Smart Grid Devices for Performance Management of High Voltage Transmission Lines in India

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ABSTRACT: Owing to increasing demand for bulk power transmission, and huge electric power requirement in urban areas, there is need for implementing Smart Grid technologies for power Transmission and Distribution. This paper presents smart grid devices for on-line condition monitoring of electrical equipments, technical evaluation in extra high voltage transmission lines and in substations. Smart Grid Technology is used to achieve Advanced Asset Management (AAM), to enhance asset utilization, efficiency and improve system reliability. Electrical equipment maintenance is one of the most important tasks in asset management. Using computers, sensors and other advanced monitoring technologies, conditions of overhead lines can be consistently monitored and Condition-Based Maintenance (CBM) can be implemented. Power systems cannot be tested at full power rating in the laboratories, and simulation is an extremely valuable tool for designing, operating and understanding complex systems. Real-time simulation can avoid inadvertent outages caused by human error, equipment overload, etc. Thus in this paper use of smart grid technologies for various maintenance techniques for improving performance of power system is illustrated.


I. INTRODUCTION:

In the current scenario of energy consumption in India, the power which is feeded always deficit to its demand. It is found that by transmitting power up to high KVs the power handling capacity increases with more power to be transmitted over large distance. Efficient utilization of available infrastructure & reduction of losses in a transmission System can improve the performance of existing lines. The economic advantage is also linked with reduction in losses. Renovation, Modernization and up gradation of existing projects is one of the cost effective alternatives to increase the power transmission capabilities. [1]. Indian power system is facing high AT&C Losses, poor distribution network, wide demand supply gap of energy, poor asset management etc. Smart grid technology will bring solutions to all of the mentioned problems and sustainability by way of demand side management, demand response, outage management, reduction in AT&C losses and improved customer satisfaction. This can be achieved with distribution system improvement through smart grid technologies.[2]. Smart Grid enables real time monitoring and control of power system as well as helps in power quality management, outage management, smart home energy system etc. Smart Grid will act as a backbone infrastructure to enable new business models like smart city, electric vehicles, smart communities apart from more resilient and efficient energy system and tariff structures. In this way Smart Grid technology shall bring efficiency and sustainability in meeting the growing electricity demand with reliability and best of the quality.[3]

2. The transmission lines are operated in accordance with Regulations/standards of Central Electricity Authority (CEA) / Central Electricity Regulatory Commission (CERC) / State Electricity Regulatory Commissions (SERC) [6]. Loading on transmission lines may have to be restricted keeping in view the voltage stability, angular
stability, loop flows, load flow pattern and grids. National Missions is Restructured Accelerated Power Development and Reforms Programme (R-APDRP), AT&C loss reduction, Adoption of information technology in the areas of energy accounting, consumer care and strengthening of Distribution network of State Power Utilities. Establishment of supervisory control & data acquisition system.

II INDIAN POWER SCENERIO

Present Power Scenario & Transmission Network in India. All India Installed Capacity (in MW) of Power station is 2,88,664.97 MW. The vision statement of the Ministry of Power as per the RFD document follows: “Reliable, adequate and quality power for all at reasonable prices”. Power System Operation Corporation Limited (POSOCO), is managing the National and Regional grid from National Load Despatch Centre (NLDC) and its five Regional Load Despatch Centres (RLDC) through state-of-the-art unified load dispatch & communication facilities.

Integration of Renewable Energy Resources with conventional sources is a top priority worldwide and special attention is being given in our country to harness the Green Energy. CERC has provided a framework for trading in Green Certificates (Renewable Energy Certificates or RECs) and National Load Despatch Centre (NDLC) of POSOCO has been designated as the Central agency for this purpose.

- Transmission Scenario in India.

The nominal Extra High Voltage lines in vogue are ± 800 kV HVDC & 765kV, 400 kV, 230/220 kV, 110 kV and 66kV AC lines. The capacity of transmission system of 220 kV and above voltage levels, in the country as on 29th February 2016 was 3,39,158 ckm of transmission lines and 6,40,056 MVA of transformation capacity of Substations. As on 29th February 2016, the total transmission capacity of the inter-regional links is 57,450 MW, which is expected to be increased to 68,050 MW by the end of 12th plan i.e. 31st March, 2017.

Power Grid operates and maintains more than 95,000 circuit km transmission line and 155 substations mainly at 400kV and 765kV level and plan to add about 50,000 circuit km lines in next 4-5 years. All the State-of-the-Art Load Despatch Centres in the country having SCADA / EMS have been established by POWERGRID. 1,28,200 ckt kms of transmission lines at 800/765kV, 400kV, 220kV & 132kV EHVAC & +500kV HVDC levels and 206 sub-stations. Also the transformation capacity of about 2,49,578 MVA as on 29th February 2016.

Table no.1 Executive summary of Power Supply Position (Energy & Peak) in Feb 2016.
### Issues & Challenges in Transmission Network [1]

1. **Right Of Way**
   The most notable and challenging issue of the transmission sector is the need of the hour to develop high intensity transmission corridor (MW per meter ROW) in an environmental friendly manner including protection of flora and fauna.

2. **Regulation of Power**
   Another important aspect is the need towards regulation of power flow due to wide variation in demand on day as well as seasonal basis and change in the drawl pattern/shares of the utilities from time to time.

3. **Flexibility in Line Loading**
   To handle more power as well as to optimize the use of transmission corridor it is important to load the different lines in Controlled Series Capacitors (TCSC) and similar other means is an effective method.

4. **Improvement of Operational Efficiency**
   Power system is required to be operated at the rated capacity with security, reliability and high availability. This can only be achieved through reliability based on line condition monitoring, repair and maintenance in advance and making forced outage as zero.

5. **High Density Transmission Corridors**
   In view of the above, key technological requirements for development of future power system are upgrading/up-rating of existing transmission system, technology suitable for bulk power transfer over long distances like high capacity EHV/UHV AC system, HVDC system, compact tower/substation, mitigating devices to address high short circuit level, intelligent grid etc. POWERGRID.

### Methods to minimise issues & challenges [7]

- In order to optimize right-of-way high density transmission corridors (MW per metre ROW) either by increasing voltage level, current order or both i.e. increase in voltage and current are need to be developed.

1. **Increase in transmission voltage:** Power density of transmission corridors (MW per meter ROW) is being enhanced by increasing the voltage level. Increasing the AC voltage level at 1200kV level has been planned. Research work for 1000kV HVDC system has also been commenced.

2. **Upgradation of transmission line:** Upgradation of 220kV D/C Kishenpur-Kishwar line in J&K to 400 kV S/c, which was first time in India.

3. **Upgradation of HVDC Terminal:** Upgradation of Talcher (ER) – Kolar(SR) 500kV HVDC terminal from 2000MW to 2500MW has been achieved seamlessly without changing of any equipment. That has been achieved with enhanced cooling of transformer and smoothing reactor with meagre cost.

4. **High capacity 400kV multi-circuit/bundle conductor lines:** POWERGRID has designed & developed multi circuit towers (4 Circuits on one tower with twin conductors) in house and the same are implemented in many transmission systems, which are passing through forest and RoW congested areas e.g. Kudankulam and RAPP-C transmission system.

5. **High Surge Impedance Loading (HSIL) Line:** In order to increase the loadability of lines development of HSIL technology is gaining momentum.

6. **Compact towers:** Compact towers like delta configuration, narrow based tower etc. reduce the space occupied by the tower base are being used.

7. **Increase in current:** High Temperature Low Sag (HTLS) conductor line: High temperature endurance conductor to increase the current rating is in use for select transmission corridors and urban/metro areas.

8. **Reduction in land for substation:** With scarce land availability there is a growing...
need for reduction of land use for setting up of transmission systems, particularly in Metros, hilly and other urban areas. Gas Insulated Substations (GIS), requires less space (about 70% reduction) i.e. 8-10 acres as compared to conventional substation which generally requires 30-40 acres area.

- **Blackouts – Major Reasons in India**
  [11]
  1. Depleted transmission network - Power swing - inadequate transmission lines - congested network
  2. Overdrawals attributable to frequency control through commercial signals - Low frequency - Generation loss, inadequate defense mechanism
  3. Non-compliance of directions of LDCs and Regulatory Commissions
  4. Low Voltage - Inadequate Reactive Power
  5. Protection System Issues
  6. Lack of Visualization of power system
  7. Inability to control flow on 400 kV Bina-Gwalior-Agra line

- **Techniques to overcome Blackouts**
  1. Primary response from generators
  2. Improvement in operational efficiency - Optimum utilization of available assets
  3. Operation of defense mechanism
  4. Regulation in Power Flow - Autonomy to Load Despatch Centres
  5. Intra-State transmission Planning and its implementation
  6. Dynamic security assessment and proper state estimation
  7. FACTS devices:

With electricity market opening up further, more and more need has been felt to utilize the existing assets to the fullest extent as well as regulate the power. This could be possible through use of power electronics in electricity network.

8. Condition Based Monitoring:

POWERGRID has adopted many state of the art condition monitoring & diagnostic techniques such as DGA, FRA, PDC, RVM etc. for transformers, DCRM for CBs, Third Harmonic Resistive current measurement for Surge Arrestors etc. to improve Reliability, Availability & Life Extension.

9. On-line monitoring systems :- for transformers have been implemented to detect faults at incipient stage and provide alarms in advance in case of fault in the transformers.

10. Preventive Maintenance: Preventive State-of-the-art maintenance techniques for various equipment applied in our system include, on line monitoring of various components of transformers and reactors, Circuit Breakers, Instrument transformers, Lightening arrester etc.

11. Establishing national grid in the country:- which is one of the largest synchronously operating electrical grids in the world with all its five electrical regions interconnected synchronously.

12. Smart Transmission Grid Implementation

In Smart transmission, POWERGRID has been implementing Synchrophasor Technology in its Wide Area Measurement System (WAMS), Project through installation of PMUs (Phasor Measurement Units) at different locations in all regions across the country, which facilitates better visualization and situational awareness[2].

- **Smart Grid is expected to provide benefits to Utilities, Consumers & society in the following areas**

1. Benefits to Utilities :- [7]
   A. Improved Efficiency:- Reduction in transmission and distribution lines losses, Improved load forecasting. Reduction in frequency of transformer fires and oil spills through the use of advanced equipment failure / prevention technologies

   B. Improved Economics:- Reduced operational cost, capital cost transmission congestion costs and maintenance (O&M) costs. Increased revenues as theft of service is reduced. Improved cash flow from more efficient management of billing and revenue management processes.

   C. Improved Reliability:-Increase asset utilization, improved employee productivity through the use of smart grid information that improves O&M processes. extended life of system assets through improved asset “health” management. Increased employee safety.

   D. Improved Environment:- Increased capability to integrate intermittent renewable resources. Opportunity to improve environmental leadership image in the area of improving air quality and reducing its carbon footprint.

Benefits to Consumer :- .

A. Improved Efficiency:- Higher customer satisfaction Increased asset data and intelligence enabling advanced control and improved operator understanding . Increased
capability, opportunity, and motivation to be more efficient on the consumption end of the value chain.

B. Improved Reliability:- Improved level of service with fewer inconveniences. Reduced out-of-pocket costs resulting from loss of power. Opportunity to interact with the electricity markets through home area network and smart meter connectivity.

C. Improved Economics:- Downward pressure on energy prices and total customer bills. Opportunity to reduce transportation costs by using electric vehicles in lieu of conventional vehicles. Opportunity to sell consumer produced electricity back to the grid.

D. Improved Environment: Increased opportunity to purchase energy from clean resources, further creating a demand for the shift from a carbon-based to a “green economy”.

- Smart Transmission Grid Equipment Implementation in India

1. Phasor Measurement Unit & Wide Area Technology in Power System Operation

1.1 WAMS (Wide Area Measurement System)

WAMS technology requires installation of hundreds of PMUs in each region and reliable communication network with very high bandwidth and with least latency. Phasor data concentrators (PDC) are to be installed at National, Regional and major State Load Despatch Centre (in states having 400 kV transmissions system)[7]. Availability of PMU at strategically located 400 kV/765kV substations / power stations and a robust fiber optic communication network will facilitate situational awareness (especially dynamic state of the grid in terms of angular stability and voltage stability), control and regulation of power flow to maintain grid parameters. Remedial action scheme (RAS), system integrated protection scheme (SIPS) and identifying corrective actions to be taken in the event of severe contingency to prevent grid disturbances. The process for installation of PMUs has already been started. Eight (8) PMUs (at Moga, Kanpur, Dadri and Vindhyachal in first phase and Agra, Bassi, Hisar and Kishenpur in second phase) have already been Commissioned in the Northern Region and proposal for installation of PMUs in other regions is also in the pipeline[2].

1.2 Advantages of PMU & WAMS technology

- Optimize Network Capabilities
- Accelerate the operators decision
- Avoid possible cascading effect
- Provide detailed Knowledge of system Behavior
- Improved assessment of the state of the system
- System can be operated closer to its limits (Increased transmission capabilities)

1.3 Implementation of Technology.

For Validation of the dynamic model of the system following technology are used

a. Post event analysis,
b. On-line system monitoring and enhancement to state estimation,
c. Wide area control,
d. Wide area protection.

1.3.1 Post Event Analysis
• Recording of PMU used to make a post analysis of the system after a major incident.
• This analysis gives a wide area view of the system behavior thus helps in understanding:
  – the sequence of events that led to the grid incidents
  – the inter area oscillations
  – Analyzing the performance of the oscillation damping equipments

Used by Italy, NCG, Russia, Korea, France

1.3.2 On Line System Monitoring and Enhancement to State Estimation

• PMU technology improves real time system monitoring, helps in better assessment of the state of the system
• System monitoring covers:
  A. Monitoring of basic data such as voltage, power flow and frequency for each of the nodes.
  B. Monitoring of voltage angle differences between the ends of major lines likely to be heavily loaded (to ensure that they can be easily re closed when a fault occurs).
  C. Voltage stability monitoring, i.e. supplying the dispatcher with an estimate of the margins available to the system before a voltage collapse; in such situations PMU measurements can be extremely useful for assessing the dynamic behavior of loads.
  D. Transient stability monitoring, i.e. monitoring of possible loss of synchronism between certain system areas.
  E. Inter-area oscillation monitoring, i.e. detecting the occurrence of any inter-area frequency oscillations, calculating the different modes and their damping.

Used by Italy, Korea. Planned to be used by NCG, Russia, REE.

Gaps in On line System Monitoring
– WAM’s used so far only for off line applications.
– Methods and algorithms for monitoring and evaluating transient stability, voltage stability etc are not yet available.

1.3.3 Wide area control

• Can control automatically Power system equipments like PSS, FACTS, SVC, and HVDC controllers.
• Controls can be made based on the wide view of the power system instead of local phenomena.
• Such operation will increase reliability, increase transfer capability, require a fast and reliable and secure communication signal should be transmitted in 20 to 50 milliseconds.
• Gaps
  – High cost in maintaining reliable two way communication
  – PMU technology should mature enough and trust to use this technology for automatic critical corrective action

1.3.4 Wide area protection

• PMU technology can be used for initiating System Protection Schemes.
• Wide area measurements give better understanding of the situation.
• Require a fast and reliable and secure communication signal should be transmitted in 20 to 50 milliseconds
• Gaps
  – High cost in maintaining reliable two way communication
  – PMU technology should mature enough and trust to use this technology for automatic critical corrective action

1.4 Wide Area Communications Systems

I. It comprises of the Neighbourhood Area Network (NAN) and the Wide Area Network (WAN). NAN is a localized or regional network of several smart meters in an area aggregating data at a concentrator.
II. The concentrators end data collected from the smart meters to the Meter Data Management Systems (MDMS).
III. Components are AMI Smart Meters, Home Area Networks (HANs), Wide Area Communications Systems, Meter Data Management Systems (MDMS) & Operational Gateway.

1.4.1 Home Area Network (HAN) is a kind of Local Area Network (LAN) that facilitates a two-way communication between smart home devices or appliances (such as heaters, refrigerators, air-conditioners etc.) and the Smart Meter or an in-home display for the benefit of both the consumer and utility.
1.4.2. Automatic Meter Reading
The system utilizes several different types of commendations media such as, PLC, RS458, LAN/ WAN, GSM/GPR etc 26-11-2015 10

![Fig.4 LAN Communication Network](image_url)

![Fig.5 HAN Communication Network](image_url)
1.4.2 Advanced Metering Infrastructure

Mobile: Mobile or "drive-by" meter reading is where an adding device is installed in a vehicle. The meter reader drives the vehicle while the reading device automatically collects the meter readings. Reading equipment includes navigational and mapping features provided by GPS and mappings of software. AMI is seen as an important part of any smart grid initiative.

![Advanced Metering Infrastructure](image)

Fig. 6 Advance Metering Infrastructure

1.4.3 Smart Power Management System[14]

1. SCADA (supervisory control and data acquisition system)
2. EMS (energy management system)
3. DMS (distribution management system)
4. GIS (geographic information system)
5. SER (sequence event record system)
6. DFR (digital fault recorder system)
7. Smart metering data
8. Operation event data
9. Power quality (voltage, frequency)
10. Protection system fault data (fault currents, voltages, phase angles... etc.)
11. Asset management data
12. Demand response
13. Power system operation
14. Operator training
15. Station maintenance data
17. Engineering data

2. Need for fibre optic based communication system:
For planning, implementation and maintenance of dedicated high band width, fiber optic communication network is used. For connecting the existing and new substations and power plants under central sector, the mandate should address the communication requirements in power sector in all associated areas such as Smart Transmission Grid, Protection, data, speech, audio/video etc. [8]

3. Automation
(i) To address the natural calamity, fire in substation, for quick restoration Emergency Restoration System (ERS) for substations is necessary. Design and deployment of mobile substation is considered necessary for implementation.
(ii) Process bus technology over the conventional station bus technology is used. Process bus technology has the advantage of reduction in huge copper wiring, integration of any number of IEDs at bay level etc.
(iii) Demonstration project of IEC 61850 substation automation comprising of both process bus and station bus, along with interoperability.

4. System performance improvements by [9]
• The condition based maintenance on-line diagnostics techniques will be developed.
• Condition monitoring of polymer insulators :
• Robotic inspection of transmission system:-
• NIFPES:
• Development of controllers for FACTS devices
• Development of FACTS devices and its controls

Gas Insulated Transmission Lines, EHV Cables and Submarine cables (34, 35, 36). These technologies would help power sector in meeting the projected load demand.

(i) Gas Insulated Transmission Lines are means for bulk power transfer at EHV/UHV levels. The application of GIL is viable option in densely populated areas or in environmentally sensitive regions, and where application of cables is not possible or reaches technical limits. This uses SF6 tubular conductor technology, which has been around for several decades.

(ii) Application of EHV class cables advantages, such as reduced emission into the surrounding area, of electromagnetic fields and reduced space

(iii) Application of submarine cable: For power transmission becomes unavoidable where there is no feasibility of overhead lines. The application of submarine technology in the proposed India – Sri Lanka interconnection as an exploratory project would give big boost to transmission planners.

CONCLUSIONS
Issues and challenges in transmission systems also different methods to overcome these issues in Indian Power Strategy is discussed in this paper. An overview on reasons of blackouts and possible techniques to overcome these problems are also stated. Benefits of smart grid technology and its associated equipments with its characteristics are discussed. Some other advance techniques to improve the transmission system parameters are also discussed. Thus in this paper overall methodology to improve the performance of transmission system is given.

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