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PS3: Opportunities for Sustainability and Circular Economy with Substations and HV equipment
B3: Substations and electrical installations

Optimisation of Operational Efficiency in Remote Operation

Sunil KUMAR, Manoj KUMAR, G SRIMANNARAYANA, Tarnnum GUPTA, Priyanka PATEL
Power Grid Corporation of India Limited
India
priyankapatel@powergrid.in

SUMMARY

In the year 2014, POWERGRID introduced a paradigm shift in operation of its assets from local substation level to centralized remote operations at individual regional level control centres. Supervision of overall system, maintenance of database and contingency operation is being coordinated and managed by Main & Backup control centres while maintenance of transmission assets is carried out by substations. All control centres and substations are connected by MPLS cloud which provides dedicated optical fibre-based telecom links between substations and control centres for data communication.

The purpose of this paper is to encapsulate various methodologies that have been developed with a broader view for effective monitoring & control, organizing the remote operation for improvised situational awareness, sustaining the maintenance practices at the same time, duly optimizing control centre infrastructure facilities without compromising the availability of power system.

This paper covers flexible approach in segregating number of substations among control centres, unification of signals, evaluating typical signal lists, prioritization of alarms, actionable signal points, enhancing situational awareness with intuitive displays, giving a big picture of assets status at a glance. It also captures steps taken for efficient human resource utilization, network and infrastructure management while targeting for better power system management and ensuring environmental sustainability. Case studies, best practices, challenges encountered and experience gained in remote operation in past one decade has also been discussed.

KEYWORDS

Supervisory Control and Data Acquisition (SCADA), National Transmission Asset Management Centre (NTAMC), Regional Transmission Asset Management Centre (RTAMC), Multi-Protocol Label Switching (MPLS)

INTRODUCTION

Indian power sector is growing at an unprecedented pace. Renewable integration, adoption of GIS technology, 765kV network expansion, addition of mega transmission corridors for bulk power transmission, addition of FACT devices, uprating of transmission lines, etc. have increased the complexity of operation.

Remote operation was conceptualized in the year 2010 to provide nationwide visibility of transmission assets at control centres. At present, a total of 272 Nos EHV substations ranging from conventional substations, semi-remote ready substation, SAS based substations and HVDC substations, are being remotely operated and monitored. Technology wise substations from old conventional substation without any numeric relays to latest process bus digital substations are covered under remote operation.

The operation and monitoring of the substations are real time activity which is carried out by operators strictly as per grid code, with responsibility to avoid unplanned downtime and recover quickly during unforeseen circumstances. Any outage of the transmission elements either due to faults or shutdown needs to be handled properly and restored as soon as possible. Thus, the problem statement was to provide intelligent and fast processing of data using customized analytics in order to provide operators with action invoking points and priority for real time monitoring and pro-active maintenance of assets. Working model based on various methodologies and data management tools have been incorporated at control centre level for increasing situational awareness in remote operation.

MODEL ADOPTED FOR OPERATIONAL EFFICIENCY

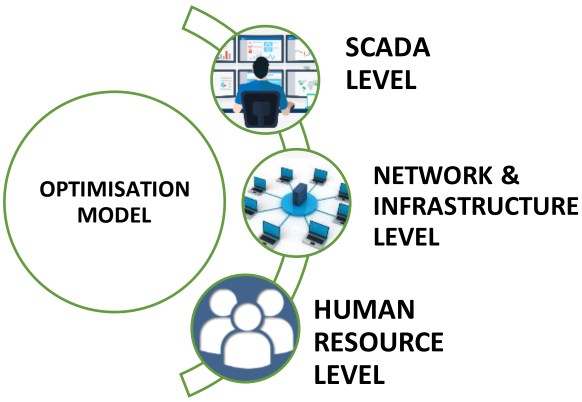


Figure 1: Model for Operational Efficiency

A. SCADA LEVEL

The SCADA system is responsible for scanning and retrieving data from all the substations. It processes the data and notifies operators of abnormal situation in forms of events and alarms. Various methodologies enlisted below have been incorporated to ensure operators are provided with processed data for prompt action.

- Signal List Standardization
- Grouping Of Signals
- Alarm Management
- Customized Displays
- Data Analytics

I. SIGNAL LIST STANDARDISATION: Typical Signal List for each equipment

At substation level detailed signal engineering is carried out for maintenance and operation point of view, while at control centre level, signal required specifically for maintenance are avoided and operation related signals are taken resulting in reduction in huge volume of data. After implementing standardised signal list, following is the signal statistics in 400kV GIS substation and for STATCOM device:

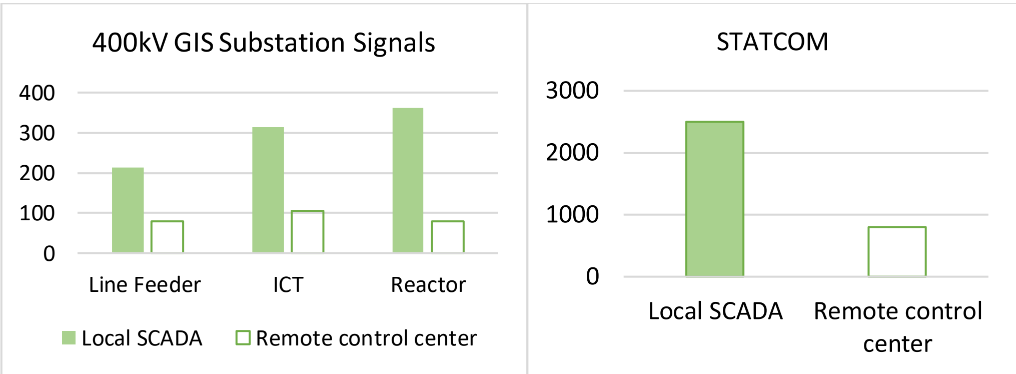


Figure 2: Comparison in signal list at Local SCADA and remote-control centre after standardisation and grouping of Signals

Uniformity across different substations is made by adopting same description of signals (maximum 16 characters) for different vendor types which enables operators to comprehend the event quickly.

Vendor-1	Vendor-2	Control centre SCADA
M1 DISTANCE ZONE-1 R-PH OPERATED	GENERAL TRIP, Z1	M1 ZONE 1 TRIP
CB SF6 GAS PRESSURE REFILL LOW ALARM	SF6 GAS LOW	SF6 LOW ALM STG1
DIFFERENTIAL PROTECTION TRIP	DIFFERENTIAL TRIP	DIFF PROTN OPTD
OVERVOLTAGE STAGE-1 -PH-N TRIP	OVERVOLATGE STAGE 1 TRIP	OV STAGE 1 OPTD

Figure 3: Uniformity of Signals in SCADA

II. GROUPING OF SIGNALS

Signals finalized for integration in SCADA are further grouped equipment wise to reduce volume and bulkiness of data. It averts cognitive overload and aids in quicker action. Grouping of signals can be done at RTU/BCU, Gateway or even at SCADA level.

Signal Type	Signals present at Substation	Grouped Signal
Distance Protection	M1 DISTANCE ZONE-1 R-PH OPERATED	M1 ZONE 1 TRIP
	M1 DISTANCE ZONE-1 Y-PH OPERATED	
	M1 DISTANCE ZONE-1 B-PH OPERATED	
GIS BAYS	GAS COMPARTMENT 1 Alarm Stage 1	GAS Low Stage 1 Alarm
	GAS COMPARTMENT 2 Alarm Stage 1	
	GAS COMPARTMENT n Alarm Stage m	

Figure 4: Grouping of Signals

III. ALARM MANAGEMENT

The primary function of the alarm system is to notify operators regarding abnormal process conditions or equipment malfunction and support the response. It is important to segregate alarms based on criticality and priority.

Priority 1 – Equipment Switching Status
Priority 2 – Protection Alarms
Priority 3 – PLCC Status, Transfer Switch Status (DMT scheme)
Priority 4 – Equipment Healthiness Status

Apart from telemetered alarms, SCADA system generated alarms are also included based on condition of the equipment and as per the logics implemented at control centre to aid operation.

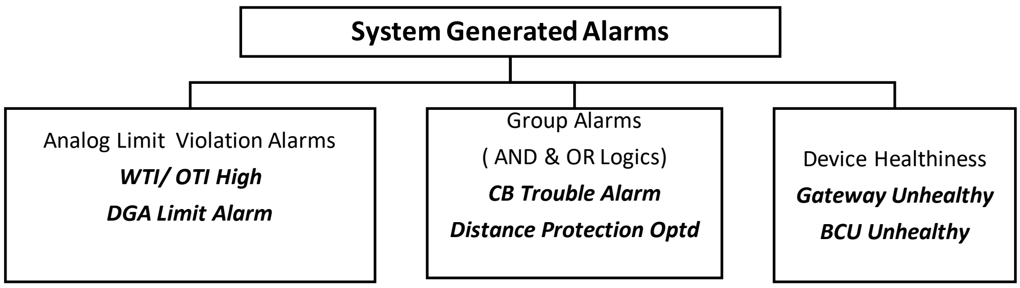


Figure 5: System Generated Alarms

Alarms are segregated region-wise and accordingly responsibility assigned to operator in SCADA. Alarms are displayed only to responsible operator designated for that specific region.

Operation guidelines have also been finalized to provide necessary guidance for system operators at control centres for streamlining operation and management of transmission assets through SCADA and various other software applications. Periodicity of alarm monitoring and escalation matrix providing frequency and course of action has also been defined in it.

Frequency of alarms and data type is finalized based on operational requirement and to maintain server performance. Optimum pre-filter time has been defined to avert event repetition during contact bounces. Digital signals with time stamp and analog signals without time stamp are required. Analog data is to be updated periodically as per defined setting and as well as spontaneously as per dead band configuration.

IV. CUSTOMISED DISPLAYS

Broader view of power system at country and regional level is required to assess Indian grid condition at any point. Interconnectivity and power flow between different regions are also need to be monitored. In view of above, customized displays namely HVDC substation summary, Voltage Profile Displays (region-wise), ICT and Reactor Summary, power map (All India, regional, metro city) has been created.

HVDC Substations Power Flow				
HVDC SUBSTATIONS	POLE-1 POWER FLOW	POLE-2 POWER FLOW	POLE-1 STATUS	POLE-2 STATUS
Substation-A	250 MW	250 MW	Deblocked	Deblocked
Substation-B	0 MW	0 MW	Blocked	Blocked

Figure 6: HVDC Substation Summary

Voltage Profile Summary (Region-wise)					
SUBSTATIONS	765 KV		400 KV		Frequency
	BUS-1	BUS-2	BUS-1	BUS-2	
Substation-A	765	765	400	400	50.02
Substation-B	766	766	401	400	50.02

Figure 7: Region- wise voltage profile summary

ICT and Reactor Summary (Region-wise)						
SUBSTATIONS	WTI		OTI		DGA Parameters (MOISTURE)	
	ICT-n	Reactor-n	ICT-n	Reactor-n	ICT-n	Reactor-n
Substation-A	82	92	72	85	3.2	4.2
Substation-B	80	81	70	71	7.1	6.5

Figure 8: Region- wise ICT and Reactor summary

For effective asset utilization of ICTs, Reactors, separate region-wise displays are provided for monitoring, so that escalation can be done promptly.

V. DATA ANALYTICS

Advanced data analytics is used to process the available information and provide operators tool for better asset monitoring.

a. Data Freeze Detection –

In SCADA, signals are reported along with quality as mentioned below.

- Good quality if it is being received from field devices.
- Suspect quality if it is not being received from field devices.

Good quality data not getting updated indicates signals from substation are in freeze/hang condition which can be detrimental for smooth operation of substation. Hang Portal identifies such cases, by analysis of analog data reporting from a given station in a particular time frame. Operator can view periodically such cases and take prompt action for resolution.

b. CT/CVT Health Monitoring

With the help of data analytics, health monitoring of CT/CVTs are being done. On the basis of current flow in R, Y and B phases, deviation in CT is calculated.

For CVT, Voltage Drift Monitoring is done for Health Prediction. Bus voltage is taken as reference voltage for a substation after assessment of quality and phase difference in voltages. Based on reference voltage, feeder voltages connected to respective bus are compared for deviation.

c. Critical Alarm Dashboard

Critical and Emergency alarms from real time data are identified based on custom logics. For selected critical alarms, Email and SMS alerts are being sent to concerned personnel for immediate information and needful action.

Alarm summary is categorised into three different groups as per periodicity e.g. alarms received in last 24 hrs, alarms persisting for more than 24 hours and summary of monthly alarms. Similarly, dashboard created for suspect quality of critical signals, alerts operator and site personnel to take necessary action.

CASE STUDIES –

I. Trip coil-1&2 faulty and CB lockout alarm was observed in Circuit Breaker of 400/220 kV ICT Bay in Substation- A in Critical Alarm Dashboard. On inspection, contactor was found faulty and replaced with spare contactor.

II. CT health monitoring dashboard indicated deviation in CT current showing Y-Phase current zero of 400kV Line at Substation-B. On analyzing, the terminal connector of the Y phase Isolator (Line dropper side) was found in improper contact on IPS tube. Problem was attended and rectified after taking shutdown of line.

B. NETWORK & INFRASTRUCTURE LEVEL

All substations reporting are organized in 11 regions (NR-1, NR-2, NR-2, ER-1, ER-2, ODISHA, WR-1, WR-2, SR-1, SR-2 and NER) for effective administrative reasons. All the substations, RTAMC, Main NTAMC and Backup NTAMC shall be connected via WAN network provided by POWERGRID. The RTU/SAS Gateway in the substation shall communicate to each of these control centres independently.

Following is the NTAMC/RTAMC/Backup NTAMC/Local Substation operation philosophy adopted in POWERGRID under normal system as well as contingency scenario:

RESPONSIBILITY / CONDITIONS	MNTAMC	RTAMC	BNTAMC	LOCAL SS
NORMAL (All S/S reporting)	Monitoring	Monitoring & Control	Acting as Backup	Maintenance Activities

RESPONSIBILITY / CONDITIONS	MNTAMC	RTAMC	BNTAMC	LOCAL SS
CONTINGENCY-1 (Some or all SSs of a particular RTAMC not reporting)	Monitoring of all S/S & Control of non-reporting substations of respective RTAMC	Monitoring & Control of remaining reporting Substations	Acting as Backup	Maintenance Activities
CONTINGENCY-2 (MNTAMC fails)	Failed	Monitoring & Control	Monitoring	Maintenance Activities
CONTINGENCY-3 (Substation non-reporting to any control centre)	Monitoring of reporting of other remaining substations	Monitoring & Control of other reporting Substations	Acting as Backup for reporting substations	Maintenance Activities & Local Operation

Figure 9: Operation Philosophy adopted for remote operation

This model uses minimum server requirements and maintains redundancy for carrying out power system operations efficiently. It resulted in compact space requirement for hardware and energy-saving of servers at control centre and regional levels. Further, NR-1 RTAMC is located in same premise of Main NTAMC, SR-2 RTAMC is located at Backup NTAMC for utilization of resources. NR-3 RTAMC and ODISHA RTAMC which were planned and executed years later (Oct'2018 and Nov'2019 respectively) have utilized servers of NR-1 RTAMC and ER-2 RTAMC respectively. The new region formation is duly supported with its centralized regional control centre in extended remote clients of original electrical region control centre servers.

C. HUMAN RESOURCE LEVEL

Prior to conception of remote operation, substations were operated locally in 24x7 round-the-clock shifts. The establishment of Control Centre and integration of information at common platform provided effective utilization of manpower assets as well as reduction in hardware and space requirement. After adoption of remote operation philosophy, manpower norms have been modified resulting in requirement of total 3 to 4 personnel per shift at RTAMC depending upon number of substations per region (less than or greater than 20 substations respectively). NTAMC has been given 5 operation manpower per shift. Now, at substation level, operation manpower is no longer required as now only maintenance is carried out.

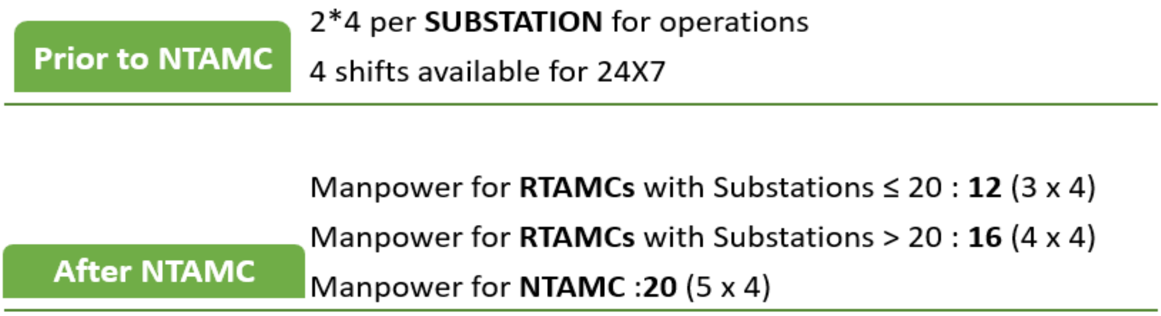
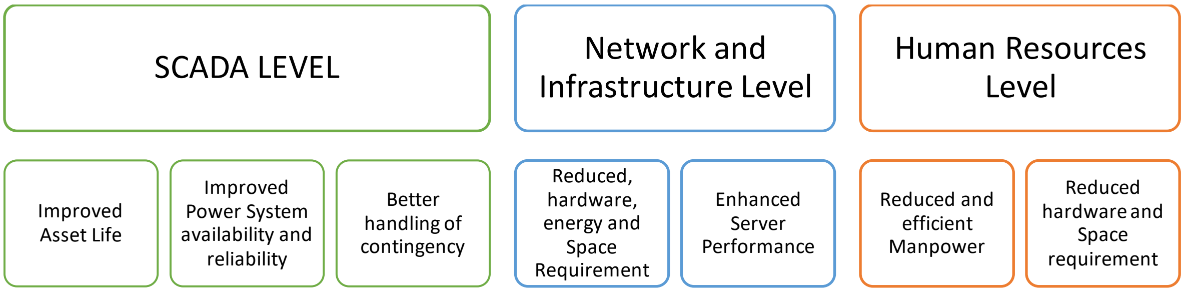


Figure 10: Operational Manpower

CONCLUSION

Summary of achievements after adopting model is as follows –



Control centre has provided real-time visibility of transmission assets, invoked prompt maintenance action and mobilized resources, ensuring smooth and secure operation of transmission assets. Remote operations are being carried out in all seasons irrespective of inclement weather conditions, covid pandemic and natural calamities. On an average, 30,000 operations per month are being carried out successfully. NTAMC has achieved the objective of remote operation of substations with least data interruption for the transmission system owned by POWERGRID.

Assets are being monitored round-the-clock and repairment as well replacement is done on the basis of inputs from operators. POWERGRID has been able to maintain its availability and reliability due to effective monitoring of substations. Conceptual design of NTAMC has led to less manpower requirement at control centre, improved asset quality as well as enhanced server performance. In future, efforts are in place to further use AI & ML based tools to increase the reliability of power system and adopt latest technologies to promote more sustainable and environment-friendly practices.

BIBLIOGRAPHY:

Working experience gained during SCADA engineering, implementation and operations under NTAMC Project.