Application of SCADA for Controlling Electrical Power System Network

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Abstract : *Due to the rapid development in automation system, the remote operation, control and monitoring are necessary for any modern system. The SCADA (Supervisory Control and Data Acquisition) facilitates this remote operation, control and monitoring for industrial automation. The SCADA is also widely used for overall operation of modern power system. This paper is about the application of SCADA in overall operation, control and monitoring of transmission and distribution system of electrical network of Dhaka city, Bangladesh. The paper justifies the suitability of utilization of SCADA for remote controlling of electrical power system network of Dhaka city which can be implemented for controlling the overall power system network of Bangladesh. The 132 and 33KV circuit breakers of power system network of Dhaka city are generally controlled by SCADA. The daily operation, load management and system faults are monitored by the SCADA for managing the overall system with minimum supervision and manpower. The SCADA system comprises RTU (Remote Telemetry Unit), microwave communication network and RCS (Remote Control Server). The SPIDER software, which is a open platform for horizontal and vertical integration of power control center uses UNIX based operating system is used for SCADA of DPDC.*

Introduction

The SCADA stands for Supervisory Control and Data Acquisition. In this study the application of the SCADA system in controlling the overall electrical network of Dhaka city, Bangladesh is discussed. The SCADA system becomes popular in the 1960's in order to monitor and control remote equipment. The early SCADA systems used mainframe technology and required human operators to make actions, decisions and maintain the information systems. Because of the increased human labor cost, early SCADA systems were very expensive. Today, SCADA is much more automated and consequently more cost-efficient. The SCADA is the foundation for the distributed automation system. The use of the SCADA system in electrical utility companies started in early sixties for smooth monitor and control of the overall power system. For remote operation of large power system network by SCADA started first in the USA in 1962[1]. The interconnection of large power grids in the Midwestern and the Southern U.S.A was the largest synchronized system in the world. The blackout of 1965 prompted the U.S. Federal Power Commission to recommend closer coordination between regional coordination groups and gave impetus to the subsequent formation of the National Electric Reliability Council which is formed in 1970. From that time the electrical utility company of the USA gave emphasis on reliable operation, control and monitor of the power system. However, the importance and urgency of closer monitoring and coordination of overall electrical network was emphasized in the USA after the blackout of the northeast grid network of 2003.

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The application of SCADA for industrial automation system in Bangladesh stared in late 80s and now it is widely used for remote operation, control and monitoring of industrial automation system. Whereas the use of SCADA in power system of Bangladesh started in late 90's and still its application is limited in controlling the transmission network of power system. Nowadays almost all critical industrial infrastructures and processes are managed remotely from central control rooms by using SCADA. The flow of gas and oil through pipes, the processing and distribution of water, the management of the electricity network, the operation of chemical plants and the signaling network for railways are some applications of SCADA [3].

The RTU, microwave communication network and RCS are the backbone of the SCADA system. The RTU of each substation gathers operational information of switchgears of the substation and transfers that to the central database through microwave linkage. Basically the RTU collects all information related to remote and manual operation. The SCADA master or control station is comprised of Local Area Network (LAN) of RCS (Remote Communication Server) and workstations. The RCS stores and processes data according to the system requirement and generates necessary commands for remote operation of the substation switchgear. Initially the SCADA software was based on VAX (Virtual Address Extension) and VMS (Virtual Memory System) and OpenVMS (Alpha) platforms. However UNIX and Windows platforms are now used for most SCADA software. Initially SCADA were used for large utility networks having 100,000 to 250,000 service points. However SCADA is now used for large automation system having many service points. The system is resided on LANs with communication front end (CFE) processors and user interface (UI) attached locally either on the same LAN or across a WAN (Wide Area Network) [2]. Basically 132 and 33 kV circuit breakers of substations of Dhaka city are operated by SCADA system. The SPAIDER, an open source software which is provided by the vendor, ABB, Switzerland is used as the main operational software for the SCADA system of electricity network of Dhaka city. This software is basically based on different programming languages such as C++, FORTRAN, and Pascal. The UNIX operating system is used for this software.

1. Scada System and its Functions

SCADA is a means of controlling from remote location by using communication technology. It is used to collect data and control processes at the supervisory level. The SCADA monitored system could be just about an oil refinery plant, a power generation system, a communication network or even a simple switch. To monitor and control the automation system, the SCADA collects data from the system and issue commands accordingly. By using sensors (discrete or analog) and control relays, the SCADA collects information about processes and control individual equipment. The system is supervised by a SCADA master station which collects data from monitoring devices and issues controls accordingly (either automatically or at the request of human operators) [4]. The SCADA system comprises of,

1. Sensors (either digital or analog):   Sensors control relays that directly interface with the managed system.

2. Remote telemetry units (RTU): These are small computerized units deployed in the field at specific sites and locations. It serves as local collection points for gathering information from sensors and delivering commands to control relays.

3. Communications network: It connects the SCADA master station to the RTU.

4. SCADA master units**:** These are larger computer consoles that serve as the central processor for the SCADA system. Master units provide a human interface to the system and automatically regulate the managed system in response to sensor inputs.

5. Remote communication server (RCS): The RCS communicates with the RTU and collect information which is also called master station. The master station, an HMI (Human Machine Interface) or an HCI (Human Computer Interface) performs data processing on information gathered from sensors [6]. The functions of SCADA are discussed below.

A. Data Acquisition

Since SCADA system monitors a large processing unit or network having various equipments therefore it collects information hundreds or thousands of sensors. Some of those sensors measure simple events that can be detected by on-off switch, called a discrete or digital input. Discrete inputs are used to measure simple states like whether the equipment is on or off, alarm for shutdown or tripping of any device or power failure at a critical facility. Some sensors measure more complex situations where exact measurement is important. These are analog sensors, which can detect continuous changes in a voltage or current input. Analog sensors are used to track fluid levels in tanks, voltage levels in batteries, temperature and other factors that can be measured in a continuous range of input [1].

A. Data Communication

In supervisory control, it is required to monitor multiple systems from a central location, so a communication network is required to transport all the data collected from sensors. In earlier SCADA systems had radio, modem or dedicated serial lines based communication network. Today the trend is to put SCADA data on Ethernet and IP (Internet Protocol) over SONET (Synchronous Optical Networking). For security reasons, SCADA data should be kept on closed LAN (Local Area Network) or WAN (Wide Area Network) without exposing sensitive data to the open internet. For data security, data protocol is maintained. Sensors and control relays can't generate or interpret protocol communication on their own. Therefore the RTU is needed to provide an interface between the sensors and the SCADA network. The RTU encodes sensor inputs into protocol format and forwards them to the SCADA master or central station. Again the RTU receives control commands in protocol format from the master station and transmits electrical signals to the appropriate control relays [2,5].

A. Data Presentation

The data presentation or display in SCADA system is mostly in visual or audio form. A SCADA system interacts with human operators through work station computers which are commended by RCS. The master station continuously monitors all sensors and alerts the operator by visual display or sound. The master station presents a comprehensive view of the entire managed system and also provides details operation of the system according to the requests of user. It maintains report logs and summarizes historical trends of daily operation of any system [5].

A. Data Presentation

The SCADA system automatically controls the overall system with minimum human interference. In case of sophisticated master station, these controls can run completely automatically without the need of human intervention. For example, if too much pressure is building up in a gas pipeline, the SCADA system can automatically open a release valve. In modern power system network, the overall control is performed by SCADA without the human intervention [5].

2. Electrical Network Operation by Using SCADA

All 132/33 kV and 33/11 kV substations of the electricity network of Dhaka city are controlled by the SCADA system. The SCADA central control room manages the electricity network by coordinating with the central load dispatch center and other related electricity authorities of Bangladesh. The SCADA manages the load demand of Dhaka city according to the power generation of Bangladesh. It also keeps proper coordination within the system and the regulating authority during any emergency situation in order to avoid overall system failure. The power flow status within the overall system, daily and monthly power supply report and overall system operation are main functions of the SCADA system [6].

A. Functional Steps of SCADA

The functional steps for managing the overall power system network of Dhaka city are briefly described below.

1. All data points at the substation equipment are connected with the RTU card by using wire. The figure 1 shows the block diagram of RTU. When any substation is remote or manually operated, the RTU gathers operational information in the central database through microwave linkage which is transferred to the RCS later. This RTU is installed at every 132/33 kV and 33/11 kV substation of Dhaka city. For collecting information circuit breaker and other switchgears of any substation are connected to the RTU card at a specific point. The installed data in the database of the RTU is transferred to outstation radio through modem.
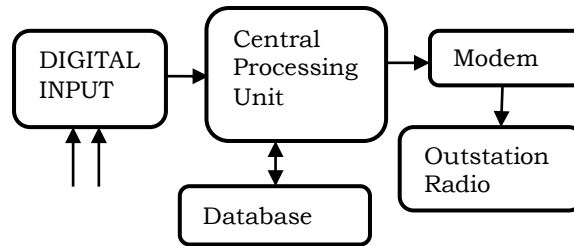
Fig. 1. Block diagram of RTU

2. The data from the outstation radio is conveyed to the nearby base station either by pilot cable or radio communication unit. The SCADA system which controls the electricity network of Dhaka city has six base stations. The base stations are Dhanmondi, Fatullah, New Mirpur, Tongi 2, Bhulta and Narshingdi. Sixty six grid and distribution substations are connected with six base stations. Each base station receives data from the substation RTU as UHF signal. The base station transforms the UHF signal into microwave signal. Each base station is associated with the microwave trans-receiver. These microwave trans-receivers form a communication ring and the master station receives data from the microwave ring. The microwave ring and the linkage between the microwave ring and the master station are shown in the figure 2.
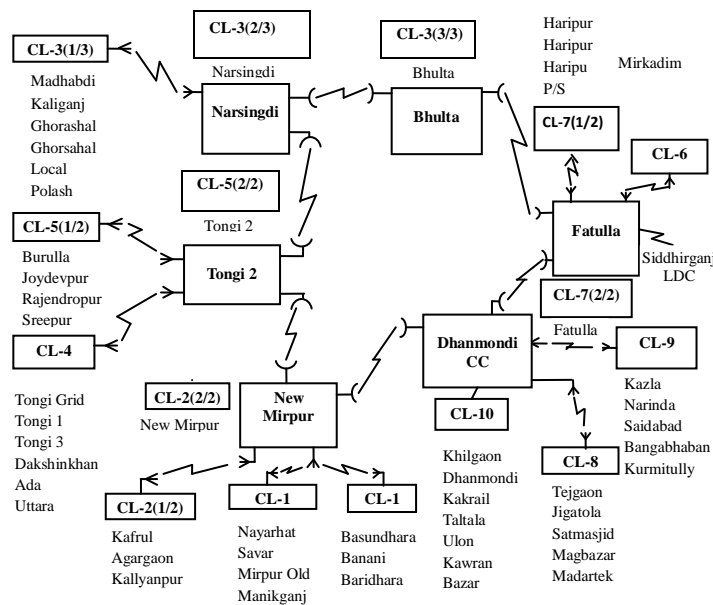

Fig. 2. Microwave communication ring

3. The master station receives data through microwave receiving antenna and later data are processed by RCS according to the status. The RCS of the master station collects all information regarding to switchgear operation of any substation. This information is processed cyclically, which is then sent to the application server. All information of the application server is stored in the database. The figure 3 shows the block diagram of the database system. The SCADA master station comprises a LAN network of a server and workstation comcomputers. The coordination between the LAN and the RTU is carried out through the communication network. The remote operation of the substation is performed by the work station pc according to the status of the single line diagram of that sub-station which is shown in the figure 4. The single line diagram generally shows the status of circuit breakers of any substation. The control room of the master station has overall single line diagram of the power system network of Dhaka city. The single line diagram visually indicates and displays the operation of circuit breaker, active line, system voltage, frequency and power factor [7, 8].
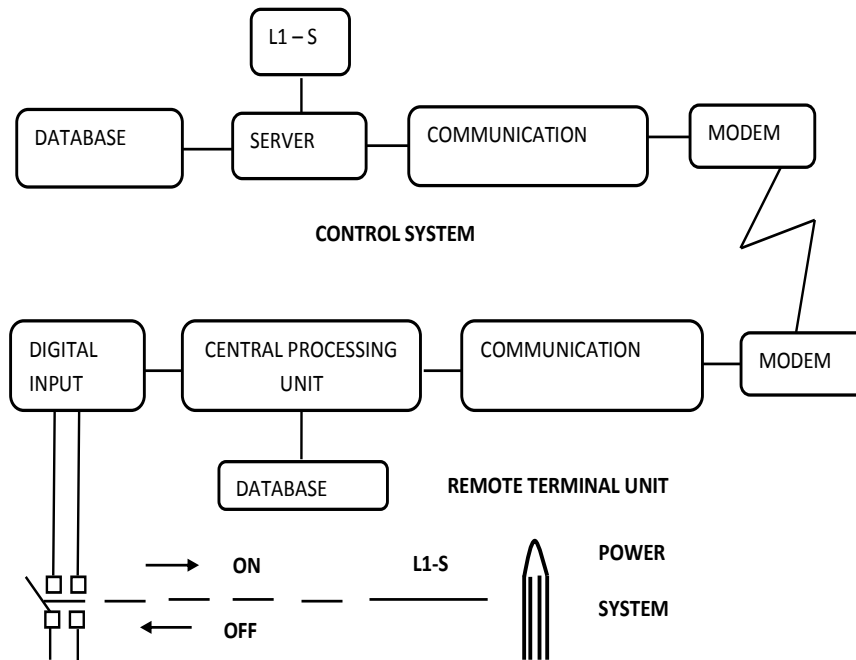
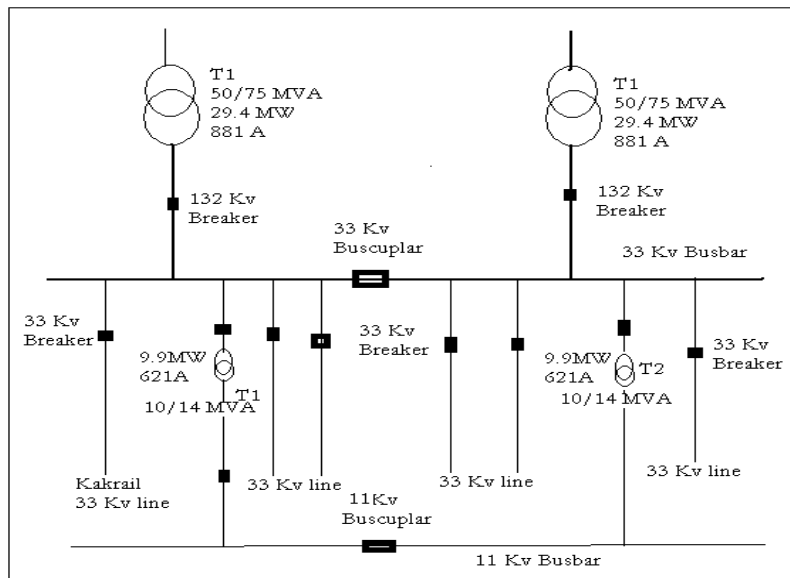Fig.3. Block diagram of database system

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Fig. 4. Single line diagram of substation

3. Operation of Electrical Network

The daily operation and supervision is maintained by DPDC for overall operation of the electrical network. For proper operation, the coordination between the manual and remote operation of the overall system is required. Besides that the maintenance schedule plan of equipments is required for uninterrupted supply of electricity [12]. The tasks which are performed for daily network operation are mentioned below,

- Supervision of network conditions
- Switching and regulation of components
- Maintenance and servicing of equipment
- Preventive and corrective action against disturbances
- Co-ordination with other utilities
- Buying and selling electricity
- Planning of the daily work schedule
- Calculation, setting and testing of protection equipment.
- Electricity billing and customer service
- Employee administration
- System design, dimensioning of expansions
- System expansion projects
- Purchase and construction

Fig. 5. On Screen Command Mode for Circuit Breaker Operation

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It is to be mentioned that the operation, control and monitoring of the overall system along with the managerial tasks are performed by HMI (Human-Machine Interface) or an HCI (Human-Computer Interface) with the help of SCADA system. Generally 132, 33 and 11 kV circuit breakers are operated remotely by using SCADA system [9]. Figure 5 shows the on screen command mode in the work station computer during circuit breaker operation of any substation. Some operational steps or commands are generally followed for circuit breaker operation which are mentioned below,

- The circuit breaker to be operated is selected from the on line application server.
- The remote control is not blocked.
- The breaker is marked as updated.
- Each breaker is connected with the RTU.
- Remote control authority for the action is established.
- Breaker is not controlled from any other work station.
- The interlocking of breaker must be in proper sequence.

If any of these prerequisites is not met, a message box explains the present status of the circuit breaker. An alarm is also issued on a command sequence error. The error message can be seen in error message box and also in the event list. If no command acknowledgement is returned within a certain time, an alarm is issued. A circuit that needs to be operated is selected by using password and later the operator operates that by using workstation pc [11]. The overall operation of the power system network and intercommunication within the system is shown in figure 6.
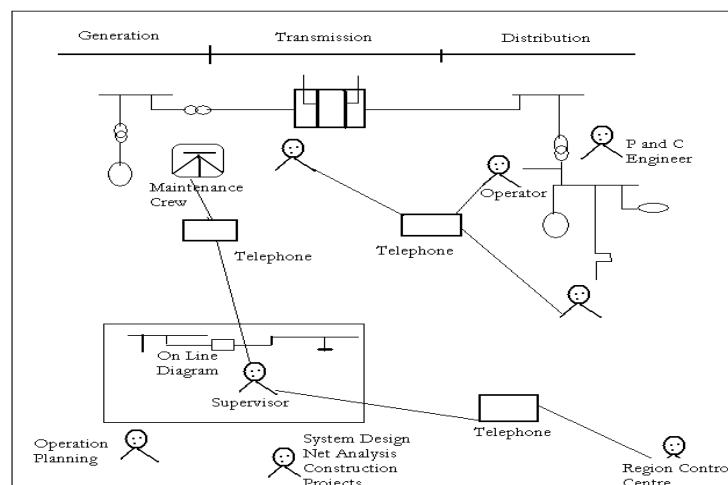

Figure 6: Power system operation

A. Load Shedding Procedure

In case of shortage of electricity generation according to the load demand, load shedding is required. The load shedding schedule is generally done according to the deficiency of the system power shortage. The circuit breakers on the 11 kV sides are operated according to the daily load shedding schedule [11].

Table1. Status of a Load Shedding Group

Status	Meaning of the Status
Free	This is the default status which means the load shed group is not used
Execute	The load shed group is executing
Restore	The load shed group is restoring
Wait for execute return	The load shed group is waiting for object return after restore
Edit	The load shed group is in edit mode. In this mode objects can be added or removed
Set	Execution is completed
Return completed	Return is completed

The work station computer displays all available load shedding (LS) groups and their group status within the electrical network. The status of a LS group is mentioned in tabular form in table 1. The identities of the LS groups can be changed from the load shedding menu of the display in the workstation computer. Generally one load shedding group shows its status, restores delay and the time of the load shedding. A maximum of 50 load shedding groups exists at the same time but one LS group can be executed at any stipulated time according to the load shedding schedule. From edit mode of the display menu any object in a load shedding group can be added or deleted according to the system requirement. In order to add or delete an object (a line or breaker) from a LS group it is required to open a new WS400 (work station) window and then select that object from the corresponding single line diagram [1, 2, 7, 11].

B. Trend Curve, Tag and System Redundancy

Trend curves are used for presenting voltage, current, power factor, frequency and daily system demand of any power system. SCADA software provides daily operational trend curve as well as pervious trend curves which is stored in the database of the server and can be retrieved according to the requirement [11].

B. Tagging (Safety Document Function)

TABLE 2. Priority, graphical symbol and meaning of tags

Priority	Text	Graphics symbol	Meaning
1	PtW	P	Permit to work
2	Sf T	S	Sanction for test
3	LoA	A	Limitation of access
4	LLW	W	Live line work certificate

The single line diagram is marked by using tags for proper operation and safety during operation. A tag is used to indicate the status of an object in the single line diagram. It is possible to set more than one tag on the same object. Only the tag with the highest priority is presented in the screen of the workstation computer. The table 2 represents the priority, graphical symbol and meaning of different tag.

C. Tagging Fault Record and Event List

The fault record generally keeps information about the fault while the even list keeps all information regarding fault and normal operation of any system. If a circuit breaker in a substation trips the fault record list records the tripping time of that breaker. However any change in voltage level and current level, circuit breaker on and off etc are recorded in the event list. The event list also provides information regarding to the system fault.

C. Data Security and Redundancy

The SPIDER software is used by the SCADA system of DPDC which is installed by ABB, Sweden. Data security and redundancy are realized on several levels in the SPIDER concept. The system will automatically take the suitable input for processing from one of two redundant inputs. Though the RTUs of DPDC system is not configured for data redundancy however it is possible to have redundant RTU in SPIDER configuration. The communication servers are commonly found in pairs where they share the system from the connected RTU lines. The switch over between lines is done by connecting each RTU line through a line splitting board in communication server pair. If a failure occurs in one board, a switch over is initiated and the new on-line board continues to communication with the system. The system configuration by SPIDER for electricity network is shown in figure 7.
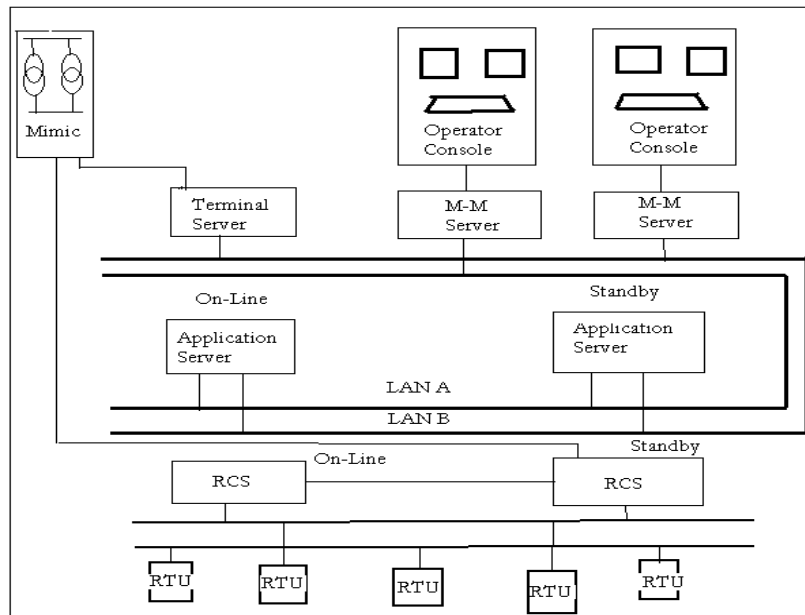
Fig. 7. Designed system configuration by SPIDER

The degree of reliability of operation depends on the application which is executing the server. The switch over of a redundant server pair is performed within 10 seconds without any loss of data. All non-empty message queues are restarted from the not treated message in the new line server after a switch over. By defining the sequence for database update, a full security for data loss during switch over can be achieved. There is a back up console in the SCADA system which automatically takes over the responsibility if one HMI or HCI server fails [4].All updated data is secured in the database of an application server. But database security is not sufficient for temporarily stored data in message queues during power failure. Therefore SPIDER saves the current status of the massage queues in the stand by computers. All non empty massage queues are restarted from the non treated massage in the new on line server after a switch over. By defining the sequence of database update, massage sent and massage treated, a full security for data loss during the switch over is achieved [7, 10].

4. Conclusion

The SCADA system helps in monitoring and controlling of the overall electricity network of Dhaka city which provides uninterrupted electricity supply to the consumer. It keeps record of the system operation which is helpful for getting a clear picture of the overall status of the system. Since the status of the overall system network can be understood within few seconds, the daily load demand can determine according to the requirement. The application of SCADA has simplified the managing of the electricity network of Dhaka city with minimum human interference. From this study it can be said that in order to improve the

overall system performance, reliability and stability it is necessary to implement the SCADA system for controlling the whole electricity network of Bangladesh. The manual operation of power system in Bangladesh requires huge manpower which increases the overall system cost. Moreover quick decision making becomes difficult in manual system during system failure or unbalanced situation. For proper operation, control and monitoring of the overall power system of Bangladesh it is necessary to implement the SCADA system.

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