Adaption of IoT (Internet of Things) over Indian Railways

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Abstract - *With the growing influence of the Internet of Things (IoT) across various sectors, Indian Railways has embraced this technology to enhance the efficiency of its operations. The integration of SCADA over WDFC demonstrates the application of IoT in critical infrastructure, allowing real-time monitoring, control, and automation of the electrified freight network. The key features of WDFC's SCADA, including its use of TCP/IP communication protocols based on IEC 60870-5-104, the deployment of Remote Terminal Units (RTUs), and the advantages of real-time data acquisition and fault detection, are discussed.*

Key Words: *IoT, SCADA, RTU, WDFC, communication, bus, fault location. Railways*

1.INTRODUCTION

The rapid adoption of the Internet of Things (IoT) has brought transformative changes to various industries, including transportation, where interconnected devices and systems facilitate real-time monitoring and control. IoT has become an enabler of smart infrastructure, revolutionizing its operations by integrating sensors, data analytics, and communication networks to improve efficiency, safety, and reliability. IoT devices deployed across vast railway networks collect and transmit data, allowing for predictive maintenance, enhanced fault detection, and automated decision-making. These advancements are critical for managing the complexities of modern rail networks, including electrification, signaling, and traffic control.

One of the most prominent examples of IoT in Indian Railways is the integration of Supervisory Control and Data Acquisition (SCADA) systems for monitoring and controlling railway traction power networks. SCADA systems in IR, previously based on electromechanical designs, have evolved into sophisticated digital platforms using IoT and communication technologies. These systems enable real-time supervision of equipment across wide geographical areas, allowing for continuous control of vital components such as substations, transformers, and circuit breakers. The transition to PC-based SCADA systems, which work on standard protocols such as SPORT (Standard Protocol for Railway Traction) and TCP/IP, ensures seamless data exchange between devices and the control center. This evolution has enhanced the reliability and safety of railway operations, while also enabling remote access and automation.

A specific and critical use case of SCADA in Indian Railways is its implementation in the Western Dedicated Freight Corridor (WDFC), a 1,500-kilometer-long electrified freight corridor designed for double-stack container movement. The WDFC, partly financed by the Japan International Cooperation Agency (JICA) at an estimated cost of 470 billion INR, is the world's first electrified freight corridor capable of running double-stack containers with a height of 7.1 meters. To accommodate this height, the traction contact lines must be installed at a height of 7.54 meters, which introduces significant challenges in the design and operation of the electrification system. The WDFC has adopted a 2x25kV AC traction system, which requires an additional feeder wire and aerial earth wire, further complicating the overhead electrification (OHE) infrastructure.

The SCADA system implemented on the WDFC plays a critical role in managing these challenges by providing centralized control of the traction power network. The system monitors and supervises the network's various components, ensuring operational efficiency and minimizing downtime. It allows operators at the Operations Control Center (OCC), located in Ahmedabad, to control multiple Remote Terminal Units (RTUs) deployed across the corridor. These RTUs interface with various field devices such as circuit breakers, transformers, and auxiliary equipment. Using both digital and analog inputs, the RTUs gather data from Intelligent Electronic Devices (IEDs) and transfer it to the OCC for real-time monitoring and control. This data is then displayed through a Graphical User Interface (GUI), enabling operators to make informed decisions regarding network performance.

The SCADA system also enables advanced functionalities such as remote configuration of RTUs, automated fault detection, and dynamic network control. Using IEC 60870-5-104 communication protocol over TCP/IP, the system ensures seamless, real-time data transmission between the OCC and the field equipment. The integration of IoT within SCADA systems thus empowers WDFC's electrification network to operate more efficiently while overcoming the logistical and technical hurdles associated with its unique requirements.

2. Brief Description of 2x25kV AC System

The 2x25 kV, 50 Hz system is used for high-performance traffic in worldwide railways. This type of feeding is characterized by additional auto-transformers and a return line at a potential of 25 kV. In this system, the line is supplied by a Scott Connected traction transformer without center tapping. The power is fed from the TSS at 50 kV and utilization is achieved at 25 kV by providing Auto-Transformers of adequate capacity and by providing one additional conductor normally referred to as a negative feeder wire between the auto-transformer stations and the traction substations. The center point of the Auto Transformer is connected to the earth/rail. This arrangement facilitates +25 kV voltage between OHE and rail and -25 kV voltage between Rail/earth and the Feeder Wire.

The substations need to be designed for two phases instead of one. Because of this, twin-pole switch gear is required in the overhead line network. Also, the protection of the contact line is more cost-effective because of the double-phase design

3. Developments in SCADA Systems

SCADA systems in Indian Railways (IR) have evolved alongside advancements in computing technology, transitioning from electromechanical systems to modern PC-based systems using customized protocols like SPORT, derived from IEC 60870-5-101. This ensures efficient operation even at slow data transfer rates.

The conventional 25kV AC traction SCADA system uses slow-speed V-23, FSK modems at 600/1200 bps over OFC and copper cable mediums in half-duplex, unbalanced communication mode, with hardwiring between RTU and Control & Relay panels.

With rapid developments in electronics, substation automation, and protection technologies, devices like numerical protection relays now combine protection, control, and monitoring functions. This enables the transmission of useful data such as event sequences, disturbance reports, and system parameters.

SCADA's primary functions include:

- Quick isolation of faulty OHE sections
- Remote monitoring/control of switching posts and transformers
- AFL equipment monitoring and fault reporting
- Health monitoring of CBs, interrupters, isolators, etc.
- OHE catenary indication

The latest SCADA systems over WDFC use open architecture, allowing functionality distribution over a WAN and real-time access via SQL and web-based applications. WAN protocols like IP enable communication between master stations and RTUs, which use RS 485 ports and Ethernet connections. A 100Mbps Ethernet LAN, GOOSE, and object-oriented data models manage both non-critical and time-critical data transmission.

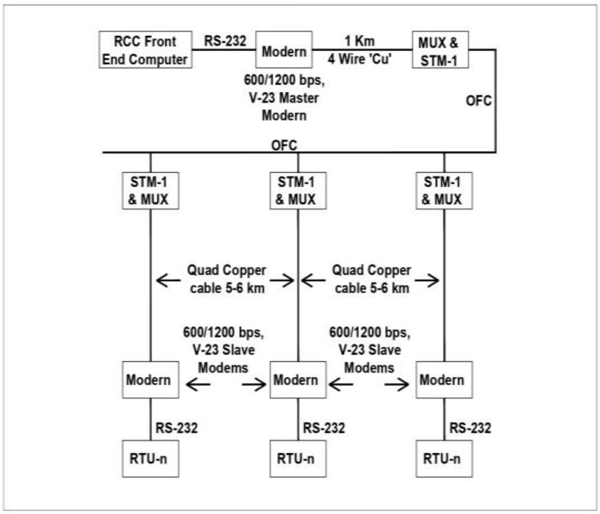

Figure 1 Schematic diagram of conventional SCADA

Recent advancements include optimized computers at OCC, reduced hardwiring, compact RTUs, enhanced reliability, and satellite-based time stamping. Key benefits of the system are:

- Less hardwiring with numerical relays
- Compact RTUs, saving space
- Fewer components for higher reliability and reduced maintenance
- Lower communication load with 485 ports
- Local HMI for parameter settings
- GPS synchronization for uniform time stamping
- Compatibility with Auto Fault Locators
- Integrated acquisition of analog parameters like voltage and current.

4. SCADA System Design and Architecture

The functional block diagram of SCADA system adopted over WDFC as shown in Fig.2 follows two main concepts as given below:

(i) Distributed Architecture - to ensure that various components can assume different responsibilities. Moreover, it is easier to increase the capacity of system in future by including more no. of similar components.

(ii) Modular Design - to make it possible to configure the whole of the system in a single computer, thereby, leading to flexibility in terms of sizing of the system.

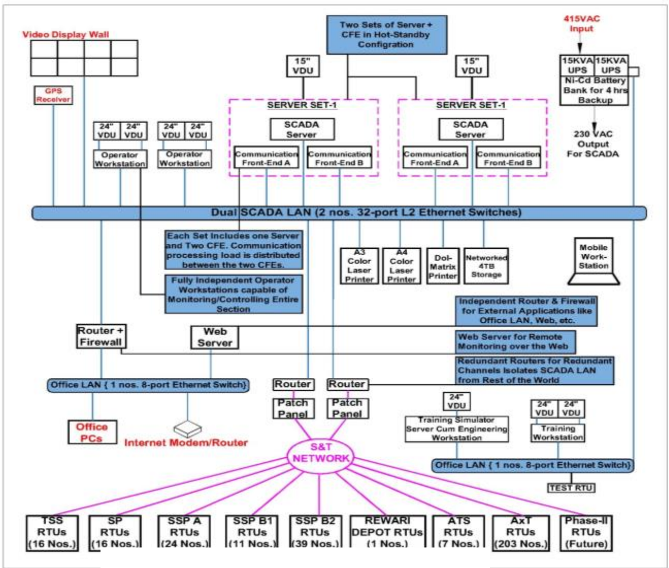

Figure 2 Schematic diagram of conventional SCADA

5.1 SCADA Functioning

The SACDA servers, operator workstations and other front end devices located at OCC are used for monitoring and control of the entire traction network over WDFC. The RTUs provided along the network will interact with local switchgear equipment, other IEDs and shall act as a gateway between the OCC and the field equipment.

The SCADA servers operate in hot standby mode thereby, offering dual redundancy of the SACADA server functions. These servers also host historian database, thereby, ensuring dual redundancy of the historian too. Two sets of Communication Front Ends (CFEs) have been configured in hot-standby mode, which will communicate with the RTUs. Additionally, two work stations grade machines have been provided for Man Machine Interface (MMI) functions to the Traction power controller. The main computer interacts with communication processor and work station computers. It collects the formatted RTU information from communication processor and sends the processed information to Operating work station (OWS) computer. The main computer also responds to the requests of the OWS computer which receives commands from TPC. This information is sent to the communication processor. The SCADA server also provides the following third part interfaces:

- Open database connectivity (ODBC), SQL to its historical and real time database
- IEC 60870-5-101/104 for transfer of data to other SCADA systems
- OPC unified architecture (OPCUA)

These interfaces allow exchange of data between SCADA and third party systems. For preventing cyber attacks from external world, the SCADA LAN has been isolated through suitable firewalls placed at the point of interface with external world. These firewalls create an electronic security perimeter (ESP) as per IEEE 1686 guidelines.

The typical architecture of SCADA system is shown in Fig.3.

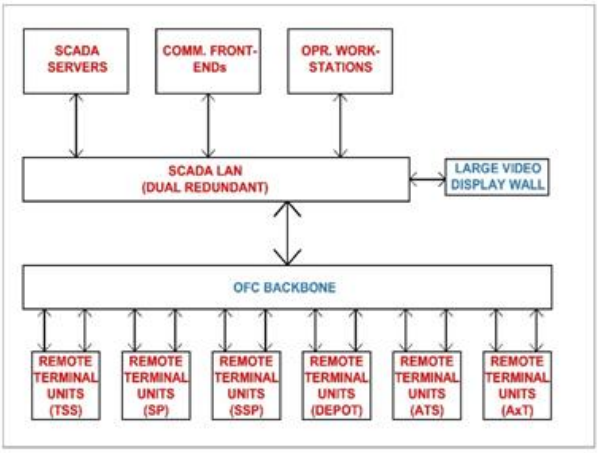

Fig.3 Typical architecture of SCADA

5.2 Remote Terminal Units (RTU)

Remote Terminal Units (RTU) are installed at traction control posts across the WDFC network, interfacing with electrical switchgear via hardwired digital/analog inputs and communicable IEDs (e.g., multifunction transducers, numerical relays). Husky RTUs are used to acquire and control signals from field equipment and gather data from IEDs and other RTUs.

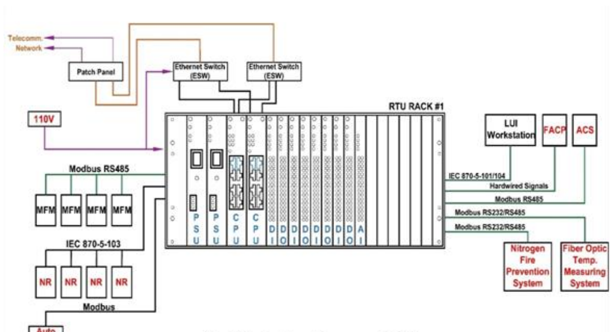

Fig.4 Typical architecture of RTU

RTUs support serial and Ethernet communication using protocols like RS232, RS485, and fiber-optic Ethernet. GSM/GPRS/CDMA modems provide wireless connectivity. They can also act as a gateway, using IEC 61850 to collect data from IEDs and transfer it to master stations over protocols like IEC 870-5.

Key features of Husky Studio include I/O module configuration, protocol mapping, time synchronization, real-time monitoring, and offline logic simulation.

RTUs for TSS/SP/SSP/AT/PP are modular and rack-based, with redundant power supplies and CPUs. They support both DC and AC power, ensuring uninterrupted operation.

RTUs for Auxiliary Transformers (AxT) monitor transformer status at stations and huts, transferring data to OCC using fiber optics. These mini-RTUs are non-redundant, boxed, and wall-mounted, with ingress protection conforming to IP54.

5.2.1 RTUs for Auxiliary Transformers (AxT)

The status monitoring of the auxiliary transformers provided at stations, ALH (Auto Location Huts) and TH (Telecom Huts) locations has been carried out with the help of a mini-RTU. The status of each auxiliary transformer in terms of availability of power output from the transformer would be captured and sent to OCC. The mini-RTU is provided in a boxed form factor (and hence not interchangeable with other type of RTUs) and in non-redundant fashion. It has two 100 Base FX Ethernet ports for interfacing with the fiber optic backbone.

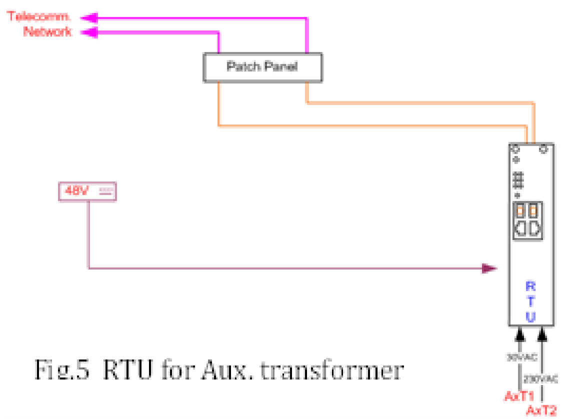

Fig.5 RTU for Aux. transformer

The secondary of the AxT, i.e. 240V AC, has been connected to the RTU for measuring the voltage. The RTU would derive the status based on the measured voltage and transfer the data to OCC using the fiber optic backbone.

The RTU has been housed in a wall-mounted panel and located in the respective station building or ALH/ telecom hut. The panel has got ingress protection in conformance to IP54.

5.3 Communications

The details of communication between OCC and other equipment are as given below:

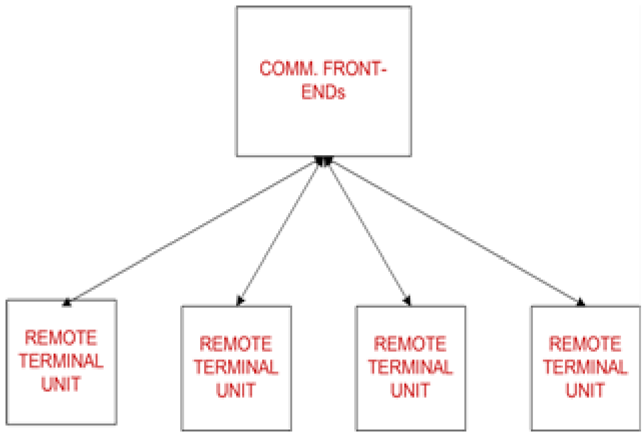

Fig.6 Communication between OCC and RTU

5.3.1 Between OCC and RTUs

Communications between the RTUs and SCADA system takes place over TCP/IP.

The logical topology of the communication between the OCC and the RTUs is star-type, although the physical topology may be ring-type or daisy-chain type. Each RTU will be communicating directly and independently with OCC. The architecture, therefore, has the advantage that failures of one or more RTUs does not affect the response times of other RTUs.

The IEC 60870-5-104 communication protocol has been used for communicating between the OCC and RTU. Therefore, data transfer is unsolicited and no explicit polling is performed by OCC. The RTU has been configured to report analog values on cyclic basis & status changes by exception to OCC. However, RTU also provides exception reporting of analog data in case of any limit violations. Digital status data is having higher priority than the analog data.

All the analog values and status data has also been assigned to scan groups for integrity check by OCC at every 10 minutes configurable up to 60 minutes RTU wise. In addition, RTU will report energy values to OCC on periodic basis. The periodicity is configurable from 5 minutes to 24 hours (initially set for 15 minutes).

5.3.2 Between OCC and AFL Equipment

The RTU at TSS locations will interface with AFL equipment located at TSS on IEC 60870-5-104 protocol and collect the fault, status information. This information is then transferred by RTU to OCC along with other signals.

5.3.3 Within OCC

At the operations control center, a dual redundant SCADA LAN has been established to operate in fault-tolerant mode. This has been achieved through use of two L2 managed network switches. All SCADA computers connected to the SCADA LAN are having two Ethernet ports configured to operate in fault-tolerant mode. One port of connected to LAN1, while the other to LAN2. In this scheme, a single point of failure will not causes for loss of any function.

The status of both the LANs for each computer would be monitored and recorded in the SCADA alarm/event list.

5.3.4 Between OCC and External World

Connectivity to an external LAN or office network from the SCADA LAN has been provided through a firewall. The firewall secures the SCADA LAN and will not allow any traffic except web server traffic between the two LANs.

5.3.5 Time Stamping

The RTU performs time stamping of hardwired inputs on individual I/O modules. It also preserves the time stamping of any event done by another external (slave) device. Thus, any time stamped event received from any slave is passed to SCADA master without any modifications.

5.4 Integrated Development Environment

The SCADA is also provided with an Engineering tool known as Integrated Development Environment (IDE) mainly used for configuring the SCADA application and is having following features:

- Makes use of single application to configure SCADA and allows distributing configuration on multiple machines from the engineering machine.
- IDE is a complete integrated development environment that allows rapidly designing and distributing SCADA projects.
- Database editing, graphics editing, topology, report editing etc.
- Export/import of database points via Excel.

Thus, it is possible to configure SCADA database through this workstation without interfering with the functioning of the online system. The changes become effective through manual switchover from the standby server to the main server.

5.5 Automatic Fault Localization (AFL)

One important difference of SCADA system being provided over WDFC viz-a-viz IR is the capability of integration with Auto Fault Locators (AFLs) provided over the complete traction network for the purpose of localization of faults in automatic mode for quick restoration of healthy section. The AFL equipment installed at TSS and other switching posts (equipped with Auto Transformers) have been interfaced with respective RTUs over IEC 60870-5-1047 protocol. There are two AFL equipment at each TSS (one for the left side feeding zone and another for right-side feeding zone).

6. CONCLUSIONS

The integration of Supervisory Control and Data Acquisition (SCADA) systems with IoT technology marks a significant advancement in the management and control of critical infrastructure, particularly in the case of Indian Railways. The implementation of SCADA on the Western Dedicated Freight Corridor (WDFC) demonstrates how modern digital systems can address the complex challenges posed by the 2x25kV AC traction system and the unique requirements of double-stack container operations. By leveraging real-time data acquisition, remote monitoring, and automation, SCADA ensures the seamless operation of the WDFC's electrification network.

The shift from traditional electromechanical systems to modern, IoT-enabled SCADA has allowed Indian Railways to enhance operational efficiency, reduce maintenance costs, and improve fault detection and response times. The use of TCP/IP-based communication protocols, in compliance with **IEC 60870-5-104**, facilitates reliable data transmission and effective management of field equipment through Remote Terminal Units (RTUs). This transition not only supports the growing demand for freight movement but also lays the foundation for future technological advancements in railway infrastructure.

In conclusion, the adoption of SCADA systems across Indian Railways, particularly on the WDFC, showcases the potential of IoT in revolutionizing railway operations. The system's ability to integrate intelligent devices, monitor network health, and respond to faults in real-time offers a robust solution for managing large-scale, unmanned power networks. As railways continue to modernize, SCADA systems will play a critical role in ensuring the safe, reliable, and efficient operation of electrified corridors.

7. ACKNOWLEDGEMENT

I would like to extend my heartiest thanks to Dr. Vipin Kumar, IRSEE, for their invaluable support and guidance during the formulation of the text, verification of factual inputs and providing necessary figures; without which, this would have been incomplete.

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