching solutions&Real Time Monitoring of RE generation, can closely coordinate with the Grid Operations team for safe, secure and optimal operations of the overall grid.

This report summarizes the findings of the assessment performed by the consultant in State Load Dispatch Centre across 6 states namely, Gujarat, Rajasthan, Andhra Pradesh, Himachal Pradesh, Karnataka and Tamil Nadu. Further the assessment also includes Regional Load Despatch Centres of Northern Region (NR), Southern Region (SR) and Western Region (WR) and National Load Despatch Centre (NLDC), in the course of a first mission undertaken from 15th February to 15th March 2015 on the subject of SCADA/EMS Systems, Telemetry Systems and Telecommunication infrastructure installed throughout the Electric Power Grid of India.

The assessment was performed by way of preliminary research followed by structured interviews with key personnel of the relevant entities in India, based on questionnaires.

The assessment has shown that:

- The existing SCADA/EMS systems in the NLDC, RLDC or SLDC are of different ages, providing more or less state of the art SCADA/EMS functionality
- The existing SCADA/EMS systems are from different vendors with different project specific characteristics over and above a common standard set of functionalities.
- Most of the systems follow international standard protocols for inter-control centre integration and for field RTUs.
- Most of the RE developer's pooling stations are currently not monitored in real time. However, most of the interconnecting substations are monitored.

[1]Large Scale Grid Integration of Renewable Energy Sources - Way Forward, Central Electricity Authority, November 2013

- The communication infrastructure for telemetry at the interconnecting stations ranges from OFC to VSAT to PLCC.
- Typically, the real-time refresh rates at control centre levels is of the order of 10-15 seconds, although this was found to be 2-4 seconds in the state of Karnataka (with dedicated VSAT communication infrastructure).
  .

Analysis of the existing systems and processes in place, has led the consultant to make following recommendations regarding REMC:

- Establish REMCs at all levels of Grid Operations i.e. State, Region and National levels with REMC system co-located with companion xLDC.
- Establish REMC desk immediately with staff drawn from existing xLDC at State, Region and National levels.
- Interim REMC desk operations through dedicated operator consoles in the current xLDC systems
- Establish new independent and standardized SCADA Systems for the REMCs, which are specifically designed for their needs. For the necessary exchange of information with the existing SCADA/EMS systems international standard interfaces and communication protocols should be used. This approach enables for competitive tendering of a standardized control system for all REMCs.
- REMC systems at all levels should have standard functionalities realised through modules that can be introduced seamlessly into the system at any time as per need.
- Invest in a good communication infrastructure ideally based on fibre optics with a high transfer capacity to connect all interconnecting and pooling stations to the REMCs via IP-based standard communication protocol IEC 60870-104
- Partner with RE developers to obtain online RE generation data from Pooling Substations.
- Enforce regulation of mandatory RE Developer SCADA interface capability before allowing integration of RE power into the grid.
- Dedicated SCADA and Communications teams required at all XLDCs
- Redefine Roles and responsibilities of stakeholders namely; Power Procurement Committees, Renewable Energy Development Authorities, RE Developers and other new actors at policy and regulatory levels.
- Supervise implementation of all REMC systems through a single nodal agency
- Define a blueprint for Capacity Building in the area of large scale RE integration into the grid.

This report gives details of the methodology adopted for the study, findings of the study, recommended conceptual design and functional specifications of REMCs, implementation strategy, broad cost estimates, and staffing requirements for REMCs.

1. Methodology

The assessment was performed by the Consultant from 15th February to 15th March, 2015 in India. The chosen methodology was as follows:

- Step 1: Preliminary research and interactions with Subject Matter Experts in India and design of structured Interview framework for assessment.
- Step 2: Assessment of existing SCADA/EMS systems and their capabilities in terms of hardware, software and auxiliary facilities by interacting with concerned officials. Field visits to actual sites for 4 states, 2 regions and National Load Despatch Centres.
- Step 3: Assessment of existing Telecommunication infrastructure and their capabilities for data acquisition from the process of the interconnected network and interconnectivity / data communication with other systems throughout the country
- Step 4: Discussions with Experts responsible for setting up, operating and handling the SCADA/EMS System to garner their observations on major shortcomings and their views for necessary improvements

The aforesaid steps were performed by way of structured interviews with key personnel of the relevant entities in India, based on questionnaires, which had been conveyed in advance.

In the course of the interview sessions performed in February –March 2015 in India, site visits of the SCADA System and the related facilities were undertaken for a set of representative locations.

The Consultant would like to express his gratitude and appreciation for the very valuable and close co-operation with all the authorities and personnel that were involved in the data collection, review and discussion of the preliminary findings described in this Assessment Report.

In addition to aforementioned site visits and interviews, telephone interviews with responsible key personnel were performed for some sites, which could not be physically visited. Such telephone interviews were based on a structured questionnaire.

2. ASIS Study Findings

2.1 General Structure of Monitoring and Control Systems

Starting with grid management on regional basis in the sixties where only state grids were interconnected the electrical grid of India was split up into 5 regions (see Figure 1:) namely:

1. Northern,
2. Eastern,
3. Western,
4. North Eastern and
5. Southern region

As indicated in Figure 2, each of the five regions has a Regional Load Dispatch Centre (RLDC), which is the apex body to ensure integrated operation of the power system in the concerned region. The RLDC will be monitored by a national load dispatch centre (NLDC).

The RLDC will monitor grid operations, exercise supervision and control over the inter-state transmission system, and will be responsible for optimum scheduling and dispatch of electricity within the region.

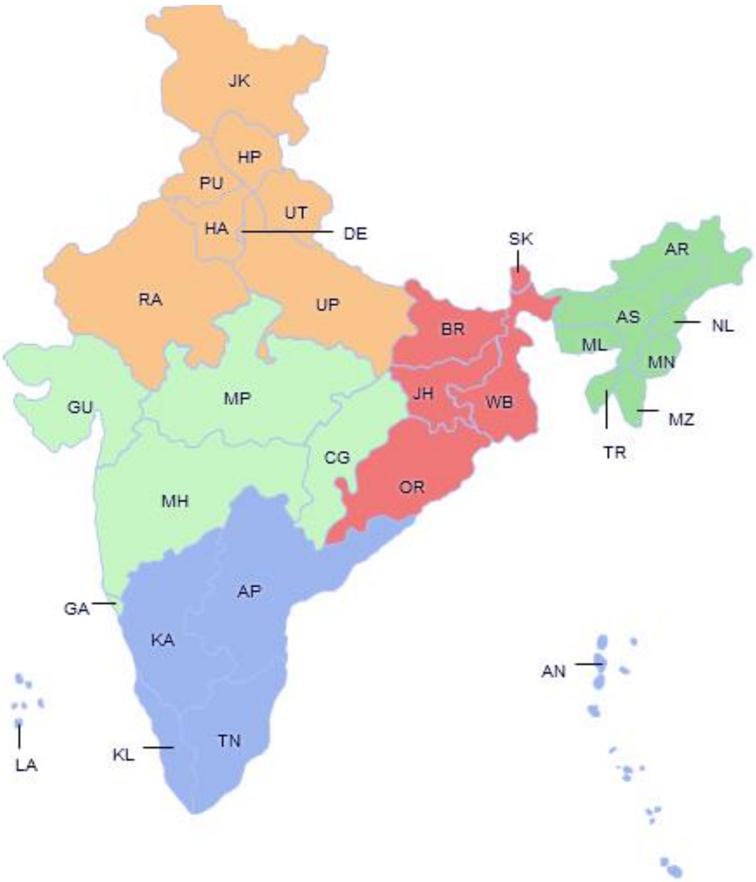


Figure 1: Power Grid Control Regions in India

With start of the 90-ies the regions have been interconnected. Since August 2006, regional grids except the Southern Grid have been integrated and are operating in synchronous mode, i.e. at same frequency. Consequently, the Northern, Eastern, Western and North-Eastern grids have been treated as a single grid named as NEWNE grid. The grid interconnection process has been completed in 2013 with the connection of the southern region in a synchronous mode on the 765 kV level.

Below the 5 RLDC's mentioned above in total 34 State Control Centres are installed. Every state has a State Load Dispatch Centres (SLDCs), which is the apex body to ensure integrated operation of the power system in the state.

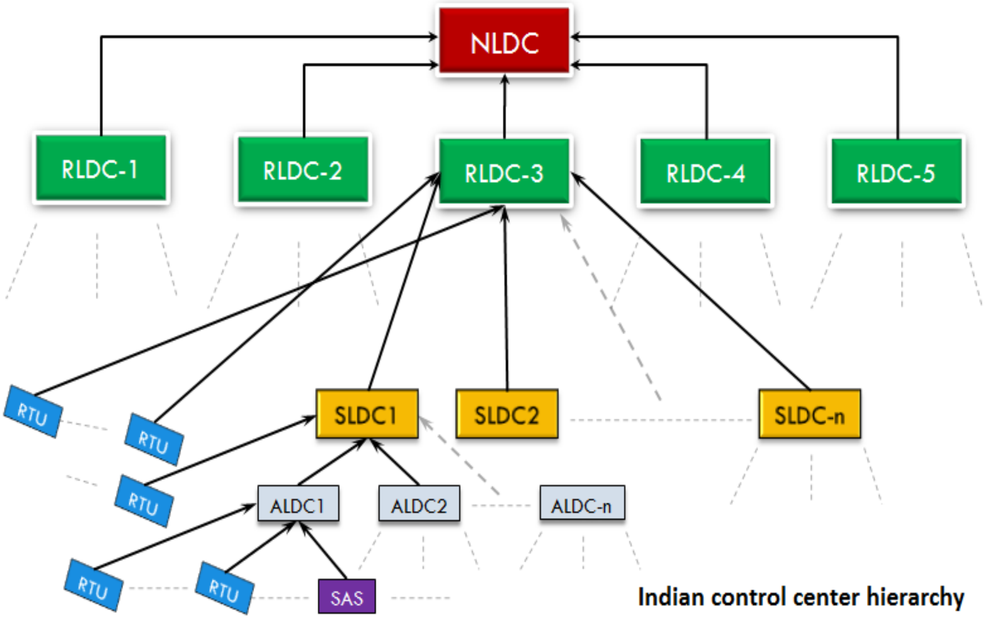


Figure 2: Grid Control Centre Hierarchy in India

The SLDC shall be responsible for optimum scheduling and dispatch, monitor grid operations; keep accounts of the quantity of electricity transmitted through the State grid; exercise supervision and control over the intra-State transmission system; and be responsible for carrying out real time operations for grid control and dispatch of electricity within the State through secure and economic operation of the State grid in accordance with the Grid Standards and the State Grid Code. Below the SLDCs 51 Area Load Dispatch Centres (ALDCs /LDC's) on the district level are located. At the sub level, approximately 1800 remote terminal units (RTU) are connected.

2.2 National Load Dispatch Centre NLDC

NLDC located in Delhi was visited on 24th February 2015.

2.2.1 SCADA/EMS

The current NLDC system was manufactured and commissioned in 2008 by Alstom. It is of brand "e-terra" Version 2.3.Replacement of the current system by a new one is envisaged for year 2019.

The system configuration includes a fully redundant set-up as per standard "e-terra" philosophy including a remote workstation via viewport accommodated at the Ministry of Power. A back-up system catering for disaster recovery has been installed in a remote location.

The Software package comprises a full set of SCADA and EMS network applications including state estimation, contingency analysis and a training simulator system, which was reported to be utilized not very extensively due to constraints in maintenance of training scenarios.

Operation is performed in monitoring direction only, as the duties of NLDC are focused on safeguarding security and do not comprise direct controls of the interconnected Power Grid. The control room accommodates 3 operator desks which are operated on a 24/7 base in 3 shifts. In near future it is envisaged to add a fourth operator desk and to extend the shifts on 4 operators. A video wall of Barco serves as the main visualization device apart from the video screens arranged around the operator desks.

Details on the current size of data model could not be investigated, but it was emphasized that NLDC includes all data provided by the subordinated RLDCs necessary for proper monitoring of the Indian interconnected power grid. CIM capability is not provided with the current system but shall come with the envisaged replacement system.

It was observed that actualization time for measurements is in a range of 15 and more seconds, which is not considered adequate for SCADA/EMS applications on top of national level.

It should be mentioned that NLDC control room includes visualization of Wide Area Monitoring System (WAMS) which is currently in the process of being built up by deployment of Phasor Measurement Units (PMU) throughout the power grid. At present a number of 63 PMU are in operation, it is planned to extend coverage of the WAMS during forthcoming years by deploying a total of 1400 PMU. Assessment of security and stability of the Indian power grid will be increasingly improved by application of this WAMS.
Currently extension program is constraint by lack of suitable high bandwidth communication links to the remote locations where PMUs shall be accommodated, but will be continued as soon as relevant communication links have been provided.
Data acquisition, processing and visualization of WAMS data is performed by a system procured from SEL, Schweitzer Engineering Laboratories, USA. Presentation of WAMS data is done via large screen flat screens arranged in the area of the operator desks.

2.2.2 Telemetry

NLDC SCADAEMS system acquires majority of information from the subordinated RLDCs (and their subordinated SLDCs) via ICCP protocol.
ICCP links are mainly realized applying fibre optic links and leased lines as a back-up media.

There are no Remote Terminal Units (RTUs) connected to NLDC directly. RTUs for interregional links are connected to the respective RLDC from where information flows to the NLDC.

2.3 Regional Load Dispatch Centres RLDCs

In order to get a good insight in the capability of the existing RLDC control systems, the following two RLDCs were visited in the course of the interview session.

- Northern Regional Load Dispatch Centre (NRLDC)
- Southern Regional Load Dispatch Centre (SRLDC)

2.3.1 Northern Regional Load Dispatch Centre NRLDC

NRLDC located at New-Delhi was visited on 17th February 2015.

2.3.1.1 SCADA/EMS

The former SCADA/EMS system was of type “Habitat” originally supplied by Areva/Alstom and had been set into operation around 1992.
It was replaced by a new SCADA/EMS system of type “Spectrum SP7” procured from Siemens and installed by the end of year 2014.
Spectrum SP7 is the actual mainline product of Siemens for SCADA/EMS systems on national TSO level. It is in the market since mid of 2014, therefore brand new and considered a state-of-the-art solution for SCADA/EMS application in a high voltage power grid on national level.

The new System is currently in trial operation while the old Habitat system is operated in a stand-by mode to cater for a fall back in case of malfunction of the new system.

It was reported that there are some open issues with the new system mainly in the area of high level EMS functions and system performance which are in the process of being rectified by Siemens.

The SCADA/EMS system is arranged in a fully redundant hot-stand-by configuration. Servers and other equipment for the vital system functions such as SCADA servers, Front End, Historical Archive, Time & Frequency System are consequently duplicated in order to cater for redundancy, while other equipment such as Operator workstations are in a single set-up only.

Redundant Virtual LAN sections for SCADA have been established which are separated from the Data Acquisition LAN towards/from the outstations. In addition, a redundant LAN for communication towards/from other systems is decoupled from the inner SCADA LAN via Demilitarized Zone (DMZ) to cater for enhanced security against cyber-attacks or intrusion from outside. Redundant Thin Client Servers, carrying a read-only copy of the database, form a dedicated and secure interface to other users off the system.

The arrangement of the computers and peripheral components covers the requirement of a distributed system approach with dedicated application servers allocated to individual functions of a SCADA System, such as Historian, Training System, Back-Up Facilities etc.

Three operator desks are accommodated at the control room consisting of workstations each of them include a set of up to 4 screens. Visualization of the Power System is mainly managed by a video wall accommodated in the background of the Control Room.

The video wall consists of 28 (7 * 4 array) of large projection screen cubes, applying the rear projection principle using Digital Micro Mirror Devices with dual, hot swappable lamps. The Video Wall was manufactured by Barco of Belgium, which is considered a state-of-the-art product for such applications.

NRLDC operation is handled by 3 operators on a 24/7 base, managed in 3 consecutive shifts.

In terms of functionality the new system comprises:

- SCADA
- EMS package for network management such as state estimator, contingency analysis etc.
- Dispatcher Training Simulator (currently for 400kV only)

The system configuration includes a back-up system for disaster recovery following a state-of-the-art multi stage redundancy concept. The back-up system is accommodated at a different geographical location in one of the other Load Dispatch Centres.

It was confirmed by the NRLDC Dy. General Manager Mr. Debasis De that:

- All RLDCs in the Indian Power Grid do have a dedicated back-up system accommodated in a remote location (usually an RLDC of another region) to cater for disaster recovery
- All communication links between RLDCs, NLDC and subordinated SLDCs are realized as redundant links utilizing international standard communication protocol as per IEC60870-6 (ICCP).

The data base currently includes approximately 70 k data objects. Data model was imported via Common Interface Model (CIM V12 according to IEC 61970) from the old system; some problems during conversion were reported by the interviewed key experts.

However, the new system includes CIM capability for data model exchange with other systems supporting CIM standard.

Performance of the current system was reported to be unsatisfactory for the time being due to pending problems in the data model. Refresh rate of measurements is currently in a range of 10 seconds but is expected to improve after rectification of open issues and corresponding tuning measures.

2.3.1.2 Telemetry

Remote Terminal Units (RTUs) are connected to the SCADA/EMS system for data acquisition towards/from related substations.

RTUs are interfaced utilizing international standard telecommunication protocols IEC 60870-5-101 as per majority, some RTUs are connected via IEC 60870-5-104 (IP-protocol). It was reported that no proprietary telecommunication protocols are in use to connect to SCADA equipment at outstations.

Dedicated communication links are utilized for interconnection to RTUs and other Control Centre systems on SLDC level and to NLDC, means communication is de-coupled from public communication links. A SDH network is available for STM-1 (155 Mbit/s), in some parts even STM-16 is available.

There are fibre links available to all 400kV Stations and to all Generating Stations connected to 220kV. No usage of radio links.

2.3.2 Southern Regional Load Dispatch Centre SRLDC

SRLDC located at Bangalore was visited on 18th February 2015.

2.3.2.1 SCADA/EMS

The former SCADA/EMS system was of type “XA21” originally supplied by General Electric GE and had been set into operation in the early years of 2000.

It is currently in the process of being replaced by a new SCADA/EMS system of type “e-terra” procured from Alstom.

“e-terra” is the actual mainline product of Alstom for SCADA/EMS systems on national TSO level. It is in the market since the early years of 2000 and considered a state-of-the-art solution for SCADA/EMS application in a high voltage power grid on national level.

The new system is currently in the commissioning phase which has been ongoing since end of last year.

Operation is currently managed via the old system from an interim operator room which has been temporarily installed to cater for operational environment in the course of the transition phase.

The new e-terra system is currently operated in “listening mode” and receives process data in parallel to the old system.

The new SCADA/EMS system is arranged in a fully redundant hot-stand-by configuration. Servers and other equipment for the vital system functions such as SCADA servers, Front End, Historical Archive, Time & Frequency System are consequently duplicated in order to cater for redundancy, while other equipment such as Operator workstations are in a single set-up only.

Redundant Virtual LAN sections for SCADA have been established which are separated from the Data Acquisition LAN towards/from the outstations. In addition, a redundant LAN for communication towards/from other systems is decoupled from the inner SCADA LAN via Demilitarized Zone (DMZ) to cater for enhanced security against cyber-attacks or intrusion from outside. Redundant Thin Client Servers, carrying a read-only copy of the database, form a dedicated and secure interface to other users off the system.

The arrangement of the computers and peripheral components covers the requirement of a distributed system approach with dedicated application servers allocated to individual functions of a SCADA System, such as Historian, Training System, Back-Up Facilities etc.

Three operator desks are accommodated at the control room consisting of workstations each of them include a set of up to 4 screens.
Visualization of the Power System is mainly managed by a video wall accommodated in the background of the Control Room.

The video wall consists of 26 (5 * 4 array, and extension by 2 x 3 array) of large projection screen cubes, applying the rear projection principle using Digital Micro Mirror Devices with dual, hot swappable lamps. The Video Wall was procured from Delta, a domestic supplier. As commissioning of the Video Wall is still in progress, a final assessment of the device could not finally be performed. However, it was observed that some deficiencies in the alignment of the individual video cubes of the wall have still to be rectified.

SRLDC operation is handled by 3 operators on a 24/7 base, managed in 3 consecutive shifts. There are 4 such teams.

In terms of functionality the new system comprises:

- SCADA
- EMS package for network management such as state estimator, contingency analysis etc.
- Dispatcher Training Simulator

The system configuration includes a back-up system for disaster recovery following a state-of-the-art multi stage redundancy concept. The back-up system is accommodated at the Northern Regional Load Dispatch Centre (NRLDC).

All communication links between RLDCs, NLDC and subordinated SLDCs are realized as redundant links utilizing international standard communication protocol as per IEC60870-6 (ICCP).

The data base currently includes approximately 50 k data objects.
Data model was not imported from the old system as the old system does not support Common Interface Model. As a consequence the data model of the new system was built up from scratch by means of manual data engineering.

However, the new system was reported to include CIM capability for data model exchange with other systems supporting CIM standard.

Performance of the current system was reported to be unsatisfactory for the time being due to pending problems in the data model. Refresh rate of measurements is currently in a range of 10 to 15 seconds but is expected to improve after rectification of open issues and corresponding tuning measures to reach a range of 2 to 4 seconds.

2.3.2.2 Telemetry

A total of approx. 52 Remote Terminal Units (RTU) are connected to the SCADA/EMS system for data acquisition towards/from related substations.

RTUs are interfaced utilizing international standard telecommunication protocols IEC 60870-5-101 as per majority, some RTUs are connected via IEC 60870-5-104 (IP-protocol). It was reported that no proprietary telecommunication protocols are in use to connect to SCADA equipment at outstations.

Mainly fibre optic media and dedicated communication links are utilized for interconnection to RTUs and other Control Centre systems on SLDC level and to NLDC. Some RTU connections are still realized using PLC links, mostly analogue PLC.

In Karnataka VSAT links are in use for the relevant SLDC.
A SDH network is available for STM-1 (155 Mbit/s), in some parts even STM-16 is available.

There are fibre links available to all 400kV Stations and to all Generating Stations connected to 220kV.

No usage of radio links.

2.4 State Load Dispatch Centres SLDCs

In order to get a good insight in the capability of the existing SLDC control systems, the four SLDCs were visited in the course of the interview session. The received information is summarized in the following sections.

- SLDC Karnataka
- SLDC Gujarat
- SLDC Rajasthan
- SLDC Andhra Pradesh

In addition to aforementioned site visits and interviews, telephone interviews with responsible key personnel were performed to assess the following SLDC:

- SLDC Himachal Pradesh

Such telephone interviews were based on a structured questionnaire. Results are summarized in Annex 2.

Information on Tamil Nadu SLDC could not be gathered directly from the concerned SLDC team in the state. However, some details have been collected based on publicly available information and interactions with the SRLDC, of which this state is a constituent.

2.4.1 SLDC Karnataka

SLDC Karnataka located at Bangalore was visited on 18th February 2015.

2.4.1.1 SCADA/EMS

The SCADA/EMS system was of type "ABB Network Manager 3" originally supplied by ABB and had been set into operation in the years of 2006 / 2007. "Network Manager" is the actual mainline product of ABB for SCADA/EMS systems on national TSO and also regional level. It is in the market since the early years of 2000 and considered a state-of-the-art solution for SCADA/EMS application in a high voltage power grid.

The SCADA/EMS system is arranged in a fully redundant hot-stand-by configuration. Servers and other equipment for the vital system functions such as SCADA servers, Front End, Historical Archive, Time & Frequency System are consequently duplicated in order to cater for redundancy, while other equipment such as Operator workstations are in a single set-up only. A disaster recovery System is located in a separate location.

Redundant Virtual LAN sections for SCADA have been established which are separated from the Data Acquisition LAN towards/from the outstations. In addition, a redundant LAN for communication towards/from other systems is decoupled from the inner SCADA LAN via Demilitarized Zone (DMZ) to cater for enhanced security against cyber-attacks or intrusion from outside.

The arrangement of the computers and peripheral components covers the requirement of a distributed system approach with dedicated application servers allocated to individual functions of a SCADA System, such as Historian, Training System, Back-Up Facilities etc.

For the SCADA/EMS a valid service contract exists, running until 2018.

Multiple operator desks are accommodated at the control room consisting of workstations each of them include multiple screens.

The Visualization of the Power System is mainly managed by a video wall accommodated in the background of the Control Room. The video wall consists of 10 (5 * 2 array) of large projection screen cubes, applying the rear projection principle using Digital Micro Mirror Devices with dual, hot swappable lamps.

In terms of functionality the new system comprises:

- SCADA
- EMS package for network management such as state estimator, contingency analysis etc.

For the generation control there is the POSOCO Scheduling Software in operation. This software package is based on Internet technology and enables the nation-wide control of the power plants from all SLDC with a timeframe up to 6x15 minutes in advance.

All communication links between RLDCs, NLDC and subordinated SLDCs are realized as redundant links utilizing international standard communication protocol as per IEC60870-6 (ICCP).

The data base currently includes approximately 500.000 data Objects. These are divided in:

- 300.000 measurements
- 157.000 Status Objects
- 80.000 Control Object (tap changer, breaker, etc.)

This means, in concrete terms, that for example the information of every breaker down to 11 kV is online available.

The refresh rate of measurements is currently about 10 seconds it should be tried to optimize this to reach a range of 2 to 4 seconds.

2.4.1.2 Telemetry

A total of approx. 1300 Remote Terminal Units (RTU) are connected to the SCADA/EMS system for data acquisition towards/from related substations.

All RTUs are connected via international standard telecommunication protocol IEC 60870-5-104 (IP-protocol).It was reported that no proprietary telecommunication protocols are in use to connect to SCADA equipment at outstations.

Mainly VSAT communication links are utilized for interconnection to RTUs and other Control Centre systems on SLDC level and to NLDC. Leased Lines function as backup communication links.

It was reported that the running cost for VLAN communication is about 20 Million Rupees per year.

For the VLAN communication equipment a valid service contract exists, running until 2018.

There is no usage of fibre, GPRS or PLC links.

2.4.2 SLDC Gujarat

SLDC Gujarat located at Vadodara was visited on 19th February 2015.

2.4.2.1 SCADA/EMS

The existing SCADA/EMS system of type GE XA 21 is currently being replaced by a new SCADA/EMS system of type “e-terra” procured from Alstom.

"e-terra" is the current mainline product of Alstom for SCADA/EMS systems on national TSO level. It is in the market since the early years of 2000 and considered a state-of-the-art solution for SCADA/EMS application in a high voltage power grid on national level.

The new SCADA/EMS system will be arranged in a fully redundant hot-stand-by configuration. Servers and other equipment for the vital system functions such as SCADA servers, Front End, Historical Archive, Time & Frequency System are consequently duplicated in order to cater for redundancy, while other equipment such as Operator workstations are in a single set-up only.

The arrangement of the computers and peripheral components covers the requirement of a distributed system approach with dedicated application servers allocated to individual functions of a SCADA System, such as Historian, Training System, Back-Up Facilities etc.

For the SCADA/EMS a valid service contract is in place.

Two operator desks with 2 screens and 6 operator desks with 1 screen are accommodated at the control room. Visualization of the Power System is mainly managed by a video wall accommodated in the background of the Control Room.

SLDC operation is handled by 2 operators on a 24/7 base, managed in 3 consecutive shifts.

In terms of functionality the new system comprises:

- SCADA
- EMS package for network management such as state estimator, contingency analysis etc.

The system configuration of the SCADA/EMS system includes a back-up system for disaster recovery following a state-of-the-art multi stage redundancy concept.

All communication links between RLDCs, NLDC and subordinated SLDCs are realized as redundant links utilizing international standard communication protocol as per IEC60870-6 (ICCP).

The data base currently includes approximately 5.000 data Objects. These are divided in:

- 3.000 Measurements
- 2.000 Status Objects
- < 100 Control Object (tap changer, breaker, etc.)

The system is only running in listening mode. The command direction is not active.

The refresh rate of measurements is currently about 8 - 10 seconds. It should be tried to optimize this to reach a range of 2 to 4 seconds.

2.4.2.2 Telemetry

There are Remote Terminal Units (RTUs) in operation since 1983. A total of approx. 126RTUsand 74 Sub RTUs are connected to the SCADA/EMS system for data acquisition towards/from related substations through Sub LDCs.

Mainly redundant PLC links are used for the interconnection to the RTUs. The available bandwidth is only 200 Baud and therefore there is only the telecommunication protocol IEC 60870-5-101which can be used.

The communication links to other Control Centre systems are realized using ICCP protocol via leased lines.

It was reported that the reliability of the ICCP links are satisfactory.

It should be pointed out here, that the available bandwidth to the RTUs is very low. This leads to a measurement refresh cycle of 8 - 10 seconds which should be optimized further to reach a range of 2 - 4 seconds.

2.4.3 SLDC Rajasthan

SLDC Rajasthan located at Jaipur was visited on 20th February 2015.

2.4.3.1 SCADA/EMS

The existing SCADA/EMS system of type Habitat from Areva/Alstom is currently being replaced by a new SCADA/EMS system of type “Spectrum Power 7” procured from Siemens.

Spectrum SP7 is the actual mainline product of Siemens for SCADA/EMS systems on national TSO level. It is in the market since mid of 2014, therefore brand new and considered a state-of-the-art solution for SCADA/EMS application in a high voltage power grid on national level.

The new System is currently in trial operation while the old system is operated in a stand-by mode to cater for a fall back in case of malfunction of the new system.

The new SCADA/EMS system will be arranged in a fully redundant hot-stand-by configuration. Servers and other equipment for the vital system functions such as SCADA servers, Front End, Historical Archive, Time & Frequency System are consequently duplicated in order to cater for redundancy, while other equipment such as Operator workstations are in a single set-up only.

The arrangement of the computers and peripheral components covers the requirement of a distributed system approach with dedicated application servers allocated to individual functions of a SCADA System, such as Historian, Training System, Back-Up Facilities etc.

For the SCADA/EMS a valid service contract is in place.

Visualization of the Power System is mainly managed by a video wall accommodated in the background of the Control Room.

SLDC operation is handled by 4 teams of 5 persons each on a 24/7 base, managed in 3 consecutive shifts.

In terms of functionality the new system comprises:

- SCADA
- EMS package for network management such as state estimator, contingency analysis etc.

The system configuration of the SCADA/EMS system includes a back-up system for disaster recovery following a state-of-the-art multi stage redundancy concept.

All communication links between RLDCs, NLDC and subordinated SLDCs are realized as redundant links utilizing international standard communication protocol as per IEC60870-6 (ICCP).

The data base currently includes approximately 50.000 data Objects.

The system is only running in listening mode. The command direction is not active.

The refresh rate of measurements is currently about 8 - 10 seconds. It should be tried to optimize this to reach a range of 2 to 4 seconds.

2.4.3.2 Telemetry

A total of approx. 128 RTUs are connected to the SCADA/EMS system for data acquisition towards/from related substations. The state is in the process of installing 136 RTUs at 132kV Substations

Mainly redundant/single PLCC links are used for interconnection RTUs to the Sub LDCs. The available bandwidth is only 300 Baud and therefore only the telecommunication protocol IEC 60870-5-101 can be used there. A few RTUs are connected on OPGW lines.

The communication links from Sub LDCs to the state LDC are realized using ICCP protocol on OPGW lines.

It was reported that the reliability of the ICCP links are satisfactory.

It should be pointed out here, that the available bandwidth to the RTUs is very low. This leads to a measurement refresh cycles of 8 - 10 seconds. . It should be tried to optimize this to reach a range of 2 to 4 seconds.

2.4.4 SLDC Andhra Pradesh

SLDC Andhra Pradesh located at Secunderabad was visited on 12th March 2015.

2.4.4.1 SCADA/EMS

It should be noted that the erstwhile State of Andhra Pradesh was recently bifurcated into two states – Andhra Pradesh and Telangana. The unified state was in the process of implementing a new SCADA/EMS system from Alstom – eTerra. Control Version 3.7. This is currently in commissioning stage and states are using the older GE system. The new state of Andhra Pradesh plans to procure a new SCADA/EMS system for its SLDC operations. At this point, the Alstom system will be used as disaster recovery system.

Visualization of the Power System is planned through a video wall comprising of a grid of 6 X 3 panels of size 70inches each.

SLDC operation is handled by 4 teams of 4 persons each on a 24/7 base, managed in 3 consecutive shifts.

In terms of functionality the new system envisaged will comprise of:

- SCADA
- EMS package for network management such as state estimator, contingency analysis etc.

All communication links between RLDCs, NLDC and subordinated current and proposed SLDCs are realized as redundant links utilizing international standard communication protocol as per IEC60870-6 (ICCP).

The data base currently includes approximately 19,600 data Objects comprising of:
9000 analogue input, 9900 digital inputs and700 digital outputs.

Digital Output points are wired for Remote feeder tripping and in a few cases feeder CB-closing also. The State Transco is also insisting to have IEC 61850 client support for RTUs so that it is capable of taking data for df/dt, UFR, .protection status etc. from IED relays.

The refresh rate of measurements is currently about 4 seconds. This is considered fairly adequate.

2.4.4.2 Telemetry

A total of approx. 104 RTUs are connected to the SCADA/EMS system for data acquisition towards/from related substations. RE Developer Pooling Stations already have IEC101 compliant RTUs based on specifications issued by the State SLDC.

PLCC links are used for interconnection RTUs to the Data Concentrator Protocol Converter (DCPC) units. The available bandwidth is 300/600 bauds. A few RTUs are connected on OPGW (STM1) lines.

RTU to DCPC only single path (PLCC or OFC) is available in AP. Hence, communication from RTU is brought to DCPC location over single path, where it is split into 2 (two) channels using splitters and fed to main and backup servers in DCPC. From here it is sent to Main and Backup SLDC over IEC 104 protocol.

2.4.5 SLDC Himachal Pradesh

Information about SLDC Himachal Pradesh located at Shimla was collected through telephonic interview on March 17th, 2015.

2.4.5.1 SCADA/EMS

The state is implementing a new SCADA/EMS system of type “Spectrum Power 7” procured from Siemens.

Spectrum SP7 is the actual mainline product of Siemens for SCADA/EMS systems on national TSO level. It is in the market since mid of 2014, therefore brand new and considered a state-of-the-art solution for SCADA/EMS application in a high voltage power grid on national level.

The new System is currently in trial operation while the old system is operated in a stand-by mode to cater for a fall back in case of malfunction of the new system.

Visualization of the Power System is planned through a video wall comprising of a grid of 4 X 2 panels of size 70 inches each procured from BARCO.

SLDC operation is handled by 4 teams of 4 persons each on a 24/7 base, managed in 3 consecutive shifts.

In terms of functionality the new system envisaged will comprise of:

- SCADA
- EMS package for network management such as state estimator, contingency analysis etc.

All communication links between RLDCs, NLDC and subordinated current and proposed SLDCs are realized as redundant links utilizing international standard communication protocol as per IEC60870-6 (ICCP).

The data base currently includes approximately 2000 data Objects for measuring analogue input, digital inputs and digital outputs.

The refresh rate of measurements is currently about 10 seconds. It should be tried to optimize this to reach a range of 2 to 4 seconds.

2.4.5.2 Telemetry

All 220kV Substations and a few 132kV and 66kV have RTUs from various vendors. These communicate with the SLDC directly on IEC101/104 protocols. Data from substations that are not telemetered is obtained on the telephone or extrapolated from other substation data.

Generally, analogue PLCC links are used for interconnecting RTUs to the SLDC at bandwidth of 300/600 bauds. There are a few Fibre Optic STM1 communication links also. Around 10-12 Power House Substations are connected to the SLDC on GPRS links.

2.4.6 SLDC Tamil Nadu

Information about SLDC Tamil Nadu located at Chennai could be collected based on interactions with the SRLDC team and publicly available data.

2.4.6.1 SCADA/EMS

The state is implementing a new SCADA/EMS system of type “eTerra” procured from Alstom.

“e-Terra” is the current mainline product of Alstom for SCADA/EMS systems on national TSO level. It is in the market since the early years of 2000 and considered a state-of-the-art solution for SCADA/EMS application in a high voltage power grid on national level.

The system configuration of the SCADA/EMS system includes a back-up system for disaster recovery following a state-of-the-art multi stage redundancy concept.

All communication links between RLDCs, NLDC and subordinated SLDCs are realized as redundant links utilizing international standard communication protocol as per IEC60870-6 (ICCP).

Information on data objects being monitored and controlled could not be obtained.

Remote Terminal Units are connected to SCADA/EMS system for data acquisition towards/from related substations through Sub LDCs.

Information on prevalent communication channels could not be ascertained.

In terms of functionality the new system envisaged will comprise of:

- SCADA
- EMS package for network management such as state estimator, contingency analysis etc.

All communication links between RLDCs, NLDC and subordinated current and proposed SLDCs are realized as redundant links utilizing international standard communication protocol as per IEC60870-6 (ICCP). Sub LDC to SLDC follows ICCP protocol.

2.4.6.2 Telemetry

All 400kV, 230kV and 110kV substations in the state have Remote Terminal Units (RTUs) from different vendors. These communicate with 3 Sub LDCs installed at Madurai, Chennai and Erode.

2.5 Overall Communication infrastructure

In the context of the visits and the discussions held with various xLDCs it has been observed, that over the whole country there is a very diverse telecommunication infrastructure, which is currently individual in each state.

However, in the whole country power utility’s telecommunication infrastructure is solely used by power utilities. It is not shared with other companies or with service providers. Power utility’s telecommunication infrastructure has a very high security standard, hence. This is valid for all levels of communication as described below.

For the communication between NLDC, RLDCs, SLDCs (and Sub-LDCs) in the whole country ICCP has been established as a standard. At this communication level predominantly fibre optics is available as layer 1 medium.

Telecommunication facilities for the communication from SLCDs or Sub-LDCs downwards (to the energy power sites), however, are very diverse in India. This issue will be considered in this scope.

In general there are four types of layer 1 media which are used to transport SCADA data:

- Fibre Optics
- PLC or DPLC
- VSAT
- Leased Lines

Since telecommunication providers do not offer tailored services according to the needs of power utilities and due to reservations about safety issues GPRS is currently not used as the preferred medium of communication. However, in a few locations where other modes of communication are not available, GPRS is being used.
Microwave radio is currently not in use for the transport of SCADA data.
In some Indian states, fibre optics is partly available down to substation level, so that SCADA data are transported by redundant optical SDH technology on STM-1, STM-4 and STM-16 level. Also, PLC is still in use as a fall-back option - or at places where fibre optics is not available.

In other Indian states, redundant PLC or digital PLC (DPLC) technology is available to transmit SCADA data. For example, redundant DPLC is available in the whole North Region. As a fall-back option leased lines are used. Solely in Karnataka, the entire SCADA communication is exclusively realised by VSAT from Gilat (Israel; set into service in 2009), transmitting at a data rate of about 150kbps. More than 1200 RTUs in total are connected with two VSAT hubs via satellite, from which one hub is redundant. The royalty for the usage of the transmission channels via satellite is about 20 Million Rupees per year. As a fall back option leased lines are used.

OFC communication infrastructure is being established for the Central sector and a few state sector substations to enable implementation of Special Protection Scheme (SPS), PMU and SCADA systems. Power Grid, the Central Transmission Organisation that manages the interstate transmission network, is covering this network with OFC for all Substations up to 220kV level. The Ministry of Power is exploring extending OFC up to 132kV level.

As soon as they are installed, these fibres preferably can be used to transfer any data from power energy sites in rural areas or from pooling stations to SLDCs or RLDCs.

2.6 Other Observations

2.6.1 Accommodation of SCADA/EMS Systems

At Northern Regional Load Dispatch Centre NRLDC it was observed that the SCADA/EMS system hardware components (servers, peripherals, communication equipment etc.) are accommodated in 19 inch rack mount cubicles which are located at a dedicated equipment room in the basement of the building.

Equipment of both systems (main and stand-by system for NRLDC) are accommodated side by side in the same room.

This is not compliant with international standards common for SCADA/EMS systems as it imposes danger for the availability of the overall system in the event of fire and other disasters. Even the back-up system for the Southern RLDC (as mentioned in the above sections) is accommodated in the same room.

It is therefore urgently recommended to split the systems by accommodating relevant subsystems in separate rooms.
This will considerably increase overall system availability and security against disasters.

During site visits performed in February it could not be assessed whether the pooling of SCADA/EMS systems together in common equipment is applied for other Control Centres as well. If this is be the case it is urgently recommended to split the systems as indicated above.

2.6.2 Performance of Data Acquisition

Data acquisition of measurements was reported to be in a range of around 10 seconds for two consecutive measurement sets.
At NLDC it was observed that time between two consecutive measurements sets (i.e. frequency) is even more than 15 seconds.

It could not finally be identified whether such long actualization times are rooted in either slow transmission speeds in the data transmission from the interconnected RTUs or in the number of information objects to be transmitted.
Based on information gathered so far, it appears that communication infrastructure is the bottleneck for this.

In any case such actualization times are not considered adequate for SCADA/EMS applications on national TSO level.

Particularly in view of the fact, that the Indian Power Grid is envisaged to undergo secondary Load-Frequency Regulation in a forthcoming step, actualization times for measurements need to be dramatically shortened down to 2 seconds in order to reach state-of-the-art secondary regulation features.

3. Establishment of Renewable Energy Management Centres (REMC) – A Conceptual Framework

Based on the assessment of the existing control systems and grid operations practices, Consultant arrives at following conclusions:

Potential for large scale RE generation (especially of wind and solar) is high in a few states of the country. These states are struggling with integration of RE generation into their transmission grids due to the uncertainty and variability of power generation of such plants. In most cases, states face challenge of balancing RE generation within their area of responsibility due to lack of visibility of forecasted RE generation. Large Scale RE plants have come up very recently in India. Therefore expertise at the grid operations levels for safe, secure and optimal despatch of RE is not widely available.

Further, analysis of ASIS systems and processes shows that impact of integration of RE generation at various levels of operation (state, region and national level) is markedly different from that of conventional generation. This calls for a dedicated RE management system at each level of grid operation i.e. a Renewable Energy Management Centre (REMC).

Renewable Energy Management Centre (REMC) is the "hub" for all information regarding RE power generation in its area of responsibility which could be on SLDC-, RLDC- or even on NLDC level.

Establishment of Dedicated Renewable Energy Management Centres, to facilitate large scale integration of renewables into the grid, is a global best practice. Renewable Energy Management Centre (REMC), equipped with advanced Forecasting Tools, Smart Dispatching solutions, &Real Time Monitoring of RE generation, can closely coordinate with the Grid Operations team for safe, secure and optimal operations of the overall grid.

REMC should have a dedicated REMC team for managing forecasted RE generation, its despatch and real-time monitoring to ensure safe, secure and optimal operation of the grid. REMC acts as the RE Single Point of Contact for the main Grid Operations team. In order to facilitate better coordination between REMC and the main xLDC teams, it is essential that REMC team should be co-located with the main LDC team.

3.1 Functional Scope of new REMCs

Recommended functionalities of REMCs are:

- Forecasting of RE generation (day ahead and intra-day, ramp prediction etc.)
- Online geospatial monitoring of RE Generation – at the transmission grid boundaries & at RE pooling Stations (through direct Data Acquisition OR through interface with RE Developer monitoring Systems)
- Responsible for quality and reliability of RE data
- Propagate RE related data to its partner xLDC, Forecasting, scheduling and balancing systems.
- Coordinating with xLDC for dispatching and balancing RE power
- Central Repository for RE generation data for MIS and commercial settlement purposes
- Coordination agency on behalf of xLDC for interacting with RE Developers
- Training and Skill building for RE integration into the grid.

REMC shall therefore comprise the following features:

- Data Acquisition, Monitoring and Control
- Geo-Spatial Visualization of RE Generation within the area of responsibility
- Information exchange with xLDC, forecasting, scheduling and control reserve monitoring/balancing tools
- Data Engineering
- Data Archiving and Retrieval

- Reports and MIS to support commercial settlements
- Future Readiness for advanced functions such as Virtual Power Plants, Storage etc.

The following sections provide an overview of the integration of several REMCs into the landscape of the existing control systems in India.

As described in chapter 2.1 the control systems in the Indian power system are hierarchically structured. Figure 3 below gives an overview.

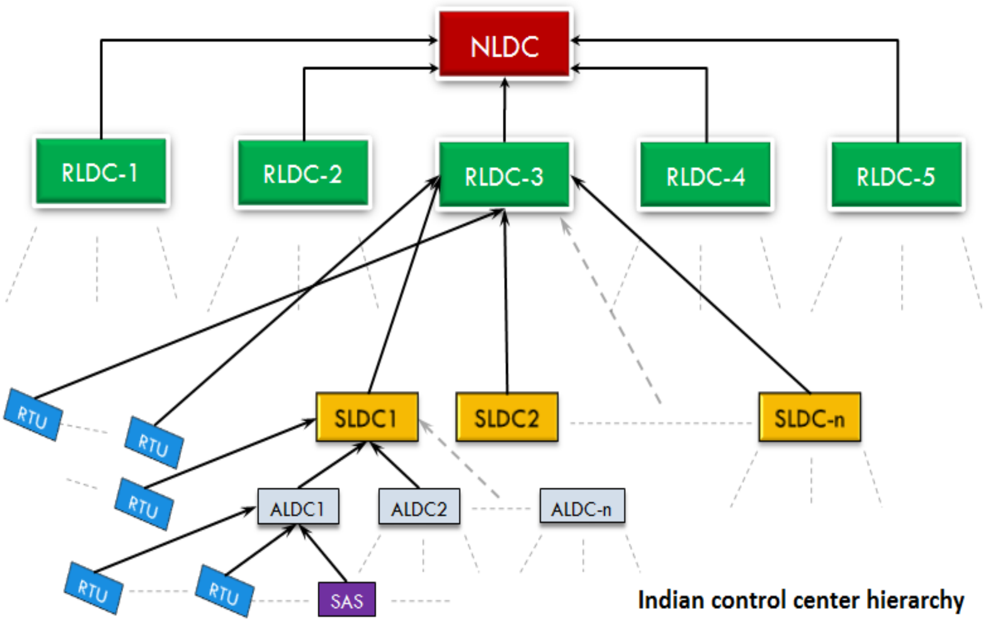


Figure 3: Indian Control Centre Hierarchy

Under the supervision of the National Load Dispatch Centre (NLDC) there are 5 Regional Load Dispatch Centre (RLDC) which are the apex body to ensure integrated operation of the power system in the concerned region. The RLDC will monitor grid operations, exercise supervision and control over the inter-state transmission system, and will be responsible for optimum scheduling and dispatch of electricity within the region.

Below the 5 RLDC's mentioned above in total 34 State Control Centres are installed. Every state has a State Load Dispatch Centre (SLDCs), which is the apex body to ensure integrated operation of the power system in the state.

On the next lower level 51 Area Load Dispatch Centres (ALDCs /LDC's) on the district level are located. At the sub level, approximately 1800 remote terminal units (RTU) are connected. The control systems are communicating with each other via standardized ICCP protocols.

It is evident from above that focus of grid operations varies according to the hierarchical level. At state level, the primary focus is optimal despatch and balancing power. At regional level, it is secure and optimal coordinated operation of the regional connected grid whereas at national level the main focus is safety of the grid. Consultant recommends that a companion REMC system should be established at each level independently to discharge similar duties from an RE integration perspective.

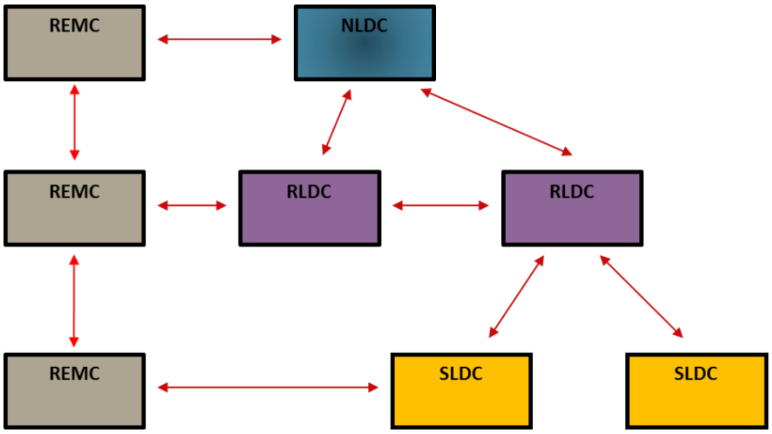


Figure 4: REMC Hierarchical Structure

REMCs at various levels are recommended to interact with each other on similar lines as the main xLDCs. Therefore, all state level REMCs provide information on RE generation in their state to the “parent” Region’s REMC. Similarly, data from all Regions’ REMCs is propagated to the National level REMC.

3.2 Roles and Responsibilities of new REMCs

Roles and Responsibilities of REMC at the State, Regional and National level are provided below.

Table 1: Roles and Responsibilities of REMCs at the different levels

Functionality	SLDC	RLDC	NLDC	Remarks
Real time Acquisition and monitoring of Renewable energy Generation data from Interconnecting Stations	Y	Y	capable (to support feature)	
Real time Acquisition and monitoring of Renewable energy Generation data from Pooling Stations	desirable	desirable	future (when inter-region/international grid exchange starts happening)	
exchange RE generation data with partner xLDC	Y	y	y	
Real time monitoring of control reserves in area of responsibility	Y	capable	capable	Feature can be enabled at SLDC and/or at RLDC levels as decided in the final approach
Geo-spatial visualization of RE generation	capability	capability	capability	External GIS tool integration required.
Forecasting - day ahead	Y	y	future (when inter-region/international grid exchange starts happening)	
Forecasting - now casting	y	y	future (when inter-region/international grid exchange starts happening)	
Forecasting - ramp etc....	y	y	future (when inter-region/international grid exchange starts happening)	
Provide data to scheduling tool as per pre-agreed interfaces	y	y	capable	
Enable RE developers to provide proposed generation schedules as per their own forecasts	y	y	capable	
Enable manual overriding of forecasted RE generation before propagating this information to the existing scheduling tool.	y	y	capable	

Coordinate with partner xLDC for scheduling and despatching renewable energy generated in area of responsibility in a secure and safe manner	y	y	capable	
Data repository for analysis, trends, reports and analytics in area of responsibility	y	y	y	
Maintain Data integrity across REMCs at various levels	y	y	y	
Centre of excellence for RE generation integration	y	y	Y	
Coordinate with RE generators in area of responsibility	y	y	y	an RE developer is attached to one REMC
RE generation grid injection remote control	capable	Capable	capable	
Load forecasting				Load forecasting is expected to be done in the main xLDC level.

In order to discharge the above roles smoothly, consultant recommends that REMC tool be implemented independently at each level – at each state, region and national level. The Tool should have standard features that can be invoked or configured as per the expected requirements at the particular hierarchical level. It should be noted that in future, roles and responsibilities at the state, region and national levels may evolve due to change in policies and/or regulations. Therefore, consultant recommends that REMCs at all levels should be capable of performing a standard comprehensive set of functionalities. These can be invoked at the particular level as per need.

3.3 Guiding Principles for REMC System

The following requirements are mandatory for a REMC system:

- State of the art SCADA – Functionality
- Support real-time monitoring at refresh rates of at least 2-4 seconds and capability to perform remote control operations
- High availability, based on fully redundant hot standby configuration
- Utilization of existing market standards
- Compliance with all IT-Security standards
- Prevention of cost intensive new developments with high error rates
- Potential for later extension and upgrading without difficulty
- Security of the investment for the next 10 - 15 years

Generally there are two main approaches to establish the REMC system.

1. Integration of new software features into the existing SCADA/EMS - Systems

Most of the existing SCADA/EMS systems are from well-known international Control-System manufacturer and they are the mainline products of these vendors. Some parts of the features needed for the REMC are already available in the SCADA/EMS software platform. Apart from the standard SCADA functionality which is also needed for the REMC, also parts of the EMS functionalities can be used after adoptions to fulfil the requirements for dispatching the generation of renewable energy. However, the SCADA/EMS Systems currently in use are procured from various vendors; therefore the structure is not homogeneous. A significant number of systems is already approaching the end of their life cycle and need to be replaced.

2. **Development of new independent REMC Systems with Interfaces to the existing SCADA/EMS - Systems**
   This approach assumes that all REMCs require identical functionality and it would be easier to introduce one new control system platform (based on state of the art standard products from reputed SCADA vendors available in the market) and install as much instances of this control system type as are needed. For the necessary information exchange with the existing SLDCs and RLDCs international standardized telecommunication protocols shall be used. The advantage of this approach is the independence from the existing SCADA/EMS - Systems and their different stages in the evolution process. This will ensure more flexibility and less complexity.

The assessment of the existing SCADA/EMS systems has shown that the control systems installed in the Indian Power Grid are of different type and make. Although they are based on the mainline standard products of the different vendors, they have different software releases and different project specific software packages installed. This means that software adaption would need to be project specific for individual xLDCs. As described above this is very error prone. Furthermore the procurement could only be limited to the original suppliers. Competitive procurement procedures will be difficult to implement. On the contrary, single source procurement for each individual xLDC would be advisable.

In addition it has been shown that some of the existing SCADA/EMS Systems are at their performance limits. The refresh cycles of the measurements are sometimes above 10 seconds.

These reasons are speaking against the integration of the needed functionality for the REMCs into the existing control system. To keep the complexity of the overall system as low as possible, it is recommended that each REMC is exactly assigned to one of the existing SCADA/EMS Systems (SLDC, RLDC, or even NLDC).

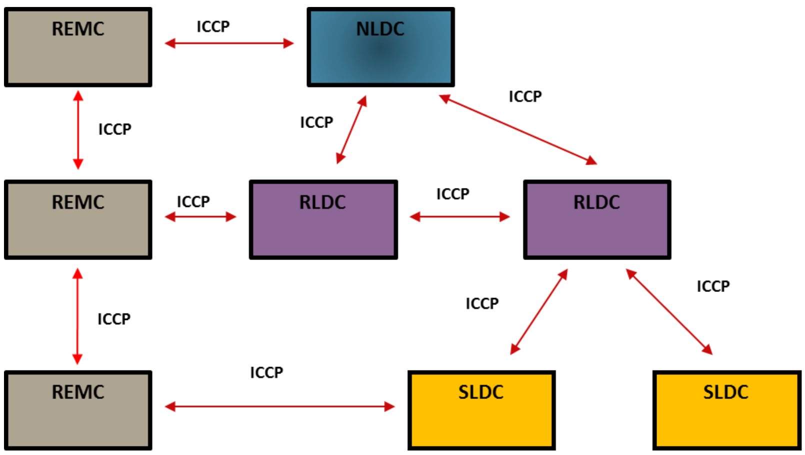


Figure 5: Integration of REMCs

.As shown in Figure 5, the approach for integration of separate REMCs into the existing control system landscape described in this section enables the interfacing of the standardized REMC System to each of the existing control systems wherever the respecting functionality is needed.

The consultant assumes that most of the Renewable Energy Sources are physically connected to the grid which is supervised and directly controlled by the SLDCs. In this case the corresponding REMC should also be connected to this SLDC.

The consultant therefore recommends that new SCADA-Systems specifically designed for the needs of the REMCs should be defined and installed. For the necessary exchange of information standard interfaces and communication protocols should be used.

It should be noted that at present, the state of Himachal Pradesh does not have much wind and solar renewable generation as of now. Therefore, establishing an REMC in this state may not be required. This needs to be validated by evaluating the state's roadmap for wind and solar renewable generation integration into the transmission grid.

3.4 Recommendation for independent standardized REMC Systems

As in the previous section well-founded the consultant recommends to establish new independent and standardized SCADA Systems for the REMCs, which are specifically designed for their needs.

Additional benefits of this approach are:

- State of the art SCADA- Functionality on a common system platform
- High flexibility for further extensions especially for new software packages which support the Management of Renewable Energy sources
- The opportunity to install and operate identical software systems in all needed states and regions leads to high quality while keeping costs low
- Due to the fact that all REMCs will be identical an effective patch-, update- and upgrade-process can be installed to satisfy all the requirements regarding to cyber security
- Necessary systems can be specified on a standard basis allowing easy procurement and competitive bidding processes.

Application of ICCP connections between the various levels of Control Centres as shown in Figure 5 above are indicative and should be considered in more detail during detail engineering phase under the project. It is recommended to apply additional ICCP connections between various levels only in case necessary, as too many ICCP connections could limit overall system performance.

As shown in Figure 6, the distribution of this information to the other control systems is done by the established mechanisms via ICCP Communication between the existing SCADA/EMS Systems. Alternately, Communication from State REMC to Region REMC can happen over ICCP link between the REMC in order to reduce dependency on companion xLDCs.

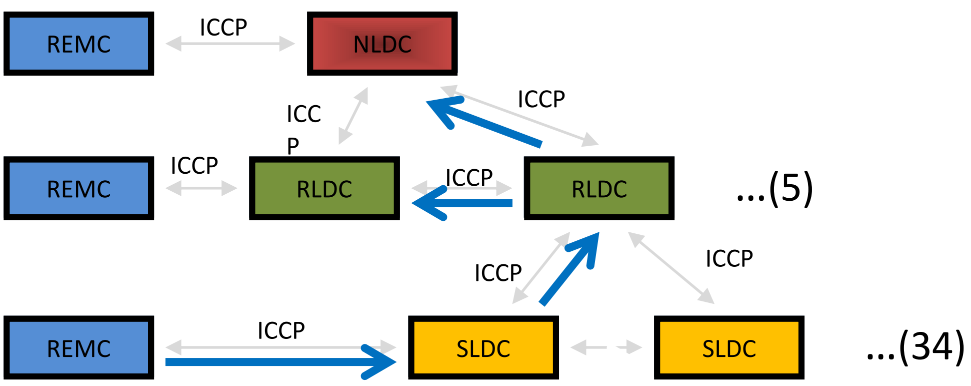


Figure 6: Information flow across REMCs

3.5 REMC System Conceptual Architecture

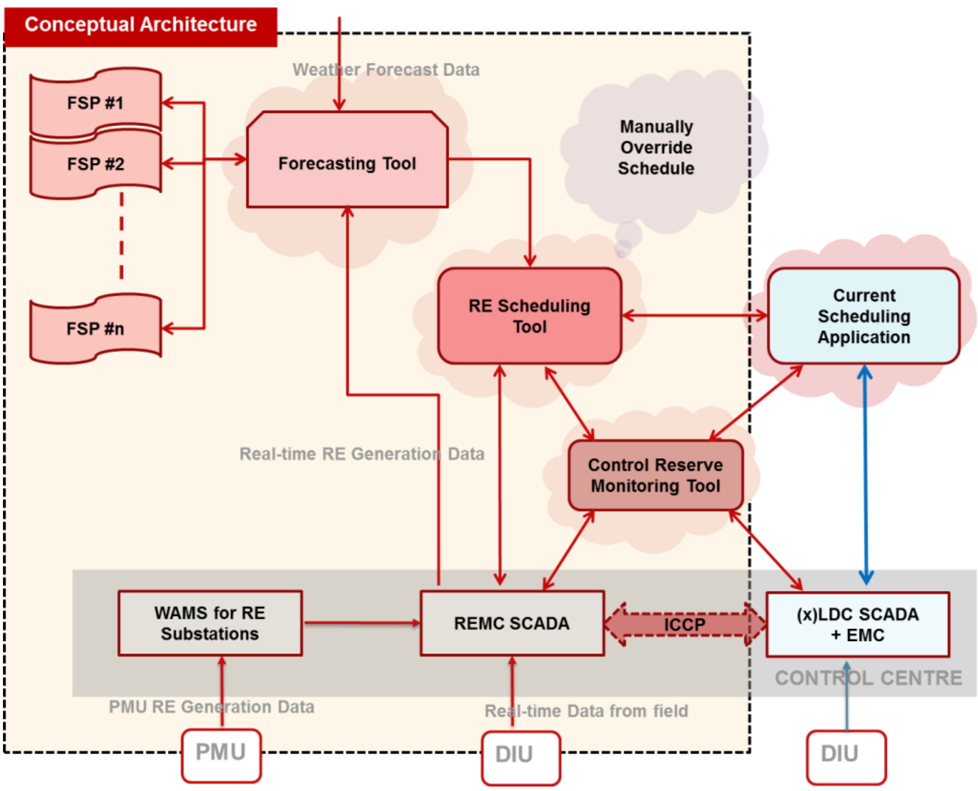


Figure 7: Scheme of logical interconnectivity between various Software modules

Figure 7 shows Conceptual Architecture of recommended REMC. REMC at control centre comprises of following modules:

1. REMC SCADA
2. Forecasting tool (can be a 3rd party tool)
3. RE Scheduling Tool

4. Control Reserve Monitoring Tool
5. WAMS for RE Substations (optional)

REMC components in the field comprise of Data Interface units at the Grid interconnecting and RE developer pooling substations (can be RTUs or Data interface units for integrating with existing RTUs).
REMC can integrate with SCADA systems of RE developers provided these support standard interface protocols.
Phasor Measurement Units (PMUs) can be provided at critical substations where remote monitoring is required at each power frequency granularity level.

These modules are described below.

3.5.1 Forecasting Tool

REMC system will support interface with one or multiple 3rd party forecasting service provider systems through an REMC Forecasting tool. Real-time actual RE generation at various sites in the area of responsibility will be propagated to the forecasting tool from the REMC SCADA tool. Weather forecast data (for day ahead and intraday updates) can be obtained at this tool level and propagated to the individual FSPs.

This tool can be configured to accept potential forecast in the area of responsibility from these external FSP systems in a standard data interface format. The tool will combine the multiple forecasts as per predefined algorithms into a single potential forecast generation for the overall area of responsibility.

RE developers in the area of responsibility can subscribe to this tool to obtain the potential forecast values for the region and downscale the same to their site so as to forecast possible generation for their specific sites. This is useful when RE developers do not have their own forecasting tool at individual level. However, accuracy of the forecast after downscaling itis likely to deteriorate as described in the Forecasting Report.

Objective of this tool is to support REMC in validating accuracy of the forecasts/schedules provided by individual RE developers. Forecasting can be done for day-ahead or for intraday. It can be done for RE generation or ramp generation etc.

Forecasted data (for points of injection in the area of responsibility) will be propagated to a RE scheduling tool.

3.5.2 RE Scheduling Tool

Forecasted RE generation data (for point of injection) will be received in the RE Scheduling tool. REMC team can manually override the forecast data so obtained (in order to correct any perceived inaccurate data or to provide missing data) before submitting this to the existing general scheduling tool.

Individual RE developers can upload their schedules to the REMC's RE scheduling tool for seeking support from REMC expert team for optimal RE scheduling. This is the case when RE developers have their own forecasting systems and therefore, they are in a position to provide "proposed RE generation schedule" to the REMC.

The final RE schedule mutually agreed between REMC and RE developers can then be propagated to the main scheduling tool of the XLDC.

3.5.3 REMC SCADA Monitoring Tool

REMC will support SCADA of RE generation injection at the grid interconnecting and RE Developer Pooling Substations. This system will be capable of acquiring data from existing RTUs that support standard protocols like IEC104.

Alternately, the REMC SCADA can obtain data from RE developer's local SCADA systems on a predefined standard interface protocol.

In some cases, existing RTUs are already connected to the main xLDC. It is recommended that there RTUs be connected to the REMC for telemetry of RE generation, if they support dual masters. As an interim measure, RE generation data can be acquired by the main xLDC (As is current practice) and be pushed to the REMC SCADA over standard ICCP protocol.

Refresh rates at REMC control centre at any hierarchical level should be in the range of 2-4 seconds. This may require up gradation of the communication infrastructure.

In absence of RTU and local SCADA systems, REMCs can acquire data from RE meters installed at the point of injection into the grid or at sending end of RE pooling stations for online monitoring of RE generation, if meter based systems support at least 15 minute refresh cycles at control centre end. This is an interim measure and not recommended. Efforts should be made to install new RTUs at such Substations.

Data Engineering in REMC SCADA System is recommended to be done independently as not all xLDCs are CIM compliant. However, REMC SCADA must be CIM compliant.

For data acquisition from Pooling Stations that may not have through communication connectivity to the Control Centre, RE developer can provide telemetry data in real-time (2-4seconds refresh) at the point of injection of RE power. The RTU/Data Acquisition Unit at the interconnecting Substation should be capable of integrating with the "last node" RTU on a predefined standard protocol. Data so obtained will be propagated to the Control Centre REMC over the ICT-CC communication infrastructure. If this connectivity is not there, GPRS communication can be considered as an interim method. However, it should be noted that reliability of GPRS connections is generally not good enough for such mission critical applications.

RE Developers can subscribe to REMC SCADA system for monitoring their plant generation levels.

It is recommended that a GIS tool based visualization layer be provided as an option in Control Centre, that can be used by the main as well as REMC SCADA systems.

REMC operations team will be able to monitor RE generation data, get alert notifications and create and view MIS reports for various purposes.

3.5.4 REMC WAMS

Indian Grid Operators have started using PMU based WAMS to exercise finer monitoring of critical locations. On same lines, Phasor Measurement Units (PMUs) can be provided at critical substations where remote monitoring is required at a finer granularity in order to diagnose/trace sequence of events (example LVRT behaviour).

Data from these PMUs will be obtained at the pre-existing WAMS system in control Centre and then propagated to the REMC SCADA system over a predefined interface protocol. It is expected that data from WAMS should flow into the REMC system at 1 second granularity. For sub-second granularity monitoring, REMC team should have access to the main WAMS system itself.

It should be noted that PMU-WAMS is an evolving field and hence not too many SCADA suppliers are likely to have standard interfaces for data exchange with such systems.

3.5.5 RE Control Reserve Monitoring Tool

In future, a dedicated module to facilitate real-time monitoring of control reserves in area of responsibility as well as neighbouring regions can be introduced (control reserve monitoring tool).This tool can be used to perform scenario analysis for balancing RE generation based on technical and market instruments criteria.

Basic functional capabilities of REMCs at all levels – SLDC, RLDC and NLDC should be same. This will give freedom to configure the REMC as per prevailing regulations. REMC system will be the single point window for RE developers to help them view and submit data pertaining to their plants (at pooling S/S) level. REMC system will also be the base reference and repository for commercial settlements.

3.6 Structure of the REMC

This section deals with the hierarchical structure, operational and technical requirements which are the basis for the design of the SCADA Systems for the new Renewable Energy Management Centres (REMCs) as it is proposed.

3.6.1 Establishment of new Renewable Energy Managements Centres (REMCs) in India

The new Renewable Energy Management Centres (REMCs) shall be designed to cover the requirements regarding Monitoring &Control of the Renewable Energy Sources in India:

- Standard SCADA System which is a state-of-the-art product of a reputable vendor's actual mainline,
- Open System Architecture applying state-of-the-art hardware with scalable performance and standard SCADA software functionality based on standard operating systems such as UNIX or Linux,
- Applying state of the art standard intercommunication via high speed WAN/LAN connections in redundant configuration using international standard protocols such as IEC 60870-5-104, UCA international Utility Communication Architecture which incorporate TASE.2 IEC60870-6 (Inter-Control Centre Communication Protocol, ICCP), CIM IEC 61970 etc.,
- Extensive expansion capability to cope with the anticipated growth of the Transmission and Distribution Network and the respective requirements for data acquisition and processing during the life time of the system, without limitations on capabilities, availability and performance of the System,
- High availability of the System applying a state-of-the-art and multi-stage Redundancy Concept,
- High availability of the interconnections between REMCs and the associated SLDC or RLDC for data exchange via Inter Control Centre Communication
- Integrated solution for unified Database Engineering and Management for multi user access in a multi stage redundancy environment, compliant with the EPRI Common Information Model (EPRI-CIM) and providing automated interfaces compliant with CIM specifications

The software system provided with the SCADA system for the REMCs shall include:

- Control Centre Software
- Human Machine Interface (HMI) Software
- SCADA Software
- Database and Database Management System
- Interface for the exchange of forecast data
- Expandability for new software packages which support the Management of Renewable Energy sources

Requirements for the SCADA Application Software are detailed in Section4.2 of this Report.

3.6.2 Potential for subsequently setting up a Back-Up Control Centre

According to state-of-the-art international practice for high availability control systems and the structure of the existing SCADA/EMS systems on NLDC, RLDC and SLDC level, a Back-Up Control Centre should be possible to be established in a later phase covering the requirement for back-up functionality for the Renewable Energy Management Centres in emergency situations or natural/manmade disasters.

Due to the fact that there is a shortage of communication infrastructure in the first phase it would be already difficult to link all the pooling stations with the REMCs in general. Establishing the Back-Up Control Centres requires the double amount of communication links.

From our present point of view the new REMCs shall be installed at one site with the opportunity to be expanded to a control system with back up control centre, but the final decision should be taken prior to the start of the procurement process.

The new REMCs must satisfy the following requirements in any case:

A) INTERNAL REDUNDANCY

The SCADA system shall provide internal redundancy. Thus the equipment of the SCADA systems shall be realized by applying a redundant “hot stand-by” concept for hardware and software.This is to ensure taking over of functionality in case of outage of crucial components by redundant components such as servers or communication links.

B) OPERATOR CONSOLES REDUNDANCY

The Operator Consoles shall be redundant in such a way, that each of the Operator Consoles installed shall be capable to cover the whole functionality of the SCADA System. Each Operator Console shall be capable to use the full system redundancy and internal redundancy.

There shall be no restrictions in redundancy being determined by neither the hardware nor the system.

The redundancy described above shall be supported by a facility for the arrangement and assignment of Power System areas and responsibilities to dedicated Operator Consoles and/or Operator Identifications.

3.6.3 Standard Product vs. tailor-made solutions

The consultant’s recommendation is, to tender SCADA systems for the REMCs which are of standard make, not to tender tailor-made solutions.

Although tailor-made solutions may be captivating with respect to their close adherence to customer specifics and processes, utilization of proprietary development will involve the risk of uncoupling from the mainstream.

State-of-the-art Standard SCADA systems of reputable vendors reflect mainstream functionality and will provide expansion capability for future Software Packages, release-updates and optional functional extension. Standard Systems available in the market nowadays allow for parameterization and customization of functionality, in order to closely meet the customer specifics.

In general, migration strategies for extension of the systems’ life cycle will be available on a higher likelihood compared to tailor-made systems. Thus, procurement of a standard system will increase safety for capital expenditures.

The SCADA systems to be tendered shall fulfil the following requirements:

- Standard Product of a reputable vendor’s actual mainline
- Product suitable for SCADA application to control a huge amount of distributed renewable energy sources
- Documentary evidence of at minimum 3 projects realized applying the offered Software System in an environment of similar complexity
- At least 2 of the minimum number of projects shall already be operational and in service, documentary evidence via communication with respective operating companies.

3.6.4 Hardware and Software Platforms

The consultant recommends that only open architecture SCADA systems, applying international and industry standard equipment, protocols, and procedures shall be accepted.

The tendered System shall be based on latest technology open architecture SCADA hardware comprising reliable computing power, system real-time display, historical data storage and retrieval, operator consoles, training and simulation facilities and office integration.

International standards shall be applied for hardware and software interfaces to allow a stepwise implementation and system expansion in terms of equipment, software functions and interconnection to other computer systems. The system shall be compliant with the Open Standard Foundation (OSF) distributed computing and network management definitions.

All hardware equipment shall be selected from reputable suppliers and brands in order to ensure the availability of support, spare parts, consumables and replacements.

More detailed requirements for the Hardware Equipment of the SCADA systems are included in section “Master Station” of this Report.

The software supplied under the Project shall provide all required functions for operation, maintenance, test and diagnostic for all supplied equipment, components and functions. Specific software requirements are dealt with in section “Application Software” of this Design Report.

Regarding Operating System, the consultant recommends:

- The SCADA systems to be tendered shall utilize a UNIX or Linux or MS Windows operating system in order to achieve a maximum of flexibility concerning future hard- and software expansion.
- UNIX or LINUX operating software shall be preferred for the Main Application Functions because of their wide spread application in SCADA systems and the proven evidence regarding real time applications and stability
- MS-Windows operating software shall be preferred for HMI applications because of the wide spread knowledge of the MS Windows’ “look and feel”.
- Specific operating systems and special tools shall be avoided in order not to be limited to a single contractor and ensure a maximum of adaptability to future equipment and software, thus avoiding obsolescence of the system.

3.6.5 Communication applying Standard Protocols

The SCADA systems to be tendered shall include a Communication Sub-system applying state-of-the-art standard communication protocols with a high bandwidth communication backbone

Standard protocols shall be used to exchange information between the equipment in the substations and the SCADA facilities.

- IEC60870-5-101 (in balanced and unbalanced mode) as minimum requirement
- IEC60870-5-104 wherever possible and supported by the communication
- IEC 61850 for future applications, since this standard will be further developed for SCADA applications.

The implementation of standard protocols IEC 60970-5-104 and -101 in the Communication Subsystem has to follow the specific interoperability criteria set up for the Project.

All of the RTUs newly provided under the project must have a valid certification stating their compliance with IEC 60870-5-101 and -104 from an internationally accredited organization such as KEMA or equivalent.
For interconnections to other Control Centres and here in particular the interconnection to the dedicated SCADA/EMS system the system to be provided under the Contract shall be suitable for data exchange using the following standards:

- IEC60870-6-TASE.2 (ICCP) protocol (in some cases also encrypted TASE.2) for data exchange between the SCADA systems, as well as with the other Systems which will be established in the future.
- For the exchange of historical data and other data, a file transfer Protocol (FTP) and SFTP shall be available.

- For interconnection with computer systems of other organizations that are / might be established in future, software is to be foreseen like XML/IP, SQL, ODBC.

In order to cope with future requirements, the ICCP Servers shall be capable for communication with encrypted TASE.2

For the purpose of exchanging data with external systems like off-line calculations or other applications, the data shall be exportable in a CIM (IEC 61970) compliant format.

In addition to the above, the new SCADA systems shall comply with the IEC Security Standards for "Power Systems Management and associated information exchange" as laid down in the IEC 62351 series.

3.6.6 Expandability of the new SCADA Systems

Special attention shall be paid to expandability of the new SCADA systems, which is one of the most crucial requirements to ensure long-term safety for operation as well as for long-term safety of the investment.

Expandability of the System must be provided as regards:

- Expandability in terms of additional I/O-data to be acquired from further substations / Pooling stations connected in future and from planned expansions of the Renewable Power Sources
- Expandability in terms of additional data to be processed within the SCADA systems as a consequence of the above.
- Expandability of hardware and software to be provided under the Project for incorporation of additional functions and/or equipment, which will be required to cope with future strategies for the integration of decentralized Renewable Energy Sources (RES) in the Indian Power System.

To cope with the expected growth of information quantities arising from the planned extensions and in order to ensure practicable and reasonable system performance, it may be advisable to realize a step-by-step approach for the implementation of the new SCADA systems.

The number and the functionality of the REMCs must be possible to be extended in the future with a minimum of effort and costs.

In addition the SCADA systems configuration shall be designed in such a way that it will be open and flexible for communication with other Control Centres and software systems.

3.6.7 Real Time Data Acquisition Unit

3.6.7.1 General Considerations

For proper monitoring and control of the RE process and the related power grid the REMC needs to have adequate and reliable **data acquired from the process in real time.**

Alternative approaches aiming at exploiting of data made available by metering devices installed in the field are not considered appropriate due to the fact that such data is focused on the electrical work (MWh not MW) and is usually not deterministic as typical values are only provided in 15 minutes intervals without relevance to real time.
The same applies to data acquired by RE developers, which typically are being collected from the Wind Generators and submitted to their remote management centres via public internet. Such data cannot be used as a basis for real time monitoring and control in SCADA systems of the REMCs.

For supervisory control and acquisition of data dedicated Data Acquisition Units are required at the pooling stations. In accordance with the general statements above in section 0and 3.5the consultant recommends the introduction of standard Remote Terminal Units (RTUs) with a standardized technical design.

To avoid complexity when interfacing the RTUs with the REMCs standardized technical connection conditions should be defined with binding specifications for:

- Authorized Telecommunication Protocols
- Standardized Signal List

The consultant recommends that above mentioned specifications for the Data Acquisition Units shall be embodied in the respective statutory regulations such as Grid Code etc.
In other words: No RE developer should be allowed to connect to the power grid unless compliance with the respective regulations has been evidenced.

It shall be the responsibility of the contractor to supply and install all necessary equipment and material including transducers, auxiliary relays, cables, wiring, terminal blocks, test switches, isolation devices, conduits, cable trays/trenches and any other equipment required to interface the RTUs with the pooling station / substation equipment, if necessary.

The type and amount of data to be acquired and processed, together with the functional- and performance requirements, are a major factor for the design of a System Control Centre and the associated communication network. It is the design basis

- for the sizing of the RTUs
- for definition of the processing capacity and performance of the master station
- for definition of the performance requirements and the design of the data transmission links and the telecommunication network

3.6.7.2 Standardized Teleinformation plan

Wherever new RTUs shall be installed or existing RTUs shall be connected to the future REMCs the consultant recommends to implement a tele-information plan, means a scheme where all remote controls and all data to be acquired (status indications, alarms, measurements) for the typical structure of a pooling station is defined.

To get an impression of the amount of signals and commands a typical signal list for a RES plant respectively pooling station could be as indicated below:

Information related to electrical system

Table 2: Typical Signal List for a RES plant pooling station

Telecom failure
Number of plant units available
Number of plant units unavailable
Total active energy production / Day
Total reactive energy production / Day
Total active energy production / Month
Total reactive energy production / Month
Total active energy consumption
Total reactive energy consumption
Operating State
Event List
Actual active power
Actual reactive power
Actual active power - max values/day
Actual reactive power - max values/day
Frequency
Operation (reset)

Bus bar voltages of each section
Current of each phase for indication
Current of each phase for cable protection
Voltage of each line side phase for indication
Voltage of each line side phase for synchronization
Bus bar voltage selected by bus bar isolators for synchronization
Power factor
Circuit breaker ON/OFF
Bus bar isolator ON/OFF
Line isolators ON/OFF
Grounding switch ON/OFF
Circuit breaker OFF trip coil 1
Circuit breaker OFF trip coil 2
Circuit breaker ON
Feeder faulty
Release of synchronization
Generation Curtailment Level 1 to 8

Information related to meteorological station

Table 3: Meteorological Station Information

Global horizontal irradiance
Global plane of array irradiance
ambient temperature (Deg C)
Back of PV module temperature
Wind speed
Wind direction
Battery charge
Dust fall

Commands and Setpoints

Table 4: List of Commands and Setpoints

Circuit Breaker position ON/OFF
Busbar Isolator ON/OFF
Line Isolator ON/OFF
Setpoint active power (for Generation Curtailment)
Setpoint reactive power (voltage stability)
Generation Curtailment Level 1 to 8

As an outcome of this, it is now possible to make a statement about how many signals to be expected in each pooling station. This determines the sizing of the required new RTUs.

Based on the assumption that the pooling stations will have a maximum number of 4 feeders the following quantity structure results (rounded up to the next decade):

Status Info	**80**
Measurements	70
Commands	40
Setpoints	10

The exact number of signals per pooling station shall be finally determined prior to initiation of the procurement process.

Note:

Currently, Renewable Energy generation data from interconnecting substations flows to the SLDC system. REMC system will acquire this data from the SLDC over ICCP link. However, going forward, it is recommended that this data flows to REMC directly from the Substation.

3.6.7.3 RTU design concept

Modern RTUs are microprocessor-based intelligent terminal equipment with modular design for easy installation, operation, maintenance and expansion. The RTU modules shall be installed in standard size racks. The module racks shall be easy accessible and therefore be installed in hinged frames within steel sheet cubicles. New, state of the art RTUs typically perform two functions, that is:

- receiving and processing of command messages coming from the Control Centre so as to feed them to the substation equipment where the RTU is located
- processing and transmitting of indication signal change messages, telemeasurements and telemetering signal messages picked-up by the RTU at the respective power station or substation

Depending on the way of the data acquisition, 3 different types of RTUs are listed, as shown in**Error! eference source not found.**:

- **Type A:** RTUs, which are able to acquire the process information on a classical way (parallel data acquisition)
- **Type B:** RTUs, which are able to acquire the process information on a serial way
- **Type C:** RTUs which are able to acquire the process information on both ways

The types B and C can be optionally extended with a Substation Control and Monitoring System as shown in **Error! Reference source not found.**in order to control and monitor the pooling station quipment from both, the substation and the REMC.

The type of the data acquisition depends mostly on the data collection methods at the primary equipment. In this project, digital protection relays are mainly used.

However, we propose to avoid any kind of adjustments at the primary equipment, as far as possible but to select the RTUs to be used in the project such that they are appropriately adapted to any type of data acquisition.

Therefore, in order to make provision for the various types of data acquisition as experienced in the project (serial, parallel or both), we propose to tender exclusively RTUs of **Type C**.

This proposal has the following advantages:

- The majority of data acquisition ways at the substations are covered by this type. Thus, a high degree of standardization over the entire network can be achieved.
- The required spare parts can be limited to a single RTU type.
- Training on the RTU as well as Operation and maintenance are simplified because only one type of RTU needs to be adjusted/trained on.

A brief description of the different types can be found in the following sections.

RTU SUBTYPES

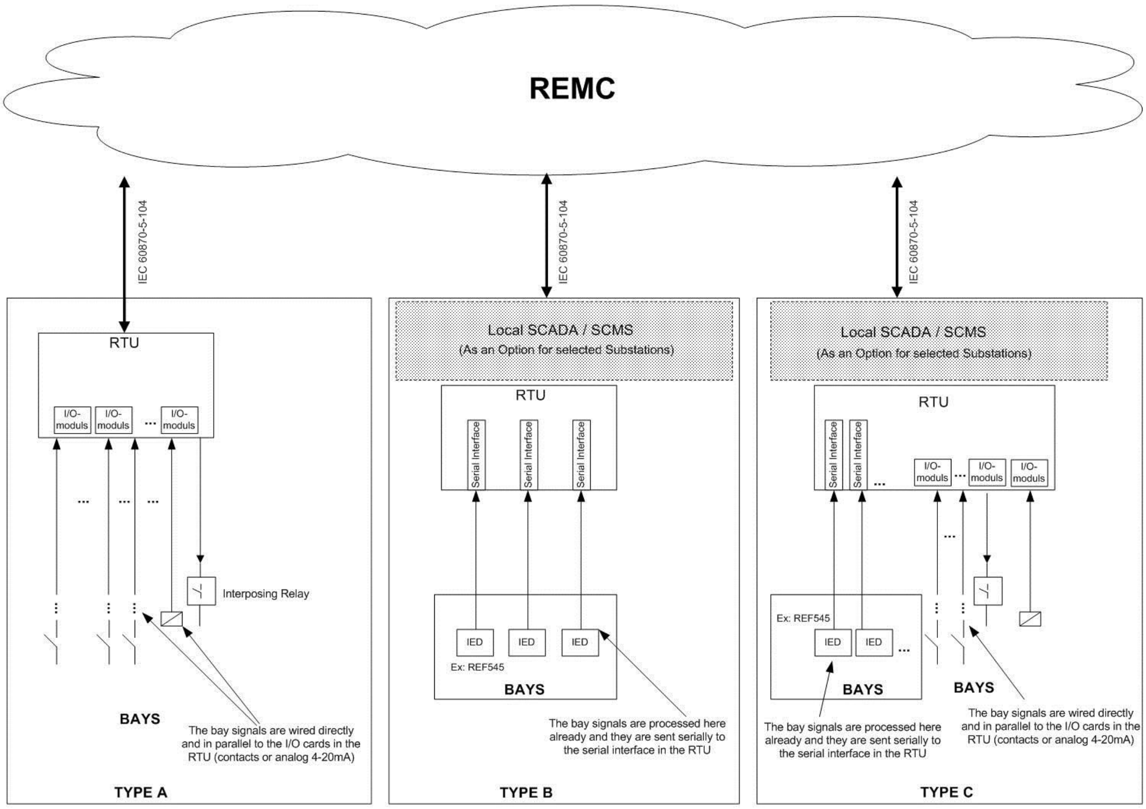


Figure 8: RTU Subtypes

RTU Subtype A

The process information is routed directly and in parallel to the I/O modules in the RTU (using potential free contacts, relays or transducers for analogue signals (4-20mA; 0-20mA; 0- -10mA; 0- +10mA; 0-5V, etc.).

RTU Subtype B

Type B includes process information which are already processed at the primary equipment using Intelligent Electronic Devices (IEDs) and then transmitted serially to an interface in the RTU.

RTU Subtype C

Type C includes both, Type A and Type B.

3.6.8 Interfaces

The SCADA System for the new REMCs is interconnected to other systems and processes via standardized interfaces. **Error! Reference source not found.**Figure below gives an overview.

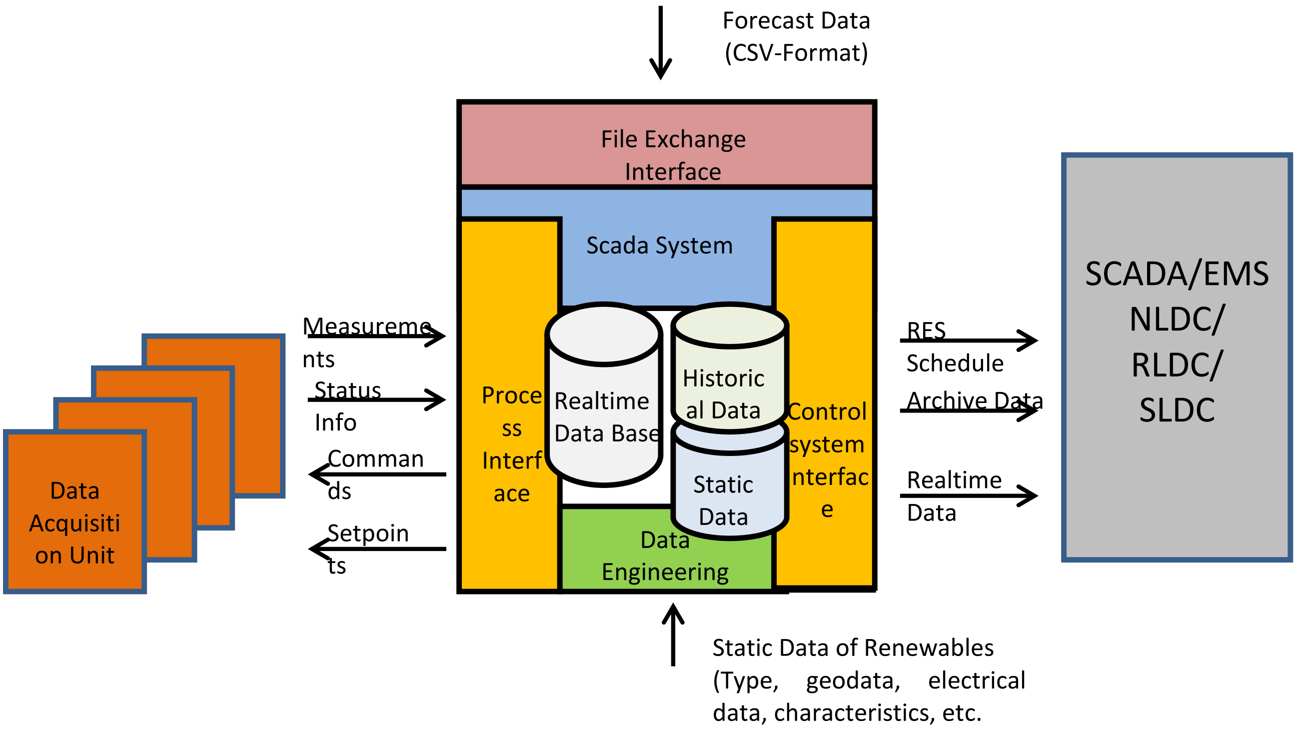


Figure 9: SCADA Interfaces

Most of these interfaces are already described in the sections above.

The SCADA System is connected to the Data Acquisition Units via the standardized telecommunication protocols IEC 60870-5-104 resp. -101. The communication links between the Data Acquisition Units and the SCADA System should have a bandwidth of:

- Min. 9,6 kB for IEC 60870-5-101
- Min. 64 kB for IEC 60870-5-104

For the data exchange between the REMC and the existing SCADA/EMS system the ICCP Protocol is used. Due to the fact that these systems are at the same location there should be enough bandwidth for the communication links.
The static data of the Renewable Energy Resources, the elements and structure of the pooling stations and all other process elements are defined by data engineering. The new SCADA System must have extensive software functions for comfortable data engineering manually. In addition a CIM-Interface for the import of new objects / exchange of objects with existing xLDCs needs to be included.
For additional data exchange like the Forecast Data a file Exchange Interface is used. The forecast data for the next day ahead are imported via 96 data for each 1/4 hour in CSV- or XLS- Format. The data import should be done by file transfer using the sftp - protocol via a Demilitarized Zone. The detailed concept is described in section 4.1.3.

4. Functional Specifications for the REMC

4.1 REMCs Master Station Equipment

4.1.1 Introduction

This section deals with the basic design and the components required to implement modern and reliable SCADA systems for the Renewable Energy Management Centres REMCs, satisfying the requirements as lay down in the previous sections.

Special attention shall be paid to expandability of the systems in terms of additional data to be processed from further substations / pooling stations connected in future and from planned expansions of in feed of Renewable Energy Sources (RES). In addition, the hard- and software to be provided under the Project shall be expandable for incorporation of additional functions and equipment which will be required to cope with future RES operation strategies and extension of the Power System.

The design of the new REMC Systems shall be based on the recommended layout as presented in section 3.6 “Structure of the REMC” of this Report.

The SCADA system configuration shall be designed as a Multi Stage Redundancy Configuration in such a manner that the number of Control Centres can be extended in the future with a minimum of effort and costs.

The SCADA system configuration must also be open and flexible for communication with

- the existing SCADA/EMS Systems on NLDC, RLDC or SLDC Level
- other Control Centres of neighbouring Transmission System Operators (TSOs)
- other Control Centres of generation and distribution companies or subsidiaries,
- Other organizations e.g. regulatory authorities, participants in a future structured market environment.

As a consequence of the above mentioned, only open architecture SCADA systems applying international and industry standard equipment, protocols, and procedures supporting such extension requirements shall be accepted for:

- reliable data acquisition for a large number of binary signals like circuit breakers, isolators, grounding switches, transformer tap-changer positions, alarms as well as analogue measurands including bus bar voltages, frequencies, active / reactive power flows, currents, temperatures, humidity and visibility, interfaced via hardware and software protocols to the Communication Servers.
- latest technology open architecture SCADA/ hardware comprising reliable computing power, system real-time display, historical data storage and retrieval, operator consoles, simulation facilities and office integration.
- Reliable operation and SCADA software, ensuring that the operational situation is correctly displayed in real time, not being only an economic requirement but also reflecting safety considerations.
- Communication Subsystem applying state-of-the-art international standard communication protocols with a high bandwidth communication backbone

4.1.2 Principle Layout of the REMC SCADA Systems

4.1.2.1 General Approach

It is envisaged to introduce a standard SCADA System for the supervisory and control of the Renewable Energy Resources for each SLDC, RLDC and NLDC where needed in a one to one arrangement.

Each of the Control Centres shall be designed as a redundant, hot standby Control Centre in order to provide for internal redundancy.

All Control Centres shall have identical layout regarding both hardware and software. Differences may only consist regarding the extent of associated peripherals such as operator consoles or printers.

It should be possible to establish a Backup Control Centre to get location based redundancy if it is desired at a later time.
The principle layout of the Master Stations shall basically be identical for all Control Centres. A sketch showing the principle layout of the Master Stations is presented in figure 8 below.

Bidders shall, however, not be limited from offering their standard solutions for realization of modern SCADA systems. In general, deviations to the minimum requirements stipulated with the Technical Specifications will not be accepted.

Vendor's standard solutions shall be allowed to be offered to the extent possible - as long as they at least fulfil or exceed the minimum requirements stipulated with the Functional Specifications.

However, bidders are obliged to clearly indicate such alternative solutions for the respective requirements and to state the compliance with the requirements of the Functional Specifications within a "Table of Compliance" to be included in their offer.

For the design of the offered system configuration the following aspects are crucial and must be considered:

- The offered systems must be able to cover the requirement of location based redundancy while providing Back-Up Control Centre functionality in case of emergency or disaster.
- The sizing of the systems must be suitable for guaranteeing the performance, availability and reliability requirements, regarding the quantities for the actual information extent including reserves
- Provision for increasing processing performance shall be provided (e.g. CPU performance, main memory, auxiliary memory)
- The systems shall be operated in an operating mode ensuring interruption-free switchover to redundant components without any operational disruption or loss of any data and information.
- The systems shall support an instant database synchronization method. That is, if the databases were updated in one of the Control Centres, the other Centres shall be synchronized immediately with the new update to ensure accuracy and consistency of databases at both locations.
- After power failure (despite of UPS) the components of the systems must pass over to a state which ensures problem-free restart after power restoration.

Bidders shall be obliged to give with their bids a detail description of their offered system configuration including a graphical presentation thereof.
All redundant and non-redundant components shall be clearly indicated.

4.1.2.2 Overview Master Station Equipment

This section outlines the typical structure of REMC SCADA system. Depending on the vendor's system concept, deviations are possible.

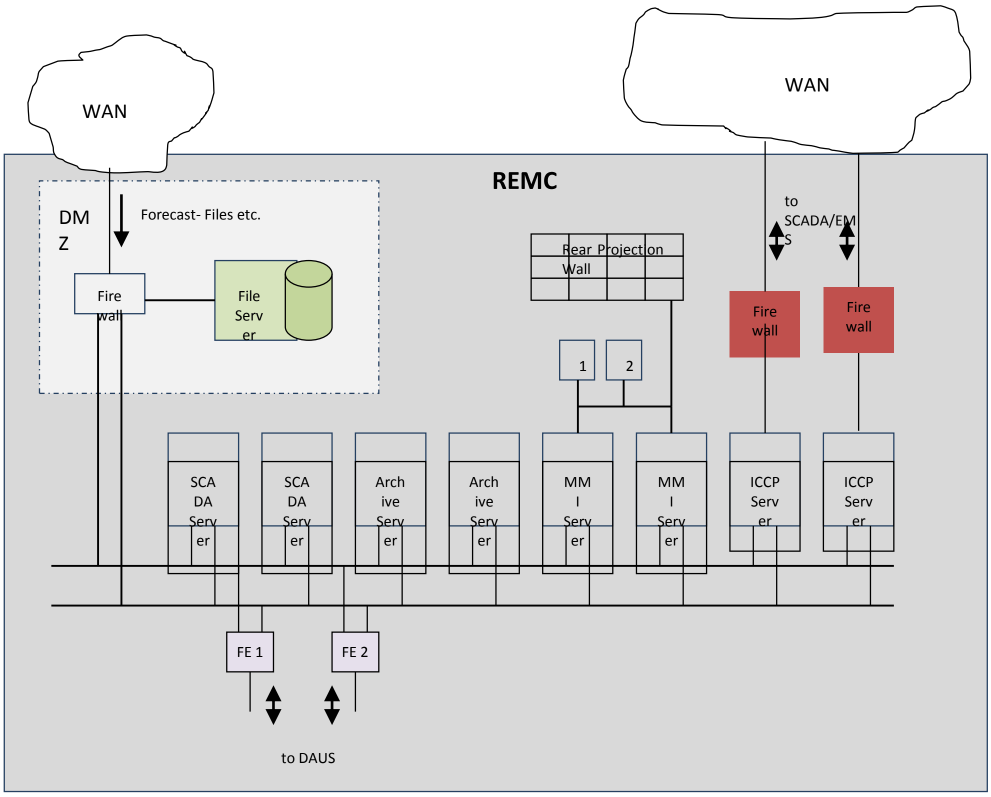


Figure 10: Structure of SCADA System

Table below shows an overview on the equipment to be provided under the Project as a minimum:

Table 5: Master Station Equipment

Equipment	Quantities for initial Scope per REMC
Main- Servers - redundant	2
Archive / Historical Servers - redundant	2
Mass Data Storage - redundant Hard Disk Arrays RAID	2
Backup and long term storage Media (Tape drives)	2
Process LAN HUB/Switch - redundant	2
Communication Servers / Telecontrol Interface - redundant	2
ICCP Servers for interconnection between REMC and existing SCADA/EMS System	2
File Exchange Servers - redundant	2
Time and Frequency Facilities - redundant	2
Operator Consoles (4 Monitors) with KVM Extenders	2
Engineering Consoles (4 Monitors)	2
Laser Printers A4 colour (Process LAN)	2
Colour Printers A3 colour (Process LAN)	2

Equipment	Quantities for initial Scope per REMC
DMZ-LAN - redundant	2
Gateways / Firewalls / Routers	4
Rear Projection Wall	1

Quantities indicated in the table above are not mandatory, because they depend on the solution, offered by the respective bidders in order to fulfil the specific requirements stipulated with the Technical Specifications. Bidders will be obliged to clearly indicate and describe the offered quantities in their bid.

The quantities given in the above overview table are preliminary and may need to be altered prior to initiating procurement.

Any additional equipment not explicitly mentioned in the table above, but necessary to achieve proper function of the systems while guaranteeing the required performance, reliability and availability, shall be quoted by the bidder.

Parts of the equipment for the SCADA systems shall be supplied and installed in short term after contract signature in order to serve as a Development System, as stipulated in chapter "Development System" see below.

4.1.2.3 Reserves for future expansion

Beyond the number of equipment specified with the above table for the initial project stage, the SCADA systems shall be expandable for accommodating of at least

- 2 additional Operator Consoles as specified
- 2 additional Engineering Consoles as specified
- 100 % spare capacity for Printers as specified

Referring to the numbers in the table valid for the System (1).

Exploiting the reserves shall not make necessary any re-engineering of the System but shall already be considered in the system engineering during project execution under the Contract. Bidders shall include respective costs in their offers.

4.1.3 Control Centre Equipment Hardware

4.1.3.1 Basic Design Principles

The following chapters outline the basic functional descriptions of the hardware equipment for the SCADA systems to be installed.

However, it is the Tenderer's responsibility to ensure the feasibility of the solution proposed with the bid regarding functionality, availability, reliability and performance with respect to the requirements stipulated in the Functional Specification.

Tenderers shall include in their bids detail technical descriptions of the offered equipment and furthermore the duly filled "Data Sheets", with the information required.

International standards shall be applied for hardware and software interfaces to allow a stepwise implementation and system expansion in terms of equipment, software functions and interconnection to other computer systems.

In general, all SCADA relevant software functions shall be based on open architecture standards so that applications can be moved between classes of the different servers. The software shall provide enhanced integration flexibility with other low costs and generic application software, which shall be shared with general off-line application tasks like statistics, reporting and additional analysis.

All hardware equipment shall be selected from reputable suppliers and brands in order to ensure the availability of support in the country of the Employer, spare parts, consumables and replacements.

All servers and other equipment to be supplied under the Contract and foreseen to be located at the computer rooms shall be rack mounted. Assembly and interconnection of the servers in the racks shall be done by the hardware manufacturer at the manufacturer's premises.

The performance requirements for the computers depend on the functions to be performed and on the amount of data to be processed. In order to cater for future system performance requirements, extensions and system disturbances, sufficient performance margin shall be available; 64 bit architectures shall be applied.

The system shall be compliant with the Open Standard Foundation (OSF) distributed computing and network management definitions.

At the initial stage 2 operator workstations and a Large Rear Projection Screen are foreseen at each of the REMCs.

Additional workstations shall be located in the engineering rooms for system engineering and maintenance purposes without interrupting the main system supervision and control functions. Software and hardware shall basically be identical and compatible to the operator consoles. Each of the identical consoles shall be capable of taking over the function of any other console.

4.1.3.2 Main Servers

The SCADA systems shall preferably be equipped with separate Main Servers and separate Applications Servers. The Main Servers shall be used for the SCADA functions and the Real Time Data Base (RTDB).
Additional applications shall preferably be located at separate application servers.

The main servers (main system) shall be implemented according to the full hot-standby redundancy concept respectively multi server concept and shall be equipped with sufficient main memory and hard disc capacity to hold the complete real-time data base and to perform basic data analysis, verification, filter and calculation functions like topology analysis, etc. Redundancy for the hard discs shall be provided by using Disk Arrays applying RAID technology or equivalent alternative solutions. The main system shall also provide full server capabilities including fast backup and restore functions.

In order to optimize process LAN and overall performance, all application programs which build-up the real-time database shall preferably also be implemented on the main system. Consequently, the redundant Main Servers shall form part of the general application. The servers shall be equipped with magnetic tapes and DVD RW drives.

According to the statements given with the above Chapter "general approach", the requirements stipulated above shall not limit bidders from offering their standard solutions with respect to the allocation of functions to dedicated serves and data-bases being centralized or distributed. Vendor's standard solutions will be allowed to be offered, provided they at least fulfil or exceed the minimum requirements stipulated with the Functional Specifications.

Bidders are in any case obliged to state the compliance of any alternative approaches with those requirements.

The Main Servers shall have a 64- bit structure and shall be operated under a standard operating system supporting real time applications, preferably UNIX or LINUX.

Each main system shall be interconnected to both process LANs. The redundancy shall be independent for each server and shall provide the server with internal data back-up features and automatic monitoring for switchover analysis and switchover execution.

An overview over the minimum technical data required will be set out in the “Data Sheets” of the Specification, where Tenderers shall fill in the technical data of the offered equipment and shall include the “Data Sheets” duly filled in their offer.

4.1.3.3 Application Servers

From point of view of performance, higher level applications shall preferably be allocated to additional application servers to be installed within the SCADA systems.

In order to meet the availability stipulated with the Functional Specifications and with respect to the importance of the applications, the application servers shall be implemented according to the full hot-standby redundancy concept.

According to the statements given with the above Chapter “general approach”, the requirements stipulated above shall not limit bidders from offering their standard solutions with respect to the allocation of functions to dedicated serves and data-bases being centralized or distributed. Vendor’s standard solutions will be allowed to be offered, provided they at least fulfil or exceed the minimum requirements stipulated with the Technical Specifications.

Bidders are in any case obliged to state the compliance of any alternative approaches with those requirements.

The Application Servers shall have a 64- bit structure and shall be operated under a standard operating system supporting real time applications.

Each of the applications servers system shall be interconnected to both process LANs. The redundancy shall be independent for each server and shall provide the server with internal data back-up features and automatic monitoring for switchover analysis and switchover execution. Each of the servers shall be fully equipped with the required processing power, main memory, hard disc space, console, keyboard, pointing device and networking facilities.

An overview over the minimum technical data required will be set out in the “Data Sheets” of the Functional Specification, where Tenderers shall fill in the technical data of the offered equipment and shall include the “Data Sheets” duly filled in their offer.

4.1.3.4 Operator Consoles

Each of the operator consoles shall consist of a high-end 64 bit workstation with three full graphics flat screen displays (TFT), at minimum 24 inch (diagonal width), at minimum resolution according to Full HD (1920 x 1080).

Each of the consoles shall be fully equipped with the required processing power, main memory, hard disc space, keyboard, pointing device and networking facilities. For noise reduction in the control room, the Workstation shall be installed in the Computer Rooms and connected via Keyboard-Video-Mouse (KVM)-Extenders with Keyboard, VDU and Mouse. For acoustical signalization each operator console shall be equipped with sound card and speakers.

An overview over the minimum technical data required will be set out in the “Data Sheets” of the Technical Specification, where Tenderers shall fill in the technical data of the offered equipment and shall include the “Data Sheets” duly filled in their offer.

Operator consoles shall be connected to the fully redundant Process Local Area Network (LAN).

The operator consoles shall be arranged according to **Error! Reference source not found.** while he number of TFT displays per Console shall be up to 4.

The Graphical User Interface (GUI) of the operator consoles shall comply with available standards like OSF/Motif, X-Windows or MS Windows. Each computer system associated with a console shall be an intelligent full-graphics device (high-end workstation), providing local, high-speed processing capability to off-load the main computer systems. Modern, intuitive and clearly structured windowing techniques shall be applied for displaying, analysis and operation purposes. Advanced system display and windowing features with an object-oriented Human-Machine Interface (HMI) shall be available for different system display levels including:

- semi-geographical system representation, e.g. Renewable Energy Sources and pooling stations as well as bulk power flow and voltage stability margins
- single-line representation for detailed information on power flow and voltage support for the different voltage levels
- Detailed substation representation for the provision of circuit breaker and isolator status, with option to show also the detail of the remote end substation on another window.
- individual object (element/type) representation for status and loading condition indications
- plots, lists, matrixes, etc. to display events, alarms, reports, trends
- Implementation of auxiliary functions such as manual data entry, integrated user handbook for renewable generation operation and control system handling, on-line help, etc.

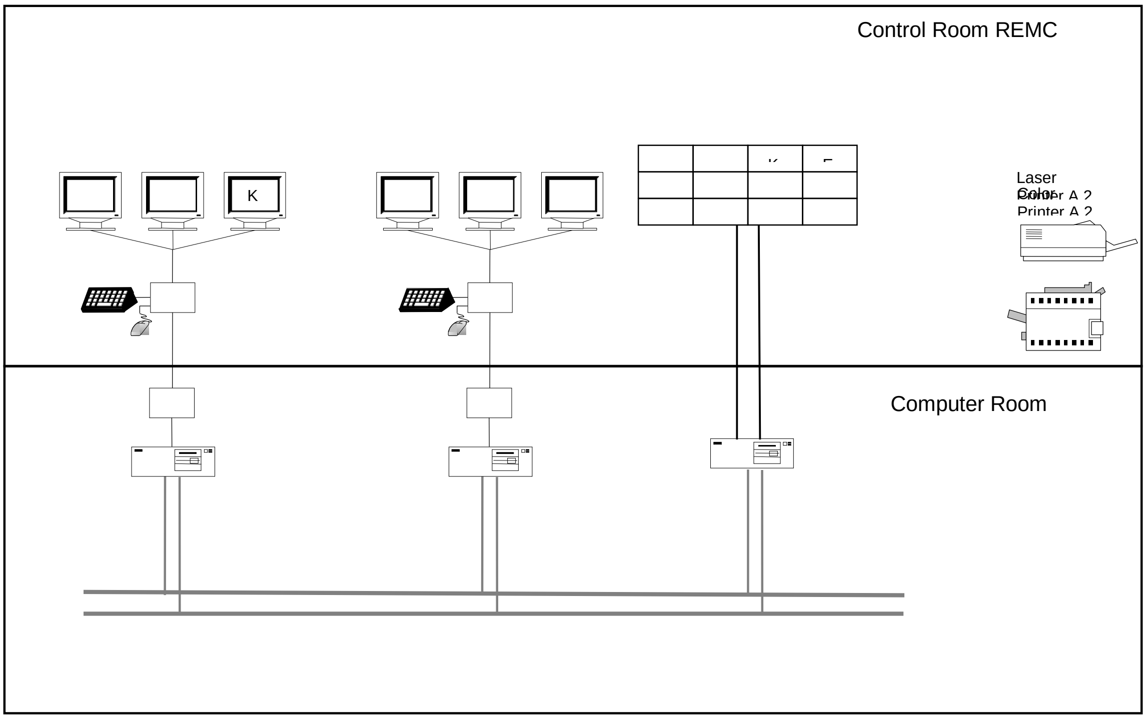


Figure 11: Operator Consoles, Principle Arrangement

There shall be no limitations for assigning different groups of windows and activities to a certain screen. Cursor operations by pointing device movements between the different screens of a console and also the Large Projection Screen shall be possible without requiring any further action by the operator. All activities to be performed by the operator shall be handled via interactive dialogues using the keyboard and/or pointing device.

4.1.3.5 Time and Frequency Facility

A time and frequency facility to determine the system wide coordinated time, power system time, time deviation, power system frequency, and power system frequency deviation shall be provided in each Control Centre.
The reference time shall be obtained from Contractor-supplied receivers using Global Positioning System (GPS) satellite signals. The time receiver shall include propagation delay compensation to

provide an overall accuracy of ± l ms and shall also include an offset to permit correction to local time. The internal time base shall have a stability of 1 ms per hour or better.

The time and frequency facilities at each of the Control Centres shall be redundant.

Note:
Existing time and frequency facilities in the control centres might be considered for the REMCs. Feasibility of this approach needs to be assessed in the engineering phase

4.1.3.6 Communication Servers for Telecontrol Interface

For each of the SCADA systems the Contractor shall provide redundant telecommunication interface units/servers to the data transmission network for RTU/SCS.

Redundant communication servers shall be connected through a communication back bone to the RTUs or SCSs collecting data from substations and control orders & request to substations.

The communication server shall be implemented based on a redundant processor configuration. Each processor of a redundant server shall be connected to one of the two process LANs in order to cope with the high availability criteria.

Communication server interfacing shall be based on

- the routable standard protocol IEC 60870-5-104 for all RTUs where IP based communication will be supported by the telecommunication infrastructure
- The standard protocol IEC 60870-5-101 for those RTUs where the IEC 104 protocol cannot be supported by the telecommunication infrastructure

The implementation of standard protocols IEC 60970-5-104 and -101 in the Communication Subsystem has to follow the specific interoperability criteria which will be set up for the Project.

All of the RTUs newly provided under the project must have a valid certification stating their compliance with IEC 60870-5-101 and -104 from an internationally accredited organization such as KEMA or equivalent.
Additional requirements for the Communication Servers are laid down in Chapter “SCADA Functions”.

The communication servers shall feature the configuration of the communication links in such a way that a single fault will not cause communication interruption. Consequently, the communication links shall be switchable between communication servers on an individual basis.

The communication server configuration shall allow for failure of a single server without loss of communications to any RTU/SCS. If one communication server has a failure, the communication line shall be reconfigured to connect all RTUs/SCSs to the remaining servers. Time synchronization of the new RTUs/SCSs shall be done by individual GPS receivers at the RTUs/SCSs.

Existing RTUs without GPS receivers shall be synchronized via the data transmission system using the synchronizing time signal from the Master Station’s GPS.
An overview over the minimum technical data required will be set out in the “Data Sheets” of the Functional Specification, where Tenderers shall fill in the technical data of the offered equipment and shall include the “Data Sheets” duly filled in their offer.

4.1.3.7 ICCP Servers

Redundant ICCP servers shall be connected through the communication backbone for data exchange between the REMC systems and SCADA/EMS systems at NLDC-, RLDC- or SLDC-level.

Since the interconnection between the Control Centres is crucial for data exchange, bidders shall include in their bid at least a set of redundant ICCP servers.

Each processor of a redundant set of servers shall be connected to the process LANs in order to cope with the high availability requirements.

Communication Server interfacing shall be based on standard IEC 60870-6 TASE.2/ICCP (Inter Control Centre Protocol)

In the event that REMCs need to be interfaced with subordinated Control Centres of DSOs this can be realized via ICCP connections on precondition that respective DSO Systems include ICCP capability as well.

4.1.3.8 Engineering Consoles

Engineering consoles shall be located at the computer room of the Control Centres or at the engineering rooms. They are to be used mainly for system configuration, database engineering and maintenance work.

The engineering consoles shall be connected to the redundant LAN of the SCADA systems.

In order to achieve a uniform and homogenous system concept, the hard-ware and software of the engineering consoles shall be of identical type and performance characteristics as that of the operator consoles.

4.1.3.9 DMZ LAN

For security reason all servers with access from external networks (except Communication and ICCP Servers) shall be located in a separated part of the network, called the “De-Militarized Zone” (DMZ). The DMZ shall be redundantly connected to the process LAN via firewalls/routers.

Any communication between SCADA System and users/applications located external shall be decoupled via the DMZ and the related firewalls.

In order to be able to differ between applications which will be accessed internal and those which will be accessed by external users, the DMZ shall be subdivided in at least two DMZ LAN segments.

The firewall cascades for decoupling the different zones shall be of different type and make to enhance security against intrusion and hacks.

Any communication to the external networks (Corporate IT, Office LAN) shall be secured and encrypted wherever possible. All kind of services provided shall be highly secured, for example using secure ftp instead of simple ftp, https instead of http etc. All servers and workstations shall be hardened by removing or disabling any unnecessary services.

4.1.3.10 Archive / Historical Servers

The Archive/Historical Servers shall be implemented according to the full hot-standby redundancy concept and shall be equipped with sufficient mass storage capacity, main memory and back-up facilities to hold the complete historical data and to perform basic data analysis, verification, filter and calculation functions etc. which are required for efficient historical data storage, recovery and handling.

The servers shall be provided with sufficient mass storage media to meet the sizing requirements for the archive dimensions as specified with the Technical Specification.

The servers shall preferably have a 64-bit structure and shall be equipped with a state-of-the-art standard relational data base system such as Oracle.

4.1.3.11 Remote Diagnostics

To provide for remote diagnostics and support by the Contractor the new SCADA systems shall be equipped with a Remote Diagnostics Interface. Interfacing and security requirements (such as RSA secure ID or others) will be detailed during Specification Phase.

Bidders shall outline the offered solution for remote diagnosis and the procedures for secure interconnection with the System. All expenses in connection with remote diagnostics including all costs for establishing and usage of local and international telephone lines for remote diagnostics up to the end the maintenance guarantee period and subsequently in maintenance contract period shall be included in the total contract price.

4.1.3.12 Rear Projection Screens / Video Walls

Each of the REMCs shall be equipped with Rear Projection Screens incorporated into Video Walls.

The Rear Projection Screens shall in normal operation show an overview over the complete Power System.

It shall be possible to display any of the windows visualized on a VDU in single window display mode as well as to display multiple windows, individually to be arranged on the Rear Projection Screen. The selection shall be possible from any of the operator consoles but shall not be occupied by any VDU permanently.

The rear projection screen shall be connected directly to the SCADA LAN via redundant data links.

The applied technology of the rear projection screen shall be rear projection using Digital Micro Mirror Devices such as DLP of Texas Instruments or equivalent alternative solutions, since this is state-of-the-art technology for 24/7 application in Control Centre environments . The Rear Projection Screens shall be composed using multiple cube elements to be seamlessly arranged.

The Rear Projection Screen shall fulfil the following minimum requirements:

- resolution Full HD1920 x 1080colour pixels per cube minimum
- designed for 24/7 application
- wide viewing angle of
- Full Viewing angle: 160 ° min
- Daylight operation (luminance >600 ANSI Lumen, contrast >1000:1, brightness uniformity > 90%)
- flicker-free projection, no screen burn in, long term operation without re-adjustment or follow-up adjustments
- lifetime of lamp > 6000h
- 2 Lamps: automatic switchover, replacement of lamp during operation shall be possible

Standard Rear Projection Screen cubes currently available in the market at reasonable prices are
- 50 inch diagonal cubes; dimensions approx. 800 x 1000 mm (height x width)
- 67 inch diagonal cubes; dimensions approx. 1030 x 1370 mm (height x width)

The necessary dimensions of the Large Projection Screens as well as further specifications will be detailed during Specification Phase later on, once decision has been made on the locations for the new REMCs.
In case of space and/or budget constraints, VPS can be replaced by flat screen monitors (up to 4 nos.) for the REMC. Alternately, feasibility of using the existing VPS of xLDCs for the REMC can be explored in the engineering phase.

Tenderers shall with their bid provide layout and construction drawings for the Video Walls for each of the Large Projection Screens at the respective Control Rooms with incorporation of the necessary Large Scale Displays as output.

The conceptual design of the Video Walls shall be in-line with the proposal for the refurbishment of the Control Rooms to be elaborated by the Tenderers.

In particular, the following aspects shall be covered with the conceptual design of the Video Walls:

- Optimization for visibility of the contents on the displays (viewing angles, bending of display segments etc.)
- Arrangement under consideration of ergonomic needs and rules
- Consideration of the Migration Strategy as outlined in the respective Chapters of the Report, particularly for the transition period of operation at the Control Centres (construction of new Walls vs. demolition of old Mimic Boards - if any).

4.1.4 Development System / Quality Assurance System

4.1.4.1 General Requirements

Parts of the SCADA systems shall be delivered and installed as a Development System at site not later than 3 months after signature of the Contract. The Development System shall then be used for initial training, database migration, database population, and display and report generation.

The development system shall be considered part of the SCADA system and subject to all its requirements unless stated otherwise in this section.

The development system hardware and software shall be delivered in three phases:

PHASE I: INITIAL DEVELOPMENT SYSTEM
The equipment and software for Phase I shall be delivered within three months after contract award. The Phase I development system shall consist of sufficient hardware and software for initial training of personnel and for preparation and test of database migration, database population, generation of displays and reports under the responsibility of the Contractor.

PHASE II: COMPLETE DEVELOPMENT SYSTEM
For Phase II, hardware and software shall be added to the development system configuration to enable the conduction of preliminary testing of the contractor-generated displays and database with contractor-supplied test equipment.

PHASE III: REPLICA SYSTEM FOR USE AS A QUALITY ASSURANCE SYSTEM
Phase III shall be accomplished during the installation of the SCADA systems. In Phase III, the development system shall become a complete and independent Replica System of the SCADA system configuration. The Replica System shall be capable to run each and all of the functions realized in the main systems in order to serve as a Quality Assurance System for testing any modifications prior to their implementation to the main SCADA systems.

All development system hardware and software shall be brought up to the revision of the corresponding SCADA system software. Once the Development System being upgraded to the Replica System, the user shall be able to maintain all SCADA system software, displays, database, and reports on the equipment used as development system in phase I and II and transfer the resulting changes directly to the appropriate processor(s) at the main SCADA systems.

Details will be set out in the Technical Specification during Specification Phase.

4.1.5 Master Station Facilities

4.1.5.1 Necessary Facilities for new Regional Distribution Control Centres

It is assumed that existing buildings can be reused for the new REMCs. Where necessary, these buildings have to be refurbished prior to installation of the equipment.

The Buildings itself will not be included in the scope of services and supply under the current Project.

Furthermore the following key facilities need to be considered in more detail prior to initiation of the procurement process for the current project:

- Uninterruptible Power Supply (UPS)
- Diesel Generator Unit
- Associated Low-Voltage Switchgear and Distribution Panels
- Communication facilities
- Air Condition facilities
- Fire detection and Firefighting facilities
- Emergency Lighting

4.1.5.2 Local RTU

In addition a separate Local RTU will be required for each of the designated locations of the REMCs. Those local RTU shall be utilized to collect and make available to the REMC System all the information which reside from the auxiliary equipment at the REMC buildings such as UPS, Diesel Generator Unit, Low-Voltage Switchgear at the REMC buildings, Communication Equipment at the Master Stations and other auxiliary facilities.

The local RTU shall be of the same make as the RTUs installed at the substations and shall satisfy the same requirements as specified in Section 4.3 of this Report.

A new local RTU might not be required in case that all the above parameters are already covered in the existing xLDC systems.

4.2 REMCs Application Software

4.2.1 Control Centre Software

4.2.1.1 General Software Requirements

The software to be supplied under the Project shall provide all required functions for operation, maintenance, test and diagnostic for all supplied equipment, components and functions. The following paragraph specifies the required general characteristics applicable to all software provided with the SCADA systems. It specifies the minimum requirements for the software and the software features.

Even if special features are not explicitly described in this section, the Contractor shall provide all software necessary to satisfy the SCADA system functional requirements described in the Technical Specification.

CONFORMANCE WITH INTERNATIONAL STANDARDS

The software to be provided under the Project shall comply with industry standards produced by national or international organizations, such as the IEEE, ISO or OSF. Specific standards are stated where applicable. The application programs and software servers shall use industry standard programming languages and shall run under operating systems using industry standard interfaces to the applications.

Standard protocols shall be used to exchange information between the equipment in the substations and the SCADA facilities:

- IEC60870-5-101 (preferably in balanced mode) as minimum requirement
- IEC60870-5-104 wherever possible and supported by the communication network
- IEC 61850 for future applications.

For interconnections to other Control Centres, the systems to be provided under the Contract shall be suitable for data exchange applying the following standards:

- IEC60870-6-TASE.2 (ICCP) protocol (in some cases also encrypted TASE.2) for data exchange between the REMCs and the SCADA/EMSSystems (SLDC, RLDC, NLDC)
- For the exchanges of forecast data and other data a Secure File Transfer Protocol (SFTP) shall be available.
- For interconnection with other computer systems that are / might be established in future, software such as XML/IP, SQL, ODBC shall be available

In addition to the above, the new SCADA Systems shall comply with the IEC Security Standards for “Power Systems Management and associated information exchange” as laid down in the IEC 62351 series, in particular with:

- IEC 62351-3: Data and Communication Security – Profiles Including TCP/IP
- IEC 62351-4: Data and Communication Security – Profiles Including MMS
- IEC 62351-5: Data and Communication Security – Security for IEC 60870-5 and Derivates
- IEC 62351-6: Data and Communication Security – Security for IEC 61850 Profiles
- IEC 62351-7: Data and Communication Security – Security Through Network and System Management

Bidders shall clearly indicate in their reference list under which projects the above protocols and procedures have been implemented and utilized.

COMMON INFORMATION MODEL (CIM)

For the purpose of supplying data to external systems like Geographical Information Systems (GIS), off-line calculations or other applications, the data shall be exportable in a CIM (IEC 61970) compliant format.

EXPANSION CAPABILITIES

All software provided under the Project shall be easily expandable to accommodate the anticipated SCADA system growth.

The sizing and configuration of the software shall be possible by means of parameterization via dedicated software tools and shall be possible to be specified by easily modified parameters contained in centralized system parameter files.

All SCADA system software shall be expandable beyond the initial system expansion planned and described in the Technical Specification.

Tenderers shall with their bid clearly identify all SCADA software sizing and addressing limitations for future expansion beyond the specified sizing.

MODULARITY

All software shall be modular so as to reduce the time and complexity involved in making changes to any program.

MAINTAINABILITY
The software provided under the Project shall be completely and entirely maintainable and expandable by Employer's personnel using the software services and the documentation provided with the SCADA systems.

All tools and documents necessary to develop and maintain software such as compiler, CASE tool-kits and version control software shall be delivered with the SCADA software.

INTERRUPTABILITY
Software that requires long execution times to perform complex calculations or extensive data processing shall be interruptible and shall safely recognize and process a user request on abortion of such calculations or processing.

SECURITY
The software shall provide security mechanisms meeting at least the following requirements:

- Protection against unauthorized access and intrusion
- Check of utilization rights
- Check of access rights
- Check of registration
- Check on user- and group- passwords
- Attack detection and prevention
- Security settings of applications

The results of the security checks shall be alarmed and documented in a detailed security protocol.

The system shall have the capabilities to disable any process/service at any time.

For interconnection between Process LAN and other networks, firewall systems shall be used. The purpose of these firewall systems is to provide an additional layer of security (in addition to the security and access control mechanism provided by the SCADA software system).

By default the firewall shall deny any network traffic from other networks destined to the SCADA network. Only traffic which has been explicitly allowed in the firewall configuration shall pass the firewall. The firewall system shall monitor the state of all established connections and shall automatically update its internal connection table accordingly.

There shall not be more than one network connected to one firewall interface. Additional interconnections to other networks shall be equipped with additional firewall interfaces.

SOFTWARE LICENSES
Tenderers shall with their bid provide a detailed breakdown of all necessary software licenses (own licenses as well as third party licenses) for the entire System with prices and details of license (single / multi-user, no. of licensed users etc.).
The license fees of all required licenses have to be included in the offered price for the entire lifetime of the system.

4.2.1.2 Operating System Software

The SCADA systems to be provided under the Project shall utilize a UNIX or Linux or MS Windows operating system in order to achieve a maximum of flexibility concerning future hard- and software expansion.

For the Main Application Functions UNIX or LINUX operating software will be preferred because of their wide spread application in SCADA, DMS and EMS Systems all over the world and the proven evidence regarding real time applications and stability.

For the HMI applications MS-Windows operating software will be preferred because of the advanced connectivity capabilities and the wide spread knowledge of the MS Windows' "look and feel".

Specific operating systems and special tools shall be avoided in order not to be limited to a single contractor and ensure a maximum of adaptability to future equipment and software, thus avoiding early obsolescence of the system.

4.2.1.3 System Level Software

The system-level software provided shall include real-time capabilities and device input/output control programs.

Upgrades shall be possible to be easily implemented without requiring modifications to hardware, application programs, support programs, or operating system interfaces.

Upgrades shall not require the whole system to be shut down.

On-line facilities shall permit adding and deleting programs from the list of periodic or scheduled programs. The scheduling of periodic programs shall be automatically corrected for manual and automatic adjustments of time.

TIME AND CALENDAR FUNCTION
The time of day and date shall be maintained for use by other software.
Leap years, century rollover and holidays shall be recognized.

The handling of daylight saving shall be included.

NETWORK SOFTWARE AND NETWORK SERVICES
The system software shall provide programs that support the data communications network within the SCADA systems and its connections to external networks. Network software for communications, security, services, and management shall be provided.

Users shall be able to communicate within a network of user interfaces, processors, and memory resources that are part of the SCADA system configuration and operate as described in the Technical Specification.
The SCADA system networking communications software shall support standardized local area network (LAN) protocols, such as TCP/IP and be capable of linking dissimilar hardware nodes, such as printers, terminals, workstations and applications processors, into the SCADA system data communications network.

Network services shall be provided for all users of the SCADA system LAN(s) and its interfaces to the external Digital Communication Network (DCN). These services shall provide user access to software that supports the functional requirements set forth in the Technical Specification. Access to these services shall be controlled through the SCADA system network security software. Monitoring and routing control for the users of these services shall be provided by the SCADA system network management software.
The minimum set of networking services shall include:

- network file transfer
- remote program execution
- Synchronized network time keeping.

NETWORK SECURITY
The network configuration shall be inherently open structure that provides network access to many users. The system network security software shall restrict user access to the system programs and data within the SCADA system portion of the network. A user authentication scheme shall be provided to validate the user before the user may access any SCADA system programs or data.

User access security shall control:

- the programs and data that the user may access through a software window or terminal, and

- The functions that the user may perform with those programs or data.

User identity keys and terminal usage codes shall be provided to enable or restrict access of a user to each task that may be performed at that terminal. Each user identity key and terminal usage code shall be capable of having any or all of the programming tasks assigned to it.

NETWORK MANAGEMENT SOFTWARE
The Network Management Software shall provide the following SCADA system capabilities:

- fault management
- configuration management
- performance monitoring
- accounting management
- security management

The Network Management Software shall be based on the Simple Network Management Protocol (SNMP) or the Common Management Information Services and Protocol over TCP/IP with additional proxy software extensions as needed to manage SCADA system resources (such as the SCADA system RTU channels).

The Network Management Software shall:

- Maintain performance, resource usage and error statistics for all managed links and devices and provide this information to the user by means of displays, periodic reports and on-demand reports.
- Maintain a graphical display of network connectivity and device status.
- Be capable of issuing alarms when predefined error conditions or resource usage problems occur.

4.2.1.4 Firewall and Antivirus Software

In order to protect the SCADA systems from malware such as viruses, Trojans, spy ware etc. all incoming traffic shall be scanned by suitable antivirus software of a reputed vendor. The definition files of this software shall be updated automatically on a daily basis. Tenderers shall include necessary licenses for the lifetime of the system. Firewalls shall be used, to prevent direct access to the SCADA kernel system from outside.

All settings of the firewalls have to be closely coordinated with the Employer’s IT department.

4.2.1.5 Backup Software

The SCADA systems shall include Backup Software, suitable to store images (real time) of all servers and workstations on the mass storage media (e.g. disk array) for rapid system restoration. It shall also be suitable to automatically backup the complete system on mass storage devices such as optical drives or tape drives (fully and incremental).

The backup software shall be a state of the art standard software product of a reputable vendor, such as ‘VERITAS’ or equivalent.

4.2.1.6 Remote Administration Software

The SCADA systems shall include Remote Administration Software to enable the safe remote access of system administrators.

The software package shall have capabilities comparable to HP “Open View” and shall provide all state of the art mechanisms to prevent any unauthorized access, such as call-back, VPN etc. Independent from the type of access, the additional identification by an RSA secure ID shall be used.

For each remote session a detailed log containing all actions shall be recorded.

4.2.2 Human Machine Interface (HMI)

The Human-Machine-Interface (HMI) is the interface between the SCADA system and the users / operators. This HMI interface covers the visualization and the user interaction.

The principal interface between the user and the SCADA System will be realized by the operator- and engineering consoles. The consoles shall be based on full graphics workstations as defined in chapter “Master Stations Equipment”. Printing devices, display colour printers and projection screen displays shall augment and enhance the user's ability to interact with the SCADA system.

The fundamental interface between the Operator and the System are representations of the Renewable Energy Sources, the Pooling Stations, its surroundings and the Control System equipment presented on workstation monitors and on the Rear Projection Screen Units.

A complete and flexible windowing mechanism shall be provided to allow the user to keep track independently of several network control tasks. It shall be possible to display a picture in a window on any of the console monitors. It shall also be possible, through the windowing mechanism, for a user to access applications external to the network control system.

The HMI shall be compliant with the widely recognized X-Windows standard (compliant with OSF/MOTIF) or Windows standard, associated with a Graphical User Interface (GUI) designed from de facto standards, such as OSF/MOTIF.

The HMI shall also be compliant with the IEC 61970 series which defines:

- the integration of applications developed by different suppliers in the control centre environment,
- The exchange of information to systems external to the control centre environment.

The scope of these specifications includes other transmission systems as well as distribution and generation systems external to the control centre that need to exchange real-time operational data with the control centre.

The HMI shall further comply with

- the EMS-API reference model IEC 61970-1,
- the Common Information Model base(CIM) IEC 61970-301,
- the Component Interface Specification (CIS) framework IEC 61970-401,

Displays shall be used to accomplish the main following tasks:

- view the state of the monitored power system,
- monitor and control power system equipment,
- Monitor and control the system configuration.

The other HMI equipment, such as printers, loggers, hard copy devices, digital displays and projection screen shall be used to enhance the user's interaction with the Power System.

Major features to be provided by the HMI Systems are (as an excerpt in keywords only):

- User Interface Design
- Window Features
- User Interaction Features
- System Access Security
- User interactions
- Full graphics displays
- Temporary Objects displays
- Printing
- Trend displays
- Operator notes
- Graphic display editor
- Web Interface

The features listed above, required for the HMI System to be supplied as integral part of the SCADA System and shall be described in detail by the bidder in his offer.

4.2.3 SCADA Software

The SCADA software to be provided under the Project is one of the most important items for the functionality of the system. The software shall fulfil, among others, the following functions for ensuring a reliable and safe operation of the system:

- Administration of the remote data acquisition, considering the system topology and facilitating frequent modifications and additions to the system as it is in the nature of an Energy Management System
- Data base management and data base maintenance.
- Telecontrol for all kind of commands in a uniform operation procedure independent from the control systems and principles applied at the outstations.
- Sequential control with operator guidance in control sequence definition, checking of stepwise execution of command sequences and interlocking conditions including reporting and storage of command outputs and events.
- Optimization of complex switching operation such as feeder switching, bus bar changing etc. by application of pre-definable control sequences, with automatic check of topological and interlocking conditions.
- Switching Order Management to provide operator guidance for all cases of switching operations in form of documents containing the whole switching orders and actions to be followed by the operators.
- Group Commands: The SCADA systems shall provide a function to allow the operator to define sets of rules and conditions for execution of automatic switching actions in case of certain definable conditions are fulfilled. (e.g. opening all the transformers LV breakers of a group at a time in a substation, meant for performing manual load shedding and in case of emergencies
- Status indication, event and alarm processing including the actual real time of their occurrence.
- Processing of measurements with data collection, validation and performance monitoring, supervision of limit values and alarming of limit violations, calculation of operational values such as sums of load, calculation of trends, etc.
- Network topology monitoring and dynamical colouring indicating separated networks, energized and de-energized network elements and other element statuses such as overload, earthed, not updated etc.
- Report generation for continuous or spontaneous printouts of event and alarm logs, regular and spontaneous measurement reports, and network and control system performance reports.
- Historical data storage with selectable time resolution and duration for post mortem reviews, network and control system performance analysis, statistics. Historical data shall also be accessible to operational planning / analysis, maintenance planning and to the management in a “Power System Data Warehouse” separated from the real-time control system via gateways, DMZ LAN bridges or routers.

The following general requirements apply to the system functions defined in this section as well as to functions stated in other sections:

- All parameters in the SCADA system shall be defined in the database and shall be adjustable. Adjustments made to parameters by the operator or software engineer shall become effective without having to reassemble or recompile programs or regenerate all or portions of the database.
- All input data and parameters, whether collected automatically by the SCADA system or being the result of an operator action, shall be checked for reasonability and rejected if they are unreasonable. All intermediate and final results shall be checked to prevent unreasonable data from being propagated or displayed to the operator. When unreasonable input data or results are detected, diagnostic messages, clearly describing the problem, shall

be generated. All calculations using the unreasonable data shall either be temporarily suspended or continue to use the last reasonable data as designated by the user.

- Access to the functions shall be limited to authorized users. Users that do not have access to a function may view displays associated with the functions. Functions shall either be designated as single-user or they shall be assumed to be multi-user functions. For a single-user function, the user with access to the function must relinquish access to it before access can be granted to another user. For a multi-user function, any number of users may have access to the function simultaneously.

The SCADA System shall include a data model which shall comprise but not be limited to

- Buses
- Nodes
- Lines / power cables
- Busbar couplers
- Series capacitors/reactors
- Shunt capacitors/reactors
- Static VAR compensators
- Transformers
- Loads
- Generators
- Network islands
- Voltage levels

The functionality and requirements concerning the SCADA software shall be described in detail in the offer.

However, Bidders shall not be limited from offering their standard SCADA solutions. In general, deviations to the minimum requirements stipulated with the Functional Specifications shall not be accepted.

Vendor’s standard solutions shall be allowed to be offered to the extent possible - as long as they at least fulfil or exceed the minimum requirements stipulated with the Functional Specifications.

However, bidders are obliged to clearly indicate such alternative solutions for the respective requirements and to state the compliance with the requirements of the Functional Specifications within the “Table of Compliance”.

Major features to be provided by the SCADA Software of the new REMC Systems are (as an excerpt in keywords only):

- General requirements
- Data acquisition
- Data processing
- Alarms and Events Processing
- Supervisory Control
- Tagging
- Dynamic Network Colouring
- Intelligent Alarm Processor
- Report Generation Utilities

The features listed above, required for the SCADA Software to be supplied as integral part of the RDCC Systems shall be described in detail in the offered solution and will be subject to detail technical evaluation.

4.2.4 Database and Database Management System

4.2.4.1 General Requirements for the Database System

The database system of the new SCADA shall consist of

Global SCADA (modelling) database,
Containing static data that depict the Power System model as well as all structure definitions and content for the functional requirements of the SCADA system

Real Time Database (RTDB)
Being the repository for variable data provided by the real time acquisition, for manually entered data (by operators) and for those resulting from application software processing SCADA

The Database System shall cover the redundancy requirements stipulated for the new SCADA in the previous chapters, in particular the required location based redundancy for the Main and Emergency Backup System.

In case the communication network between the different locations of the Control Centres or parts of it shall be separated temporarily, the systems must work autonomously during this time, and the data must be matched automatically after restoration of the network.

The Database System in its whole must be designed to meet the requirements regarding availability and performance stipulated for the new System in the Technical Specifications.

The database system provided under the Project shall be designed in a way ensuring a complete independence between user programs and data, thus allowing both evolution of application software (SCADA and/or EMS) and evolution in nature and quality of data

The global database shall include all data required by the data acquisition and user interface functions, the SCADA application functions, and all other Contractor-supplied software. The operational (real-time) database shall be derived from the global database. The global data base shall be a standard relational data base like ORACLE and not a proprietary one.

The Contractor shall implement the initial database structure considering the amount of data to be acquired and processed given in the tender documentation which will be defined in the Specification Phase.

There shall be no built in limits for future expansion of the database beyond the initial data base set-up. The Bidder’s proposal shall state all constraints to expand the size of the SCADA system databases and the application software data tables.

4.2.4.2 General Requirements for Database Management

The new SCADA Systems shall include a powerful Database Management System with consistent, coordinated procedures to manage the database regardless of the location of the data or the residency of database management functions.

The Database Management System shall co-operate with a standard relational database such as Oracle or equivalents and shall cover the following major tasks:

- define the structure of the database
- locate, sort, retrieve, update, insert, and delete data
- ensure database integrity
- provide a common interface for all applications that use the database in the SCADA system
- provide a user interface for workstations, processor terminals, and programming terminals
- Provide for backup and recovery of database files.

The database management system to be provided under the Project must be capable of covering all tasks arising from the monitoring and control of the Power System inclusive software, utilities and test equipment.

All primary and secondary elements of the Power System must be possible to be described and presented in the database(s).
Multiple or redundant data entries shall be prevented.

The database management system shall be accessible interactively from any workstation, subject to user authority assigned.

Execution of database management on any operator console or workstation of the system must not interfere with the online operation functions of the SCADA System.

It shall be possible to have multi-user access to the database management system in order to allow multiple users for parallel working on database engineering at the same time. The System shall prevent overwriting of entries from different users. Limitations and restrictions in this respect, given by the offered System shall be clearly stated by bidders in their bid.

The database management system shall comply with the EPRI Common Information Model (EPRI-CIM) and shall provide an automated interface compliant with CIM specifications.

The bidders offer shall include a detail description of Database Management functions provided by the new REMC Systems, considering aspects such as population, modification, maintenance, retrieval, validation, generation and distribution of databases.

4.2.5 Software Package for the operation of Renewable Energy Sources (RESs)

4.2.5.1 General Requirements

As part of the new control systems for the REMCs some functions which are specifically tailored to the operation of Renewable Energy Sources are required.

In the initial step the REMC systems shall provide functionality in order to efficiently solve the tasks of

- Importing the result of the forecasts which are provided by the separate Forecast System
- Converting this forecasts to different schedules which are required from the SLDCs, RLDCS or NLDC
- Manually updating of these schedules
- Transferring of the schedules to the existing SCADA/EMS systems of SLDCs, RLDCS or NLDC

In addition to the above mentioned features, the software of the new REMC system shall include software solutions for

- Monitoring of all available energy resources and their usage in the respective area of responsibility
- Support online monitoring of control reserves in the area of responsibility and in future, be able to provide recommended schedules for these based on technical and market despatching criteria in the context and boundaries of a legal framework to be established in the Indian power market

Above mentioned functionalities have been described in the conceptual architecture sub section. These will have to be further detailed in the engineering phase under the project.

4.2.5.2 Future Enhancements

The Software Package for the operation of Renewable Energy Sources has to be open for future enhancements.

Depending on the rules of the Indian energy market and the grid code consideration could also be given to the use of functionality specifically tailored to the operation of Virtual Power Plants (VPPs).

REMC system will be capable of integrating with standard GIS based visualization module to support GIS based renewable energy monitoring.

REMC can also support connectivity to Distribution System Operator systems on standard ICCP protocol.

The vendor shall give an overview of already existing additional functionality in his standard software portfolio.

4.2.6 Implementation of Synchro-Phasor Measurement Units (PMU)

As investigated during site visits and reported in section 3 of this report, Synchro-Phasor Measurement Units (PMUs) have already been deployed in the Indian power grid in various locations.
Currently a number of 63 PMUs are already in place and it is envisaged to increase the number of PMUs up to 1400 during the forthcoming years.
It is obvious that through deployment of PMUs and the subsequent implementation of a Wide Area Measurement System (WAMS) quality of monitoring the power grid will be significantly improving.

However, evaluation and analysis of potential threats and weak points in the network is currently managed by a system procured from SEL which is separate from the existing SCADA systems in the xLDCs. This is mainly due to the fact, that SCADA systems currently available in the market do not include capability for data acquisition from PMUs and their analysis & presentation as a standard functionality.

As the REMCs to be procured under the current project shall ensure future safeness in terms of functionality over the expected life cycle of around 10 to 15 years, it is recommended to include the feature of implementation of PMUs in the catalogue of mandatory functionalities to be fulfilled by the offered REMC systems.

It is not expected that bidders can offer a solution fully integrated in the SCADA system, as for PMUs typically different standards are applied as it is the case for SCADA systems (IEEE C37.118 and not IEC 60870-5-series).
Furthermore standard SCADA system HMI solutions are usually not prepared for analysis and presentation of the results in typical WAMS applications.

It is therefore proposed to call with the tender for a solution with separate systems for PMU presentation and SCADA presentation while the PMU/WAMS application will be accommodated in one or in a set of servers running in the same software environment as the SCADA system. Interfacing between the individual systems should be based on international standard protocols in order to provide the opportunity for future standard solutions which might be offered in the world market.

With regard to extension of the number of PMU units in future this is currently constrained by the telecommunication system, forming the major bottleneck in terms of bandwidth availability. PMU units need to acquire data from the network in the range of 50 times per second and therefore require adequate communication links based on fibre optic media.

It is therefore proposed to identify in a first step such regions/states, where necessary communication infrastructure will be available and which are qualified for further deployment of PMUs.

Once identified respective REMCs should then be equipped for implementation of PMUs in the SCADA system following an implementation plan structured in a separate “PMU track” (see section “Implementation Strategy”.

4.2.7 Contractor’s Future Software Changes

The client shall be placed on the Contractor’s regular mailing list to receive all announcements, including new software releases and other improvements that could be made to the software furnished with the SCADA system.

Solutions to problems with Contractor-supplied software, whether discovered and corrected on the SCADA system or elsewhere, shall be documented and supplied to the client without additional charge.

This service shall include announcements pertaining to Contractor-produced software for 15 years after final system acceptance and shall include announcements pertaining to software produced by third-party suppliers for the same period.

4.2.8 SCADA System Maintenance and Technical Support Agreement

For a period of five years, beginning after signing the final system acceptance protocol, a System Maintenance and Technical Support Agreement for all of the SCADA systems shall be offered and quoted. The Agreement shall include an option to be extended yearly up to five more years.

The agreement shall cover the following services and conditions:

- Maintenance and Technical Support Requirements
- Preventive Maintenance
- Malfunctions repair
- Security Patches
- Technical Support
- Hardware and Spare Parts
- Warranties
- Penalty Clauses
- Contract Validity

4.2.9 Performance Requirements for the REMC SCADA system

4.2.9.1 General

The time parameters referred to in this chapter are those concerned with the performance of the SCADA systems together with the transfer and processing of information.

In general, the overall transfer time is given by the sum of the times taken by the information to pass through the individual sections of the SCADA systems. It reflects not only the equipment performance, but is also influenced by such factors as:

1. The data network configuration
2. The transmission methods
3. The transmission link bandwidth
4. The pre-processing functions in the sending station
5. The processing functions in the receiving station
6. The noise level on the transmission line
7. The accumulation of events in a given time period
8. The priority facilities of the data transmission protocol.

INDICATIONS

The telecontrol equipment shall detect and process any change of a state information which is maintained for longer than the given scan cycle and acquisition time. Important status indications and alarms shall be brought to the attention of the operator within 1 second as an average, excluding data transmission time from the RTU to the SCADA systems.

CONTROLS
The operator shall be able to supervise the execution of an initiated command. This requires adequate data transmission supervisory functions, as well as return information or measurands in order to confirm the following:

- acceptance and correct transfer of the command message by the telecontrol equipment;
- Execution of the initiated action in the peripheral equipment.

Any control command shall be processed with priority. It shall be initiated by the RTU output module within 1 second as an average value. The completion time of the command at the station depends on the primary HV/MV equipment.

MEASUREMENTS
The cycle time for measurements (= time after significant change of the value until presentation on the screens) shall not exceed 2 seconds.
For a set of special measurements (e.g. analogues needed for AGC functionality, measurements for tie lines etc.) shorter cycle times will be necessary.

TELECOUNTING/ACCUMULATOR VALUES (TRANSMISSION OF INTEGRATED TOTALS)
Energy meter values shall generally be transmitted in intervals of 15 minutes for statistical and accounting purposes. For operational purposes, one minute counter values shall be acquired to establish trend curves for monitoring of contractual obligations.

SYSTEM START-UP TIME
The time for the start-up of the SCADA system after initialization shall not exceed 15 minutes, counting from the start-up command until actualization of all process information, reconciliation of all data bases and archives between the systems within a Multi-Redundancy-Configuration and the system being ready to accept and execute operator’s requests for control commands.

SYSTEM TAKE OVER TIME
Time for the taking over of process control from one System to another within a Main/Back-Up or a Multi-Redundancy Configuration. Time counted from the request for take over until the system being ready to accept and execute control commands.
The System Take over Time shall not exceed 15 seconds.

4.2.9.2 HMI Performance Requirements

The HMI performance requirements concern the responsiveness of the SCADA systems in connection with display requests, display updates, image scaling and translation, alarms and events, reports, display hardcopies, trend displays and large projection screen display updates.

The SCADA systems shall meet the specified response time requirements under both scenarios, normal and avalanche condition.

DISPLAY RESPONSE TIME
Display response time shall be measured from display request to appearance of the requested display on the screen complete with data values. Display data entry response time shall be measured

from data entry to completion of the data entry operation, signified by appearance of the newly-entered data in its final displayed form.

Requests for displays with lengthy response times shall be acknowledged immediately with an indication that the request is being processed. At no time the SCADA systems shall delay the acceptance of a display request or "lock out" console operations due to the processing of lengthy application functions.

ALARM AND EVENT RESPONSE TIME

Alarm and event response times shall be measured from the time the SCADA systems receive the scan response message at the front ends from the telemetry source until the alarm or event message appears on the screen. The alarm and event actions shall include message production, highlighting of alarm conditions, and audible and visual annunciation.
Alarm acknowledgement and deletion shall be measured from the time the Operator initiates the action until the Operator observes the system's completion of this action.

PRINTOUT AND HARDCOPY RESPONSE TIME

The response time for printouts and hardcopies shall be measured from the time the request is made until the printing or hardcopy processing starts on the printing or copying device. Requests for timely printing or hardcopy jobs shall be acknowledged immediately with an indication that the request is being processed.

The user interface performance requirements given in the table below are to be fulfilled by the SCADA systems and to be demonstrated during performance tests under the Contract.

Table 6: HMI Performance Requirements

Action	**Response Time under normal conditions**	**Response Time under avalanche conditions**
Visible reaction of the system upon any operator's request (e.g. selection of graphics, acknowledgement, selection of printouts etc.).	< 1 s	< 1 s
Time from operator's request until complete actualization of any graphic display on the screen inclusive actualization of all process information and topological network colouring – precondition: graphic display has already been selected on the respective screen.	< 1 s	< 2 s
Time from operator's request until complete actualization of any graphic display on the screen inclusive actualization of all process information and topological network colouring – precondition: new selection of the graphic display on the respective screen.	< 1 s	< 3 s
Time from operator's request for any control command until execution (= output of control command at the communication servers) without application of special functionality such as "Security Checked Switching" etc.	< 1 s	< 2 s
Time from operator's request until complete presentation of any Alarm List on the screen (presentation of one complete page of list).	< 1 s	< 3 s

Time for update of any Alarm List already being selected on the screen (time counted from appearance of the telegram at the front ends to actualization).	< 1 s	< 2 s
Time from operator's request until complete presentation of curves derived of the archive on the screen	< 3 s	< 10 s
Time from operator's request until start of processing of printouts or hardcopies on the printers (precondition: printers in ready-state, not in sleep modus).	< 3 s	< 10 s
State Estimator execution time (for converging case).	< 10 s	n/a

The definition of the respective scenarios
- Normal condition
- Avalanche condition

This shall be determined during engineering phase under the project.
The performance requirements stipulated above have to be fulfilled even in the case of a necessary release update of the software or hardware for the duration of the liability period.

Even in case, the operational condition should be more severe than given with the avalanche scenario, the SCADA systems must operate in a safe and reliable manner.
Under no circumstances the System shall lose any information or shall break down.

4.3 SCADA Equipment at Substations (Data Acquisition Unit)

4.3.1 New Remote Terminal Units (RTUs) and Adaptation Works at Substations

This section describes the new Remote Terminal Units (RTUs) for distribution appliances to be supplied to the Pooling Stations. The intent of the section is to describe the needs for the new RTUs to be provided as part of the 'Renewable Energy Management Centre Project'.

The Section also describes the equipment and works necessary to interface all controls to be executed and all data to be acquired from the substation control and switchgear equipment to the new RTUs.

4.3.1.1 General Information and Scope

4.3.1.1.1 Remote Terminal Units

The new RTUs in the project shall be supplied by the Contractor and installed at various substations and pooling stations.

We propose that each RTU to be supplied in the course of the project shall be fully equipped for the actual amount of data to be acquired and commands to be executed as per teleinformation plan plus a spare capacity of **25%** for each type of data.

In addition, each RTU shall be expandable in the field by at least **50%** of the size of the initial point capacity by addition of Input and Output cards only. The addition of enclosures, internal cabling/wiring, chassis, or power supplies shall not be necessary when adding these I/O cards.

The RTU shall include sufficient serial interfaces to enable the serial data acquisition. The necessary number of serial interfaces including spares to be provided for each RTU shall be determined by the Contractor during the site survey.

All of the RTUs newly provided under the project must have a valid certification stating their compliance with IEC 60870-5-101 and -104 from an internationally accredited organization such as KEMA or equivalent.
The Contractor shall be responsible for the complete design, installation, signal duplication, wiring, testing, commissioning and documentation of the new RTUs, including any required new or parallel connections to field equipment as described in this document.

4.3.1.1.2 Data Acquisition Principles

At all substations where new RTUs are to be installed, interfacing of the supervisory controls to be executed and data to be acquired under the project, described above in section 3.6.7under “Data Acquisition Unit”, shall be provided.

4.3.1.1.3 Interfacing Works

At all the substations where new RTUs are to be installed, the Contractor shall supply and install all necessary equipment and material including auxiliary relays, cables, wiring, terminal blocks, marshalling racks, test switches, isolation devices, conduits, cable trays/trenches and any other equipment required to signal doubling and interfacing the RTUs with the substation equipment.

The required modification works shall not affect the current operation of the existing substation equipment.

The Contractor shall be responsible to perform any modification to substation facilities to accommodate the RTU equipment, power supply and other associated equipment as well as to accommodate the communication equipment supplied and installed in the course of the project.

If in some substations with RTU equipment (new or not), the existing DC supply system is in bad condition, the Contractor shall supply and install in those stations new 48 volts DC batteries, chargers and associated distribution equipment required to supply the RTU as well as the communication equipment supplied or installed in the course of the project.

The points of interfacing of controls, status indications, alarms, measurements and metering at the substations are mainly the existing marshalling panels or terminals - it is to be expected that in most of the stations without RTU there are no marshalling panels; in this case they need to be brought in by the Contractor.

4.3.1.2 Functional Requirements for the new RTUs

New RTUs to be installed in the course of the project shall provide at least the following functions:

- Single command outputs, double command outputs for supervisory (on/off) control of circuit breakers, isolators etc. with check-before-execute function.
- Regulation command outputs e.g. raise/lower command outputs for generator or transformer tap changer control and setpoint transmission with validity check before execution.
- Single and double state digital inputs. Each status (open / closed) of two state devices such as circuit breaker or isolator position shall be acquired independent from each other and checked for validity.
- Transformer tap changer position indication shall be processed as BCD coded signals or alternatively, by analogue measurement input modules (0 - 20 mA or 4- 20 mA).
- Analogue measured inputs with pre-processing including validity check, local limit supervision and measurement transmission on exception (only if a significant individually selectable change occurs).
- Measurement transmission with a resolution of at least 11/12 bit and sign as this is the most economical way to increase the overall accuracy of measurements.

- Sequential event recording with time stamping of events at the RTU level (time stamp 10 ms, resolution 1 ms) and RTU time synchronization via individual GPS receivers installed at the RTU for disturbance analysis.
- Self-testing and diagnostic functions for detection and reporting of any error. The error indications / messages to be generated shall allow fault localization down to the card level.
- Freely programmable local automation functions.
- Selectable priority levels for data transmission to speed up the acquisition of circuit breaker status changes and important measurements.
- Generation and maintenance of database by menu-controlled dialogues either from a local PC or directly from the Control Centre by using the downloading function. Parameter downloading shall also be possible for modification of local automation functions
- Provision of multi-port facilities for communication with different control centres using different data transmission protocols. The communication protocol to be used by the new RTUs shall be IEC 60870-5-104 wherever possible and supported by the telecommunication system, IEC 60870-5-101 in all other cases.

4.3.1.2.1 Telecontrols

The RTU shall have the capability for the SCADA system master station to select and control specified power system devices. It shall be possible to control the following power system devices from the RTU

- two-state devices such as circuit breakers and isolators
- Multi-state devices such as transformer tap changers.

Telecommands

The RTU shall ensure that only the correct output is selected for two state devices before command execution. Operation of control outputs shall be via a select-check-execute command sequence. The control sequence shall include the following:

- The SCADA system shall transmit a command message addressing the proper RTU and the control point within the RTU, and indicate the control action desired.
- The RTU shall initialize its control logic, reassemble the command message, and transmit the reassembled message to the SCADA system. The message sent to the SCADA system shall be generated by the RTU's point selection logic.
- The SCADA system shall check the returned message for validity and, if valid, shall issue an execute command to the RTU.
- The RTU shall operate the control point selected only after the execute command has been received.

The control action shall be executed only if the select-check-execute sequence is performed without error or interruption. The RTU shall reset its control logic upon any error in the sequence or if the execute command is not received within a pre-defined time after the command message is received at the RTU.

The impedance of the output circuit shall be measured to detect jammed contacts.

The point selection logic for the control output shall be designed to preclude operation of an unselected output under single component failure conditions. That is, no single component shall be capable of selecting and operating an output point by itself.

In no case, any unwanted telecommand shall be given to the process in case of an RTU power failure.

The RTU communications protocol shall also support "immediate execute" contact outputs (where an operation can be commanded without the validity check and execute message exchange) for control output types such as On Load Tap Changer (OLTC) raise / lower command outputs.

Analogue and / or digital setpoint control

The RTUs shall provide for analogue and digital setpoint control and variable pulse width outputs as it would be required for control of local automation devices at the substation in future.

4.3.1.2.2 Teleindications

Teleindication refers to status information of operational equipment monitored by the system. Such teleindications include status information of switching devices, event information, alarms, etc.

The RTU shall report teleindications by exception but shall also allow the SCADA system to demand - scan status data even if the data has not changed.

Status indications
The status (open / closed) of two state devices such as circuit breakers or isolators shall be acquired by 2 independent, potential - free contacts or by 2 interposing relays, one for each position. Position indications shall be checked for validity and undefined states like open and closed (1 **|** 1) or neither open nor closed (0 **|** 0) shall be alarmed. The new RTU shall provide for run-time-monitoring, adjustable to the MV equipment operation parameters, to avoid alarming of undefined states while the equipment (e.g. isolator) is operating.

Alarms
Alarms shall be acquired as single indications via potential - free contacts which are either available at the initiating equipment or to be generated by paralleling relays to be provided under the project.

Digital parallel inputs
The RTUs shall have the ability to handle digital measurands, e.g. two digits BCD. Transformer tap position other than BCD coded shall be re-coded by means of a diode matrix to a BCD code before connecting to the digital parallel inputs of the RTU.

4.3.1.2.3 Telemeasurements

In analogue measurands the information to the RTU is given in the form of an analogue current supplied by the output of an analogue measuring transducer.

The analogue signals shall be converted to digital mode by an analogue-to-digital converter, to which the inputs are connected. All inputs of a module shall be measured within one cycle, regardless of the number of inputs in use, thus new points can be added to the RTU without reprogramming.

Analogue measurements shall be transmitted to the master station with a resolution of 12 bits or 11 bits + sign bit.

4.3.1.2.4 Telemetering

The transmission of integrated totals refers to the transmission of measurable quantities which are integrated over a specified period of time. The integration shall take place before transmission.

In case of a failure to scan, e.g. due to failure of the telecommunication system, 1-minutes integrated totals over a period of not less than 1 day shall be stored at the RTU.

4.3.1.2.5 Sequence of Event Recording (SER)

The new RTUs shall be capable of Sequence-of-Events (SER) data collection at a time resolution less than the operating speeds of the power system devices. Any digital input points in the RTU may be assigned, programmable as an SER data point. In general, a breaker position change and any alarm from a protection device that has initiated a trip signal is defined as an event for SER. Multiple transitions of a device, such as the tripping and subsequent reclosing of a breaker, shall be considered as a series of separate events. Each time an event is detected, the RTU shall time-tag the event and store it together with the time-tag of the event for transmission to the SCADA system.

The buffer shall be sized to store, as a minimum, a number of events equal to three times the number of SER points implemented in the RTU. The time-tag recorded with each event shall be generated from a clock internal to the RTU.

Separating capability
The RTU shall be capable of correctly determining the sequence of events for which their occurrence is separated by >= 1 ms (separating capability class SP4 of IEC 870 - 4)

Time resolution
The resolution of the time tag shall be 1 ms.

4.3.1.2.6 Common time base

The internal clock of each RTU shall be synchronized by Global Positioning System (GPS).

The synchronization shall be done periodically such that the time-tags in each RTU shall be within one millisecond (1 ms) accuracy between all RTUs.

In the RTU there shall be a digital output from which time synchronization messages can be forwarded to external devices. The frequency of the activation of the message shall be adjustable.

4.3.2 Communications Interfaces

Communication with Master Station(s)
The SCADA data transmission network will consist of dedicated data channels utilizing mainly fibre optic transmission media but may also use power line carrier, pilot cables, radio or microwave transmission.

The proposed RTUs shall have multi-port-capability allowing utilization of different protocols on separate RTU communication ports to support simultaneous communications with multiple independent master stations. Communication protocols shall be implemented by modifiable firmware in the RTU.

We recommend the use of the IEC 60870-5-104 communication protocol for communication with the master stations, wherever possible and supported by the telecommunication network, IEC 60870-5-101 protocol shall be utilized in all other cases.

Communication with Intelligent Electronic Devices (IEDs)
The RTUs shall be capable of supporting the following communication protocol for communicating with intelligent electronic devices:

- IEC 60870-103
- IEC 61850
- Modbus RTU

Configuration and Maintenance
RTUs shall have communications ports for connection to a portable configuration and maintenance PC.

Failure of transmission
In case of a failure of transmission, e.g. due to failure of the telecommunication system, status points over a period of not less than 1 day, up to 200 entries, shall be stored in the RTU with original time stamp in an non-volatile memory. The numbers of entries shall be adjustable.

4.3.3 Adaptation works at the Substations

This section is dealing with the interfacing equipment and works to be performed at substations.

4.3.3.1 Analogue and Digital Input Data to RTU

Power system analogue and digital input data shall be collected from the interfaces of the primary equipment via marshalling cubicles and provided to the new RTUs.

Interfacing shall be designed to minimize electromagnetic and electrostatic interference.

Analogue measurements
The interfacing shall consist of analogue transducers, isolating/test devices, wiring, cabling and terminations to the secondary PT/CT circuit in the control or relay cabinets. The output signal from the analogue transducer shall be transmitted to the appropriate input at the RTU.

Status indications
The interfacing shall use spare potential free contacts where available or auxiliary paralleling relays to be provided in the course of the project, (one independent contact / relay for each position) actuated by the switchgear equipment, isolating and test devices, wiring, cabling and terminations to the digital input point at the RTU.

Alarms
Input wiring to the RTU from alarm points shall use spare contacts available on the actuating device wherever possible. Where spare contacts are unavailable, auxiliary "contact multiplying" relays shall be supplied and wired to provide the required digital input signal to the RTU.

4.3.3.2 Supervisory Control Interface

The Substation adaptation works for device control will be required to take an output signal from the RTU, actuate an auxiliary control relay, and have a contact from the control relay to initiate a control action such as breaker trip/close, etc. on the substation equipment by the appropriate connections to the substations equipment control circuits.

The supervisory control interface shall consist of outputs from the RTU, interposing relays, isolating/test devices, and wiring, cabling and terminations to the appropriate control circuits and control relays and switches in control cabinets.

Each RTU control output shall drive an auxiliary control relay, which shall be located in the control panel or locally. The interposing relay shall be normally de-energized during normal operation. A normally open contact of these interposing control relays shall actuate a breaker tripping/closing coil.

In no cases shall the relay contacts supplied in the RTU directly control any equipment.

In no case shall the closing commands for circuit breakers by-pass any station internal interlocking.

For OLTC devices, appropriate latching relays shall be utilized.

4.3.4 Equipment Characteristics

4.3.4.1 Remote Terminal Units Hardware

4.3.4.1.1 Enclosures

The Contractor shall provide enclosures meeting the following requirements:

- Swing racks supported by heavy gauge hinges shall be provided so that only front access to components and wiring is required for routine maintenance and troubleshooting.
- Provisions for top and bottom cable entry. Cable entries shall be provided with protection against insect and animal entry, and sealed to prevent dust and sand contamination.
- Protection class of the enclosures shall be
- for indoor cabinets IP52 minimum
- For outdoor cabinets IP64 minimum.
- Suitable signal and safety ground networks within the enclosure.
- Convenience outlets at 230 V AC, shall be provided.

4.3.4.1.2 Power Supply

The Contractor shall supply any hardware required to convert the 48 V battery voltage to the required internal voltages for the RTU hardware. The RTUs shall be capable of operating with ungrounded or grounded (either polarity) input power.
In RTU DC distribution, Miniature Circuit Breakers (MCBS) with alarm contact shall be used, i.e. fuses are not accepted.

4.3.4.1.3 Control Disable Switch

For each station a manual key type selector switch shall be provided to locally disable all control outputs at a station. The key-type selector switch shall be installed at the RTU such that it can be operated without opening the RTU panel. The outputs from the RTU shall be disabled by breaking the power supply connection to the control output. An auxiliary contact on this switch shall be wired to a contact input in the RTU to report the control disable switch's status to the SCADA system.

4.3.4.1.4 Interconnections

All connections between the RTU's termination facilities and signal wiring shall be through barrier-terminal blocks with knife-switch isolation, mounted in the RTU panel or an adjacent marshalling cabinet, if not already existing in the Substation. Terminal blocks shall be screw-type, with full depth insulating barriers.

4.3.4.1.5 Distributed RTUs

RTUs shall have the capability to gather data from other smaller or distributed RTUs or local intelligent substation instrumentation using directly connected RS-232C- or RS 485- channels with or without modems. The distance between the different control locations may reach up to 500 m.

4.3.4.1.6 Digital Inputs

The digital inputs shall be opto-isolated, signal voltage 48 V DC. Other voltages shall also be possible by changing the matching resistor in the input circuit.

Contact bouncing of the interposing relays shall be filtered. The bounce filtering time shall be 7 ms. Input circuits with selectable bounce filtering time setting are preferred.

The indications shall preserve the chronological order of events inside the RTU.

Oscillating inputs as a result of e.g. a faulty relay chattering shall be blocked locally at the RTU.

4.3.4.1.7 Analogue Inputs

In analogue measurements, the information to the analogue input modules of the RTU is given in the form of analogue current supplied by the output of measuring transducers. Measuring transducers shall normally be installed in the switch/control gear.

In analogue input modules, the following current input ranges shall be available:

- unipolar 0-5 mA, 0-10 mA, 4-20 mA
- Bipolar +/- 5 mA. +/-10 mA, 4-20 mA.

It shall be possible to change the input range for each individual input, preferably by software means, instead of changing the input resistor.

The analogue input circuit shall have a precise DC impedance less than 200 ohms for current inputs. This impedance must not vary more than half of the accuracy of the Analogue-to-Digital Converter (ADC) with influence values such as temperature, etc.

In the input circuit galvanic isolation shall be provided from mechanical earth and electrical earth, and, preferably, between different inputs.

The circuits of the analogue input module shall be protected against disturbances caused by switching transients and against disturbances from power and radio frequencies present at Substations.

The scanning of each input shall not introduce any error on the analogue information.

For each input it must be possible, without disturbing the other inputs,

1. To isolate the input from the ADC and close the analogue circuit,
2. To connect, on the ADC side, a test set for maintenance or adjustments,
3. To measure the analogue input value without disturbing the measurement (addition of an mA meter over a link which is then disconnected).

The analogue information shall be converted into digital value by the ADC which can be common for all inputs. Analogue measurements shall be transmitted to the master station with at least 11 bits plus sign bit.

The total accuracy must be better than 0.5% of the nominal range of a measurement calculated from RTU's analogue input up to control centre.

The input circuits must withstand a permanent overload of 30% without any damage.

In case of input overload the output message shall be either

- the exact value corresponding to the input or
- The maximum value that is possible to code (with the correct sign).

4.3.4.2 RTU Firmware Requirements

The RTUs shall meet the following characteristics of the firmware to support the functions of the RTUs. The Contractor shall use standard firmware as much as possible.

All firmware shall be completely and consistently documented. It shall not be necessary to perform modification to firmware, logic, or data for expansion within the sizing parameters defined for the RTU.

At the time the RTU is accepted, all firmware delivered must be up to date and in final form, including all standard firmware changes and field changes initiated by the Contractor or the Contractor's suppliers prior to acceptance. The firmware documentation must reflect these changes.

Firmware shall be loadable by service notebook locally at minimum, download of firmware and parameter sets trough SCADA system, using the data communication links will be preferable. In any case changing of EPROMs or similar devices shall not be necessary when updating RTUs firmware.

4.3.4.2.1 Initialization / Restart Program

Firmware shall be provided to enable the RTU to restart itself upon manual request and automatically under the conditions of power restoration, memory parity errors, and hardware failures. The firmware shall initialize the RTU and begin execution of the RTU functions without intervention by the SCADA system. All RTU restarts shall be reported to the SCADA system.

4.3.4.2.2 Fail Safe Processing

In the case of irrecoverable faults such as power supply failures, firmware malfunctions, or any other detected condition that may affect the security of indications and controls, the RTU shall place itself in a secure state that prohibits the transmission of false indications or the execution of erroneous control outputs. The detection of these error conditions shall be the responsibility of the RTUs self-test and operations monitoring firmware.

4.3.4.2.3 Database Maintenance

The Contractor shall supply software to configure each RTU's database where this information is located in software and/or firmware at the RTU. The software shall completely generate or modify the database of the RTUs. The database software shall have error detection services and shall produce a printed listing of the input data and the resulting RTU database configuration.

4.3.4.2.4 Down Loading of Database from SCADA System

The RTU shall support the change of the RTU's configuration and processing parameters by messages from the SCADA system. These changes shall include, but not be limited to scan group definitions, analogue limits, SER point allocations and buffer definitions.

4.3.4.2.5 Diagnostic Firmware

The Contractor shall supply diagnostic firmware for both off-line local tests and on-line self-diagnostic capability built into the RTU. The RTU shall enter an off-line state during the execution of off-line diagnostics, and this off-line state shall be reported to the SCADA system.

The RTU shall include a remote diagnostics communication port and shall be capable of executing off-line diagnostics from an external computer terminal connected to this remote diagnostics port.

4.3.4.3 Interfacing Equipment

4.3.4.3.1 Interposing Relays

Where not already existing, interposing relays for telecommands and digital inputs shall be provided by the Contractor. The relays shall be installed in the switch / control gear and shall have the following characteristics:

For telecommands:

1. Coil voltage shall be 48 VDC; Coil voltage variation shall be +-20%.
2. Signal voltage on the contact circuit shall normally be 110 VDC, but other voltages may also exist.

3. The rated contact current shall be minimum 5 A DC making/breaking. In exceptional cases, where CB coils are to be switched directly by the interposing relay, installed under the contract, additional contactors might be required to cope with the switching currents of the CB coils. In such cases, these contactors shall be provided under the contract.

For teleindications:

4. Coil voltage shall normally be 110 VDC; (other voltages may also exist) coil voltage variation shall be +-20%.

5. Signal voltage on the contact circuit shall be 48 VDC.

6. The rated contact current shall be minimum 3 A DC making/breaking and 1A continuously

Relays with two (2) normally open and two (2) normally closed contacts shall be provided. Contact bounce shall be less than 8 ms and contact age shall be 10 exp. 6 operations.

Dielectric strength shall be 2 kV, 50 Hz-1 min between one circuit and the earthing point and between independent circuits, 1 kV, 50 Hz for 1 min between two terminals of the same circuit, Impulse test voltage: 5 kV (IEC 60255-5).

Plug-in type relays and sockets shall be used with sockets directly mounted on a DIN rail.

All necessary arrangements must be made so that the plugging - in and out are easy and performed without any risk of damaging of relay parts.

The relays shall be fitted with a visual operation indicator (either mechanical or LED).

4.3.4.3.2 Cables

The instrumentation cables from the RTU electronics cabinet to the interface terminals at the substation control / switchgear shall be delivered by the Contractor.

The characteristics of the cables shall be as follows:
- Number of cores n * (2+1) * 0, 8 = 2, 4, 8, 12, 24, 48, with 2 + 1 = a pair of conductors + surrounding screen and 0.8 = cross-sectional area of screen.
- The outer PVC sheath shall be rodent proof and meet flame test requirements of IEC 60323-3 category C. Manufacturer’s name, manufacturer’s type, core quantity and cross-section, year and month of manufacturing shall be indicated.
- Individual leads shall have colour coding.
- Pair-twisted cores, each pair and the whole core surrounded by protective screen shall be used for connection of transducer secondary to the RTUs. For connection of controls, status indications and alarms cables with protective screen surrounding the whole core are acceptable.

In the design made by the Contractor the following shall be taken into account:
- Separate cables shall be used for:
- telecommands,
- teleindications and alarms
- measurements transducer secondary outputs (mA)
- The number of cables should be as low as possible.

4.3.4.4 Power Supply for Substations

At all stations where no adequate power supply exists and new RTUs and telecommunication equipment shall be installed, the Contractor shall supply, install and wire a new and complete 48V DC power supply system including a 48V DC battery, charger(s), low voltage disconnect switch, all

DC distribution equipment and cabling required for the uninterruptable supply of 48V DC power to the RTU as well as the communications equipment provided in the course of the project.

At first priority substations as well as at major communication nodes duplicated battery chargers (2 times 100%) shall be installed whereas at second priority substations, single chargers will be sufficient.

The battery and charger sets shall be sized to adequately supply the loads to be connected to the battery. The rectifier output shall be k x S where

k = 1.5
S = sum of the following:

- input power in kVA of the largest tendered RTU
- Input power to the new telecommunication equipment provided under the contract.

The battery capacity shall be C = 1.5 x Cn, where Cn is the capacity to feed the above total load for eight (8) hours.

It shall be noted that the statements made in this section are based on the IEEE standards 535, 485, 450 and 1184. An aging factor of 1.5 (initial capacity 150% of the design capacity) instead of 125% (as suggested by the standards) was chosen to ensure that the battery can meet the design requirements throughout its life.

The battery chargers shall provide normal system power and shall be capable of recharging a fully discharged battery in twelve hours while supplying normal system power. The chargers shall have 240 volt, 1 phase input power. Where duplicated chargers are to be provided, both chargers shall have an output diode in the positive pole to prevent back-feeding a failed charger.

At first priority Substations; both battery chargers shall be energized and shall be connected in parallel with a load sharing circuit. Both chargers shall be equipped with external AC disconnect breakers and external DC breakers.

The batteries shall be sealed, maintenance free lead acid type. As they are sealed, there are no special ventilation requirements, and as such the batteries may even be placed in the substation control rooms or telecommunications equipment rooms, if existing.

A low voltage disconnect switch shall be provided for protection of the battery. The 48 Volt DC system distribution panel shall be a fused switch distribution panel board. The low voltage disconnect switch and fuse panel shall be provided with local alarms as well as alarm contacts. The low voltage disconnect switch shall be equipped with external by-pass switch to be used for maintenance purposes.

4.3.4.5 Spare parts and test equipment

4.3.4.5.1 Spare parts

The Contractor shall furnish a list of recommended spare parts and test equipment for the purchased RTUs to maintain reliable RTU operation. The spare parts list shall be subdivided into:

- Mandatory spare parts those are necessary for two (2) years of operation. These spare parts shall be included in the contract.
- Recommended additional spare parts that are necessary for ten (10) years of operation.

RTUs shall be provided as spare. One RTU for each REMC. Spare modules shall be installed at these RTUs which shall be installed at the REMC equipment room and serve for maintenance, testing and training purposes.

The Contractor shall guarantee the availability of spare parts for a period of at least 15 years and shall make available at no cost to the client the manufacturing drawings and rights to manufacture those subassemblies which the manufacturer will not support, or discontinues support thereafter. For each subassembly, the specific components supplied shall be identified and referenced in the supplied documentation.

4.3.4.5.2 Portable test set

The Contractor shall supply 4 portable RTU test sets (notebooks) for testing RTU operation. Each test set shall be capable of emulating communications from both the SCADA system and the RTU. The test sets shall have the capability of interfacing to an RS232C serial port for the RTUs being supplied on the project.

Test sets shall be capable of passively monitoring all communication traffic on a channel without interfering with channel operation. In addition each test set shall include interface testing equipment for simulation of digital and analogue inputs, digital and analogue outputs.

4.3.4.6 RTU / Telecommunication rooms

It is assumed that all the substations / pooling stations have appropriate RTU/telecommunication rooms. If this is not the case, we propose the construction of adequate rooms under the responsibility and management of the client before the project starts.

The Telecommunication rooms in the substations shall meet the following minimum requirements:

- They shall be lockable in order to grant the entry only to authorized personnel.
- Although the SCADA and communication equipment supplied by reputable manufacturers operate in an environment with ambient temperatures between -15 and +50 degree Celsius, constant temperatures reduce the failure rate and increase the lifetime of the equipment. Duplicated wall unit type air-conditioners will be sufficient for this purpose and shall be made available
- Already existing telecommunication rooms shall be free of obsolete equipment.
- Cable trays or cable ducts shall be installed where necessary

The size of the rooms shall be sufficient to locate the RTUs and the telecommunication equipment.

Additionally, adequate spare capacity shall be provided for the air conditioning system.

It is not recommended to install the RTUs and the telecommunication equipment in the same room as the primary equipment cabinets because there is no possibility to regulate their access.

The Contractor shall make sure during the site survey that SCADA and telecommunication rooms are available in all substations of the project.

4.3.5 RTU performance requirements

4.3.5.1 Availability

An availability of 99.9% is recommended exclusive of communication channel availability. An RTU shall be considered unavailable when:

- any function is lost for all points of a single type
- one input card or output card of each type fails
- More than one input card or output card of the same type fails.

4.3.5.2 Maintainability

The RTU design shall facilitate isolation and correction of all failures. The following features which promote rapid problem isolation and replacement of failed components shall be included:

- self-diagnostic capabilities continuously monitoring operation of the RTU
- on-line error detection capabilities including detection of memory, CPU, communication faults, and input/output errors and failures with detailed reporting of detected errors to the SCADA system
- Local indication of RTU failures.

4.3.5.3 Message security

Each message transmitted shall include an error detection code to exclude erroneous messages being accepted as valid.

4.4 Telecommunication System

4.4.1 Introduction

This section relates to the telecommunication system and equipment for all substations and pooling stations controlled and monitored by the new SCADA system for the new Renewable Energy Management Centre (REMC) as laid down in the previous sections.

A reliable telecommunication system adapted to the specific needs is indispensable for operation of the power system. The telecommunication network has to cater for the transmission of voice and SCADA data between the supervised substations and the new Control Centre(s) as well as on the link level between the substations for teleprotection and voice.

In the context of the site visits it has been observed, that over the whole country there is a very diverse telecommunication infrastructure, which is currently individual in each state.

For the communication between NLDC, RLDCs, SLDCs (and Sub-LDCs) in the whole country ICCP has been established as a standard. At this communication level predominantly fibre optics is available as layer 1 medium.

Telecommunication facilities for the communication from SLCDs or Sub-LDCs downwards (to the energy power sites), however, are very diverse in India. This issue will be considered in this scope.

In general there are four types of layer 1 media which are used to transport SCADA data:

- Fibre Optics
- PLC or DPLC
- VSAT
- Leased Lines

Generally it is noticed that the bandwidth of the communication links to the substation is very low. This leads to very low transfer rates.

In order to substantially spread out the fibre optics infrastructure, however, in the whole country - even in rural areas and villages - there is a project of the Indian Government called “National Optical Fibre Network” (NOFN) which has been initiated at the end of 2011 and which is currently under construction.
However, based on information gained in the course of discussions held with Powertel, NOFN project is not expected to be used for transmission corridors but for public infrastructure only.
This issue might be reassessed at a later time during engineering phase of the project.

4.4.2 General Requirements

Since telecontrol systems for operation of electrical networks have to operate in real time mode, limitations / disturbances imposed by the telecommunication system used for data acquisition and control centre interconnections may heavily impair the performance of the overall telecontrol system. Thus the data transmission system has to be considered as an integral part of the telecontrol system.

For the design and the configuration of the telecommunication network various aspects have to be taken into consideration:

- Required number of channels for
  - Teleprotection signalling
  - Voice transmission
  - SCADA data transmission
- Required transmission speeds (bandwidths) for SCADA data on the different sections of the transmission system
- The communication protocols used
- Number of Control Centres and their location
- Number of stations connected and their location
- Reliability, redundancy and availability requirements

Besides these basic planning principles it is very important to consider the long-term requirements for the future needs of the telecommunication network. Therefore the design basis of the initial telecommunication network configuration has to consider the future needs for extendibility and the ability to upgrade.

The new telecommunication system shall be based on state-of-the-art international standard communication protocols with a high bandwidth communication backbone.

Utilizing “Next Generation Network” technology, it needs to be ensured that a defined minimum bandwidth for the data transmission between the REMCs and the outstations (IEC-104) and between control centres (ICCP) is guaranteed under all circumstances and at all times.

4.4.3 Recommendation for the future Telecommunication System

For the Information Transfer in real time a high bandwidth is indispensable.

The communication links between the Data Acquisition Units and the SCADA System should have a bandwidth of at minimum:

- Min. 9,6 kB for IEC 60870-5-101
- Min. 64 kB for IEC 60870-5-104

To achieve these objectives the implementation of fibre optic links wherever possible is highly recommended.

Leased Lines and VSAT can be used as interim solution in connection with the use of the IP-based telecommunication protocol IEC 60870-5-104.

PLC links are not practical for IP-based communication. In this cases the serial IEC 60870-5-101 protocol has to be used.

5. Proposed Approach for Procurement and Implementation

Based on the assessment of current situation in the RE rich states, it is evident that REMC is required immediately in the states. However, implementing of the SCADA based tools as required for REMC typically takes 18-24 months.

At the same time, all states, regions and national LDCs already have RE generation monitoring in the existing SCADA/EMS systems covering most of the interconnecting Substations. Reliability of data acquisition for RE generation is not too good due to field level and communication infrastructure bottlenecks.

Moreover, staff required for REMC operations and management has to be drawn from the existing pool of xLDC teams as good experience of grid operations is a mandatory pre-requisite for REMCs.

Keeping in mind the urgency of the REMC requirement, following approach is recommended:

- Establish REMC desk immediately with staff drawn from existing xLDC.
- Initiate Interim REMC desk operations through additional dedicated operator consoles in the current xLDC systems
- Upgrade Communication Infrastructure
- Partner with RE developers to obtain online RE generation data from Pooling Substations
- Enforce regulations for Mandatory RE Developer SCADA interface capability before allowing integration.
- Create dedicated SCADA and Communications teams at all XLDCs for managing main and REMC systems.
- Implement REMC in all locations through a single nodal agency
- Redefine Roles and responsibilities of stakeholders - Power Procurement Committees, Renewable Energy Development Authorities, RE Developers and other new actors should be defined at policy and regulatory levels.
- Blueprint for REMC Capacity Building
- Initiate REMC system procurement immediately.

5.1 REMC Procurement Strategy

REMC procurement can follow three alternate approaches.

- Alternate #1: Procure all systems under a single contract for all sites.
- Alternate #2: Each Region procures REMCs for its RLDC and constituent states. Here, REMC at National level NLDC can be procured separately.
- Alternate #3: All Regions and NLDC procure REMC systems in one contract and each state procures REMC independently.

A comparison of benefits and risks of these alternates is provided below.

Table 7: Alternate Procurement Strategies

Alternate	Benefits	Risks
Alternate #1: All REMCs in one contract	1. Features of the systems will be uniform across all sites. 2. Single contract for all sites can help in optimizing total cost. 3. Project Management from client side becomes smoother.	1. All REMCs tied to a single technology solution. 2. Dependency on single contractor for all REMCs. 3. Contractor execution capacity capabilities can lead to stretching of the project duration as parallel execution at multiple sites may not be achievable.
Alternate#2: Region wise procurement for RLDC and constituent state SLDCs.	1. All REMCs are not tied to a single technology solution or to a single vendor. Healthy competition amongst contractors can lead to improved technology solution proposals. 2. Projects can be executed in parallel. 3. RLDCs and States have prior experience in this kind of implementation; hence contract execution is expected to be smoother.	1. Different makes and therefore different implementation can lead to challenges in technology solution governance across sites. 2. States are tied to their parent RLDC for implementation.
Alternate #3: Procure REMC for each state independently and for all RLDCs and NLDC under a separate independent contract.	1. States can drive implementation at their level as per their own priorities, independently.	1. Coordination and integration of REMCs of RLDC and constituent states is likely to be a challenge technologically and on execution timelines. 2. Technology solution governance challenges will be high. 3. Overall program management for client side will be challenging due to large no. of independent contracts.

Irrespective of which alternate strategy is adopted, following are the recommendations on overall procurement strategy of the project.

1. A standardised model technical specification of REMC that is applicable to all levels (SLDC, RLDC and NLDC) should be followed. This will help improve overall quality of the REMC systems.
2. The states and regions can consider engaging a single agency for project management of the projects at all levels (states, regions and national level) so that contract technology solution governance quality can be optimised and integration aspects can be better managed.
3. Follow modular approach for procurement of main components – Forecasting and Scheduling module, REMC module and future Control Reserve Monitoring tool with standard predefined interfaces.
4. Backup REMC is not necessary to be added at all xLDCs in first instance. This can be added later.

The next section gives recommendations on implementation strategy that should be followed.

5.2 Implementation Strategy

Existing Data Interface units/RTUs at substations should be evaluated for their readiness to interface with the new REMCs directly or through xLDCs. These should be replaced by new RTUs where it is not feasible to integrate them with REMC for providing data at 2-4 seconds refresh rates.

Communication Infrastructure **up gradation** should be taken up as a parallel project to support reliable and fast data acquisition cycles from Data Interface units/ RTUs at Substations (especially all interconnecting substations). RE Developer Pooling substations should be provided with reliable communication infrastructure. The REMC project can use existing communication infrastructure as an interim measure until the new communication links are provided.

It is recommended that quality of data flowing from REMCs to forecasting tools and quality of forecasts should be monitored jointly by all constituents so that best practices and learnings can be disseminated across xLDCs. Components of the forecasting tool are described in the Forecasting tools section of the main report.

Implementation of PMU in the REMCs shall be treated as a further parallel track to be performed for those REMCs which have been identified to be qualified for PMU implementation as they will dispose of a telecommunication system infrastructure appropriate for deployment of PMUs.

Acquiring data at REMC from meter based systems of Renewable Energy developers is not a permanent solution as such systems cannot support 2-4 second level refresh rates at the REMC level. It is recommended that all Renewable Energy Developer pooling Substations should mandatorily have SCADA systems that support integration with REMC on an international standard protocol with refresh rate of 2-4 seconds.

Implementation of forecasting and scheduling tools can be done as parallel tracks to the REMC implementation track in the main project. It is recommended that implementation of control reserves monitoring tool should be taken up as a separate project in future as algorithms in this tool are likely to keep evolving during implementation as the team gains experience.

Figure 12 below shows expected timelines for the individual tasks to be performed under the project.

Timelines estimated are deemed to be very tight but achievable on condition that experienced staff will be involved in the individual tasks to be performed on Employer's side. It is also expected that field and site conditions are amenable for implementing field equipment on site as per field integration timelines of the project.

Notes:

- RTU integration may take longer as this depends upon availability of requisite communication infrastructure – an external project.
- Communication infrastructure project has been taken as an external project in the REMC program. It is assumed that communication infrastructure will be available independent of the REMC project as per integration timeline requirements at individual sites.
- SCADA projects typically take 18-24 months for implementation. However, keeping in mind the urgency for implementation, a 12 month timeline schedule can be achieved if pre-project engineering (surveys, specifications and readiness of sites, data and interfaces) is done with good quality, reliability and accurately; and support for field, data and interface integration is available on time.

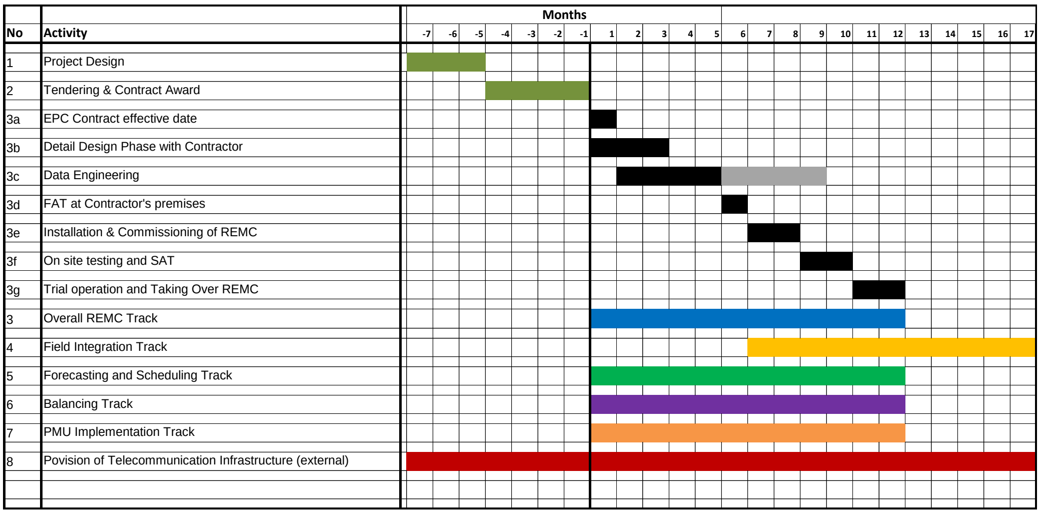


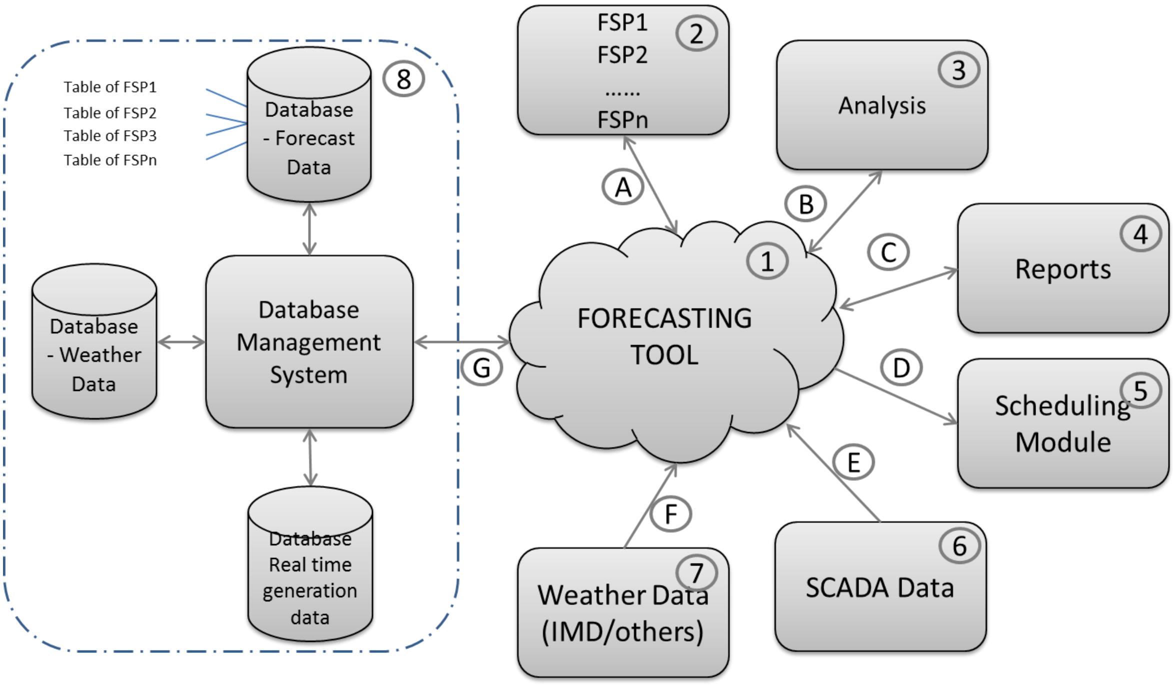
Figure 12: Tentative Implementation Schedule

6. Forecasting tool

6.1 Description of functionality

The forecasting tool is a combination of hardware and software systems at the REMC. The hardware systems would be configured appropriately to support the requirement of the software systems described in detail below. The system has been designed following a services oriented architecture (SOA) where individual modules or applications provide services on demand or automatically to other components of the system. This enables us to interface systems with diverse technical specifications.

Figure 13: Forecasting tool architecture



The above block diagram elucidates the various modules of the forecasting tool.

Table 8: Key for Figure 1

Modules of the forecasting tool		Suggested Mode of data exchange	
1	Forecasting tool	A	Bi-directional, SSL encrypted server to server
2	Forecast service providers API (Multiple)	B	Bi-directional, SSL encrypted server to browser
3	Forecasting tool analysis module	C	Bi-directional, SSL encrypted server to browser
4	Forecasting tool reports module	D	Uni-directional, SSL encrypted server to server
5	Forecasting tool scheduling Interface module	E	Uni-directional, SSL encrypted server to server
6	SCADA data interface module	F	Uni-directional, SSL encrypted server to server
7	Weather data interface module (IMD/others)	G	Internal to software, Software to DBMS
8	Data Base Management System		

The various components of the tool and their individual functionality are defined in detail below.

6.1.1 Modules of the forecasting tool

1. Forecasting tool:
   The consultant recommends it should be custom made software which will be a collection of numerous individual modules with the below mentioned functions:

   a) Raw data collection from multiple sources: (APIs for FSP, SCADA and Weather data)
      This is explained below with respect to individual data sources in later sections.
      i. FSP application interface to collect and organize the forecasts provided by the FSP and also provide the relevant data to the FSP
      ii. SCADA application Interface module will collect and organize the data from the SCADA systems
      iii. Weather data application interface will collect and organize the data available from the various weather data providers.
   b) Data processing (Analysis module)
      This is the core forecasting module of the system. It will have the below mentioned capability explained in detail in the analysis module section of the report.
      i. Forecast aggregation
      ii. Forecast evaluation
      iii. Misc. evaluations
   c) Data management (DBMS)
   d) Information dissemination (Reports module, API for scheduling tool, Data to FSP)
      i. Web browser based views
      ii. Printable report formats downloadable over the internet
      iii. Excel or CSV formats as required
      iv. Application interface for communication with other servers in the system
   e) Access control
      The tool will need to have the capability to compartmentalize data and functionality access. A system admin should be able to provide as well as restrict access to databases as well as processing modules. The system admin(s) should be able to control the access by people as well as software APIs

2. Forecast service provider API
   The forecast service providers are expected to provide their forecast data to the forecasting tool server over an encrypted SSL connection via an application interface (API). This mode of data transfer is secure and is currently utilized by the banking industry for online transactions. The FSP API will be able to deliver the below mentioned facilities for any number of service providers. This module is supposed to have the two below mentioned functionalities:
   a) Transfer of Input data to FSP:
      Data with regard to live generation details at a frequency of 1 min or higher needs to be provided to the FSP. This data would be collected from the SCADA system by the SCADA interface of the forecasting tool. Details of the SCADA interface are described in the relevant section. Below is a list of data that needs to be transferred to FSP.
      i. Pooling station Name
      ii. Pooling station wise installed Capacity
      iii. Pooling Station Area / District
      iv. Longitude and latitude of each pooling station
      v. 96 block pooling station wise wind energy generation data of last 3-4 years
      vi. Real time pooling station wise data at a frequency of 1 min or higher
      vii. Real time over all control region wise Wind and solar Energy Generation at every 1 minute interval
      viii. Further xLDC may provide the static data of RE generators of respective pooling
      ix. Static but modifiable list of installed RE generators with the below details wherever possible

- Total Nos. of indivisible generating units in pooling station (for wind and solar)
- Installed capacity (for wind and solar)
- Blade length(for wind only)
- Swept area (For wind only)
- Longitude and latitude of RE generator

b) Receive Forecast data from FSP

The FSP is required to provide the forecast data over an encrypted SSL server to server communication. The servers would use server certificates for authentication. This is known to be more secure than browser certificates which will have to be used for a web downloadable file or SFTP which is currently proposed. The module will perform the below mentioned functions:

i. Receive the data at the designated frequency and append to the database with separate tables for each FSP. These tables have to be designed to enable storage and updating of data as mentioned below.
   - Day ahead and Real time schedule:
     FSPs shall provide forecast of wind generation in MW in 96 blocks before 10.00hours (morning) for next day and may update at every 3.00 hours starting from 00.00hrs. i.e. 8 revisions per day (Increased to 16 post notification of CERC draft regulation)
   - Weekly Forecast:
     Wind/Solar generation for next 7 days in MW over 96 blocks.

ii. The total wind and solar power production in the respective region (one of the selected states) has to be predicted according to the subsequent requirements. Wind and solar power forecasts have to be delivered separately. The power has to be given as average (e.g., in MW) for the respective time interval (see 4).

iii. The forecast horizon is 72 hours. The FSP should also offer an optional 120 hour forecast.

iv. The temporal resolution of the forecasts is 15 minutes for the first 24 hours and 1 hour for the time thereafter.

v. The forecasts have to be provided 16 times per day.

vi. Each forecast value has to be provided with uncertainty information. Confidence intervals or equivalent measures are expected at least. A detailed description of the uncertainty calculation has to be presented.

vii. The forecast system shall include a special module for ramp prediction. This module shall also give alarms in case of extreme situations.

3. Forecasting tool analysis module:

This is the data processing and analysis module of the system. The broad functionality of this module would provide the user with an ability to select data with a variety of filtering criteria and define analysis rules for it. Once a new analysis rule with a particular data selection structure has been defined, it should appear as an additional function in the report module. This module will serve the below key functionalities.

i. Forecast aggregation:
   This module should be accessible over the web to anyone with the required authentication credentials. This is the process of aggregating the forecasts provided by the various FSPs. In the initial stage it is suggested that a simple comparison may suffice. The module design should facilitate the introduction of statistical analysis on a later date.

ii. Forecast Evaluation:
   This module would calculate and display the accuracy of forecasts on demand. The accuracy would be estimated using the databases of real time generation data and FSP data tables accumulated over time. The consultant recommends that the method for evaluating the forecast would be a root mean square error of 5% (relative to installed capacity). However the module should cater to the the

methodology suggested by the regulator and shoud be flexible enough to address it.

iii. Misc evaluations:
The software however should provide functionality for the addition of statistical evaluation modules as desired by system operators.

4. Forecasting tool reports module:
This module should be accessible over the web to anyone with the required authentication credentials. This module allows the users to obtain reports from any of the predefined analysis. The reports may be made available to the user in PDF, DOC, XLS, TXT, CSV or any other standardized document format.

5. Forecasting tool Scheduling interface:
This is one of the most critical aspects of the tool as it would be transmitting the final power forecast for the region in various temporal resolutions at desired frequencies (Every 15 mins based on current operational requirements). The transmission of this data should happen over an encrypted SSL connection. The communication should happen as described. The RE forecasting tool would provide a schedule to the REMC server. This schedule would then be vetted by the authorized operator and forwarded to the xLDC scheduling tool over the required protocol in a pre-specified format. In a case where the xLDC systems do not support this and cannot be adapted, the forecast schedule maybe downloaded over the internet from the reports module or automatically be updated in a folder at the xLDC server via SFTP.

6. SCADA data interface module:
SCADA data is currently available in a variety of formats. These formats broadly are XLS, TXT, and CSV. A porting module needs to be developed which will read of any of the specified formats and port the data into the REMC data base. A suggested upgrade would be to obtain the data from the SCADA systems also over SSL encrypted connections. This encrypted data should then be stored directly into the databases. Data being moved in files exposes it to the risk of theft as files are easier to hack when compared to SSL encryptions.

7. Weather data interface module:
This module is very similar to the SCADA module above. The file formats and format of data received is similar to SCADA data. The difference is in how the module will handle data. The Weather data would be appended to the weather data tables. The SCADA data would be appended to the real time generation data base.

8. Database management system:
This is the most crucial function of the forecasting tool after the forecasts. This module would be an industry standard DBMS system with the following functionality.
   a) Data filtering, sorting and preprocessing before appending to database
   b) Data security (Via encrypted databases)
   c) Ability to access the data based on every possible selection criteria based on the available list of variables in a given table.
   d) Data redundancy
   e) Data consistency (with other state/regional REMCs). A proposed mechanism would be to synchronize the various REMC databases multiple times a day. The limit on number of synchronizations depends on the bandwidth of communication and physical infrastructure used. Theoretically with sufficient infrastructure it is possible to synchronize them multiple times a minute.

   The DBMS will also have to maintain the following tables.
   a) Real time generation data (temporal resolution suggested is 1 min)
   b) Forecasts by service providers. There is a requirement of one table for every FSP. This is required to facilitate evaluation of forecasts
   c) Weather data
   d) Analysis rules (Updated every time a user defines a new method of analysis)

6.2 Role of the India Meteorological Department (IMD)

IMD shall be involved in any forthcoming RE forecasting activities. The selected FSP shall establish a close cooperation with IMD in order to

i. evaluate if model output provided by IMD can be included in the forecast system,

ii. train IMD staff members on the topic of RE forecasting.

6.3 FSP selection criteria

Our recommendation is to select more than one vendor (e.g., three). The costs for the forecasts should be a selection factor. In a situation where only little experience is available, the comparison of several forecasts could improve understanding of specific characteristics of individual forecasts and therefore improve overall quality. For Indian condition, the consultant recommend that the forecast providers providing three highest accuracies should be selected. However if a cost of forecast is above a predefined limit of budget, then that forecast provider should be disqualified.

In order to select FSP through accuracy check, the consultant further recommends a duration of a trial run to be conducted by contract provider and thus quantify the accuracy of forecast.

The selection then should be done based on more informal criteria: responding to the specific needs in India, complete list of references, full set of descriptions of the methodology and the software product, offered support.

6.4 Expected Accuracy

% Accuracy shall be evaluated as under:

% Accuracy = [(Actual data – Forecast data (Schedule data))/Forecast data (Schedule data)]*100

Accuracy will be measured with the actual ABT meter data. Pooling station wise and whole region RE generation data considered by SLDC will be binding to all FSP.

Accuracy measured of forecasted value for each 15 minute block should not deviate against actual value

- **more than ± 15%[2], during high wind scenario** i.e. actual wind generation - above 10 MUs per Day for total amount RE generation
- **more than ± 30 %,during low wind scenario** i.e. actual wind generation - 10 MUs per Day and below for total amount RE generation

The system should also allow the forecast accuracy to be monitored for all projects undertaken by the FSP.

[2] However, this percentage is subject to changes as per the regulations.

7. Cost Estimate

Please find our preliminary cost estimate attached in Annex 3.

As expected, cost for the project are depending on the procurement strategy finally chosen to be applied, our cost estimate has been elaborated as follows:

Column (1) in the attached preliminary cost estimate shows expected cost for the first REMC without Back-Up System setting the Standard for all further REMC systems to be subsequently procured under the project.

Column (2) gives expected cost for the first Data Acquisition Unit to be established at substations/pooling stations based on the teleinformation plan and associated I/O volume as specified in Section 4.1 of this report.

Column (3) indicates expected cost for each Back-Up REMC System to be procured and to be implemented in parallel with the Main System

Column (4) indicates expected cost for any further REMC based on the Standard System as per Column (1) which will be procured additionally under the same Contract lot.

Factors for discounts given by prospective bidders for software licenses as well as expected ratio potentials for the works performed in parallel (engineering, commissioning, training etc.) are based on experiences made in the course of recent projects of similar complexity carried out in the world market.
Prices given by prospective bidders in the course of the procurement process under the real project may vary due to specifics in the Indian market or due to actual situation in competition among the various vendors.

As can be taken from the individual schedules in Annex 3 cost for Training have been included. Details can be taken from the respective Training sheet.

8. Recommendations and Staffing

RE developers (state as well as from private sector) are keenly participating in bids for setting up RE power plants in the country. Our regulations are gradually drifting towards schedule based despatching of renewables from a must run despatch. Grid Operations are slowly getting autonomous in states. Envisaging the same, we hereby recommend the below:

- Renewable Generation is currently encountering despatch problems due to inadequate commercially viable balancing capabilities within the states' area of responsibility. In order to address such issues a Forum of Load Despatchers has been formed recently. It is recommended to standardise and harmonise LDC operations across the county through FOLD (Forum of Load Despatchers).

- There is a need to set up REMCs as soon as possible. It is recommended to transfer xLDC staff. Consultant recommends that REMC staffing should not be done directly from external recruitment. REMC teams should always be staffed from XLDC team and the void thus created in xLDC should in turn be filled appropriately. This is essential because Grid Operations is a prerequisite for REMC. Accordingly, RE generation management can acquire the necessary skill set through appropriate training. Moreover, creation of dedication teams for SCADA/Communication should be considered.

- Partner with RE developers to obtain online RE generation data from Pooling Substations.

- Implement Communication and Telemetry projects as an essential component of main core infrastructure project.

- It is recommended to redefine the roles and responsibilities of stakeholders - Power Procurement Committees, Renewable Energy Development Authorities, RE Developers and other new actors at policy and regulatory levels.

- Define a blueprint Capacity Building in the area of large scale RE integration into the grid.

- Enforce regulation that mandate the RE Developer to have SCADA interface capability before integrating RE power into the grid.

- HP has formed a State Load Dispatch Society that will be independent of the state Transco. This society will take over grid operations and the functions of State Load Dispatch Centre from HPSEB Ltd. It is recommended to implement similar societies in other states also.

- There is need to define a Standard Operating Procedures and Quality standards. A Grid Operations maturity model should be developed.

- Knowledge repository should be developed to disseminate best practices and learnings.

- Incentivise REMC and XLDC staff to create certification courses and obtain the same. As per feedback received in the 1st series of workshops conducted in April 2015, it was understood that the number of operating staffs have been increased for individual states/regions. The new staffs will be certified in Grid and LDC operations. Similarly, we recommend conducting certification courses in renewable energy generation forecasting, operations.

Given below is the recommended staffing structure for REMCs:

- REMC should be part of the xLDC as a specialist group for renewables generation management.

- REMC team can be staffed with 5 teams of 2 persons each operating in 3 shifts for operations.

- A separate team of Renewable Energy experts comprising of 4 people is further recommended to be in a general shift. The hierarchy of the 4 experts will be such that there is one Divisional Head who would report to the Head of Load Despatch Centre (LDC). Under the Divisional head, there will be one Chief. Under the chief, there would be 2 executives reporting. The hierarchy structure will be similar to the organization chart of a typical LDC proposed in the Gireesh Pradhan Committee report. The role of the executives preliminary would be data acquisition system, energy management system, coordination with SLDC, technology management, telemetry, real time supervision control.

- REMC and XLDC staff should be rotated.

- An Exchange program between Indian official and global grid operators should be implemented.

Annexes
Annex 1 –Stakeholder Consultation Findings

Approach: Stakeholder interaction and Field visits

Stakeholders:

- GEC champion – Powergrid Kashish Bhambhani - 9th and 16 Feb 2015
- CTU Planning SME- Powergrid Ashok Pal - 16 Feb 2015
- CEA Planning SME – CEA Pankaj Batra - 9 Feb 2015
- LDC systems SME - Powergrid A K Mishra - 9 Feb 2015
- NLDC systems SME: Mr S K Soonee and Team - 24 Feb 2015
- RLDC Systems SMEs: NRLDC Mr Debasis De - 17 Feb 2015, SRLDC Mr Raghu Ram and team – 18 Feb 2015
- SLDC systems SMEs: Karnataka SLDC Mr Sreenivas - 18 Feb 2015, Gujarat SLDC Mr Negi, Mr BB Mehta and team - Feb 19 2015; Rajasthan SLDC Mr Barwar, Mr Arvind Agarwal and team - 20 Feb 2015
- SLDC stakeholder interaction – Himachal Pradesh Mr N P Gupta March 17, 2015

Field visits:

- NLDC, NRLDC, SRLDC, SLDCs – Karnataka, Gujarat, Rajasthan, Andhra Pradesh.

Findings:

Planning:

Detailed planning studies with Renewables in specific locations not yet done due to lack of visibility of the actual sites, sizes of the plants etc. Dynamic studies with Renewables are yet to be done.

Forecasting:

Gujarat Piloted forecasting of Renewables with 5 FSPs at 5 locations. The forecast accuracy was outside 30% limit (forecast value-actual value/actual value). Note- RMSE forecast error not computed. NVVN does accurate forecasting for its pool of solar developers as it operates in the market. Rajasthan Power Procurement Cell (RPPC) has called tenders for forecasting load. No penalty for not providing forecast or for giving accurate forecasts. VLPGO team finding is that Centralised AND decentralised forecasting both are required.

Met service provider is not actively involved in Forecasting for Renewables as a business line.

GEC recommends meteorological masts at 50metre height.

Based on discussions with Rajasthan, the SLDC cannot trade in power, whereas DISCOM Power Procurement Cells (DISCOM PPC) can. Therefore, let the DISCOM PPC do the forecasting and coordinate with SLDC for scheduling.

As per Rajasthan, DISCOM Power Procurement Cells exist in all states. These act as nodal agencies for providing load forecasts and power procurement at affordable costs. Therefore, they should participate actively in scheduling and despatching of renewables – by getting visibility into forecast and price of renewables.

Visibility - Monitoring and Control

Deviation Settlement Mechanism (DSM) mechanism is there for ensuring secure operations near about 50Hz. There is a DSM based scheduling and despatching package implemented in SR and KR SLDCs.

ABT-DSM based scheduling system under implementation for NR and SR. Plans to implement a unified system for the whole country soon.

Renewable generation hot spot location is far away from load centres. Many states already have conventional energy capacity to meet most of their current and large % of their future projected demand. Therefore, market mechanisms to promote renewables generation are required.

CEA says regulations are already there to bind developer to provide data. Karnataka and Gujarat are already getting Renewables SCADA data at SLDC. Karnataka installed SCADA systems on their own and made developer pay for the same. Note- Developers have sophisticated captive Remote control centres for managing plants up to individual turbine level, and provide real time visibility to their investors/turbine owners on web/mobile based tools.

Strengthen FOLD activities by rotating engineers across XLDCs. SLDCs can be made independent of STUs to give them more autonomy?

Balancing

Planners, XTUs feel a larger area beyond state is necessary for optimal balancing. However, ISO feels XTUs must practice operational discipline w.r.t. forecasting-scheduling-despatching within their own areas before extending the area of balancing. DSM can be relooked at as both XTUs and operators feel there are loopholes in this mechanism. The country's seasonal variations and diverse load patterns can be leveraged for balancing. The 150MW ISTS transfer variability constraint can be expanded to accommodate renewables (provided concerned Developer/LDC alerts in time and all measures of within constituent area have been exhausted. ACE needs to be monitored closely to assess performance efficacy. Power Procurement Committees can play a more active role in scheduling and despatching (example Rajasthan DISCOM PPC).

Experience till date says up to 15% renewable penetration is manageable, but beyond this is challenging in current scenario.

Renewable Energy Systems

Standards for specifications and certification mechanism for Renewable systems is required. Transmission lines dedicated for solar plants need to remain charged during night hours to prevent theft and reactive power excursions.

REMC:

A dedicated team is required to handle Renewables at XLDCs – REMCs. REMCs should be co-located with the existing XLDCs. Explore feasibility of using currently stranded Gas Power projects as a balancing resource. However, it should be noted that Gas plants cannot be used as pure balancing resources- as these have minimum gas offtake LTAs with the gas supplier. A threshold gas pressure has to be maintained in the gas grid.

SCADA and Communication:

Communication infrastructure – varies from OFC to VSAT to PLCC. It is gradually moving towards OFC. Some data is coming on GPRS (but experience on link reliability is not good). Microwave was retired after the free band was taken back by DoT. SLAs/QoS not yet institutionalised for communication links. A few states have dedicated teams to monitor communication and SCADA links. Operators across XLDCs communicate over phone and email/fax.

SCADA Infrastructure:

For RTU to LDC level, IEC 101/104 protocols and LDC northbound/peer level, ICCP is used. Heterogeneous systems by design can be found across the states. Very large data volumes are being handled with refresh rates of approx. 10-15 seconds. Newly installed systems are state of the art latest versions, but posing performance issues due to large volume of data. CIM aspirations were there but not completely fulfilled. Sub-LDCs not required for telemetry of Renewables. Secondary control requires 2 second refresh rate visibility into the systems which is not currently supported in the XLDCs. Existing non OFC based communication infrastructure is likely to pose a challenge for this. CIM is a challenge. No remote controls in practice. Remote control of feeders from SLDC is in practice in AP. Mr Debasis De from NRLDC said as per Act, Remote control not allowed from RLDCs.

NOFN rollout for covering transmission substations up to pooling substations is not envisaged yet for providing dedicated bandwidth to Power Sector applications.

Upgrade roadmap for CIM compliance and CIM based interoperability should be there. RTUs should be certified by a certified laboratory for IEC 101/104- to be incorporated in “model RTU specs.” That will be binding on all constituents – through Grid Code/corresponding BIS code to incorporate this.

Recommendations for REMC SCADA- get data from all pooling substations to a REMC SCADA System over “interim” or final OFC channels. This may require data to be routed through nearest XLDC Interconnecting S/S from where it can be conveyed to DCPC/ALDC etc. via a “Gateway”. From REMC SCADA to main SLDC and to backup SLDC data is sent on CIM or ICCP. For states that want to go in for a backup REMC SCADA system, RTU can send data to backup REMC SCADA System as dual master. Note- all RTUs should therefore support 4 masters (main SLDC + backup SLDC + REMC main SCADA + REMC backup SCADA).

There is a CE (communications) in Rajasthan and AP.

Weather monitoring data should also come to REMC.

WAMS - PMUs being installed in the various XLDCs and giving very good insights into system behaviour. But WAMS for Renewables may not be warranted as on date – too early in the technological evolution of this technology.

Annex 2 –Questionnaire on Existing Control Centres

Load Dispatch Centre	**National Load Dispatch Centre (NLDC),Delhi**
Region	National
Brand of SCADA System	Alstom
Type of SCADA System	eTerra Habitat Version 5.6 Release 2006. Data Historian - ISR (Alstom own)
Software release	2006
Year of commissioning	2009 - Planning to upgrade to newer system in the control period 2014-19. Have planned provision for integration with REMC system.
Last upgrade	ISR patch updated in 2013
Extension capability	CiM capable
System architecture scheme available	NLDC Architecture: RLDC to main and backup NLDC over ICCP link. Main to Backup NLDC over Alstom Proprietary protocol. Backup NLDC in a different location.
Service-/Maintenance Contract in Force	Comprehensive AMC with Vendor for NLDC. 1 SW and 1 HW onsite engineer
No. of RTUs connected	No RTU directly connected to NLDC. (RTUs for Interregional links are connected to the corresponding RLDCs from where data comes to NLDC). RLDCs coordinate with NLDC for operations of these links. 5 RLDCs connected.
No. of elements	>45K Analog measurands; >75K DI inputs. Not required.
RTU protocols	RLDC to NLDC is ICCP.
Actualization for measurements	2-10 second update for measurands;
RTU com. Media	RLDC to NLDC link is F.O 2MPBS (STM1 at the minimum)
O & M	1AGM + 1 Mgr. + 2Sr. Engg. + 2 Engg. for O&M of NLDC SCADA system. Communication Infra is looked after by Powergrid Telecom department.
Remarks	
Capability of CIM	CIM Capable
XLDC communication with stakeholders	NLDC communicates only with RLDC on Leased Line. Going in for Internal Orange Hotline communication between NLDC, RLDCs and SLDC (being commissioned through Powergrid). Central Sector substationswill also be covered. Separate in-house developed DSM web based scheduling SW used. Plan to go in for a 3rd party unified system soon.
Related to REMC	
XLDC users: Operations manpower	4 person X 3 shift X 4 teams
XLDC display	BARCO 4 X 2 nos. 67" diagonal.
Training	Support System Operations Certification courses (basic and specialist level). Recertification is required every 3 years. Majority of System operations staff at NLDC and RLDC level are certified.

Load Despatch Centre	**Northern -Regional Load Despatch Centre (NRLDC),Delhi**
Region	Regional - NRLDC
Brand of SCADA System	Siemens
Type of SCADA System	Siemens system SP7 gone live in Dec 2014. Earlier Alstom system (from 1996 to 2014 Sep). SP7 supports online reconfiguration. Historian being part of system, performance of reports expected to improve.
Software release	Service Pack 5 implemented in Feb 2015 all across NR constituents and NRLDC
Year of commissioning	Shifted to Siemens system completely, in Feb 2015. Old system not in use. Facing challenges on MMI response; SOE/ Alarm tuning is going on. EMS tuning is going on. Defect Liability period not yet started for any of the constituents.
Last upgrade	Service pack 5 implemented in Feb 2015.
Extension capability	Yes- as per contract with Vendor, another 100% data element can be added during anytime of warranty+ AMC period. CIM -compliant. Compatibility with other vendor not yet tested (will be done shortly).
System architecture scheme available	SLDC to RLDC is ICCP. RLDC to NLDC is ICCP fully implemented. RTU to RLDC directly on IEC101/104 on F.O. or GPRS or VSAT/MPLS. NRLDC Main CC in Delhi and Backup in a different geographical location (based on Siemens Multisite control centre). Generation capacity has to be >50MW for evacuation connectivity at RLDC level.
Service-/Maintenance Contract in Force	1 year warranty and 6 years AMC contract already signed with Vendor. One Software and one Hardware Engineer resident at NRLDC Delhi from Vendor. Resident engineer may not be there at Backup RLDC from vendor site Maintenance of RTUs for RLDC is under the concerned CTU/ISGS/IPP.
No. of RTUs connected	No. of RTUs connected directly to NRLDC = 102 nos. on F.O/MPLS/GPRS/VSAT etc. EMS is fully configured for 400kV but data availability not reliable at 220kV- especially that coming from state SLDCs.
No. of elements	70K data elements (measurands +contacts). Data engineering - Older Alstom system data ported to CIM (CIM version 12) There were issues around Schema as Alstom CIM version was lower.
RTU protocols	Older Alstom system did not support IEC 104 but migrating to IEC104 with Siemens system. BBMB 10 stations RTUs have implemented IEC 104. All new substations will be on IEC 104 but older substations are on IEC 101.

Load Despatch Centre	**Northern -Regional Load Despatch Centre (NRLDC),Delhi**
Actualization for measurements	10 second update for analog; digital on status change; GI in 10 minutes. Same philosophy for all constituents.
RTU com. Media	RLDC RTUs on wide band nodes. All 400kV substations and above are proposed to be on OPGW communication by Powergrid; All generators connected to 220kV substations and above are required to be OPGW. Separate F.O network for monitoring and control. Others based on criticality. SDH STM1 at the minimum and in some places STM16. There were challenges around PLCC performance as last mile connectivity. NRLDC and ERLDC use digital PLCC but had problems with it. GPRS connectivity performance is poor in terms of reliability and speed. Tried VSAT but encountered QoS issues as the channels were being shared. Recommend - Priority #1 Comm. media should be F.O wide band then GPRS then Leased line. Not in favour of PLCC or VSAT. Microwave link frequency band had to be released to the Govt. so no longer available dedicatedly to Power Sector. Do not give consent for operation of substation unless telemetry is provided.
O & M	Communication infra. Setup by CTU Powergrid. CTU responsible for its maintenance that is outsourced to a 3rd party. It takes minimum 2 hours to restore a F.O link within city. Separate channels for general communication (voice/data/video). There is dedicated communication infrastructure for POSOCO (RLDC and NLCDC). NRLDC has a dedicated team for SCADA and MIS separately.
Remarks	RLDC main concern is security and not commercials. RLDC computes transfer capability on day-ahead basis and if ST market fits in, it is approved. In case of security alert, RLDC curtails ST market. ACE is being monitored but no controls. (RTUs directly reporting to NRLDC do not have DO). Same for all RLDCs. Not allowed as per Act.
Capability of CIM	CIM compliant but testing interoperability with other vendor.
XLDC communication with stakeholders	Voice over PLCC exchange. Will get hotline on F.O. soon (IP phones). Chat group. Dedicated website for scheduling for each RLDC. Going in for a single unified application for all RLDCs- going live in a month. SW will allow entry of data manually or through interface by SLDC.
Related to REMC	REMC proposed in RLDC for independently monitoring scheduling (including forecast) and despatch of RE generation at regional level from a grid security point of view. Concept stage. Active forecasting - scheduling-despatch for ISGS plants.
XLDC users: Operations manpower	3 persons per shift,3 shifts, 4 teams

Load Despatch Centre	Northern -Regional Load Despatch Centre (NRLDC),Delhi
XLDC display	Video Projection System (VPS) from BARCO and Delta. Find BARCO performance better.
Training	DTS training simulator yet to be installed. Already procured. Proposed plan to train the constituents also on this.

Load Despatch Centre	Southern Regional Load Despatch Centre(SRLDC),Bengaluru
Region	Regional – SRLDC
Brand of SCADA System	Alstom
Type of SCADA System	eTerra
Software release	Version 3.7
Year of commissioning	in process 2015
Last upgrade	
Extension capability	CIM and ICCP capable.
System architecture scheme available	52 RTUs to SLDC on IEC101. SLDC to RLDC is ICCP. RLDC to RLDC and to NLDC is ICCP. Main RLDC in Bengaluru and backup RLDC in a different geographical location.
Service-/Maintenance Contract in Force	SRLDC team for O&M.
No. of RTUs connected	52 RTUS direct (IEC 101). All new RTUs in SRLDC will be IEC104 through Gateways making RTUs redundant. RTUs on Wideband OFC or wideband PLCC.
No. of elements	50K data elements Data Engineering done afresh in the new system purposefully.
RTU protocols	Existing RTUs are IEC101 compliant. New RTUs will be IEC104. New concept of DCPC being implemented in SR.
Actualization for measurements	10-15 seconds (for PLCC links it is 15 sec).
RTU com. Media	Wideband OFC or Wideband PLCC. AP, TN and Telangana have OFC-PLCC. Karnataka has VSAT.
O & M	
Remarks	Forecasting should be done by SO for operational despatching and by developer for market participation and avoiding penalties.
Capability of CIM	CIM capable
XLDC communication with stakeholders	Over Telephone/email.
Related to REMC	
XLDC users: Operations manpower	
XLDC display	VPS from Delta of 26 arrays. Older BARCO system was there (can be used for REMC VPS)
Training	

Load Despatch Centre	**Himachal Pradesh**
Region	State under Northern Region - NRLDC
Brand of SCADA System	Siemens
Type of SCADA System	Spectrum Power 7 (Service Pack 5).
Software release	Service Pack 5 implemented in Jan 2015. (S/W version management in tandem with NRLDC).2
Year of commissioning	Jan 2015. Currently in operational acceptance period. Project executed as part of one contract administered by NRLDC/Powergrid for NRLDC and its constituents.
Last upgrade	Service pack 5 implemented in Feb 2015.
Extension capability	Yes- at same rates more RTUs and CC for 2 years. CIM compliant.
System architecture scheme available	RTU- SLDC directly on IEC101. Main SLDC in Shimla and Backup SLDC being implemented in a different geographical location. Main SLDC to Backup SLDC on CIM/ICCP under implementation. SLDC-RLDC is ICCP done. SLDCs are fully redundant, independent versions of RLDC systems. There are replica servers for web servers. Micro-hydel plants below 5MW are not yet covered under SCADA. Propose to cover all Generators >=2MW in SCADA - on GPRS initially later F.O.
Service-/Maintenance Contract in Force	1 year warranty and 6 years AMC contract already signed with Vendor. 1 Software and 1 Hardware Engineer resident at SLDC Shimla from Vendor.
No. of RTUs connected	Multivendor RTUs. All RTUs at 220kV substations are covered. RTUs only at a few 132 kV and 66kV Substations. 28 such Substations. (All substations are not covered due to budget constraints). Data from unmonitored substations is obtained on the telephone once a day or can be extrapolated in power diagram. MW, MVAR, V, Hz, OLTC Tap position, C.B Status (NO+NC), Isolators (NO) and protection Trip contact (NO).
No. of elements	approx. 2000 data elements. Data Engineering done afresh in Siemens system using IMM (Information Model Management) tool.
RTU protocols	Older Alstom and ABB make RTUs on IEC 101; Motorola RTUs on 101/104. New RTUs 101/104 (PLCC/F.O).
Actualization for measurements	10 second update for AI; DI on change of status; Full Refresh GI (General Interrogation) every 10 minutes.

Load Despatch Centre	**Himachal Pradesh**
RTU com. Media	RTUs at substations>66kV level on analog PLCC. PLCC links 300/600bps (1200 bps not supported). F.O. link 2MBPS and 64KBPS links. F.O link from RTU-SLDC is STM1; above SLDC to RLDC is STM16. 10 Power houses of 10-12MW Gen. capacity are integrated to SLDC over GPRS link- and links are satisfactory. No communication network for small hydro plants; hence will use GPRS.
O & M	HP Load Despatch Society (HPLDS) formed under Govt. of HP- will independently take over grid operations. Staffing awaiting Govt. cabinet approval. HP has a SCADA + Communications team: 3 person team (1 ASE + 3engineers + 1 JE).
Remarks	
Capability of CIM	CIM compliant
XLDC communication with stakeholders	All substations are manned. PPP substations are also manned. Communication from SLDC to these over cell phone/PLCC exchange/Landline. ABT -DSM mechanism in force with 15 minute day ahead scheduling. Do not have any S/W for scheduling at present.
Related to REMC	HP mostly run of the river must run hydel with around 3 hour storage capacity. No irrigation constraints. These are integrated at 66/132/220kV levels (48 nos.) and 33kV (168 nos.). Would like to have 1/2 additional manpower to manage Renewables specifically. New IPPs may like to evacuate power out of the state through REMC.
XLDC users: Operations manpower	(1EE + 1AE + 1 JE + 1 Helper) 4 persons X 3 shifts X 4 teams.
XLDC display	A Video Wall (LED) BARCO 4 X 2 panels of 70" each.
Training	DTS not taken. Simulator training planned for later.

Load Despatch Centre	**Rajasthan**
Region	State under Northern Region - NRLDC
Brand of SCADA System	Siemens
Type of SCADA System	SP7. eDNA historian
Software release	Service Pack 5 implemented in Feb 2015. (S/W version management in tandem with NRLDC).
Year of commissioning	Currently in Acceptance testing phase. Project executed as part of one contract administered by NRLDC/Powergrid for NRLDC and its constituents.
Last upgrade	Service pack 5 implemented in Feb 2015.
Extension capability	Yes- at same rates more RTUs and CC for 2 years. CIM compliant. Not yet tested though.
System architecture scheme available	RTU-SubLDC-SLDC -RLDC. 4 Sub-LDCs. SubLDC-SLDC on ICCP and OPGW (with main and standby; STM1 with STM16 capability). Earlier had microwave links that have been withdrawn. SubLDC is connected to both- SLDC main and SLDC backup. SLDC to RLDC on ICCP. SLDC main to back up on ICCP. Main SLDC in Jaipur and Backup in a different geographical location. Sub LDC is now functioning as a Data Concentrator only. SLDCs are fully redundant, independent versions of RLDC systems. There are replica servers for web servers.
Service-/Maintenance Contract in Force	1 year warranty and 6 years AMC contract already signed with Vendor? 1 Software and 1 Hardware Engineer resident at SLDC Jaipur from Vendor. RTUs are maintained by in-house SLDC SCADA team. Some RTUs are in warranty phase.
No. of RTUs connected	Multivendor RTUs. Total 128 RTUs covering all 765/400/220kV substations and a few 132kV Substations. 4 SubLDCs. Additional 136 S/S RTUs in tender stage to cover majority of 132kV Substations. + will cover residual 132kV substations in future. In future, post the Grid code amendment; all new 132kV substations will have SCADA RTUs as a pre-req. for consent for connectivity.
No. of elements	Approx. 50K total data elements acquired from field. Data Engineering done afresh in Siemens system using IMM (Information Model Management) tool
RTU protocols	Existing RTU- Sub LDC on IEC101; new RTUs -Sub LDC on IEC104 already tested.
Actualization for measurements	10 second update for analog data refresh. DI on status change? Remote control not practised although DO points are wired in RTU.

Load Despatch Centre	**Rajasthan**
RTU com. Media	RTU-Sub LDC on PLCC 300bps (Analog mostly with a few digital). A few places OPGW especially at 400kV and above Substations and critical S/S RTUs have OPGW with PLCC backup. Other places, critical RTUs have PLCC backup. Find PLCC to be ok for small Substations. Microwave links withdrawn after Govt. took back free spectrum. VSAT links were tried by a few IPPs for their RTUs but not very successful. Also ABT-DSM based AMR metering was tried on VSAT but did not work. GPRS for small renewable developer pooling Substations, OA consumers. GPRS Works satisfactorily if no. of SCADA data points is <=50; beyond this speed issues.
O & M	RVPN has a dedicated PLCC Communications team. RTUs are managed by SLDC SCADA team. SCADA team of 1Superintending Engineer + 3 Executive Engineers + Assistant/Junior Engineers manages the system.
Remarks	Currently, System for Intra-state ABT -DSM is in tender stage. Scheduling package not available. Do manual data entry into NRLDC scheduling package. NVVN (NTPC Vidyut Vyapar Nigam Ltd) is the nodal agency for solar developers and has a good forecasting track record (they trade on the power exchange).
Capability of CIM	CIM compliant
XLDC communication with stakeholders	All Substations are manned.
Related to REMC	Would like REMC to be co-located in main SLDC and perform forecasting, for renewables and support SLDC in scheduling and despatch of renewables. REMC should also have weather monitoring to improve forecast. Backup REMC should be at Jodhpur (this is a renewable hotspot, no Sub LDC here); already connected to main SLDC over OFC. Expect pooling S/S data to go to REMC directly.
XLDC users: Operations manpower	5 person X 3 shifts X 4 teams. Need an additional team.
XLDC display	VPS BARCO system.
Training	

Load Despatch Centre	Gujarat
Region	State under Western Region - WRLDC
Brand of SCADA System	Alstom
Type of SCADA System	eTerra
Software release	
Year of commissioning	under commissioning 2015
Last upgrade	
Extension capability	CIM Capable
System architecture scheme available	RTU-Area LDC to SLDC. 3 ALDcs at Gandhinagar, Jetpur and Jambuwa. Sub LDC connects to main and backup SLDC on ICCP. SLDC to RLDC main and backup on ICCP.
Service-/Maintenance Contract in Force	
No. of RTUs connected	126 RTUs and 74 Sub RTUs (on radio links)
No. of elements	3000 AI, 8000 DI, <100 DO that do not go beyond RTU for tripping. Data Engineering done afresh.
RTU protocols	RTU-SubLDC is on IEC101. IEC104 under implementation. Sub LDC to main and DR SLDC on ICCP.
Actualization for measurements	8-10 seconds refresh.
RTU com. Media	RTU-Sub LDC on PLCC or Leased Lines or a few OFC and radio. PLCC link redundant links 100% reliable. Lines >66kV on PLCC. (200bps programmable). F band Radio modems used for some sites. .
O & M	2 persons manage SCADA Data.
Remarks	
Capability of CIM	
XLDC communication with stakeholders	
Related to REMC	
XLDC users: Operations manpower	
XLDC display	
Training	

Load Despatch Centre	Andhra Pradesh
Region	State Under Southern Region - SRLDC
Brand of SCADA System	Will use the ALSTOM system that is being commissioned currently from next month onwards. Currently, older GE system is being used.
Type of SCADA System	eTerra Control Version 3.7; ICCP Terracom 2.6.
Software release	not relevant (Refer comment in brand of SCADA system)
Year of commissioning	Plan to go in for their own new SLDC SCADA system eventually. When this happens, the ALSTOM system will be used as their Disaster Recovery (DR).
Last upgrade	not relevant (Refer comment in brand of SCADA system)
Extension capability	CIM and ICCP capable. If this does not work, ALSTOM's ISD (inter Sire Data) will be used.
System architecture scheme available	RTU-DCPC (Data Concentrator Protocol Converter) IEC101; DCPC - SLDC IEC104; SLDC DC -DR and to RLDC CIM, fall-back ICCP, Fall-back Alstom Proprietary ISD; RTU is connected to main and backup DCPCs on PLCC /OFC links. DCPC unit has main and backup servers. Main and backup DCPC are connected to main and backup (DR) SLDC on OFC link. New RTUs on IEC 104 protocol can connect to SLDC using DCPC as a gateway if OFC link is available. Otherwise several such RTUs in the neighbourhood will be connected to a network device and from there to SLDC over a common link.
Service-/Maintenance Contract in Force	Alstom system will be in 12 month warranty period and then 6 years AMC with supplier. SCADA vendor (Alstom) Resident Engineer in control Centre; No AMC for RTUs. AP TRANSCO team of 3 Engineers for SLDC system; team of 4 Engineers (1 ADE + 1 AE each in the 2 erstwhile ALDC regions - Rayalseema and Coastal) for O&M of RTUs and DCPCs; AP TRANSCO .telecom wing of 60 Engineers for O&M of PLCC and OFC links.
No. of RTUs connected	104 RTUs with 8 DCPCs; All 220kV and 400 KV Substations have RTUs; very few 132kV Substations have RTUs - reason being reliable communication infrastructure not there; currently not monitoring 33kV Substations . Note- each Pooling S/S already has IEC 101 compliant RTU for monitoring as per specifications given by APTransco supporting at least 2 masters.
No. of elements	AI - approx. 9000; DI -9900; DO 700 ; DO for Remote feeder tripping and in a few cases feeder CB closing also. APTransco is also insisting to have IEC 61850 client support for RTUs so that it is capable of taking data for df/dt, UFR protection status etc. from IED relays.

Load Despatch Centre	Andhra Pradesh
RTU protocols	Various makes of RTUs - IEC 101/104. GE RTU's model D20 supports up to 7 masters for IEC 101 but its CPU does not support IEC 104. However, by replacing the CPU with d20mx type the RTU can support IEC 104 also. APTransco has planned to replace the same in orderly manner. Remaining RTUs of ABB Areva and SAS system support both IEC 101 and 104). APTransco is also insisting to have IEC 61850 client support for RTUs so that it is capable of taking data for df/dt, UFR protection status etc. from IED relays.
Actualization for measurements	4 seconds for analog; status update every 10 minutes; status points (Breaker or isolator status) is report by exception.
RTU com. Media	PLCC (300/600 bps) or OFC (STM1 and STM4 upgradeable to STM16); there is only 1 HF link that is likely to be phased out. VSAT not explored as it is too costly; planning to use GPRS for covering 33kV Substations - here PLCC is not feasible; OFC is too costly); Open to using OFC STM1 or even OPTIMUX if this is made available under the NOFN project. Will explore Radio only if GPRS link is also not there - some areas may not have good GPRS coverage. RTU to DCPC only single path (PLCC or OFC) is available in AP. Hence, communication from RTU is brought to DCPC location over single path, where it is split into 2 (two) channels using splitters and fed to main and backup servers in DCPC. From here it is sent to Main and Backup SLDC over IEC 104 protocol.
O & M	Please see remarks in Service/Maintenance contract
Remarks	AP is considering covering the 33kV pooling Substations through GPRS based SCADA system that will get data from all these RTUs at IPP' to separate FEP servers co-located in main CC and provide or integrated to SLDC DC over ICCP.
Capability of CIM	ALSTOM is CIM capable'
XLDC communication with stakeholders	Obtain proposed generation and withdrawal schedules from constituents over email/upload on website. Communicate despatch schedule over email/upload on website. Planning to go in for a web based scheduling package. All pooling Substations are manned. For immediate actions, SLDC operator talks to S/S in charge over phone over PLCC or fibre (where available) or cell phone media. Follow up with an email and written communication.
Related to REMC	Need to address following questions: Who will setup REMC, bear its cost . What is its proposed inter-relationship with SLDC. It is suggested that the REMC should be co-located in SLDC main and DR and REMC team can be the SPOC for Renewables related activities of the Operator. REMC should assist SLDC in despatching and Operations of renewables. . RTUs at Pooling Substations can be the mini RTUs IEC 101and IEC 104 protocol compliant but must be KEMA certified. Data from these can go directly to REMC from where it can come to SLDC over CIM/ICCP.

Load Despatch Centre	Andhra Pradesh
XLDC users: Operations manpower	4 persons per shift, 3 shifts; 4 teams; Scheduling Team - 4 persons;
XLDC display	Video wall planned with a grid of 18 nos. screens of size 70 inches each.
Training	For training SLDC staff there is no simulator but for SCADA TMW protocol tester for IEC 101/104 is being used.

Load Despatch Centre	Tamil Nadu
Region	State under Southern Region - SRLDC
Brand of SCADA System	Alstom
Type of SCADA System	eTerra Control Version 3.7; ICCP Terracom 2.6.?
Software release	
Year of commissioning	under commissioning 2015
Last upgrade	
Extension capability	CIM Capable
System architecture scheme available	3 sub-LDCs at Madurai, Chennai and Erode. RTU to Sub LDC on IEC101/104? Sub LDC to SLDC on ICCP? SLDC to RLDC on ICCP.
Service-/Maintenance Contract in Force	12 month warranty and 6 year AMC contract for SLDC with supplier. RTUs maintained by in-house protection and communication team.
No. of RTUs connected	RTUs are installed at all 230kV Substations and Generation Stations. These are of ABB, GE Harris and Honeywell make.
No. of elements	
RTU protocols	
Actualization for measurements	
RTU com. Media	
O & M	
Remarks	
Capability of CIM	
XLDC communication with stakeholders	
Related to REMC	
XLDC users: Operations manpower	
XLDC display	
Training	

Load Despatch Centre	Karnataka
Region	State under Southern Region - SRLDC
Brand of SCADA System	ABB
Type of SCADA System	Network Manager
Software release	Rel. 3
Year of commissioning	2006/2007
Last upgrade	
Extension capability	yes
System architecture scheme available	
Service-/Maintenance Contract in Force	yes, another 3.5 years
No. of RTUs connected	approx. 1300
No. of elements	approx. 500 k
RTU protocols	IEC 104
Actualization for measurements	min. 2 s, others slower through threshold
RTU com. Media	VSAT (GILAD of Israel), leased lines as backup, FO upcoming due to NOFN
O & M	32 Engineers for SCADA, VSAT, MIS
Remarks	every feeder down to 11kV possible to be monitored & controlled
Capability of CIM	
XLDC communication with stakeholders	
Related to REMC	
XLDC users: Operations manpower	
XLDC display	
Training	

Annex 3 - Preliminary Cost Estimate

REMC System Cost

No	Item Description	Unit Price	1st REMC (Standard System)		REMC Backup (under same Contract)		2nd and further REMCs under same Contract		Remarks
			Qty.	Euro	Qty.	Euro	Qty.	Euro	
1	**Master Station Hardware**								
	Dual LAN equipment including Switches, Routers, Firewalls, DMZ LAN, time frequency system etc.	30,000	1	30,000	1	30,000	1	30,000	
1.1	Communication server / Front End Processors including interfaces	40,000	2	80,000	2	80,000	2	80,000	
1.2	Main SCADA Application Server (redundant)	40,000	2	80,000	2	80,000	2	80,000	
	Historical Data Servers (redundant)	40,000	2	80,000	2	80,000	2	80,000	
	Mass Storage (Raid Disk, Tape)	30,000	2	60,000	2	60,000	2	60,000	
	Extended Real-time servers	40,000	0	0	0	0	0	0	
	ICCP Servers (redundant)	15,000	2	30,000	2	30,000	2	30,000	
	WEB-/ File exchange Servers (redundant)	10,000	2	20,000	2	20,000	2	20,000	
1.3	Operator Consoles (including. Licenses)								
	Dispatcher Consoles, Work Stations w. 4 Monitors	20,000	2	40,000	2	40,000	2	40,000	
1.4	Printers								
	Logger (b/w printer)	500	2	1,000	2	1,000	2	1,000	
	Colour Printer	1,200	2	2,400	2	2,400	2	2,400	
1.5	Rear Projection Unit								
	Controller including interfaces, hard and software	40,000	1	40,000	1	40,000	1	40,000	

No	Item Description	Unit Price	1st REMC (Standard System)		REMC Backup (under same Contract)		2nd and further REMCs under same Contract		Remarks
			Qty.	Euro	Qty.	Euro	Qty.	Euro	
	Cubes including frame and connection	25,000	10	2,50,000	10	2,50,000	10	2,50,000	
1.6	Engineering Console								
	Workstation with 4 Monitors and licenses	20,000	2	40,000	2	40,000	2	40,000	
1.7	Office LAN within REMC (including. 1 Server, Firewalls, 3 printers)	10,000	1	10,000	1	10,000	1	10,000	
1.8	Rear Projection Unit for Dispatcher Training Simulator								
	Controller including interfaces, hard and software	40,000	0	0	0	0	0	0	Option DTS
	Cubes including frame and connection	25,000	0	0	0	0	0	0	Option DTS
1.6	Trainer / Trainee Console								
	Workstation with 4 Monitors including licenses	25,000	0	0	0	0	0	0	Option DTS
	TOTAL HARDWARE			**7,63,400**		**7,63,400**		**7,63,400**	
2	**Software**								
2.1	Operating Software & System Software	30,000	1	30,000	1	30,000	1	30,000	
2.2	SCADA and HMI Software, Archive Software	2,00,000	1	2,00,000	0.5	1,00,000	0.8	1,60,000	
2.3	Renewable Management Application Software	1,80,000	1	1,80,000	0.5	90,000	0.8	1,44,000	
2.4	Short Term Load Forecast Software (based on neural artificial networks)	1,80,000	0	0	0	0	0	0	
2.5	Dispatcher Training Simulator Software System (inclusive necessary Servers)	6,00,000	0	0	0	0	0	0	Option DTS

No	Item Description	Unit Price	1st REMC (Standard System) Qty.	Euro	REMC Backup (under same Contract) Qty.	Euro	2nd and further REMCs under same Contract Qty.	Euro	Remarks
	TOTAL SOFTWARE			**4,10,000**		**2,20,000**		**3,34,000**	
3	**Contractor's Services**								
3.1	System Design, Configuration and Documentation	2,50,000	1	2,50,000	0.3	75,000	0.3	75,000	
3.2	Supervision and On-Job-Training for Customer during Data Entry and parameterization	1,20,000	1	1,20,000	0	0	0.5	60,000	
3.3	Supervision and On-Job-Training for Customer for DTS specifics	1,50,000	0	1,50,000	0	0	0	0	Option DTS
3.4	Installation, Commissioning and testing including FAT, SAT	2,80,000	1	2,80,000	0.5	1,40,000	0.8	2,24,000	
	Total Services for Master Station			**8,00,000**		**2,15,000**		**3,59,000**	
TOTAL MASTERSTATION HARDWARE, SOFTWARE & SERVICES				**19,73,400**		**11,98,400**		**14,56,400**	

Training Cost

Ref.	Training Type	Target Group	Students	Training days	Calendar days	Unit Price Euro	Sum of Price Euro	Remarks
1	**Local Training in India**							
	General System Management	Control System Operators REMC Management Planning and Reporting Staff	10	5	5	1,500.00	7,500.00	
	Control System Handling	Network Operators	8	5	5	1,500.00	7,500.00	
	RTU Introduction	RTU Engineers and Technicians	6	10	10	1,500.00	15,000.00	
	RTU Service and Maintenance	RTU Engineers and Technicians	6	10	10	1,500.00	15,000.00	
	Telecommunication system Maintenance	RTU Engineers and Technicians	6	10	10	1,500.00	15,000.00	
	Sub-Total for Local Training						**60,000.00**	
2	**Factory Training**							
	Control System Management	REMC Management	2	5	7	500.00	5,000.00	
	Control System Handling SCADA	Network Operators	8	10	14	500.00	40,000.00	
	Control System Handling (Renewables)	Network Operators	8	10	14	500.00	40,000.00	
	Control System Hardware Maintenance	Hardware Maintenance	4	20	28	500.00	40,000.00	
	SCADA System Maintenance	SCADA Maintenance (H/W & S/W)	4	10	14	500.00	20,000.00	
	Software and Database Maintenance	Software	4	30	42	500.00	60,000.00	
	Database Population	Software	8	40	56	500.00	1,60,000.00	
	RTU Introduction	RTU Engineers and Technicians	4	10	14	500.00	20,000.00	
	RTU Service and Maintenance	RTU Engineers and Technicians	4	10	14	500.00	20,000.00	
	Telecommunication system Maintenance	RTU Engineers and Technicians	4	10	14	500.00	20,000.00	
	Telecom Management system HW & SW	RTU Engineers and Technicians	4	10	14	500.00	20,000.00	

3	**Travel**							
	Economy Class- to / from Delhi only		54			1,500.00	81,000.00	
4	**Accommodation**							
	- including. Health & Medical Insurance				231	100.00	23,100.00	
5	**Allowances**							
	Per day allowances (paid to staff)				231	100.00	23,100.00	
	Sub-Total for Factory Training						**5,72,200.00**	
	Total Training Cost						**6,32,200.00**	

<u>FAT Test Cost</u>

Ref.	Test Group	Type of Factory Acceptance Test	Participants of Client	Days	Unit Price Euro	Price Euro
5.1	**A-SCADA - System Test Group**	**SCADA - System Test**	4	10	not considered	not considered
5.1.1		Travel - to / from Delhi (Economy Class only)	4		1,500.00	6,000.00
5.1.2		Accommodation / including. Health & Medical Insurance	4	12	100.00	4,800.00
5.1.3		Per Diem Allowances - (paid to staff)	4	12	100.00	4,800.00
5.1.4	**Sub-Total for SCADA-Test**					**15,600.00**
5.2	**RTU - System Test Group**	**RTU - System Test**	2	5	not considered	not considered
5.2.1		Travel - to / from Delhi (Economy Class only)	2		1,500.00	3,000.00
5.2.2		Accommodation / including. Health & Medical Insurance	2	7	100.00	1,400.00
5.2.3		Per Diem Allowances - (paid to staff)	2	7	100.00	1,400.00
5.2.4	**Sub-Total for RTU-Test**					**5,800.00**
		Grand Total for Participation in Factory Acceptance Tests				**21,400.00**

Total Cost:

Subject	Cost for 1 REMC without Back-Up System (first System as Standard System under the Contract) (1)	Cost for 1 Data Acquisition Unit at Substation / Pooling-Station (2)	Cost for 1 REMC Back-Up System for (1) procured under the same Contract (3)	Cost for any additional REMC System based on the Standard System (1) procured under the same Contract (4)
	estimated Cost Euro	estimated Cost Euro	estimated Cost Euro	estimated Cost Euro
Master station Hardware, Software and related Services - for details see subfolder "REMC System"	19,73,400		11,98,400	14,56,400
Cost for planning, engineering and erection of Buildings and Facilities for the REMCs - it is assumed that REMCs will be established at premises already existing and with already existing infrastructure and facilities	not included	not included	not included	not included
Data Acquisition Unit at Substations / Pooling Stations Hardware, Software, Engineering and Parameterization		20,000		
SCADA Equipment at Substations Adaptation Works, Installation, Commissioning point-to-point Test, Documentation		5,000		
Telecommunication System Equipment and installation	not included	not included	not included	not included
Optical Fibres (OPGW, ADSS), accessories and installation	not included	not included	not included	not included
Recurring cost for operation of Telecommunication Network (lease of dark fibres, fees for V-Sat or GPRS services etc.)	not considered	not considered	not considered	not considered
Spare Parts, Tools and Instruments (10 % of hardware)	76,340	2,000	76,340	76,340

Training Measures - for details see subfolder "Training"	6,32,200	included in (1)	included in (1)	5,05,760
Participation in Factory Tests - for details see subfolder "FAT Part"	21,400	included in (1)	included in (1)	21,400
SCADA /REMC System Maintenance and Technical Support Agreement per year	not included (typically 5 to 10 % of cost for Master station)		not included (typically 5 to 10 % of cost for Master station)	not included (typically 5 to 10 % of cost for Master station)
Taxes and Duties	not considered	not considered	not considered	not considered
Subtotal	**27,03,340**	**27,000**	**12,74,740**	**20,59,900**
Physical Contingencies (5 %)	1,35,167	1,350	63,737	1,02,995
Price Contingencies (5 %)	1,35,167	1,350	63,737	1,02,995
Total Cost	**29,73,674**	**29,700**	**14,02,214**	**22,65,890**

Important notes:

- Cost indicated for REMC Back-Up System under (3) and additional REMCs under (4) are only valid under the precondition that they are being established together with the Main System under (1) simultaneously under a common Contract at the same time. Otherwise it is to be expected that cost will be considerably higher!
- REMC is capable of monitoring & control for 200 pooling stations (200 Data Acquisition Units as specified in Report Sect. 4.3.7)

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