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Challenges during integration of substations for establishment of National Transmission Asset Management Centre (NTAMC) by POWERGRID – A case Study

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SUMMARY

POWERGRID, the Central Transmission Utility (CTU) of the country and one of the largest transmission utilities in the world, is playing a strategic role in the Indian Power Sector. With the changed scenario, it would be even more important to maintain high availability of elements ensuring the economic reliability with enhancement of efficiency & productivity in the field of transmission sector. There was an urgent need to have a paradigm shift in operational philosophy i.e. to move from manual-operation mode to unmanned-operation mode from a Centralized Control Centre. If the conventional/manual method of O&M practice is continued, there would be a huge requirement in additional skilled manpower for Shift operations round the clock at substations and for quick restoration during outage of elements.

The Operation of all the substations from a Centralized Control Centre will bring down operational expenditure significantly and will allow POWERGRID to retain leadership in transmission sector. Thus, today POWERGRID is realising this dream in to reality with impeccable remote operations of 234 number of EHV substations spread across the length breadth of country.

This full paper shall cover the major challenges experienced for adaptation and integration of different type of EHV substations under NTAMC. The paper also discusses the methodology adopted to overcome the above challenges for accomplishing the inevitable task of flawless remote operation of substations. This paper is an attempt to consolidate these experiences and learning.

KEYWORDS

Supervisory Control and Data Acquisition (SCADA), Communication System,. National Transmission Asset Management Centre (NTAMC) , Regional Transmission Asset Management Centre (RTAMC), Back up National Transmission Asset Management Centre (BNTAMC).

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1 INTRODUCTION

POWERGRID is responsible for coordination and supervision for development of Inter-state and Intra state transmission system. As on May 2020, POWERGRID owns 248nos EHV class substations having 163,743ckm of transmission line and 412,459 MVA transformations capacity. POWERGRID was decided to establish NTAMC in 2010 along with Back up and 7nos as RTAMCs. The main purpose of NTAMC is to control and virtual monitoring of POERGRID owned substation's assets from a centralized location.

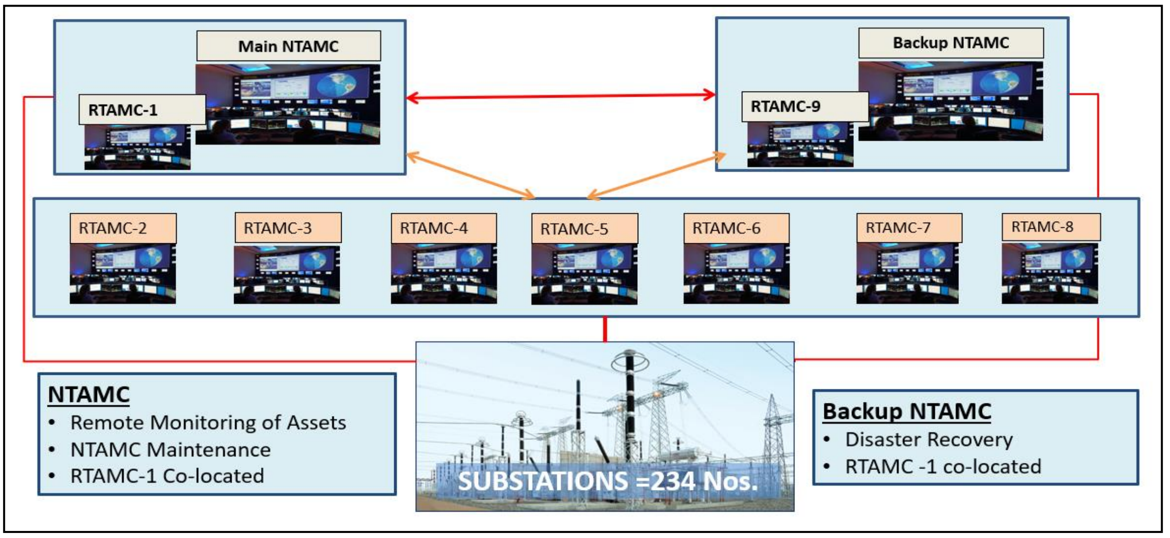

Figure 1. NTAMC System Overview

Major applications or building blocks of NTAMC system to accomplish the task of virtual remote operation of substations are as shown below:

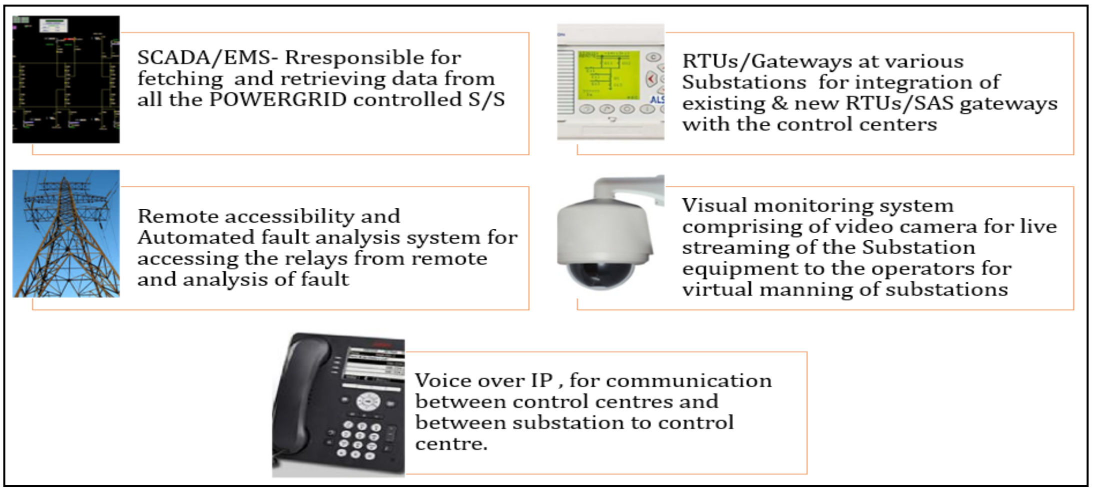

Figure 2. Major applications of NTAMC

POWERGRID has added 248 nos. of EHV substations since its inception, and currently successfully managing remote control, monitoring & analysis of faults for 234 nos. of Substations from centralised remote-control centre and working on accomplishing 100 percent remote operations of substations in near future. These substations were commissioned over the last few decades are in existence based on different type of infrastructure, hardware's, & technology evolved from time to time. Accordingly, in NTAMC, the adaptation & integration approach of substations is categorised in to 04 types of substations.

CAT-I	Conventional Substations-All the monitoring and control was carried out locally through the control panels
CAT-II	Conventional substations with RTUs were used for Remote operation.
CAT-III	SAS based substations where all the IEDs are communicating via IEC 61850 protocol with local SCADA.
CAT-IV	These are HVDC Substations.

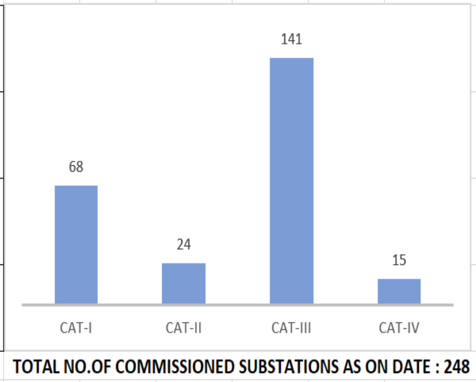

Figure 3. Different category of Substations

To meet the requirement and necessity for uniform platform of different substations following methodology/devices were adopted in NTAMC for making suitable for remote operations of substations.

1) The Remote Terminal Unit (RTU) were installed at conventional and SAS based substations for:
   - Collecting and processing the digital status inputs, analog values and transmitting to master station.
   - Communication to three number masters independently over IEC 104 protocol.
   - Acquiring the data on IEC 60870-5-101 protocol and transmission over IEC 60870-5-104 protocol to control centres at SAS based and HVDC substations.
   - Communication with existing substation IEDs in IEC 61850 communication.
   - Extending the control commands which were issued from control centres.

2) The Bay Control Unit (BCU) were also installed at conventional substations where RTUs are only used for RLDC reporting only and not meant for remote operation. One number BCU was used for 3nos bays i.e. 1-DIA to fetch the Status of Switchyard equipment and associated control. The other functions of BCU are as follows:
   - Control of devices (Switchgear like Circuit breaker/Isolators, Reset of Relays)
   - VT selection and Synchro closing of circuit breaker.
   - Interlocking to avoid unwanted operation of Switchgear.
   - IEC 61850 communication including Goose message exchange
   - Acquisition of data from low level IEDs (like Multifunction transducers) over Modbus protocol and transmitting the same to remote control centres.

3) Installation of Different types of Transducers:

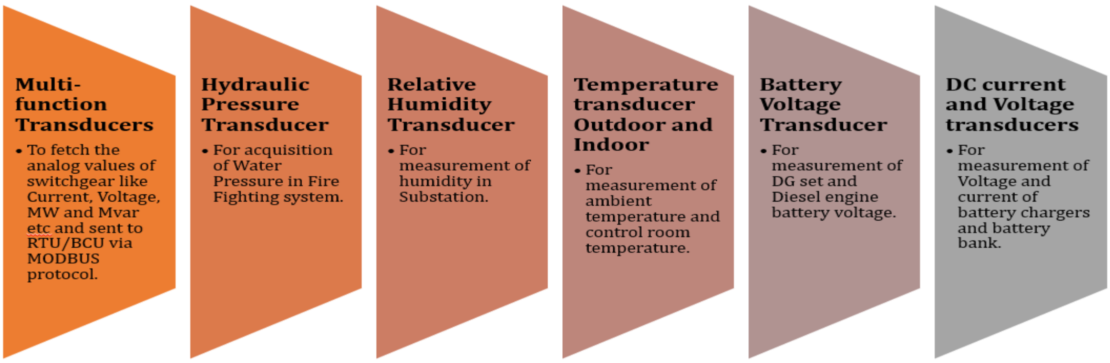

Figure 4. Different Types of Transducers

4) Installation of different type of Relays:
    - Contact Multiplying Relay (CMR) used for multiplying the contacts, where potential free contacts are not available
    - CB Open/ Close Relay used for opening and closing of circuit breaker, instead of extending control command directly from BCU/RTU.
    - Control Relays for controlling of isolators from remote and control auxiliary switchgear.
5) Installation of cameras for Virtual manning of Substations
6) Installation of Station Data Concentrator, Terminal servers and fallback switch etc to fetch the disturbance recorder (DR) to control centre during tripping and also enables the remote configuration of the Relays/IEDS in the Substation from the Control centres
7) Installation of other control, communication cables and networking equipment like switches and routers for establishing communication with control centres.

2 Challenges for integration of substations:

Implementation of architecture for remote operation of different type of substations was tedious and cumbersome task which is having the constraints attributable to following factors:

a) Implementation of adaptation work within the existing control and relay protection scheme of substation without any addition of any new major items or up gradation in most cost-effective manner.
b) Mass scale adaptation of control circuit scheme at conventional substations in live charged conditions of elements with optimum utilisation of limited physical space available in existing control room and panels
c) Ensuring the 100% safety requirement while working in the charged panels for adaptation works.
d) Taking care of economic aspect as it was complex task to adapt the old technology existing system based set up of LT system, Air-conditioning system, DG Set & Fire-fighting system.
e) Compatibility and uniform configuration of database in substation gateways existing at site in SAS based substations of different vendors.
f) Successful completion of end to end testing of huge volume of signals (approx. 6lakhsignals for 234 S/s) in limited period of time ensuring the 100% accuracy of tested signals even though some of them could not be physically simulated on account of shutdown constraints.
g) Development of dedicated communication infrastructure for reliable & secure communication between control centre and substations
h) Implementation of different type check synchronism function in conventional substations.
i) Ensuring the adaptability of relays for providing the disturbance record files in compatible format uniformly across all the substations.
j) Optimum utilisation of cameras taking care of economic aspect and meeting the requirement for 100 percent virtual visualisation of switchyard area from remote.
k) Consideration of Cyber Security related challenges.
l) Dedicated voice communication over IP (VOIP).

There were also certain other challenges which had impact on the completion of project like

- Complexities of digitizing multi-vendor legacy devices to IEC 61850 protocol
- Confidence building of engineers with new philosophy of operation
- Training to operation and maintenance man power for awareness of system.
- Timeline to complete the project
- Executing the project with full scope
- Managing human Resources

The above challenges are not explained in detail considering the length of the paper.

3 Methodologies adopted to overcome Challenges:

3.1 Implementation of adaptation work within the existing control and relay protection scheme of substation

In conventional substations, all signals are to be hardwired through potential free contacts available at site. For certain signals potential free contacts are not available at site as those contacts are already used for other IEDs like relays, Event loggers, DR etc. In this case, CMRs are used to multiply the contacts (ex: auxiliary contacts of breaker/isolators etc) and to be used to provide status input to the BCUs/RTUs as well as existing substation IEDs. One of the toughest challenges is to carry out the adaptation of CMR in existing panel due to space constraint and without disturbing the existing substation scheme.

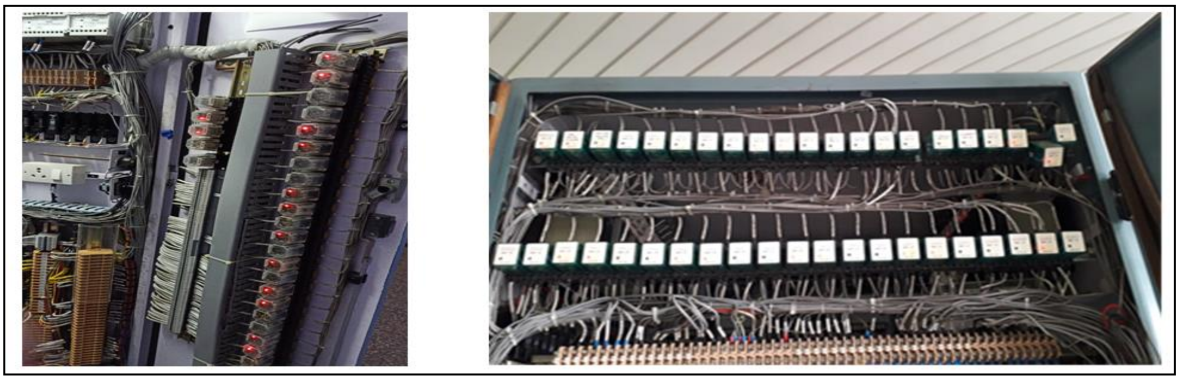

Figure 5. Installation of relays in existing Relay and Control

One number of Local/Remote was used for each bay in control panel for isolating the control commands from BCU/Control centre during maintenance activity of switchyard equipment and Heavy-duty latching relay for selection of Auto Reclosure ON/OFF from remote.

Further, the conventional substations are equipped with hand reset type Trip relays for Group-A and Group-B protection, auto reclosure lock out relays and Carrier Lock out relays. These relays are to be reset manually whenever it operates during tripping of elements. In order to carry out successful remote operation of conventional substations from remote, these relays are to be made electrical reset so that these relays can be reset from NTAMC through BCU/RTU. The most challenging part is to carry out adaptation of different make relays that are hand reset in nature for converting into electrical reset by using solenoid etc instead of replacing the complete relays.

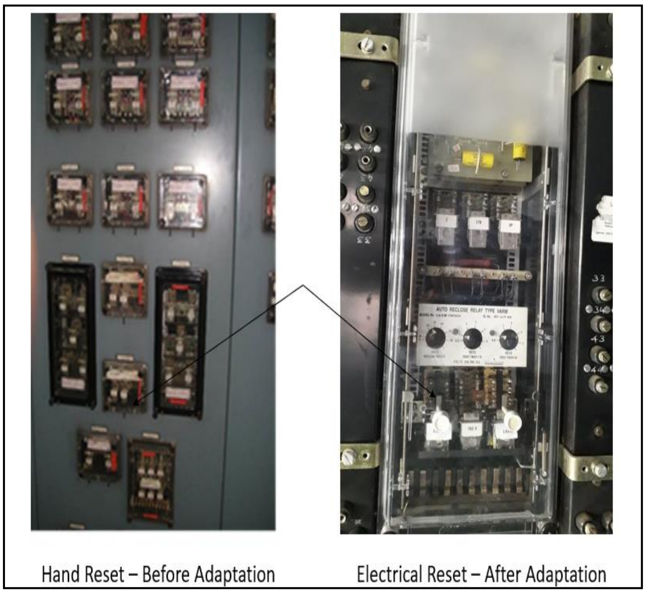

Figure 6. Adaptation of Relays for Remote Reset

3.2 Mass scale adaptation of control circuit scheme at conventional substations

At conventional substations, control was being carried out locally through control panel. While retaining the existing control scheme, adaptation of different make and type of Circuit breakers, Isolators etc were carried out by using a separate control relay instead of directly extending from BCU/RTU Digital output card

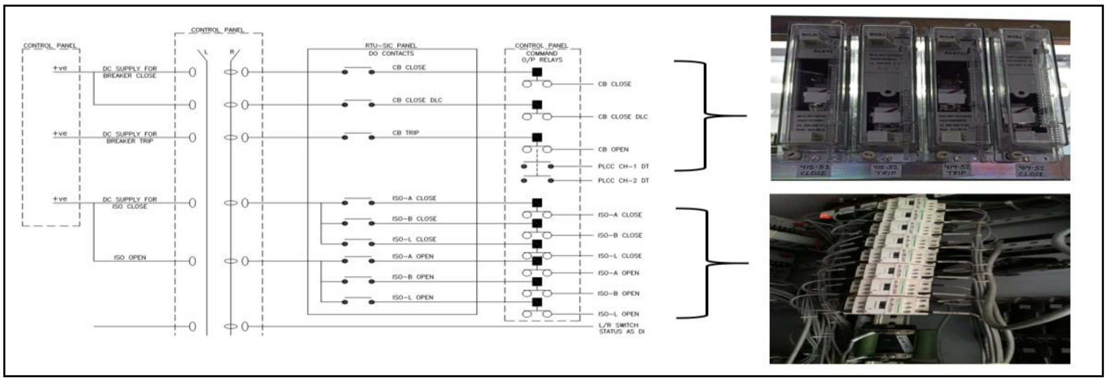

Figure 7. Adaptation of control circuit scheme

Mal operation of single switchgear may lead to failure of complete BCU /digital output card which leads to non-operation of balance switchgear. To avoid such cases, a separate relay was used for control of Switchgear of main as well as auxiliary equipment. A sample control circuit which is being adapted is as shown in Figure 9.

3.3 Ensuring the 100% safety requirement while working in the charged panels for adaptation works

Majority of adaptation work was required to be carried out in live panels as availing shutdown leads to reduction in transmission system availability which is not feasible. So, during this entire activity, safety of vendor and substation personnel was a key challenge. To ensure 100% safety of working personnel, certain precautions like maintaining minimum safe clearance from charged equipments/live parts, mandatory usage of PPE (Personnel Protective Equipments) etc, training and checklist for ensuring complete safety during adaptation works were ensured.

3.4 Taking care of economic aspect for automation of LT system, DG set and Fire Fighting system

Automation and remote control of auxiliary system is one of the major challenges as existing auxiliary system scheme was never designed for remote operation and automation. To operate the auxiliary system from remote and unmanning of substations, major changes were done in existing auxiliary system in a cost-effective manner.

3.4.1 LT System Automation:

Certain modifications were carried out in LT system for making it suitable for remote operation like installation of Phase Reversal relays in MSB, Replacement of SFU's by MCCB's/ACB's in ACDB, Installation of O/C & E/F relays in ACDB panel, if ACB's are installed, installation of VMR, Auxiliary contactors, timers, selection switch, re-wiring for each Incomers of ACDB panels and its Bus coupler and implementation of Auto Changeover scheme in MSB and ACDB by using a dedicated BCU.

3.4.2 Integration of DG systems:

Adaptation works involved for integrating DG set with control centre are laying of control cable from the DG set to BCU, ensuring the availability of 02 sets of Battery chargers & Batteries with provision of change over selection switch, scheme implementation for Interlocking b/w DG set breaker & ACDB incomers Breakers and implementation of logic for Auto start/stop of DG set through BCU and during supply failure etc. Similarly, adaptation of Air conditioning system for generating alarm to control centre in case of failure, Fire-fighting system for controlling of deluge value, diesel engine and monitoring of fire-fighting system pressure, Jokey pump running status etc were also carried out. Laying of control cable from switchyard to RTU/BCU and extending these signals to remote control centre is a challenge. Different types of transducers, CMR and contactors were used for control and monitoring of these systems.

3.5 Compatibility and uniform configuration of database in substation gateways existing at site in SAS based substations of different vendors:

SAS substations are newly commissioned substations which are having substation automation system based on IEC 61850 and have all the parameters, device states, status of protection equipment, monitored and available in a local SCADA system. These substations are equipped with gateways which send data to RLDC and RHMI in IEC 60870-5-101 protocol. A protocol converter i.e RTU was provided at these substations which converts the IEC 60870-5-101 communication protocol from the existing Substation gateway to IEC 60870-5-104.

These SAS systems are commissioned by different vendors, which are having their proprietary configuration settings. Integration of these gateway with NTAMC RTU was another key challenge. Certain major challenges are as follows:

- Support from Vendor
- Availability and healthiness of Spare communication port in existing substation gateway to acquire data in IEC 101 protocol.
- Configuration of gateways in HOT-HOT/ACTIVE-ACTIVE mode
- Identification and Mapping of IEC 101 addresses with NTAMC RTU
- Availability of all signals as per NTAMC requirement.

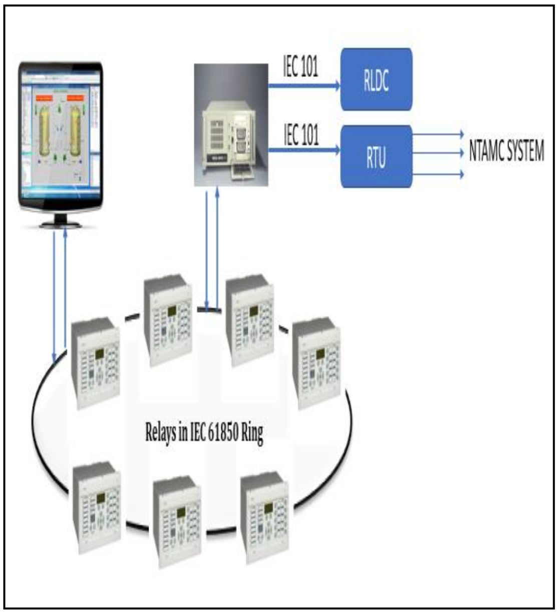

Figure 8. Basic Architecture of SAS based Substations

Fortunately, the vendor who supplied the RTU/BCU at substations and SCADA systems at control centre was also having their SAS systems at some of the substations and necessary readiness in SAS gateways was ensured in early stage of commissioning itself.

To maintain uniformity is data reporting at control centre an interoperability profile was standardised which was implemented in all type of SAS gateways as well as NTAMC RTUs for smooth data exchange between Substation and control centre.

3.6 End to end testing of Signals:

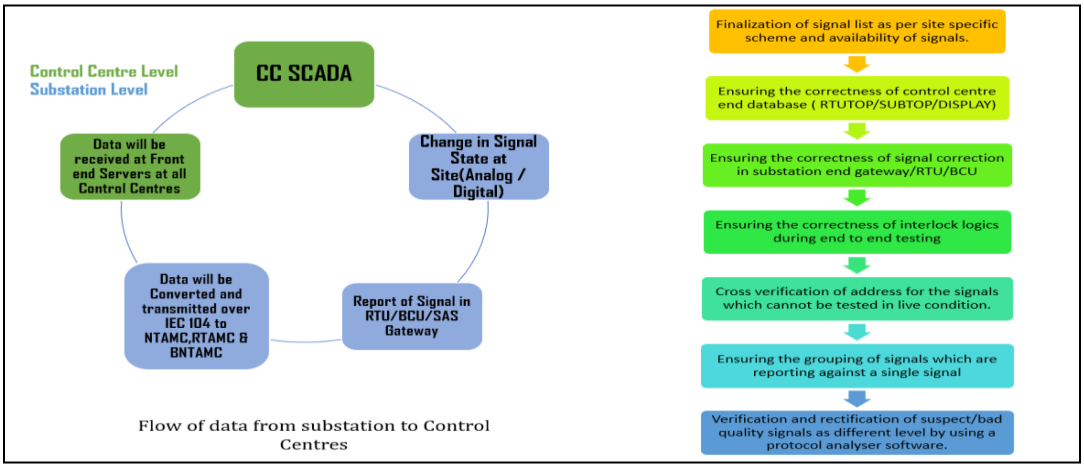

Figure 9. Sequence of End to End testing

One of the major challenges is to carry out the end to end testing of signals which are hardwired/Soft integrated from local Substation gateways to control centres. Various checks need to be done for ensuring the correctness of signals which are reporting at Control centres. Major steps involved in data validation as shown below:

3.7 Development of dedicated communication infrastructure for reliable & secure communication between control centre and substations:

The NTAMC system relies on multiple way data communication for exchanging of data and live streaming of substations between NTAMC to Substations and NTAMC to RTAMC etc. Communication between Substations to NTAMC and NTAMC to RTAMC etc is extremely important maximum utilization of remote monitoring of substations in a reliable and cost-effective way. A reliable telecommunication network capable of handling data and video channels for efficient and effective transmission asset management is essential.

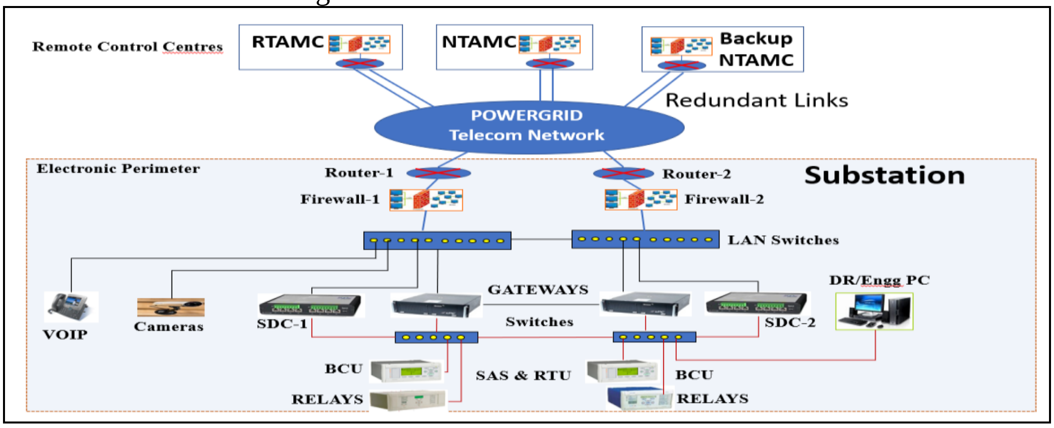

Figure 10. Data Communication from substations to Remote Control Centre

Dedicated POWERGRID's dual fibre network was used to meet the above requirement and considering cyber security aspect for remote operation of substations from centralized remote location.

3.8 Implementation of different type checks synchronism function from remote in conventional substations.

Synchro check function is used for closing of CB after measuring the two voltage's Phase angle, Frequency and magnitude to safeguard against the interconnection of two unsynchronized systems. Under NTAMC, as single BCU was envisaged for complete dia (i.e 3nos of Bays) for implementation in a cost-effective manner. The VT inputs in BCU are being used for implementing VT selection logic to satisfy the synchro check parameters defined in BCU based on substation topology like position of CB, Isolators etc.

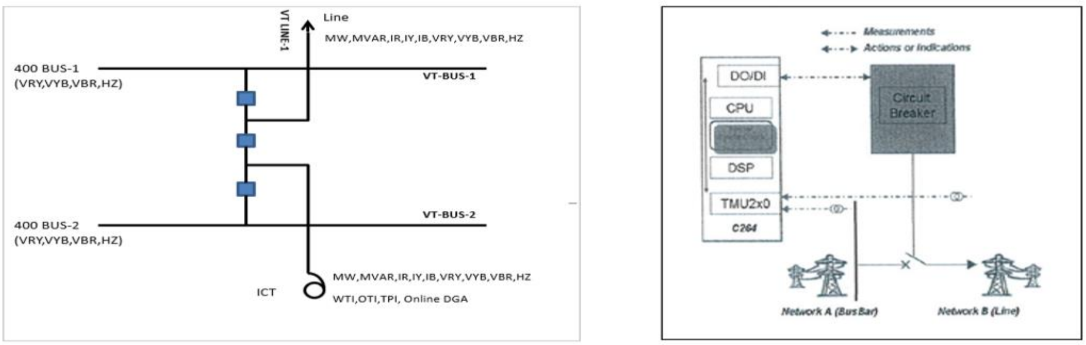

Figure 11. Implementation of Synchro check Function

At SAS based substations Synchro Check logic is being implemented in respective BCU. However, in NTAMC single BCU used for 3nos bays. To implement a suitable logic with one no. of BCU is one of the key challenges. As TMU card is having limited VT inputs, metering was done by using a MFT (Multifunction Transducers). Accordingly, synchro check function developed which manages 3 circuit breakers, with dynamically defined voltage comparisons, in a fixed topology (also called One & half breaker topology) or Double main transfer topology with 2 bays managed by Single BCU.

3.8.1 Ensuring the adaptability of relays for providing the disturbance record files in compatible format uniformly across all the substations.

Remote accessibility System (RAS) is typically used for fetching the Disturbance Recorder (DR) during fault of transmission elements and it will send the DR to AFAS server for quick analysis and generation of report. It is essential to integrate all type of protection relays in RAS system for maintaining the transmission system reliably and efficiently.

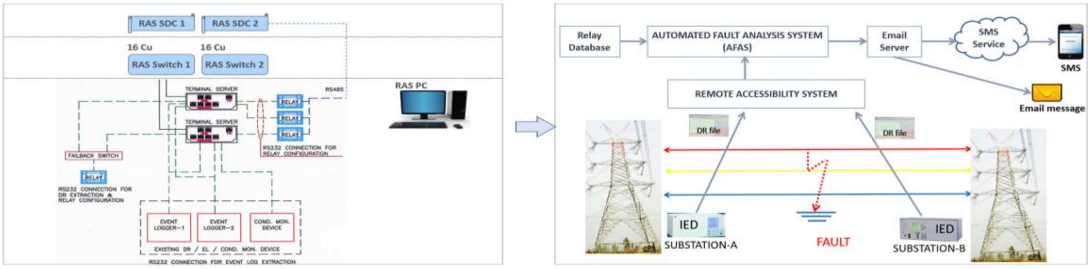

Figure 12. Basic Architecture of RAS system

The main challenge is to integrate different type of relays which are manufactured by different vendors and are communicating in different proprietary protocols. Over a period of time majority of relays are retrofitted to communicate over IEC 61850 protocol. The RAS system is used to collect the DR from different relays and converts the DR in "COMTRADE" format which are further sent to control centre. It also provides remote access of relay for modification of relay settings from centralized location on need basis. AFAS (Automated Fault Analysis system) is used to process DR file for automatic generation of Fault summary and intimation to Line maintenance crew, system operators and substation maintenance team. AFAS also maintains a centralized repository of Faults data, detailed offline analysis, Report generation etc.

3.9 Optimum utilisation of cameras taking care of economic aspect and meeting the requirement for 100 percent virtual visualisation of switchyard area from remote:

VMS system (Visual Monitoring System) enables the virtual manning of substations from centralized location. VMS system plays a key role along with SCADA system during controlling of switchyard equipments. One of the major challenges for integration of VMS system is installation of cameras in charged switchyard area and covering the complete switchyard with minimum number of cameras. So, location of cameras were finalized in such a way that each camera can cover the maximum area.

Figure 13. Switchyard view from VMS system at Control Center

3.10 Cyber Security challenges:

NTAMC is a large-scale system that accesses IEDs, Gateways and other electronic devices which are installed at substations. With large-scale data flow for remote operation of substations, ensuring cyber security and avoiding malicious activities is a prime concern. The challenges of ensuring cyber security are diverse in nature and certain major objectives are classified as follows:

1) Protecting against the unauthorized access of system to avoid unwanted operation of substation switchgear.
2) Confidentiality: Protecting privacy and proprietary information by authorized restrictions on information access.
3) Ensuring timely and reliable access to information and services.

NTAMC system security mechanism was enforced at several layers including physically and logically by using different types of equipments like firewalls, SIEM for security events/logs management etc.

3.11 Voice over IP (VOIP):

An independent VOIP communication system is used for dedicated communication between control centres and control centres to substations keeping the criticality of operation and cyber security issue.

4 Conclusion:

This paper has attempted to share the experiences and challenges faced during establishment, operation and maintenance of NTAMC system from POWERGRID's point of view. Certain challenges were faced on a daily basis due to involvement of different new technologies installed at substations as well as control centres. Each technology discussed above has its own challenges with respect to configuration, maintenance and Spares availability.

NTAMC system provides a unified platform for integrating different types of systems and substation equipment ranging from traditional legacy devices to latest Substation Automation System commissioned by different vendors over a period of time. NTAMC sub-systems present a unique and an efficient way of handling remote operation of substations with asset management solutions. The approach adopted results in optimizing the project cost as well as it helps in optimizing operational and maintenance cost of substations. By establishing NTAMC, POWERGRID has proven how to adapt new technologies in power transmission business to suit competitive environment. POWERGRID has taken a lead and become trend setter for other utilities as similar projects are now already started coming up in India.

As different types of vendors are involved in commissioning of substations, a standard architecture, naming convention, standardization of IEC 61850, IEC 104 addresses are to be adopted to overcome the major challenges which is to be explored.

Further, integration of Process bus-based substations with NTAMC and interoperability challenges posed by process bus for real time monitoring and control are also to be explored.

BIBLIOGRAPHY:

Working experience during engineering, implementation of different subsystems under NTAMC Project.