International Journal of Research
Available at https://journals.pen2print.org/index.php/ijr/
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 06 Issue 09
August 2019

SCADA in Railway Tunnel for Electromechanical Services

Mohammad Noor Iqbal
M.Tech. Scholar, Electrical Engineering
Al Falah University, Haryana, India
monoor_iqbal@yahoo.co.in

Dr. Anwar Shahzad Siddiqui
Professor of Electrical Engineering,
Jamia Millia Islamia, Delhi, India
anshsi@yahoo.co.in

Mr. Ravinder Kumar
Professor of Electrical Engineering,
Al Falah University, Haryana, India
ravi22aug1982@gmail.com

ABSTRACT— This paper discusses the SCADA control of E&M services inside the Railway Tunnels with design of automated distribution of power, control and monitoring in railway tunnel and which will provide automatic sequential power provisions for various events like emergency (derailments, collisions and fires), train in tunnel and no train in tunnel. Indian Railway employees SCADA Systems to achieve safety in tunnels - evacuation in case of emergencies by safely operation of safety EM equipment, protection and power supply automation, acquisition and parameters storage of power supply, monitoring and controlling the entire power supply distribution, alarm and logging system, load management, load shedding, power quality monitoring and management.

Keywords: SCADA, Tunnel operations, Railway Tunnel, Electro-mechanical Services

I. INTRODUCTION

In a railway tunnel, the electromechanical equipment plays a vital role from the point of safety and reliability. Therefore, such equipment must be continuously monitored for determining their working or fault status and/or their operating mode -automatic, manual or stopped by the control center operator.

In Railway tunnel, several electromechanical devices (lighting, ventilation...) are servo-controlled by sensors and operate automatically according to pre-determined boundary conditions or thresholds. Others are initiated or disabled depending on the operating conditions (temperature, humidity, illuminations) in tunnel. It is thus useful to remote control them (signaling, exit signs, ventilation, lighting, pumps ...) by an operator sitting at distant place.

Lastly, since the electromechanical equipment may be operated very differently- continuous, occasional, or very rare, it is essential for the operator to have data on the operational duration (hour used) for each of them.

These different roles of surveillance, control-command and data archiving are very often or majorly performed by a single system- Supervisory Control and Data Acquisition system (SCADA).

Derailment, collisions and fires are the three main accident types that can be occur in tunnels. Other accidents characteristic of derailment due to natural threats (e.g. flooding, avalanche) or with hindrances on the track (cars, trees, etc.) and with shunting trains or open lines such as collisions at railway crossings are generally not possible in tunnels. Thus, the rate of accidents per train-kilometer is lower in tunnels than on open track or in the vicinity of stations. Also, the simpler operating conditions that prevail is other reason for lower rate of accidents per train-kilometer.

In comparison to open track, accidents involving fire are critical in a tunnel. In a closed tunnel setting, these accidents have potentially disastrous consequences. To reduce the impact of fire in tunnel, many tunnel specific safety measures are taken or are in place while designing the tunnel E&M services and all those E&M services are in turn control by SCADA.

Due to these potentially disastrous consequences, the public acutely perceived the risks that prevail in tunnels than high frequency or low consequence

events such as accidents at level crossings. This must be taken into account in railway tunnel when evaluating safety measures and is known as risk aversion. This justifies the need to implement more extensive safety measures in railway tunnel than that would be dictated by a simple consideration of the expected number of fatalities.

Safety in tunnels is the result of combination of electrical and mechanical services, infrastructure, operations and rolling stock measures. In general, safety is based on four principles and can be summarized as:

- Prevent accidents
- Mitigate the impact of accidents
- Facilitate escape and
- Facilitate rescue

SCADA interfaces with the M&E system of tunnel, such as Ventilation system, Fire monitoring system, Hydrant System, Power System, Emergency Lights, Building Management System, Traction Power and Public Addressing system, Emergency call points, etc. to provide complete real-time control and monitoring function as applicable at a central location in Tunnel control room and with provision of required data exchange with centralized control center at station or divisional control centers.

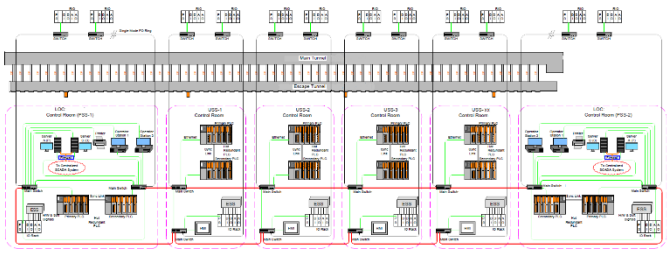

Fig.1 SCADA Scheme for Railway Tunnel

II. ARCHITECTURE

SCADA system in Tunnel are in three levels: They are

- Level 1: Tunnel/Portal Control Centre (TCC, Main/Redundant tunnel Control Centre)
- Level 2: Remote central Control (RCC)
- Level 3: Regional Monitoring

The main/redundant tunnel Control Centre allow the following operator's activities:

- E&M systems and subsystems current status in overview diagram and detailed schematics follow current train traffic load and statistics
  - current status of select individual E&M equipment in detailed schematics
  - measured values
  - E&M system controlling
  - generating alarm signals in case of emergency, such as fire event and E&M equipment failures
  - generating list of alarm statistics
  - generating of regular reports
  - possibility to execute selected predefined scenarios (for example in case of fire event)
  - monitoring of actual E&M equipment failures
  - monitoring and recording of historical E&M equipment failures events

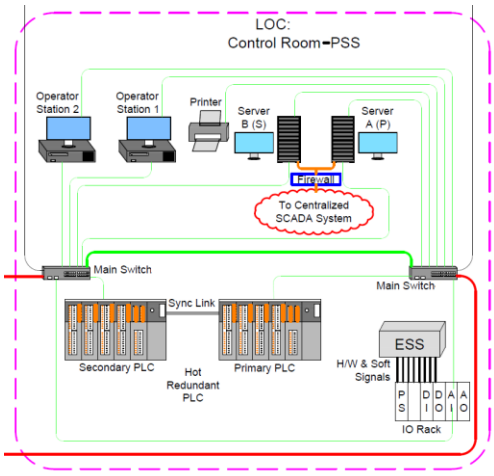

Fig.2 Tunnel Control Centre

The SCADA in the Remote central Control RCC enables centralized integrated monitoring and control function of different tunnel services. All Tunnel Control centers of Level 1 are connected to the central control through an Optic Fiber ring running through all the tunnels.

A remote data interface is provided to extract relevant and filtered data for feeding to high level monitoring at divisional Headquarter, Control room or Ministry of Railways if desired.

Level 3 can override all the control signals from the level 1 and level 2 control signals. Level 2 control system are interconnected, and remote interface is made to level 3 control.

III. ELECTROMECHANICAL SERVICES IN TUNNEL

The SCADA system realizes the control and monitoring of the following subsystems of railway tunnel:

- power supply system
- ventilation system (main tunnel, escape tunnel, adit, cross passages, technical building and Control Centre)
- emergency lighting system
- radio re-broadcasting system
- tunnel safety equipment
- emergency call system
- service telephone system
- monitoring system (CCTV system)
- public address system
- access control system
- air quality measurements system
- fire detection system
- firefighting system (water reservoir levels monitoring and firefighting pump group set control and monitoring)

A. Power Supply System

Generally, in India one 33/11 kV Portal substation are present at each portal. These portal in turn is fed from two 132/33 kV substation from each side i.e total two 33 kV circuits to feed power to railway tunnel. The 33-kV supply cables are laid inside the Main tunnel (MT) and is connected with other portal thus each portal has redundancy of two supply from each portal side as shown in figure 3.

Fig.3 Electrical Power Scheme for Railway tunnel

33 kV supply is fed through all the tunnel networks with the help of 3core, 3 nos. copper cables. These 3 nos. 3 core copper cables are used for carrying two circuits with third cable as spare. This above scheme requires 33/11 kV transformers, 33 kV Switchgears, 11 kV switchgears, 11/.433kV Transformers and 433 Switchgears at each portal substation.

11 kV level is introduced to provide the supply to Niche Substations (11/.433 kV) that are inside tunnel to feed power to E&M equipment. The niche substations are provided in each tunnel for installation of transformers, LT Panels, battery, battery chargers, UPS and auxiliary equipment etc. Niche substations are generally spaced such that no LT circuit is more than approx. 1.3 km on either side of the NSS. Thus, distance between two niche substations is approx. 2.3 km from each other or in other words one NSS supply power up to approx. 1.3km in both directions in tunnel from its location. Hence, the approx. number of substations inside the tunnel is equal to length of tunnel in km/ 2.3 km.

B. Ventilation System

Ventilation of railway tunnel is one of the most vital features related to passenger and crew comfort during passage of train inside any tunnel. It is also important for workmen at work inside the tunnel from their health point of view. Movement of trains inside tunnel alters its environmental features. Locomotives emits pollutant gases which may be potentially hazardous to the health, physiological and psychological well-being of human being. For safe operation inside the tunnel, it is necessary that these hazardous features, especially gases emitted from locomotives, should not cause distress to crew, passenger and workmen inside the tunnel. Rise in temperature of air and concentration of

pollutant gases inside tunnel depends upon effectiveness of ventilation in tunnel. Therefore, it is must that tunnels are provided with appropriate ventilation system, so that hazardous gases and rise in temperature of air inside tunnel remain within permissible limits.

Table 1: Threshold levels for pollutants inside tunnel (exposure data source: Indian Railways Bridge Manual)

Pollutant Gas	8 Hours Exposure	15 Min. Exposure
CO	50	400
NO	25	35
NO2	4	5
CO2	5000	18000
SO2	5	5

Passage of a train in a tunnel creates following environmental hazards:

- Air Quality Deterioration: Emission from diesel locomotive contains oxides of nitrogen (NO, NO2), oxides of carbon (CO, CO2) Sulphur-dioxide (SO2) and hydrocarbons which are potentially hazardous gases. These gases pollute the air inside tunnel by mixing with it. High concentration of carbon monoxide (CO) gas results in headache and discomfort for human and may be fatal if stay is prolonged. Furthermore, nitrogen oxides (NO, NO2) have poisonous effects. Sulphur-dioxide (SO2) causes bronchial and nasal irritant.
- Thermal Environment Hazards: As a locomotive/ generator car crosses through a tunnel, heat from exhaust gases is emitted. The air inside the tunnel gets heated up because of heat emitted from exhaust gasses/ locomotive surface. For safe operation of trains in the rail tunnel, the thermal environment is to be meticulous within a safe range for effective functioning of locomotive and comfort of passengers, crew and workman.
- Pressure Transient Hazards: When a train traverses through a tunnel, aerodynamic effects come into play. Because of this, the drag and propulsion power increases and the pressure atmosphere around the train gets changed. This may result in severe discomfort to passengers as there is change in pressure environment around the moving vehicle.

Under normal operation, the tunnel ventilation system of the main tunnel is managed by the air quality sensors (CO, NO, NOx, CO2, SOx, sanitary ventilation). In case of a fire, the fire detection system will localize the danger and activate the respective location dependent ventilation strategy. These fire programs are implemented and realized by the tunnel monitoring and controlling system (PLC and SCADA).

C. Lighting system

Tunnel lighting shall satisfy two levels of illumination:

- Level I: minimal illumination level for people to walk safely inside the tunnel within normal conditions,
- Level II: maximal illumination level for people to escape safely in case of critical conditions inside the tunnel. Same level is used during maintenance operation by the maintenance staffs to read and work without difficulties.

As per NFPA Standards 130, the intensity of illumination has been clearly defined. The minimal illumination levels of the train way and the walking track shall not be less than 2.7 lux measured along the path of egress at the walking surface.

The level II illumination average level of 50 lux along the tunnel as per BS 12464-1.

D. CCTV system

CCTV system allow the tunnel operator at remote Divisional Control Room to the local Control Room at Railway Station, the surveillance of the situation and the conditions inside:

- Main tunnel
- Escape Tunnel
- Tunnel Portals
- Cross Passages
- Tunnel Adit

E. Radio System

The Global System for Mobile Communications – Railway (GSM-R) is part of the Telecommunication Infrastructure recommended to enable the radio transmission along the line. This system is used for the communication between the TCC operator, controllers, drivers, etc.

Furthermore, Walkie-Talkies sets with simplex communication are provided to drivers, guards and maintainers as fall back arrangement in the tunnel. Walkie Talkies are battery-powered transceivers, able to send and receive radio messages and operating at 146-174 MHz. They have a half-duplex channel, so only one walkie-talkie on a channel can transmit a signal at one time, although many radios can receive that same signal.

F. Telephony System

Emergency telephones (Hot Line Telephones) are installed, along the emergency walkway side. These telephones connected by Optical Fibre cable to the Tunnel Control Centre and the Divisional HQ are available for crew and passengers to have a reliable connection with the central control operator in case of emergency. For reliability of communication operator at TCC are provided with emergency response equipment.

Furthermore, Emergency Communication sockets are also provided on tunnel wall with the same step as the emergency telephones

G. Public Address System

Public Address System is the telecommunication system able to inform and warn passengers, staff and maintenance personnel in case of emergency scenarios and to give instruction for a safe evacuation.

This system involves the installation in the tunnel of loudspeaker on the wall, both in the main and escape tunnel, in order that a central operator at the Tunnel Control Centre can make any emergency announcement suitable to be heard along the whole tunnel. Uninterrupted Power Supply are fed to Central equipment. PA system use Optical Fibre cable for connections as it is IP based. Facility for selecting zones in tunnels for announcement are provided to operator.

Loudspeakers are set up also inside the cross passages to better guide the passenger and staff during the evacuation.

IV. ACTIONS IN CASE OF LOSSES OF ELECTROMECHANICAL SYSTEMS

A. Loss of 11kV Power Supply

Total Loss of Cable Panel at one (Sub) Station (Portal / Niches Substation)

- The disconnection point of the HV system shifts automatically to the fault HV station. Because the tunnel is always supplied from both sides, the tunnel from the portals towards to the fault HV station will be supplied (the original used 11 kV circuit will be kept) through the other tunnel portal.
- The detection occurs by:
  - Malfunction message by SCADA
- The automatic Control and Instrumentation System activates / controls:
  - Disconnection point shall be shifted
- Operations by the Control Centre:
  - Immediate information of the tunnel's maintenance staffs
- Operation by the Emergency Organizations:
  - No

Total Loss of Transformer Panel at one (Sub) Station (portal substation / Niches substation)

- The 433 V-bus bars (part of the E&M contractor) of the "Tunnel Ventilation System" and "Rest of Tunnel Consumers" are interconnected (the 11 kV circuits will be mixed).
- The detection occurs by
  - Malfunction message by SCADA
- The automatic Control and Instrumentation System activates / controls:
  - The two 433 V bus bars of the defect (sub)station shall be interconnected
- Operations by the Control Centre:
  - Immediate information of the tunnel's maintenance staffs
- Operation by the Emergency Organizations:
  - No

Loss of High Voltage Cable between two 11 kV-Stations

- The disconnection point of the HV system shifts automatically to the fault HV station. Because the tunnel is always supplied from both sides, the tunnel from the portals towards to the fault HV station will be supplied (the original used 11 kV circuit will be kept) through the other tunnel portal.
- The detection occurs by
  - Malfunction message by SCADA
- The automatic Control and Instrumentation System activates / controls:
  - Disconnection point shall be shifted
- Operations by the Control Centre:
  - Immediate information of the tunnel's maintenance staffs
- Operation by the Emergency Organizations:
  - No

Loss of Auxiliary Voltage for 11 kV Equipment

- The detection occurs by
  - Malfunction message by SCADA
- The automatic Control and Instrumentation System activates / controls:
  - Automatic alarm messages via Control and Instrumentation System
  - Normal operation of tunnel will be continued
- Operations by the Control Centre:
  - Immediate information of the tunnel's maintenance staffs
- Operation by the emergency organizations:
  - No

The control system guarantee, that the two 11 kV circuits or the both main supply stations will not be interconnected. In case of a breakdown of the communication, the high voltage stations although continue their operation.

B. Loss and Malfunction of Relevant Operational and Safety Equipment

Generally, the tunnel stays in normal operation during loss of the following scopes of the operation & safety equipment. However, the listed emergency organizations shall be informed:

- Loss of Air Control System
  - The Control Centre monitor the tunnel more intensively by the CCTV System, especially in the area of malfunctional Air Control System
  - The Control Centre inform the tunnel's works management
- Loss of Emergency Call System
  - The Control Centre inform the tunnel's works management immediately
- Loss of Fire Detection System
  - The Control Centre inform the tunnel's works management immediately
- Loss of CCTV System
  - The Control Centre inform the tunnel's works management
- Loss of Tunnel Radio System
  - The Control Centre inform the Emergency Organizations
  - The Control Centre inform the tunnel's works management immediately
- Loss of Public Address System
  - The Control Centre inform the tunnel's works management immediately
- Loss of Room Ventilation and Climate
  - The Control Centre inform the tunnel's works management immediately

V. CONCLUSION & FUTURE SCOPE

Thus, by determining the tunnel electrical and mechanical services and coordinating them with each other properly can result in better performance of tunnel services in all scenario like normal operation, emergency option etc. SCADA help us to monitor, control and store data related tunnel lighting system, electrical power distribution, Tunnel & Cross Passage ventilation, Linear Heat System, Hydrant System, Pressure Pressurization, Telephone and Emergency Telephone system, Public Address (PA) System, Tunnel CCTV

System, Tunnel Radio Communication System, Tunnel Access Control System. These all makes the requirement of SCADA control for EnM services fruitful even though having problems like high cost, requirement of skilled person etc. Furthermore, E&M installation are more complex and networked and should be duly considered in early stage in tunnel projects to have proper integration and working of tunnels as generally client, consultant and contractors generally underestimate E&M installation.

VI. REFERENCES

[1] International Journal of Engineering Research & Technology (IJERT), ISSN-2278-0181, Vol.3 Issue 11, November- 2014.

[2] International Journal of Engineering Research & Technology (IJERT), ISSN-2229-4333, Vol.5 Spl 1, Jan-March-2014.

[3] International Journal of Computing Communication and Information System (IJCCIS), Vol 6. No.1 – Jan-March 2014 Pp. 47-54, ©gopalax Journals, Singapore, ISSN: 0976–1349 on Enhancing safety Measures in Metro Rail By Using PLC and SCADA

[4] Pir Panjal Railway Tunnel – A Dream Realized" –Published By: Northern Railway

[5] The success story of the Gotthard Base Tunnel Ed. by STS Swiss Tunnelling Society Hardcover, 720 pages Book pocket with 3 inserts (Schematic overview, Overall project schedule, Geological cross-sectional map along the east tunnel)

[6] Boyer S. A.,"SCADA: Supervisory Control and Data Acquisition, ISA-The Instrumentation, Systems, and Automation Society", 3 edition (June 2004)

[7] "Traction Power" [Online] Available: http://www.indianrailways.gov.in/railwayboard/uploads/codesmanual/ACTraction-II-P-I/ACTractionIIPartICh4_data.htm

[8] Anonymous, "Indian Railway Technical Bulletin, Vol. LXVI, No 333, Government of India, Ministry of Indian Railways.

[9] Garitano I, Uribeetxeberria R., Zurutuza U.,"A Review of SCADA Anomaly Detection Systems", In proceeding of: Soft Computing Models in Industrial and Environmental Applications, 6th International Conference SOCO 2011, 6-8 April 2011, Salamanca, Spain.

[10] International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 7, Issue 10, October 2018 on Altitude Correction Factor for Oil Immersed and Dry Type Transformers as Per IEC and IEEE Standards

[11] "Functional Description and Specifications", [Online]. Available: http://www.rdso.indianrailways.gov.in/works/uploads/File/Draft_25%20kV%20traction%20SCADA_SPECIFICATION.pdf

[12] UIC- Codex 779-9 Safety in Railway Tunnels

[13] NFPA 130-Standard for Fixed Guideway Transit and Passenger Rail Systems

[14] https://en.wikipedia.org/wiki/Pir_Panjal_Railway_Tunnel on Pir Panjal Railway Tunnel

[15] https://www.siemens.com/

[16] IS 875-1987 – "Code of practice for Structural Safety of Buildings – Loading Standards".

[17] EN/IEC 62271- HV-switchgear and control gear

[18] Indian Railway Tunnel Manual

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 06 Issue 09
August 2019

[19] Railway tunnel by Indian Railways Institute of Civil Engineering

[20] Indian Railways Bridge Manual