

1. SCADA

1.1. General

The main purpose of the Distribution SCADA system is to continuously monitor the loading, status, and performance of equipment located on distribution feeders. It also enables operators to remotely control devices located on the feeders. Controllable devices include reclosers, capacitor bank switches, voltage regulators, and any other electrically operable device.

Automating Berhampur, Chhatrapur and Narendrapur electrical distribution systems by implementing a supervisory control and data acquisition (SCADA) system is one of the most cost-effective solutions for improving reliability, increasing utilization and reduce damage under unforeseen events in these areas.

In the event of an outage caused by unforeseen events like recent Phailin cyclone and floods in Berhampur, Chhatrapur, and Narendrapur, utilization of SCADA system's advanced data collection capabilities will help field workers quickly identify the exact location of the outage without having to wait for customer calls.

Moreover, a SCADA system can significantly increase the speed of power restoration following an outage. SCADA-enabled switches and line reclosers can help operators isolate the outage and open adjacent automatic switches to re-route power quickly to unaffected sections—all without the need for a line worker to visit the site to perform a lengthy visual inspection, often followed by an educated guess as to the exact nature and location of the problem.

Under normal conditions, the SCADA system periodically acquires real-time values of current, voltage and power at various strategic measurement points and the open/closed status of all monitored switches.

Typical sources of Distribution SCADA measurement information and equipment status indications include:

- Intelligent Electronic Devices (IEDs) associated with distribution system power apparatus. IEDs include protective relays, device controllers (voltage regulators, capacitor bank controllers, etc.), and Remote Terminal Units (RTUs)
- Standalone sensors, such as faulted circuit indicators (FCIs) and line monitoring devices.

- External systems, such as Advanced Metering Infrastructure

This information is typically displayed to an operator and stored in a database for future reference and analysis. When an abnormal condition occurs (such as recloser operation due to a line fault), alarm information is reported to alert the operator to the event.

Standard protocols specifically designed for the industry such as DNP3 and IEC-60870-5-104 enable the SCADA system to collect information with the precision and accuracy required to diagnose shutdown causes and minimize downtime. This cuts time wasted on field visits, and also improves worker safety during outages and power restoration.

In India, there is increased penetration of distributed renewable sources of power due to reduction in solar PV prices, various incentives by state and central governments. These Distributed Energy Resources (DERs) can cause havoc with the electrical distribution system due to the intermittent nature and the quality of the supplied power. So, automation of DER monitoring will help in making more informed adjustment faster and to address issues before they occur. This can be done by implementing SCADA.

1.2. Objective

1. To acquire real time data from 4 Nos. of 132 kV stations, and 19 Nos. of existing and proposed downstream 33 kV stations at the Area Control Centre situated at Autonagar 132 kV station.
2. To remotely control and manage loads within the network of these 23 stations.
3. To store and manage data at the Area Control Centre for real time and historical analysis.
4. To provide redundancy at all levels for high uptime of the SCADA and communication network.
5. To communicate on real time and provide data acquisition and control of the above stations to the Main SCADA system located at SLDC or elsewhere.

1.3. Understanding of existing system

1. All the 132 kV and 33 kV stations are enabled with conventional Control and Relay panels.

2. All the 132 kV stations are provided with RTU based SCADA. RTU acquires data from conventional transducers.
3. RTUs and Sub-station Automation either based on IEC 61850 or otherwise are not provided at any of the 33 kV stations.

1.4. Architecture

1. The communication will be on an optical fibre ring (OPGW / UG) to provide alternate routes for connectivity of the SCADA network.
2. As the all the stations are provided with conventional Control and Relay panels, data shall be acquired by providing a SCADA Remote Terminal Unit at the stations. Necessary interface such as Multifunctional Transducers shall be provided in the RTU for data acquisition. Status data acquisition and control shall be engineered during detailed engineering of the system.
3. The RTUs shall be compatible to communicate to various devices on IEC 61850, Harris, DNP 3.0, IEC 870-5 101/104 and Modbus. The RTUs shall be built in with Programmable Logic controllers and shall be capable of driving logics based on data acquired and incoming control.
4. The SCADA system shall be one as specified with hardware, system software and application software engineered to deliver the required functionality. The SCADA system shall handle all points covering the proposed 17 locations and shall be scalable as detailed. SCADA system shall apart from offering real time functions, shall have a historian designed to handle storage of all points for the defined period. The System shall also provide User interfaces specified in the specifications. The system shall have well defined architecture to segregate the DMZ.
5. The SCADA system shall support Harris, DNP 3.0, and IEC 870-5 101 /104, IEC 61850. The SCADA system shall be provided with all necessary optical interfaces and routers / switches for the desired architecture.

1.5. Detailed Specifications

1.5.1. Systems Requirements

The SCADA System shall be made of integrated, well-documented and field proven standard software applications and hardware. The system shall enable, besides the

SCADA functions, a set of applications for the electrical network management and the work orders management on the network specifically designed to centrally monitor, analyse, optimize, simulate and control an electric utility's geographically dispersed fleet of generation, transmission and distribution assets in near real time.

The system should address the full lifecycle to Monitor Analyse, Control, and Optimize and Simulate the SCADA environment.

The system shall meet, but not limited to, the following characteristics:

- Scalable architecture, where all the functions, SCADA system are integrated in a modular way and can be integrated in a minimum number of servers for TCO (Total Cost Ownership) optimization
- Reliability: redundancy of critical SCADA System functions in order to warranty of high level availability
- Service-Oriented Architecture (SOA) adoption which will facilitate flawless integration of third-party software components. The de-coupled nature of the architecture will facilitate replacement or addition of new components to minimize upgrade and replacement effort and cost
- The SCADA System developed, built and installed to meet Cyber Security Compliant. Patch management and other security services enable the SCADA System more secure and resilient to cyber-attacks. The security standards and services including key areas of communications network segmentation, perimeter protection, system and communication protection, user security, centralized audit and monitoring, change management and system integrity, shared storage plus virtualization etc. The security architecture relies on security policy that is based on standards, such as NERC-CIP, NIST, MS ISO/IEC 27001:2007 ISMS. The cyber security and network architectures must meet the availability, integrity and confidentiality objective
- Open Architecture with standards-based, open platform. It is scalable and secure with deterministic response under wide range of operational loads, provide highly available, software sparing and a range of Emergency Backup Control Centre options
- Integration with a number of enterprise and external systems based on

industry standard data and exchange formats

- Support for the Common Information Model (CIM) Power System Model (CPSM) profile IEC 61970 and IEC 61968, IEC 62325 CIM Market Extension (CME), IEC 60870-TASE Inter Control Centre Protocols (ICCP) and IEC 61850 Communication Networks and Systems in Substations
- Data Historian supports bi-directional, buffered interfaces providing native collection/retrieval either from vendor own or third party data historians software
- Unified Graphical User Interface with the ability to support both Linux and Windows based workstations on the same system. The architecture will provide operators with an application-independent user interface to facilitate the implementation of workflow based displays integrating data and control from multiple applications. The GUI automatically managed thereby reducing life cycle costs by eliminating need for administration of client workstations. The GUI must be secure, reliable and fast, with emphasis on continuous improvement of operator situational awareness and the addition of advanced visualization features
- Professional SCADA functionality includes real-time alarming, alarm priority, alarm filtering, multi-level tagging, real-time calculations of point data, confirmed control actions, dispatcher commanded group load shed and restoration, defined area of responsibility by console and dispatcher, continuous recording database with disturbance triggers, video trending, logging, and real-time database editing
- Protocol flexibility with supporting several of industry standard and proprietary RTU protocols. The vendor system also must have a library of other legacy protocols that can be added
- Data Capture and Recording with automatic data collection from the Real Time Database at sampling and storage frequencies defined for point collection definitions and events as well as reporting capability
- Centralized, Online, Database Administration allows for editing database/displays online without interruption to critical processes - no failovers, restarts or reboots.

1.5.2. SCADA System Hardware Architecture

SCADA System is a network-based distributed processing environment consisting of one or more interconnected processing nodes that may be tailored for specific functions. In order to meet the requirements of a specific system, the nodes are not only highly configurable, but are very flexible and fully capable of tracking system needs as they change. Each SCADA System processing node may be assigned one or more of five general areas of functional responsibility.

- Application Processing
- Data Acquisition and Control
- User Interface
- Process Specific Applications
- Failure Detection and Recovery

The computing platform includes those hardware, system software and infrastructure components that are generally provided by vendors that specialize in providing hardware, operating systems, database management software and middleware products. An application vendor would utilize these computing components as the computing platform that supports the application.

The platform computing components include the following:

I. Hardware components:

- a. Application Servers
- b. Database Servers
- c. Storage Devices
- d. Network Devices
- e. User Interface consoles

II. Software components:

- a. Operating Systems
- b. Database Management Systems
- c. Middleware Software and Integration Software

- d. Networking Software

III. Infrastructure components

- a. Storage networks
- b. Storage snapshot features
- c. Backup features
- d. Clustering features

The computing platform should have the flexibility to support test, training, quality assurance and production systems. Further, the computing platform should be capable of supporting multiple redundant production systems either locally or remotely to support local and remote control centres. The requirements for the system hardware and software components of the computing platform are intended to support continuous operations in spite of local disruptions or disaster scenarios as well as supporting system changes or upgrades with minimal to no impact on operations. This requires that data sets and displays be kept in sync across the computing platforms.

To support business continuity the computing platform provides for multiple production system images that act as a backup for other system images on a local basis and across remote data centres or control centres. This redundancy extends down to the independent platform components of the application including the application servers, database servers and storage system.

1.5.3. Application Processing

The Application Processing (AP) function includes duties such as network wide system status, configuration management, database management, failure detection and recovery, and the management of peripherals and other resources shared across the SCADA system interconnection. The distinguishing feature of this functional area is that it relates to global tasks that are common to the network, while the other functional areas relate to tasks that are node-specific or which may be characterized by protocols between nodes or sets of nodes. Processors performing the AP function require a comprehensive set of program development tools and program execution services, as well as the ability to respond instantly to external events, service requests and other stimuli.

The AP function is comprised of the Application Processing Nodes, along with the attached shared and dedicated peripherals. Peripheral sharing is accomplished by the following means in the SCADA system.

- Devices compatible with the Serial attached SCSI Interface (SAS) standard use a shared SCSI bus. Additional SAS interfaces can be equipped in each processor to support dedicated devices.
- Devices compatible with the Fibre Channel Arbitrated Loop (FC-AL) standard are attached to a FC-AL switch or hub through copper or fibre optic cables.
- Devices such as line printers and laser printers connect to primary and secondary LANs through the system interconnect.
- The user interface with the AP nodes is accomplished through a Keyboard/ Video/ Mouse(KVM) switch to a common display console, keyboard, and mouse, an RS-232 switch to a common ASCII terminal, or a networked service port.

1.5.4. Data Acquisition and Control

Data Acquisition and Control (DAC) nodes are responsible for the collection and transmission of telemetered information from the network formed by the remote terminal units (RTUs) and subsidiary control systems in a wide area network. The DAC node is also the interface for the time subsystem, digital to analogue (D/A) converters, digital displays, and the static map boards. Rapid responses for predictable and reliable performance of its responsibilities are fundamental requirements for the DAC node. The DAC node is implemented as a redundant node with sharing of critical function.

The system's DAC module acquires measurement data via remote terminal units or data links via variety of industry standard protocols including Harris, DNP 3.0, IEC 870-5 101/104, Modbus™ and others. In addition to serial communications, the system's DAC also support TCP/IP-based transport mechanisms.

The DAC supports wide variety of options with respect to the configuration and switching of serial communication channel including.

- Single dedicated channel per RTU
- Dedicated primary and backup channels for each RTU

- Party lining e.g. multiple RTUs on a single communication circuit
- Loops (dual terminated party lines)
- Switching on the analogue side of the modem
- Switching on the digital side of the modem

For RTUs with redundancy channel circuitry, DAC will provides failover at the individual communication channel level, allowing data acquisition on remaining channels to continue unaffected. DAC also validates data for reasonability and communication failures by performing checks on process variable limits and by testing the quality and integrity of acquired data based on limits, normal/abnormal states, etc. Any abnormal conditions subsequently detected are alarmed. In addition, DAC also provides remote supervisory control via the following types of hardware interfaces:

- Raise/Lower control
- Set point control
- Contact closure

1.5.5. Communication Subsystem for Distribution System SCADA

The communication subsystem switches, combines, modifies and transmits information over the chosen media. The communication hardware consists of transmitters to convert the data signals to suit the transmission media, cabling, switches, routers, and multiplexers to combine and transmit the signals to a receiving station and vice- versa.

As in any data transmission network, many types of communication media are supported from PLC/RTU to central SCADA system via wide area networks (WAN) which can connect many different locations spread within/across different cities. The types of wide area networks can include.

1. Point to point data networks based on DSL (Digital subscriber loop) over telephony copper cables
2. Fibre Optic based high speed data networks
3. Wireless based public networks like 2G/3G/4G

The above categories of WAN are depicted in the Figure 12.

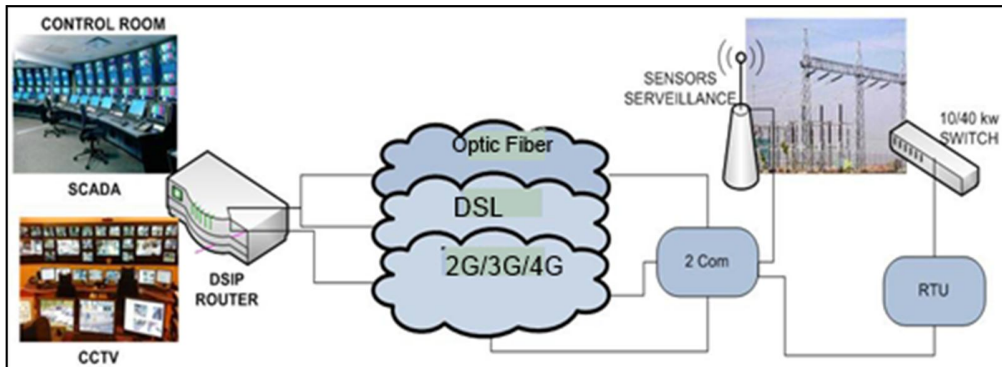


Figure 1: WAN Categories

The main functions to be handled by communication subsystems are following:

1. High-performance optical communication platform supporting Ethernet (100MbPS), PCM Links of E1s (2MBPS) and IP over SDH or GPON (Gigabit Passive Optical Network)
2. Connects SCADA Com Units
3. Cost efficient transmission of IP-based and serial control and monitoring data (SCADA), voice over IP (VoIP) and video surveillance data
4. Connectivity over optic fibre, copper (DSL) and/or radio (2G/3G/4G)
5. Supports advanced management systems

Communication subsystem for SCADA network may be built around many of the above possible combinations of networks based on standard transmission protocols most of these being based on IP and Ethernet nowadays. As per the emerging requirements more and more data is required to be transferred especially for the video surveillance applications, the optical fibre media has emerged as the main option. As far as the protocols are concerned the IP which is based on packet switching is more cost effective and can help a secured communication even through public network, is the desirable choice. Normally optical fibre communication media is logically configured in a ring mode to provide resiliency and backed by Radio based communication for media redundancy.

Though optical fibre cable which are installed along with the power cables (UG or OH, as may be the case) to increase their reliability, for redundancy purpose normally wireless networks based on 2G/3G services from public telecom operators are made use of through leased lines/ CUG/ VPN kind of arrangements to make it cost

effective. Such arrangement is depicted in Figure 13.

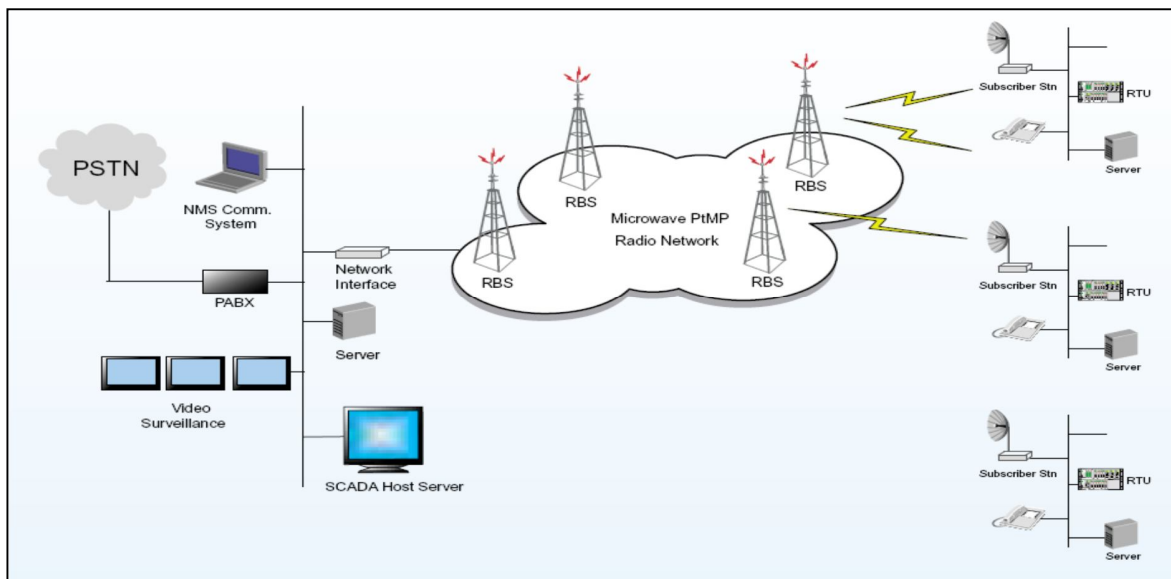


Figure 2: Redundancy with 2G/3G

The wireless network serves the following purpose:

1. Addresses remote SCADA units beyond substations
2. Suitable as a backup/redundancy during main link failure
3. UHF/VHF, PMR or 2G/3G/4G public networks for transmission of advanced control and monitoring, voice and video applications can be used.

1.5.6. Recommendations for Communication subsystem:

In view of above following recommendations are made item wise;

Suitable medium of communication network in the above towns for establishing a Distribution system SCADA

As the communication subsystem is a critical requirement for SCADA it has to be highly reliable as well as having built-in redundancy. The most reliable transmission media for such application makes use of fixed line infrastructures based on copper cables and optical fibre cables. In case this type of media is available from public telecom operators, the point to point connectivity from central location to remote locations could be obtained as leased circuits or VPN links. In absence of this it is ideal to install the captive OFC network along with transmission lines preferably in the underground mode. Also the existing overhead transmission line infrastructure for the

power line is not suitable as well as cyclone proof, the new transmission lines and communication media should be installed underground for higher reliability. This OFC based communication should be created at least to cover all the substations as the data transmission requirements from these will be increasing day by day especially to cover video surveillance. For remote locations consisting of down-stream distribution points, where the data transmission speed requirements is very low, radio based data channels provided through 3G networks of public telecom operators can be used on lease basis. Therefore a hybrid type of communication network consisting of underground OFC cable and leased 3G data channels is recommended.

As the OFC will be running in parallel with the underground HT power cables, these should be non-metallic that is without any metallic armouring. These will need to be laid in HDPE ducts at depth below 1.5 meters to protect them from rodent attacks. Generally, for such medium distances the type of fibre used is G.652D. To cover any future requirements as well as for extra revenue through leasing of dark fibres a minimum of 12 fibre OF cable is recommended as the incremental cost of higher fibre counts is minimal.

Alternate communication network as back up for SCADA;

To make the communication subsystem highly reliable and resilient some back up communication media is required in case of failure of main media. For this data connectivity from Public Telco's which is available from multiple providers is recommended to be availed. This connectivity can also be used for remote distribution points and for redundancy; the connectivity from two different operators can be obtained for each locations (Dual SIM). This arrangement does not involve any significant upfront cost and is very economic and usage based.

Optimal route for the network and also a method of laying the network (underground/overhead etc.);

As mentioned above the communication media has to be laid along the Power transmission lines and should be underground for reliability. The route will be mapped with the final route of power transmission cables.

To connect the existing sub-stations, the spur links of optical fibre cables will be laid from the nearest point of new cable routes. These will be laid as per the existing standard followed by BSNL for such cables requiring these to be laid below 1.5 meter to make them rodent proof.

A schematic diagram, depicting the OFC cable route based on the draft diagram is depicted in Figure 14.

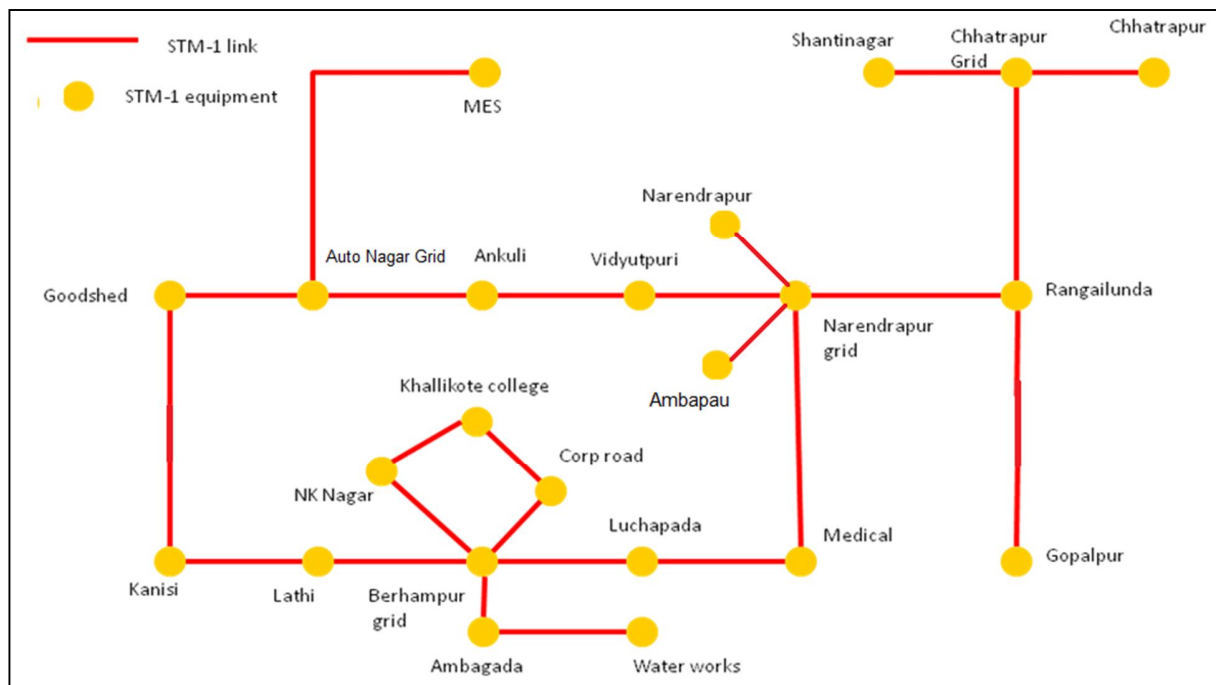


Figure 3: Berhampur electrical circle distribution network-Proposed OFC Communication Links for SCADA

1.6. User Interface

SCADA System provides the Graphical User Interface (GUI) for operators. It consists of multi-headed workstations (consoles) connected to the System Interconnection and developed as platform independent. Each user console can be configured with at least 4 graphic display devices through the use of single, dual, or quad port PCI, Accelerated Graphics Port (AGP), or integrated graphics adapters.

The SCADA GUI console is based on a three-tiered (agent/server/client) architecture that provides displays and data to a standard high performance graphics workstation

- Full function dispatch client - dispatchers or administrators inside the control room
- Full function remote client -remotely located dispatchers or administrators
- View only remote client- remotely located executives, key customers etc.

For the remote clients with control capability, VPN will be utilized to provide both user authentication and data encryption. For remote view-only client, SSL is utilized to

provide encryption of the operational data.

Beside using high-speed pan and zoom in concert with direct linkage from alarm messages to equipment locations on display, the operator can navigate large interconnected power system networks with ease and but not limited.

- I. Highly deterministic display response, irrespective of system activity levels
- II. High-speed pan and zoom with automatic display de-cluttering
- III. Single point of display definition and maintenance using AutoCAD.dxf graphic import capability
- IV. User selectable look and feel
- V. Support for embedded URL linkages, providing seamless integration with other system:
 - a. View/update documents resident on the SCADA system or other IT platforms
 - b. Launch 3rd party applications locally or remotely
 - c. Embed graphics, video, web cams
 - d. Link to existing web pages
 - e. Data content exported to PDF, HTML, Microsoft® Excel, Microsoft® Word, CSV, ASCII, delimited format etc.
- VI. Single set of online display definitions for all applications
- VII. Support for projection map boards
- VIII. Capability to review SCADA events, values and condition using the playback process.

The individual playback, not limited to, consist of continuous recording, disturbance data collection and historical database playback.

A copy of all diagram displays are optimized, compressed, and maintained on the servers, and an updated copy of all real-time points being displayed by the clients is maintained in memory on the server(s) from the agent application. Data exchanged between the server and the clients is achieved via http or https protocol transfers across the system interconnection to an enabled viewer.

Multiple servers and agents can be configured to provide redundancy and very high degrees of scalability to both internal and external users. The servers are configured to automatically update and disseminate transactions between each other when changes to a user's account or profile are made. Additional servers may be placed outside of a firewall or router to provide remote access or increased security when users are not connected directly to the SCADA system interconnection.

1.7. Process Specific Applications

Process Specific Applications are applications relating to the control process. Load Shed Restoration and Sequential Control are examples of such processes. For all but the largest systems, a single computer can serve both the process-specific application functions and the Application Processing functions. Close attention to standards, including the use of Java™, C++, FORTRAN, C language programming languages etc., assures the portability of application-specific programs to other platforms.

1.8. Failure Detection and Recovery

SCADA incorporate extensive failure protection, monitoring, and recovery facilities. The system hardware is partitioned to duplicate critical hardware and to isolate major input/output (I/O) bus failures from the end peripherals. The distributed failover subsystem is capable of detecting both transient and permanent failures. The system is designed to take instant, effective action minimizing the interruption caused by the failure, instituting appropriate recovery procedures and guaranteeing fault-free operations at an availability level exceeding 99.9%.

A basic philosophy in the SCADA product is that all critical elements are functionally redundant with provisions for independent failure recovery and task allocation among the redundant elements. In the event of an equipment failure, the system provides a smooth failover without requiring a system-wide reboot and/or restart.

1.9. Historian Data Management/ISR System

The historian subsystem provides the functionality to collect dynamic values on telemetered and calculated data from the high-performance database (real-time database) and to store this data in the Historical Database for use by applications and corporate personnel. ISR (Information Storage and Retrieval) system envisages, but not limited to, following data storage & retrieval functionalities:

- Real Time Database snapshot

- Historical Information
- Disturbance Data Collection
- Information Retrieval System

Historical data is stored in a relational database and managed by the SQL-based RDBMS on dedicated primary and backup nodes in the system. Authorized users may use standard applications to access this data for forms, reports, decision support and third-party application with an ODBC gateway. The relational database may be accessed via the LAN or WAN.

1.10. System interconnection

The backbone of SCADA System is the System Interconnection. It is a redundant Ethernet Local Area Network (LAN), which serves as a data highway connecting the elements in the SCADA system. An important feature of the System Interconnection is that it is principally a broadcast interface for the exchange and propagation of dynamically changing data that is needed at multiple nodes in the network.

Each node with critical functionality in the SCADA system connects to both Ethernet LANs, which make up the SCADA system interconnection. Either LAN can be designated as prime, with the other becoming the backup/failover. The system continuously checks the integrity of the primary and backup LANs. The dispatchers are immediately informed of a LAN failure through the generation of appropriate alarm messages. The system will automatically reconfigure itself to use the backup/failover LAN when a failure is detected in the primary LAN.

The redundant backbones consist of redundant Ethernet switches. Each switch is cabled in a star topology. Point-to-point network media is implemented with one end of the UTP cable connecting to a switch, and the other end connecting to a network device. The UTP cable is category 6. The distance per segment is 328 feet (100 meters) for 1000 Base-TX cable.

Static and structural data (such as database descriptions and parameters), display definitions, and data that are relevant only to specific system nodes are stored locally at the relevant nodes. Global editing mechanisms are provided for such data so that consistency may be maintained on a system-wide basis without the need for frequent and redundant propagation via the System Interconnection. This technique is crucial to meeting the goals of maintaining maximum local and network-wide response

characteristics.

1.11. Data Communication with Other Control Centres

It shall be possible to perform data exchanges with other control centres using ICCP I TASE 2 and/or ELCOM-90 protocol. Whatever the type of control centre, it shall be possible to exchange at least the following data:

- real-time telemetered data
- non-telemetered data
- control data
- SOE data
- scheduling data
- historical data
- energy accounting data
- operator messages

The communication protocol shall support the following data transfer mechanisms:

- One shot data- This mechanism shall be used to transfer data immediately, typically on behalf of a control centre application,
- Periodic data- This mechanism shall be used to transfer a set of control centre values within a strict time interval,
- Event data - This mechanism shall be used to transfer the data values from the server to the client every time any one of a set of event conditions occur at the server control centre,
- Exception data - This mechanism shall be used to transfer only data values which have changed since the last report.

1.12. Cyber Security of SCADA Architecture

SCADA systems are implemented with a defence-in-depth strategy to ensure the cyber security of the production environment, with processes at the business level and technical security measures at the network, host, and application layers. The SCADA system is designed to conform to industry-standard security practices, including those within the NIST guidelines, NERC CIP standard and Malaysian

Standard International (MS) Organization for Standard/International Electro-technical Commission (ISO/IEC) 27001:2007 Information Security Management System (ISMS) requirement.

Security controls at the application level include:

- The use of secure coding standards, to reduce the risk of software bugs and flaws creating security vulnerabilities
- A system that has been independently tested for security vulnerabilities
- Access Controls designed to enforce authentication and accountability, as well as minimizing the risk of unauthorized access
- Logging and Auditing capabilities that allow for traceability of access and actions

Security controls at the system level include:

- A system built with only those software packages, user accounts and services required for operational use
- Malicious software prevention tools to detect, prevent, deter, and mitigate the introduction, exposure, and propagation of malware
- Allowing only ports and services required for normal and emergency operations to communicate
- File integrity monitoring to determine if unauthorized modifications have been made to application binaries or configuration parameters
- Centralized user management utilizing a directory server
- Disaster recovery capabilities

Security controls at the network level include:

- An architecture that includes a strictly defined perimeter
- A DMZ network designed to eliminate direct communication between the critical trusted zone and the external networks
- Network device health monitoring

1.13. Work Orders Management

Work Orders Management (WOM) shall provide a flexible way to automate the management of job forms describing the construction and maintenance works on the electrical network. These job forms shall support.

The description in action sheets of the elementary operations to be performed, not limited to, for the following real time switching validation.

Real-time validation of all requested switching device change of states i.e. every control request, manual state change request, programmatic non-control state change request etc. associated with a switching device is validated against a set of configurable validation rules.

If the request is invalid, it is rejected and not performed. However, the Operators have override capability to re-issue the request and bypass validation on a system-wide basis and enable/disable the ability to override all validation rules.

Validations of request are performed by Network Status Processor (NSP) and are validated against the current real-time status of the network. Documents and Permits

Providing comprehensive management of the electronic documentation and field permits associated with switching in PDF format using Adobe Acrobat®. As the documents/permits and operational procedures vary, this feature is customizable through data configuration so that it can be easily tailored to meet the Operator/User needs. This includes the ability to support multiple types of documents and configure each type's behaviour as desired.

1.13.1. Switching Schedule Jobs

These provide comprehensive management of the electronic switching schedules associated with planned switching schedule jobs, fault switching schedules, or unplanned switching schedules. This feature is customizable through data configuration to meet the Operator/User needs. This includes the ability to support multiple types of switching schedules and configuration of each type's behaviour as desired.

- The life cycle of the job forms, from their creation through approval, execution, and eventually archival of the form
- The necessary links with the SCADA when operations fall under EMS responsibility

- facility for operators to log activities and incidents into a centralized electronic operation logbook

The WOM application shall be implemented in a Client/Server environment in order to serve different types of users. Clients of this application shall be:

- The EMS dispatchers
- Users outside the control room, such as personnel involved in these construction and maintenance activities, including Utility's planning department's staff and field personnel. For these clients, the User Interface of the WOM shall be based on Microsoft Windows™ environments.

For this information to be shared across the entire business web-based user interface shall be supported. It shall be for instance possible, for Maintenance Crews or for managers, to access information about current works and assignments over the internet or intranet.

1.13.2. System Performance & testing

Performance is critical since even though a system may process a function correctly if a function is not completed in an acceptable time the result may be of little to no value. Specific performance requirements should be based on expected operator and end user business requirements and cannot be generalized. The specific test plans need to be based on the technical characteristics of the application and business criteria for expected volumes as well as operating scenarios and events. The SCADA System (such as database, network elements, applications etc. shall be sized to accommodate expansion by 100% of the present power system size.

The goals of performance testing are to:

- Validate performance under various load profiles and identify areas where performance results exceeded the established limit criteria
- Reveal bottlenecks and breaking points
- Verify the impact of non-responsive systems on overall performance results during testing cycles
- Identify non-optimal system settings

Performance test should simulate major transactions and test all technology components of the system architecture including web layer, middleware, core

system, database, interfaces and other third-party systems. All external and internal user-facing systems and communications with all internal systems integrated with system under test are in scope. This includes validation of user and data load scenarios based on real business-day operational schedules.

Performance testing addresses performance and load validation of the integrated system, treating each individual component as a "black box". The testing uses performance criteria for each component based on the results of standalone performance testing.

For each performance scenario, the following base case conditions should be enabled:

- The system should be configured with all hardware and functions as production
- All system functions should execute at the periodicities and execution times consistent with normal operations
- Each monitor at the consoles (including operations, support and management consoles) should present all "common information" deemed to be part of the normal display arrangement
- Data should be retrieved and sent via interfaces to external computing environment

System performance should be based on detailed loading parameters for normal loading and high activity loading scenarios. Separate system performance criteria should be established for each scenario. The primary objective of system performance testing and associated loading parameters is to ensure the system properly sized to ensure minimum levels of performance during normal activity and high activity including future system expansion.

Specific criteria should be developed for both scenarios to represent expected system activities that would be expected in those states. The system activity for the high activity state should approximate the 'worst case scenario' based on volume due to abnormal business conditions, events and business growth. Alarm rates and data changes should be consistent with this level event.

1.14. On-line performance

Testing for on-line transaction based system components should be based on system performance under conditions that are close to production levels as well as stressed conditions. System behaviour may be different during specific operational time periods or events. Optimization techniques used within the system may skew the results unless proper measures are taken. Testing should include multiple load profiles to simulate real-life load on the system

The performance criteria stated below should be based on the performance requirements defined in Service Level Agreements (SLAs) and Business Specification documents.

- The system should be stable and responsive in accordance with the projected workload over typical operational time periods. A system is considered to be stable if it is capable of returning to its normal state after transient spike in load. No response time degradation should take place over the period
- The system should exhibit the defined response times typically 99% of the time under the projected workload
- The system should sustain the SLA-defined response limit over a typical workday
- The system should be responsive under the various work load scenarios that have been selected
- The system should be stable both during spike period and during the transition to normal working mode. The spike load represents typically at least 100% of the projected load within a short period of time. Intermittent peak volumes of doubled the number of transactions per second over a defined period should not impact response times by typically not more than 125% of delay limits
- The system should be responsive under the stress load or a typical high load. The system should be stable both during the stress period and during transition to the normal working load mode. An extreme variation of the stress load is sometimes used to determine the breaking point of the system
- The system should be stable with no response time degradation under the projected workload during the scheduled maintenance period

Details of components and sub systems for the proposed SCADA are given in Table 28 and Table 29.

1.15. BoM for SCADA:

Table 1: BoM for SCADA Equipment

S .No	Particulars
1	Remote Terminal Units
2	Interfaces Optical and digital Unmanaged
3.	*SAS with SCADA and database functions for Autonagar(redundancy built)
4.	Cables and other associated hardware
5	Services covering Engineering, Wiring Testing & Commissioning
6	Integration to Master SCADA system
7	Miscellaneous

Table 2: BOQ for SCADA communication system

SL. No.	Item Description
1	SDH Base OLT Equipment with 2xCentral processing Cards, Distributed dual power Supply
2	Agg. Cards with 2x STM1, 2x E1 and 4 FE ports
3	STM-1 SFP
4	DDF
5	Ethernet DDF
6	Installation accessories
7	NMS (1 server, Licenses, 4 Craft terminals)
	Mandatory Spares
8	SDH Base Equipment with 2xCentral processing Cards, Distributed dual power Supply cards and accessories (10%)
	Services-Equipment
9	Installation Commissioning and site testing for SDH
10	Installation Commissioning and site testing for NMS system
11	Training for Nominated Engineers (No of engineers 10, 5 day)

SL. No.	Item Description
	each, one batch)
B	OF Cable
12	Unarmored, 12 fiber OF cable as per G.652D specs
13	HDPE duct (40/33 mm)
	Services-OF Cable
14	Laying of duct and OFC along with UG power cable
15	Laying of duct and OFC as standalone as per BSNL specs
C	Initial Cost for alternate media
16	Procurement of 3G SIM's (2*25)

The detailed cost estimates of all equipment under the SCADA scheme are given separately in Annexure-VIII.

2. Distribution Management System (DMS) for Berhampur & Chhatrapur:

2.1. General

As part of the SCADA automation of 11 kV feeders, Distribution management system is proposed in the project areas of Berhampur, Chhatrapur and Gopalpur. All the 11 kV urban feeders of the project area would be covered under the scheme. For the purpose of controllability, the DMS control centres would be established at Berhampur and Chhatrapur. Under the scheme, Berhampur control centre would control the operation of 11 kV feeders in Berhampur city circle and also the Gopalpur feeder whereas Chhatrapur urban feeders would be under Chhatrapur control centre.

Distribution Management System (DMS) is a collection of applications designed to monitor & control the entire distribution network efficiently and reliably. It acts as a decision support system to assist the control room and field operating personnel with the monitoring and control of the electric distribution system. Improving the reliability and quality of service in terms of reducing outages, minimizing outage time, maintaining acceptable frequency and voltage levels are the key deliverables of a DMS.

A DMS can also allow operators to plan and execute complex distribution system operations in order to increase system efficiency, optimize power flows, and prevent overloads. A DMS can interface with other operations applications such as geographic information systems (GIS), outage management systems (OMS), and

customer information systems (CIS) to create an integrated view of distribution operations. A typical SCADA/DMS control room is shown in Figure 15.

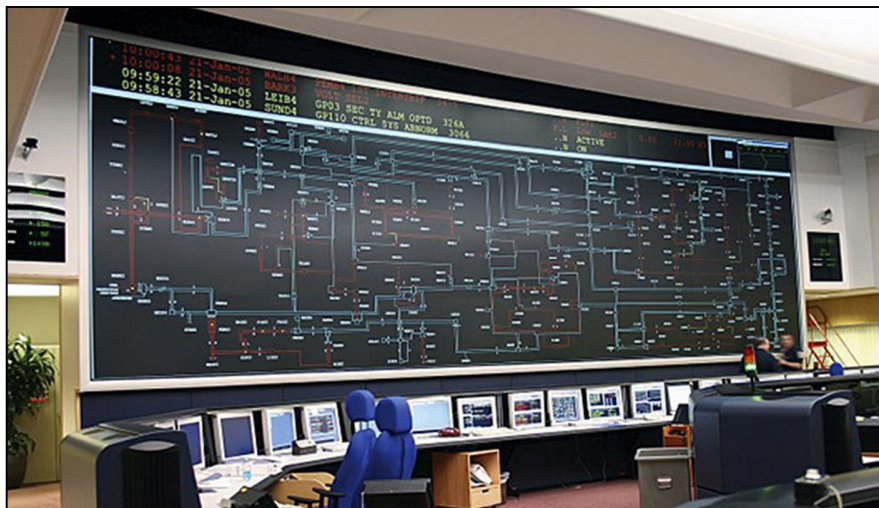


Figure 4: A SCADA/DMS control room

2.2. Functions of Distribution Management System

In order to support proper decision making and O&M activities, DMS solution shall have to support the following functions:

- Network visualization & support tools
- Applications for Analytical & Remedial Action
- Utility Planning Tools
- System Protection Schemes

The various sub functions of the same, carried out by the DMS are listed below:

2.2.1. Network Connectivity Analysis (NCA):

Distribution network usually covers over a large area and catering power to different customers at different voltage levels. So locating required sources and loads on a larger GIS/Operator interface is often very difficult. Panning & zooming provided with normal SCADA system GUI does not cover the exact operational requirement. Network connectivity analysis is an operator specific functionality which helps the operator to identify or locate the preferred network or component very easily. CA does the required analyses and provides display of the feed point of various network loads. Based on the status of all the switching devices such as circuit breaker(CB),

Ring Main Unit (RMU) and/or isolators that affect the topology of the network modelled, the prevailing network topology is determined. The NCA further assists the operator to know operating state of the distribution network indicating radial mode, loops and parallels in the network.

2.2.2. State Estimation (SE):

The primary function is to determine network state where DMS monitoring is directly envisaged. The State Estimation (SE) is used for assessing (estimating) the distribution network state. It assesses loads of all network nodes, and, consequently, assessment of all other state variables (voltage and current phasors of all buses, sections and transformers, active and reactive power losses in all sections and transformers, etc.).

SE represents the basic DMS function, because practically all other DMS analytical functions are based on its results. This is the unique function dealing with the unobservable load of the actual network, which is not directly covered by the SCADA System. Function is used for balanced and unbalanced networks. The function is based on an algorithm specially oriented towards distribution networks, with low redundancy of real time, remotely monitored data, and the deficiency of real time data has to be compensated with historical data. Beside the parameters of network elements, the real time data consists of:

- Actual topology, transformers tap changer position, etc.
- Voltage magnitudes of supply point and other nodes in the network.
- Current magnitudes (active and reactive power) at feeder heads.
- Current magnitudes (active and reactive power) from the depth of the network.

The historical data of the network consists of:

- Daily load profiles – current magnitudes and power factors, or active and reactive powers for all load classes (types, for example: industrial, commercial, residential), for all seasons (for example: winter, spring, summer, autumn), for e.g. four types of days (for example: weekday, Saturday, Sunday and holiday).
- Peak-loads for all distribution transformers and/or consumers (peak-currents and/or peak powers) and/or monthly electric energy transfers across all distribution transformers (consumers).

SE function runs in all cases from the range of networks where all historical data are known, but also in networks with no historical data available (based on parameters of the network elements).

The SE algorithm shall consider into account the non-availability of real time data and compensates them with historical data, pseudo and virtual measurements, to achieve the minimal set of input data necessary for running a consistent Load Flow.

2.2.3. Load Flow Applications (LFA):

Load flow study is an important tool involving numerical analysis applied to a power system. The load flow study usually uses simplified notations like a single-line diagram and focuses on various forms of AC power rather than voltage and current. It analyses the power systems in normal steady-state operation. The goal of a power flow study is to obtain complete voltage angle and magnitude information for each bus in a power system for specified load and generator real power and voltage conditions. Once this information is known, real and reactive power flow on each branch as well as generator reactive power output can be analytically determined.

Due to the nonlinear nature of this problem, numerical methods are employed to obtain a solution that is within an acceptable tolerance. The load model needs to automatically calculate loads to match telemetered or forecasted feeder currents. It utilises customer type, load profiles and other information to properly distribute the load to each individual distribution transformer. Load-flow or Power flow studies are important for planning future expansion of power systems as well as in determining the best operation of existing systems.

Real Time Load Flow Execution:

In DMS applications, the Real-Time LF functions are also executed:

- On event trigger
- On periodic basis
- On demand basis
- On initiation by other DMS Applications functions
- On placement of Temporary Jumper, Cuts and Ground

The Event Triggered LF execution normally has the highest priority.

2.2.4. Volt/ VAR Control (VVC):

Volt/VAR Control or VVC refers to the process of managing voltage levels and reactive power (VAR) throughout the power distribution systems. There could be loads that contain reactive components like capacitors and inductors (such as electric motors) that put additional strain on the grid. This is because the reactive portion of these loads causes them to draw more current than an otherwise comparable resistive load would draw. The erratic current results in both over-voltage/under-voltage as well as heating up of equipment like transformers, conductors, etc., which might even need resizing to carry the total current. A power system needs to control it by scheming the production, absorption and flow of reactive power at all levels in the system.

A VVC application shall help the operator to mitigate such conditions by suggesting required action plans. The plan will give the required tap position and capacitor switching to ensure the voltage to its limit and thus optimize Volt Var control function for the utility.

2.2.5. Load Shed Application (LSA):

The load-shed application automates and optimises the process of selecting the best combination of switches to be opened and controlling in order to shed the desired amount of load. Given a total amount of load to be shed, the load shed application shall recommend different possible combinations of switches to be opened, in order to meet the requirement. The dispatcher is presented with various combinations of switching operations, which result in a total amount of load shed, which closely resembles the specified total. The dispatcher can then choose any of the recommended actions and execute them. The recommendation is based on basic rules for load shedding & restoration which are project specific.

Modes of operation

The load-shed application operates in the following modes:

- Manual load shed
- Manual load restoration
- Auto load shed and
- Auto load restoration

Each mode of operation can be enabled or disabled by operator independently. The load can be shed & restore in possible combination i.e. manually shed & auto restore vice versa or both operations in the same modes.

DMS provides a modular automated load shedding & restoration application which automates emergency operation & control requirements for any utility. The application should cover various activities like Under Frequency Load Shedding (UFLS), limit violation and time of day based load shedding schemes which are usually performed by the operator.

2.2.6. Fault Management & System Restoration (FMSR):

Reliability and quality of power supply are key parameters which need to be ensured by any utility. Reduced outage time duration to customer, shall improve over all utility reliability indices. Hence, FMSR or automated switching applications play an important role. The two main features required by a FMSR are:

- Switching management &
- Suggested switching plan

The DMS application receives faults information from the SCADA system and processes the same for identification of faults and on running switching management application; the results are converted to action plans by the applications. The action plan includes switching ON/OFF the automatic load break switches / RMUS/Sectionalizers. The action plan can be verified in study mode provided by the functionality .The switching management can be manual/automatic based on the configuration

2.2.7. Load Balancing via Feeder Reconfiguration (LBFR)

Load balancing via feeder reconfiguration is an essential application for utilities where they have multiple feeders feeding a load congested area. To balance the loads on a network, the operator re-routes the loads to other parts of the network. A Feeder Load Management (FLM) is necessary to manage energy delivery in the electric distribution system and identify problem areas. A Feeder Load Management monitors the vital signs of the distribution system and identifies areas of concern so that the distribution operator is forewarned and can efficiently focus attention where it is most needed. It allows for more rapid correction of existing problems and enables possibilities for problem avoidance, leading to both improved reliability and energy delivery performance.

On a similar note, Feeder Reconfiguration is also used for loss minimization. Due to several network and operational constraints, utility network may be operated to its maximum capability without knowing its consequences of losses occurring. The overall energy losses and revenue losses due to these operations shall be minimized for effective operation. The DMS application utilizes switching management application for this, the losses minimization problem is solved by the optimal power flow algorithm and switching plans are created similar to above function.

2.2.8. Distribution Load Forecasting

Distribution Load Forecasting (DLF) provides a structured interface for creating, managing and analysing load forecasts. It should be designed to facilitate both “top-down” and “bottom-up” forecasting methodologies in the same environment without placing any restrictions on the types of models available and should support short-term, medium-term, as well as, long-term forecasting.

DLF provides data aggregation and forecasting capabilities that is configured to address today’s requirements and adapt to address future requirements and should have the capability to produce repeatable and accurate forecasts.

Proposal for 11 kV Distribution Automation / Micro SCADA for Berhampur & Chhatrapur:

The proposal involves Automation of 11 kV Distribution system in Berhampur urban area, Gopalpur and Chhatrapur by providing SCADA/DMS system for on line data acquisition and control with control centres in Berhampur and Chhatrapur to facilitate remote operation for:

- Changeover of power supply due to exigencies.
- Restoration of power supply isolating the faulty zones in the 11 kV networks.
- On line transfer of load survey data and to conduct the real time power flow analysis.

1. The salient features of SCADA/DMS System for Berhampur City HT UG Cable Network:

A. Project Details:

- 7 substations of 33/11 kV as main substations (considering only the urban substations)

- Medical substation will be the master control centre
- 82 Ring Main Units
- 137 Mini Ring main units
- 97 DTCs (compact substation)
- 50.82 km length 300 sq.mm HT UG cable
- 62.44 km length 240 sq.mm HT UG cable.

2. The salient features of SCADA/DMS system for Chhatrapur HT UG Cable Network:

A. Project Details:

- 1 substation of 33/11 kV as main substation
- Chhatrapur substation will be the master control centre
- 6 Ring Main Units
- 10 Mini RMUs
- 5 DTCs (compact substation)
- 2.91 km length 300 sqmm HT UG cable.
- 3.8 km length 240 sq.mm HT UG cable.

Salient Features

- Data acquisition and monitoring.
- Control, protection, communications, network controls
- Data processing
- SOE
- Disturbance data collection and archiving
- Historical data base.
- Generation of reports and trends
- Missing data calculations.

- Graphical reports.
- Energy data reconciliation
- Quantifying energy losses
- Provide near real time foot print for the energy.

DMS Functionalities

- Power Flow
- Network Connectivity Analysis
- Voltage VAR Control
- Fault Management and System Restoration (FDIR)
- Feeder Reconfiguration, Loss Minimization, Load Balancing, etc.
- Outage Management
- Load Shed & Restoration
- State Estimator
- Calculation of Performance Indices (such as SAIDI, SAIFI, CAIFI, etc.)

Benefits

- Faster decision
- Shorter outage time.
- Reduced maintenance schedule.
- Improved performance
- Optimizing peak loads
- Energy buy-sell decision
- Effective load scheduling plan.

Each DMS control centre will have:

- Local LAN

- DA server
- Application servers
- Operator consoles (minimum 2)
- Optical line terminal units
- Printers, GPS...etc.

Operator Console will have the following typical Screens

- Single line diagram with dynamic status and V, I, E details
- Alarm monitoring
- Station wise breaker control screens
- Logs and reports
- Energy management screen-protection and security screens.
- DMS study screens

Fibre Net

- Entire power network between Substation to RMUs and RMUs to Mini RMUs are covered with fibre net by laying armoured multi fibre cables along with proposed HT UG cabling.
- Between RMUs and Mini RMUs, loop fibre net will be covered with 8 fibre armoured fibre cables.
- This fibre net will provide for acquiring field data, energy meter files transfer, breaker control, relay signals and protection triggers, remote testing, voice communication etc. This fibre net will link all the equipment under this project in main and back up in a redundant way. Hence this proposed fibre net will be always near 100% availability.
- In the main fibre net 8 fibres out of 16 fibres will be utilized for the proposed PS net balance 8 fibre can be commercially leased out to 3rd party user. In the loop net 4 out of 8 fibres will be utilized balance 4 fibres can be commercially leased out to 3rd party user.

A schematic diagram of the proposed 11 kV ring main system under the DMS

scheme is shown in Figure 16.

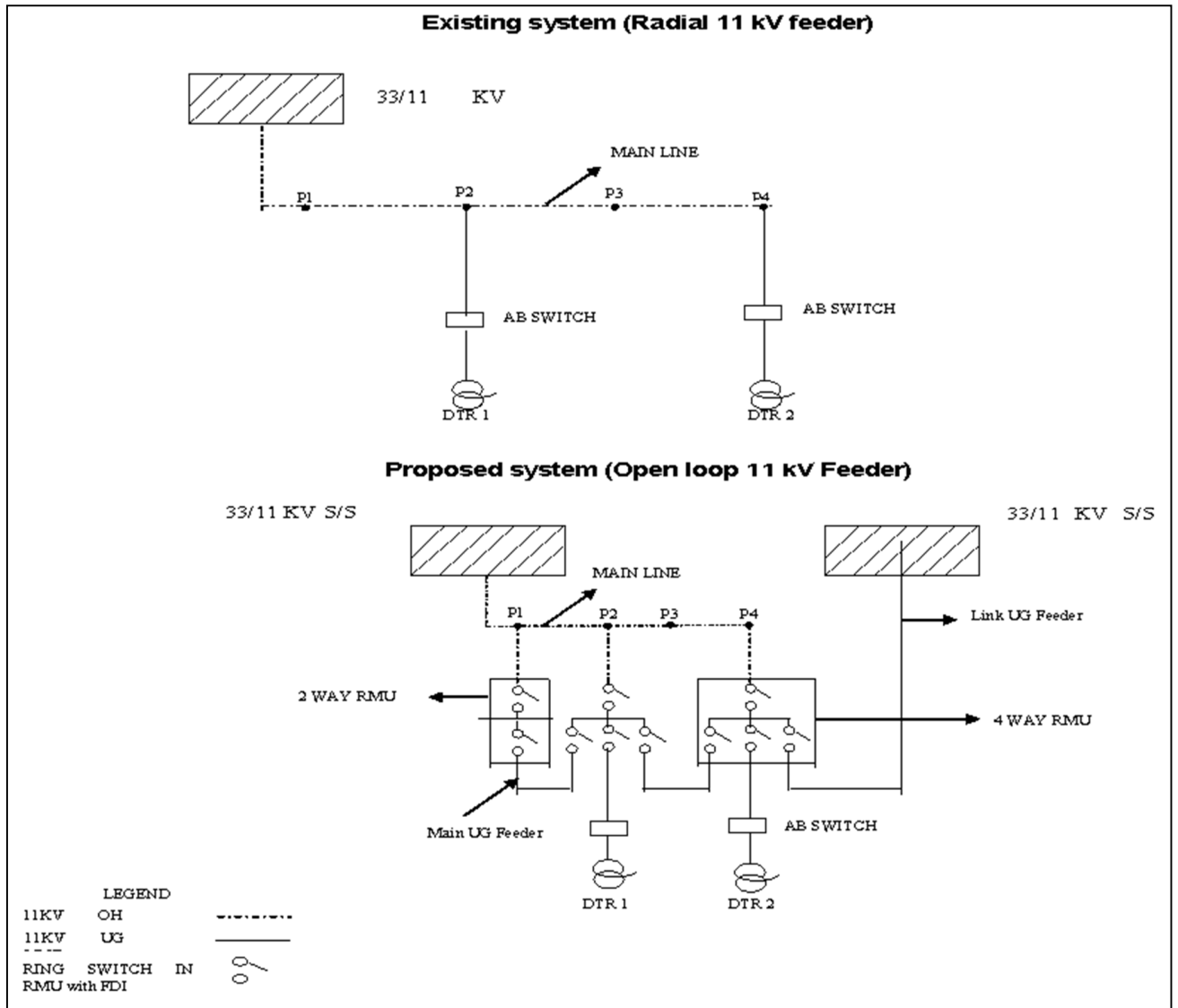


Figure 5: Schematic Network Drawing for Proposed 11kv Ring main

2.3. BoM for DMS at Berhampur

SI. No	Particulars	Item Description
1	Fiber optic cables	16 fiber Arm
		8 fiber Arm
2	Fiber optic terminal units and accessory	-
3	Laying of OFC	
4	Mini RTUs	Cat i for DTCs
		Cat ii for RMU
		Cat iii for S/S
5	SCADA Equipment	Servers, GPS, o/p console printers etc.
6	SCADA software	lump sum
7	Special DMS software	lump sum

2.4. BOM for DMS at Chhatrapur

SI. No.	Particulars	Item Description
1	Fiber optic cables	16 fiber Arm
		8 fiber Arm
2	Fiber optic terminal units and accessory	-
3	Laying of OFC	
4	Mini RTUs	Cat i for DTCs
		Cat ii for RMU
		Cat iii for S/S
5	SCADA Equipment	Servers, GPS, o/p console printers etc.
6	SCADA software	lump sum
7	Special DMS software	lump sum