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A Review of SCADA Systems in Indian Railways

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***Abstract* — The report is about the design, development & study of protection & supervisory control and data acquisition (SCADA) system to meet special requirements of 25 kV AC traction system on Mumbai suburban section. The task of supervision of machinery and industrial processes on a routine basis can be a tiring job. Always being on the side of a machine or being on a 24x7 patrol duty around the equipment performing checks would be wastage of the expertise of a person on trivial task. The existing scenario of protection and SCADA systems on IR and improvements thereupon to develop the new system for Mumbai has been covered. The merits of integration of numerical relays with Remote Terminal Units (RTU) , a** microprocessor-**controlled electronic device that interfaces objects in the physical world to a** distributed control system **or** SCADA **(supervisory control and data acquisition) system by transmitting** telemetry **data to a master system, and by using messages from the master supervisory system to control connected objects.**

The basic objective of SCADA Systems is to monitor industrial equipments and keep logs on all the information transmitted and received by the system. These systems have greatly helped in reducing the amount of manual labour required

Keywords— SCADA system, RTU, GPS, OHE, Numerical Relays, Central Railway.

I. INTRODUCTION TO SYSTEM

Supervising machinery and industrial equipments and processes on a routine basis is an extremely arduous task. One needs to spend entire days checking monitors and analyzing lines and lines of logs in making sure all the systems are in order. It is not only a huge waste of company resources but also a genuine wastage of one's talents. Thankfully, advances in technology have made it possible to employ computers to carry out these menial but very important tasks. As a result of that, control systems and it's various off springs like SCADA systems were formed. Supervisory Control and Data Acquisition (SCADA) offers the ease of monitoring of sensors placed at distances, from one central location. For example a typical general SCADA is shown in figure 1.

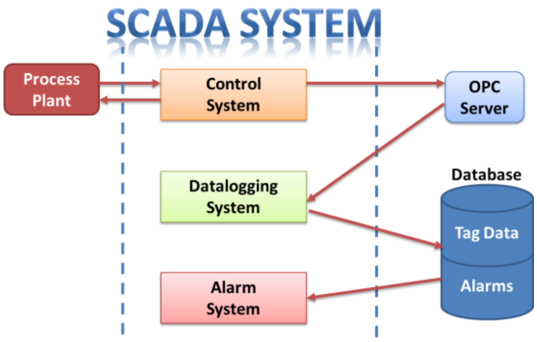

Fig.1.

Here, there are three phases of process namely the actual field from where the parameters are sensed called as the Process Plant. The actual parameter for which a desired action is to be taken is sensed here. This sensed parameter then goes to the Control System where the parameter value is received, rectified, modified correspondingly or converted to a compatible value of the processing system Then It goes to an interface server where the data is collected. The server will store the data, send it to the monitoring system where it can show the parameters to the user. The interface server feeds this received parameter data to the huge database for data logging through the data logging system. The database is a huge storage device which takes the parameters as input values and stores it in a way it is programmed to. The database will do the function of storing a data in a desired way as it has been programmed. It'll tag the data like any important data is to be highlighted or any data which is fulfilling any conditions etc. It can also give an alarm type intimation to the user is any data is crossing a certain programmed threshold value of meeting any value written in a program etc.

SCADA is an acronym for Supervisory Control and Data Acquisition. It is essentially a computer system for gathering and analyzing real time data. SCADA systems are employed all over the world to monitor and control a plant or any equipment in various industries. Indian Railways use this system in their setup to monitor and control Traction Power Distribution. It involves transfer of data between a SCADA host computer and a number of Remote Terminal Units (RTUs) and/or Programmable Logic Controllers (PLCs) and operator terminals. There was no standard specification for hardware or for protocols. They were thus proprietary in nature and systems from different vendors could not co-exist in a given network. Indian Railways formulated SPORT protocol for data transaction and corrective action of tripping the circuit breakers in case of overload etc. This paper is a review on how SCADA Systems are employed by Indian Railways to achieve protection and automation of power supply, acquisition and storage of parameters of power supply, monitoring and controlling the entire power supply system, alarm and logging system, load management, load shedding, power quality monitoring and management.

During the recent times, recuperating through the disadvantages caused by the DC sources (1500 V started in year 1925) for supplying power like, reducing distance range of operation causing increase of DC sources at every point thus deteriorating efficiency made the Indian Railways to devise an AC Traction Network for supplies (25kV, 50Hz) for trains to operate in the Mumbai Suburban section. In recent times, Indian Railways started developing AC Traction network for trains to operate in the Mumbai Suburban Region.

The 25 kV circuit breakers have to be switched off when the pantographs are in the neutral sections. The feeder circuit breakers (CB) have the ability to trip over the entire feed zone.

II. GENERATIONS OF SCADA

SCADA is based in a centralized location from where it monitors and controls the entire system. It also alarms the plant and/or regional facilities operating systems if need be. Its main objective is the communication of information between the central host computer and the many scattered units and programmable logic controllers. For example, in a water filtration plant, the remote units measure the pressure in pipes and report the readings to the central computer located somewhere in the control tower. In case of any irregular behavior, the SCADA system would alert the main station of the problem appraising it of other details like the severity of the anomaly and measurement values in an organized fashion. The system consists of the following elements:

i. SCADA Master Station Computer Systems: It is the database of the real time reported data collected from the remote units connected to it. It is mostly standard computer hardware equipment since very few SCADA system suppliers produce their own computer equipment. The back end of the SCADA software must be able to sample the remote terminal units for values and data. It should also have software for data retrieval, storage and processing. The process may involve entering data into the relevant tables and unit conversion etc.

ii. Human-Machine Interface: This is the interesting part of the host station. The values that the back end stores in the host computer are presented in a simple and lucid manner which is immediately understandable at a glance to the human operator. This is done using various techniques of Human Machine Interface designs. This presentation may include information and detailed schematics and animations representing the various states of the machines under its control. Since information in the form of pictures and graphs is immediately comprehensible without having to read through lines and lines of data, that is the preferred form of the representation of data in SCADA HMIs. Pictorial representation being more understandable to humans is the preferred form in SCADA HMIs.

Since the introduction of SCADA, it has been refined and improved and evolved into three generations. The emphasis of evolution has obviously been on increasing efficiency and user friendliness. They are as follows:

- First Generation- Monolithic
- Second Generation- Distributed
- Third Generation- Networked

III. MONOLYTHIC SCADA SYSTEM

This originated at a time when computing was mostly based on standalone mainframe Computers. Networks were almost unheard of at that time. There was a dedicated line that was used for communication between the host computer and the remote terminal units, specially designed for that purpose. The monolithic schematic working diagram can be depicted from the figure 2.

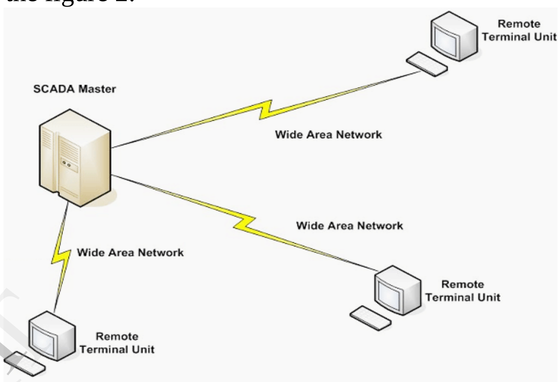

Fig.2.

The communication protocols in use on SCADA networks were developed by vendors of RTU equipment. These types of SCADA systems had very limited connectivity. Connections to the master typically were done at the bus level via a controller and fed to general unit called Central processing Unit. Redundancy in these first generation systems was accomplished by the use of two identically equipped mainframe systems, a primary and a backup, connected at the bus level. Vendors developed protocols to suit only their buyers and there was neither flexibility nor compatibility with other market products. Backup was simply provided by a similar mainframe computer connected at the bus level which monitored the system at all times and took over in case of failure of host system.

A. Distributed Scada Systems

The LAN network had by this time become a very significant part of computing. Using LAN networks, the load previously handled by just one computer was distributed across multiple similar systems. Each system was given a specific task to perform which included tasks like communication centre, database server, calculation processing etc. Information was shared in real time. The only limitation here was that it could not be extended beyond its geographical extent and thus could be not be used for widely distributed systems. Vendors would develop their protocols based on the demands of the LAN protocols and optimized them accordingly for SCADA systems. The use of WAN to provide communication between the RTUs and the main distributed system remained unchanged.

Distributed SCADA provides a low-cost modular system option for interaction with the server and the actual field installed devices. It uses a simplified data tool that is typically obtained from a programmed source. Since the distributed SCADA system is not required to manage the distribution system connectivity, it can be generated quickly and efficiently to support rapid deployment initiatives and maintenance. The Distributed SCADA may be implemented to communicate directly with the field devices using many communication modes to meet specific requirements.

IV. NETWORKED SCADA SYSTEMS

This system brought forth an open system architecture replacing vendor controlled market. This was still based mostly on the second generation. This open system took care of several problems with the older systems, particularly that of cross vendor compatibility and made it easy to design the system by allowing the use of any off the shelf standard product. This in turn brought companies like HP and COMPAQ in the market, each producing several types of hardware components. The use of WAN has also brought another layer of security to the data. Protocols like the Internet Protocol has separated the main master station from the entire network by the use of an intervening server and has thus also improved disaster survivability.

The layman working diagram of the the SCADA systems installed on the Central Railway of the Indian Railway can be depicted from the figure 3. The main function carrying out machine or the controller is a front end processor (FEP), is a compact computer which interfaces to the host computer a number of networks, number of peripheral devices, such as terminals, disk units, printers and tape units. Data is transferred between the host computer and the front end processor using a high-speed parallel interface. The advantage of using a parallel cable lines is the transfer of a huge data is fast over the bus interface. The front end processor communicates with peripheral devices using slower serial interfaces as parallel interfaces are costlier as the distance of the two devices of communication increases, usually also through communication networks. The purpose is to off-load from the host computer the work of managing the peripheral devices, transmitting and receiving messages, packet assembly and disassembly, error detection, and error correction. The next interface is the Remote Terminal Unit. The device is the connector of the data between the front end processor and the I/O devices. A remote terminal unit is a microprocessor-controlled electronic device that interfaces objects in the physical world SCADA system by transmitting telemetry data to a master system, and by using messages from the master supervisory system to control connected objects.

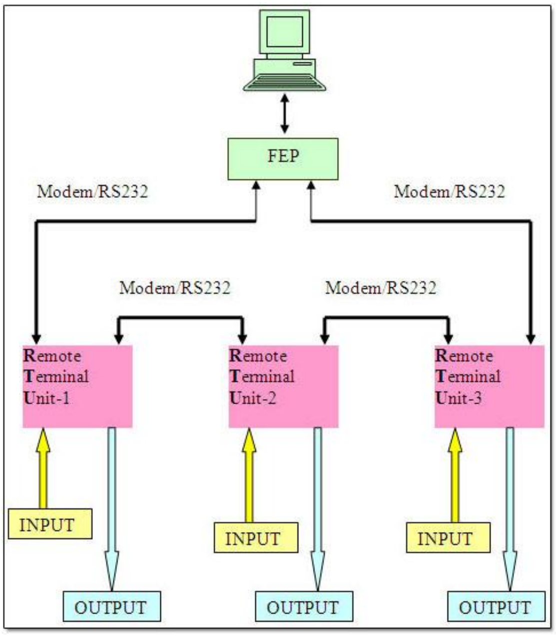

Figure 3.

V. THE FIRST GENERATION SCADA SYSTEMS

The Central Railway network comprises of the stations between and including CST station till Lonavala on the South East Route and till Borthembe on the North East Route. The sections have been broadly divided to accommodate various regions, in order to simplify communications. The primary areas have been divided as:

1. Suburban Railway Network:
    1. Vasai to Jasai
    2. CST to Kurla
    3. Kurla to Kalyan
    4. Harbour and Trans harbour.
2. South East Route- Kalyan to Lonavala
3. North East Route- Kalyan to Borthembe

The primary objective of a SCADA system is to gather information about every activity during rail commute.

The first generation SCADA systems were employed in the central railway during the year 1992. OHE forms the most vital component of the SCADA system. The Overhead Equipment or the OHE is connected to the TSS. The TSS supplies the power which is taken from the State Electricity Boards. This is then converted to 25 kV by a single phase step down transformer. Feeding posts installed at regular intervals transport this power from the TSS to the OHE. To avoid great loss of power over long distance transmissions, the TSS are spaced at a distance of 40 to 60 km from each other. The OHE itself comprises of many smaller sections. Multiple TSS supply power to various sections of the OHE, to avoid any imbalance in the power grid. There are small sections in between each different section which are known as the neutral sections. These neutral sections help avoid the pantograph of the locomotive to bridge the different sections by putting a neutral zone in between the two different sections. The neutral sections have switching stations also known as the Sectioning and Paralleling Posts (SP). There is also a sub-sectioning post (SSP) between every TSS and SP whose primary objective is to isolate the smaller sections for maintenance without having to hinder the operation of other areas. The architecture of the first generation of SCADA systems is as shown in the figure 4. Remote Terminal Units (RTU) have various data cards such as digital input cards, analog input cards which are used for data acquisition. Data controlling occurs through digital output cards which are connected to relays which in turn are connected to circuit breakers which extend the feed to OHE's.

RTU's can be interfaced to multiple devices with help of various communication interface like RS232, RS485,RS422 or Ethernet. Data transfer may be initiated from either end using various techniques to insure synchronization. The RTU supports many types of communication protocols for synchronizations like Modbus, IEC 60870-5-101/103/104, DNP3, IEC 60870-6-ICCP, IEC 61850 etc.

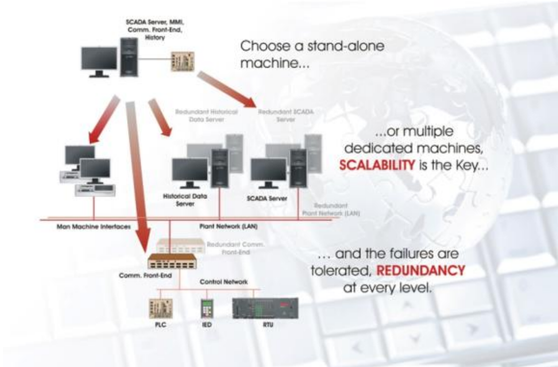

Fig.4.

VI. DEVELOPMENT OF THE SYSTEMS OVER THE FIRST GENERATTION

The second generation SCADA systems greatly improvised SCADA systems by bringing positive changes in various areas. Efficiency was greatly improved in the second generation SCADA systems.

Relays were brought in place of the I/O cards which were used for accommodating the channels. As a result, wiring issues were also addressed. There was a great increase in feedback responses and overall increase in speed.

The voltage and the current parameters are calculated on each positions of the line and are digitally shown on the interface screen as shown in the figure 5. The line where the voltage is tangibly low is considered as the possible train running on the position meaning load is present at that position at that time.

Various protective measures over the short circuiting, tripping of meters and heating issues were taken care of while designing the second generation SCADA. Bypass circuits and intimation providing signals were setup for the user to identify the fault and take possible action correspondingly.

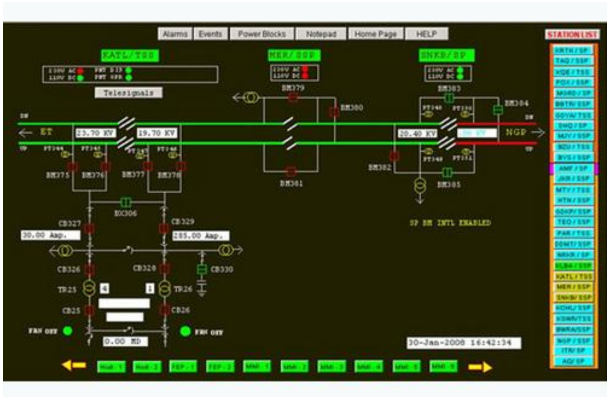

Fig.5.

VII. THIRD GENERATION SCADA SYSTEMS

The Third Generation SCADA systems have so far brought the latest technologies available in the market to make SCADA systems as reliable and efficient as possible. It brought about a lot of changes to ensure compact size and increased efficiency. The protection relays that allowed for control and acquisition of parameters helped reduce hard wiring to a great extent. To save space, compact wall mounted RTUs were used. All this has made the system much more reliable and easier to maintain. To reduce communication load on relays, the Station Controller Unit is equipped with multiple RS485 ports. The SC uses a local HMI with LCD display & push button switches for local setting of parameters like address, communication speed, etc. The Control Centre computers, LAN and SCADA software have also undergone many changes and improvements have been brought to enhance optimization and improve performance of computers in Remote Control Centre (RCC). The Typical SCADA architecture of the third generation systems is as shown in the figure 6. The GPS working over the OHE lines was the main modification of the latest SCADA systems s the GPS were powerful and faithful in providing the accurate time and location synchronization of the data without any loss.

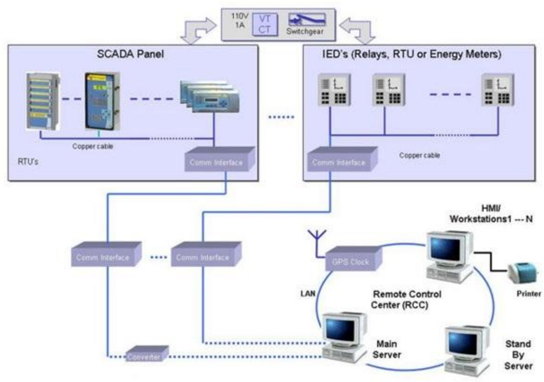

Fig.6.

A completely dependable stand-by server in case of failure of the main server with an automatic change-over has been successfully implemented. An all new innovative GPS timer has been incorporated and synchronized to satellite to ensure same time stamping at RCC and RTUs. Since all the information is now provided by relays, there is no need of separate transducers for acquisition of analogue parameters like voltage, current, supply etc thus saving a lot of money. Separate Digital In, Digital Out and Analogue modules were installed as a precautionary measure, for data that could not be read from the relays. These modules were installed in the RTU along with the associated relays. The auto-reclosure function available in the feeder protection relays was used to achieve the closing of circuit breakers. The logic used for achieving this was very simple and easy to implement. It was able to distinguish between the various operations of breaker due to operation of some protective element or by the controller at the RCC.

Because of the rapid developments in the field of electronics and computing every day, there have been rapid developments in the areas of protection, monitoring, control and integration of devices and also in substation automation technologies. Numerical protection relays have the capacity to implement multiple protections, control and monitoring functions per hardware device. A superbly designed software platform has been deployed for the same. The newer devices can use optical interface serial communication facilities extensively.

The use of these devices has made it possible to combine protection and control functions and also to transfer the useful data available in the form of sequence of events, disturbance reports, fault waveforms and even system parameters.

VI. ACKNOWLEDGMENT

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