Large Scale Implementation of Control Switching Devices in Indian Power System- A Case Study

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Introduction :

Indian EHV Power System has seen rapid growth over last two decades, both in terms of higher Transmission System voltages touching 765 KV UHV AC & 800KV HVDC & physical network size spreading throughout India. Even 1200 kV UHV AC Station has been built on experimental basis for future implementation of the highest System Voltage Transmission Lines in India. With an installed Generation capacity of 315 GW & total transformation capacity of around 670 GVA across India, EHV Power System is the back bone network to transmit power to all load centres. EHV Power Transmission networks play a vital role in management of Power supply in all Transcos & Discoms.

In order to maintain such complex bulk Power EHV Transmission System , it is necessary to ensure the reliability & availability of each Power Transmission element in the network. Power Utilities are now increasingly adopting Asset Management techniques for Life Time Management of their Power Transmission assets. Condition Based Maintenance to prevent catastrophic failures & system outages with ultimate aim of increasing Power Transmission system total life span has become important to Power Utilities.
After over a century of generating electricity centrally and building massive electric grids, the focus is now on de-centralized generation and Microgrids. This is causing the traditional boundaries between generation, transmission and distribution to disappear. Consumers are becoming 'Prosumers' by generating electricity locally and having an option of feeding it back to the grid. Hence, there is already a debate whether to invest in decentralized Generation + Storage + Local Distribution or Centralized Generation + Transmission + Distribution.

Grid Management:

Indian Power System is presently having Power Generation of around 315 GW & the National Transmission Grid of EHVAC/UHVAC/HVDC is being managed by POSOCO through NLDC at National level & 5 Nos RLDCs at Regional levels to schedule & dispatch power efficiently to all states in a very transparent manner following all Regulatory guidelines/Grid Codes. Renewable Energy is now top priority of GoI as 100 GW of Grid connected Solar & 40 GW of Roof top Solar capacity is planned besides Wind generation plans & RE will contribute about 40% of total generation by 2030.

Integration of RE Sources: Way Forward

Forecasting :

- Global at LDC level for Grid Security, Balancing
- Local at Wind / Solar farm level for scheduling and Commercial treatment

Balancing mechanisms

- Need for Flexible Generation, Pumped Storage Plants,
- Spinning Reserves, Frequency Response

Market Mechanisms

- Supply Side : Increased granularity, More frequent market
- Demand Side : More / New products, Compliance Monitoring
- Ancillary Services

Flexible Transmission

- Robust Transmission at Inter State as well as Intra State Level

Compliance to standards & Grid Code

- Fault Ride Through (FRT) and Low Voltage ride Through capabilities

Renewable Energy Management Centers (REMC)

Controlled Switching Devices :

EHV Power System is the back bone network to bring power to urban load centres from remotely located generating stations. The complexity and size of Indian Power System is increasing day by day with present installed capacity in India being around 325 GW which will touch 850 GW by 2030. Many 400KV and 765KV Substations are operational under PGCIL (CTU), States and Private Electric Power Utilities in India. This Large EHV Power System is being operated meticulously by POSOCO (ISO) maintaining Grid security & reliability.

It is experienced that one of the causes of overload and overstress in EHV Transformers and Reactors while switching on is 4-5 times of inrush current. No Control Switching Devices were installed 5-6 years ago in Indian EHVAC Power System. Sometimes Reactors and Transformers were severely damaged due to heavy inrush current while charging. The reason of the inrush current is random switching of the device. The random switching of Substation equipments like Power Transformers, Shunt/Bus Reactors, Capacitor banks, and Transmission Lines & EHV Power Cables without proper correlation with system voltage or current always cause unwanted Over Voltage stresses / disturbances in Power Transmission System. These disturbances & Over Voltages may result in electrical and mechanical stresses in associated

Power equipments leading to failures or reduction in their useful lifespan. The re-ignitions, re-strikes and inrush currents associated with these switching operations may also cause disturbance in power system stability with the high amplitude & high frequency disturbances may lead to system outage with unexpected relay operations. Though some traditional solutions were adapted in the past, they could not be evaluated for their effectiveness in controlling these disturbances on real time basis.

Controlled Switching or Point-on-wave Switching technique is a versatile and highly effective methodology to address the issues associated with the switching of power equipments leading to improved Life expectancy & cost effective asset management with better power system stability.

Controlled/Point on Wave Switching has gained greater importance in Indian Power Transmission Systems with the introduction of 765kV voltage level & downward integration with 400kV System. Power Grid Corporation of India Ltd.(CTU) decided to implement Controlled Switching Device on all Reactor compensation switching applications at 400kV Level and successfully implemented CSD on more than three hundred existing assets. SCOPE T & M was closely associated with POWERGRID in implementation of CSD on a collaborative mode.

Controlled Switching in POWERGRID :

Controlled switching is one of several technologies applied to the principle of coordinating the instant of opening or closing of a circuit with a specific target point on an associated voltage or current waveform.

Close or trip command is processed through an intelligent device and is sent to CB as per the desired instant.

Controlled Switching (CSD) has been introduced mainly for:

765 and 400kV Reactor tripping- to avoid re-ignitions

Transformer Closing operation- to minimize inrush/ magnetizing currents.

However, for Reactor closing and ICT tripping operation also, same may be utilized.

In case of CSD for Tie CB where 765kV ICT and Reactor have been provided, CSD may be programmed for ICT closing and Reactor tripping operation.

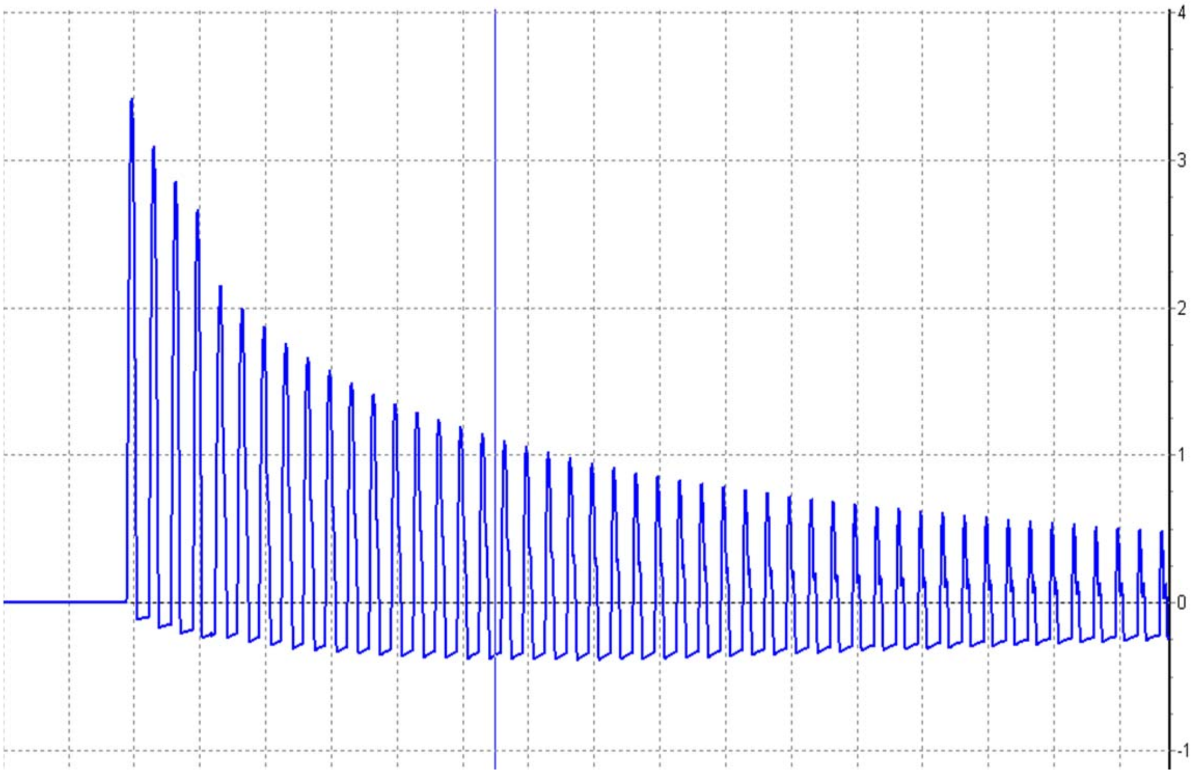
Issues /Challenges for CSD Implementation:

Principle of Controlled Switching of individual suppliers

Use of CSDs for different makes of Circuit Breakers

Check points during commissioning of CSDs including settings, Effectiveness of Controlled Switching & Status of Controlled Switching Devices at various sites for 765kV and 400kV Sub-Stations.

Case **Study 1: Power Transformers Closing at a bad instant !!**



Result :

Humming sound was observed in 765/400/33kV, 1500MVA (500MVA, single phase unit) Transformers for about 10-15 minutes.

High inrush currents of the order 1000-1500Amp were observed during charging of ICT banks even after commissioning of controlled switching device.

765 / 400 / 33 kV, 1500 MVA transformer banks are comprised of single phase having two windings with HV/IV star connected and tertiary winding as delta connected.

CSD had been set for individual voltage peak points of the phases for closing instant of the respective circuit breaker poles taking into account equal pre arcing times for all three circuit breaker poles.

With the closing of first pole of the circuit breaker, the common delta tertiary winding of the transformer bank shall get energized

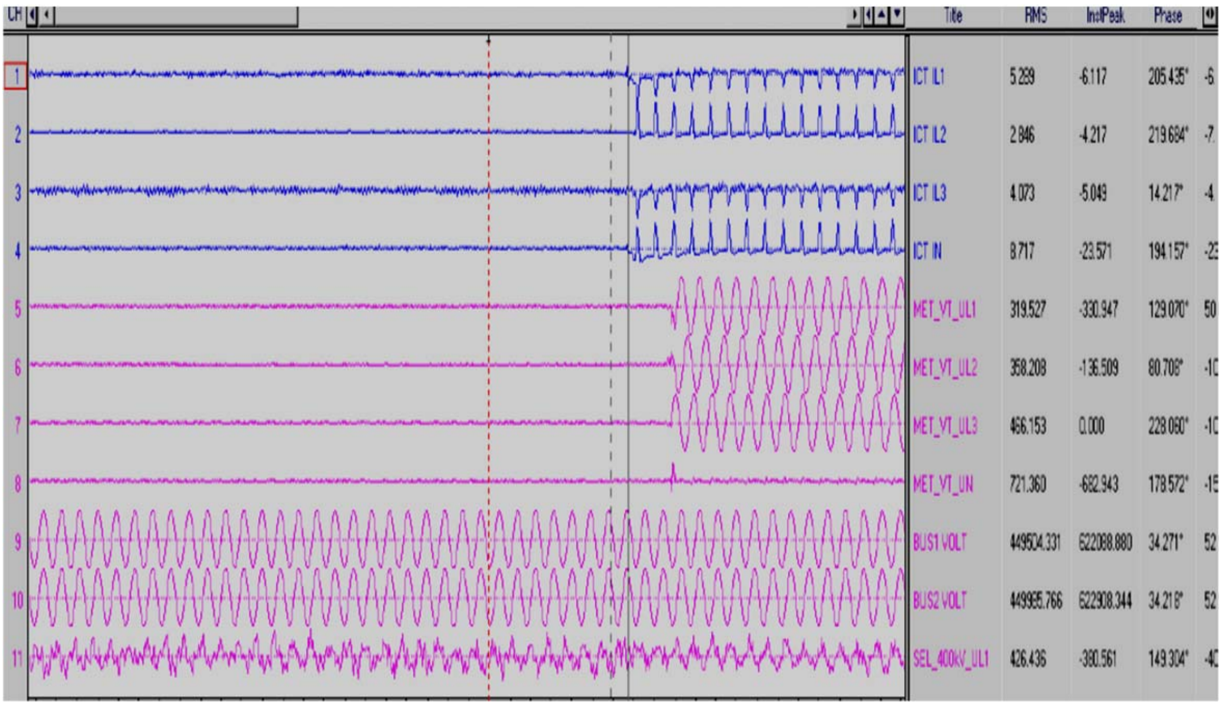
There shall be transformational voltages on the main windings of other units of the transformer bank.

Hence, for the second and third poles of the circuit breaker (closing later), there shall be different pre-arcing times than that of the first circuit breaker pole.

Accordingly, it was decided to modify the pre-acing times for the second and third circuit breaker poles. The pre arcing times set for second and third CB poles were reduced from pre-set value of 2.5 ms. After number of iterations, exact pre-arcing times were selected for second and third poles.

Controlled closing of the circuit breaker was performed with new configuration of the controlled switching device and it was observed that inrush currents have reduced to a very low value of about 10-20Amp. Humming sound levels during Transformer energization also subsided to normal level and problem was resolved.

Case Study- 2 : Magnetizing Current Problem in 765 KV Shunt Reactor



During tripping of 765 kV Shunt Reactor, increment of surge arrestor counters were observed even after implementation of point on wave switching.

Problem was suspected to be because of the re-ignition / current chopping during interruption of low inductive current by 765kV Circuit Breakers.

Settings of point on wave switching devices were verified with parameters as given by Circuit Breaker manufacturer.

Circuit breaker offline operating timing tests were carried out to find out any change in CB trip timings.

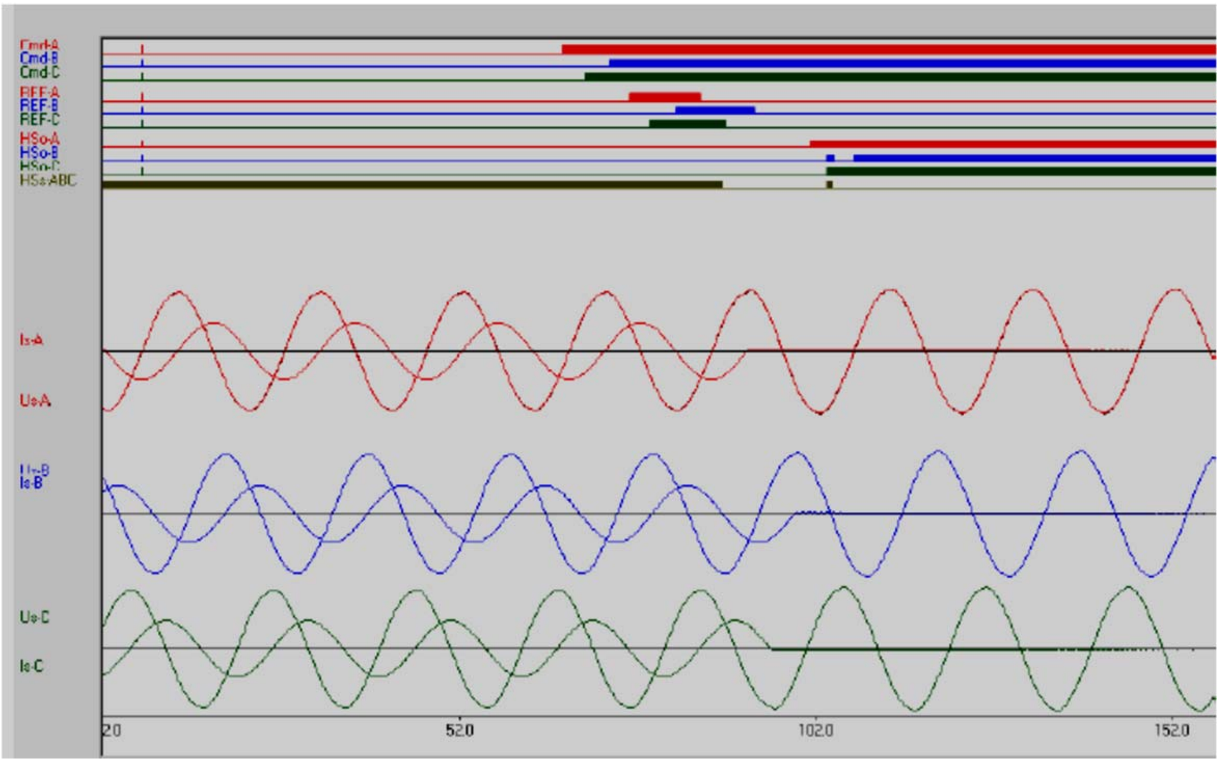
It was decided to verify the signals from the instrument transformers which were the inputs to the controlled switching device. The shunt reactor bank was energized and the voltage and current waveforms were recorded with precision oscilloscope.

A phase shift was observed between voltage and current with current lagging the voltage.

The switching program of the controlled switching device assumes 90 degree phase shift and targets Circuit Breaker Contact separation point in such a way that arcing time is more than minimum arcing time required for Shunt Reactor Switching.

Considering phase shift, instant of Circuit Breaker contact separation advanced by about 0.5ms by adjusting controller settings.

After revising the settings of controlled switching devices, there were no 765kV Surge Arrestor counter increments. Tripping Operation



Policy Decisions in POWERGRID regarding CSD Implementation:

Controlled Switching is required for “Trip” operation of Bus Reactors/ Switchable Line Reactors

Line Reactors which can be made Bus reactors with opening of Line Isolators need to be provided with Controlled Switching.

For 765kV Transformers, Controlled Switching is required for “Close” operation.

For Utilization of Diversity in Wind & Solar generation on local/ Regional level, High capacity Transmission corridors are being created by CTU & will result in increased IR transfer capability.

Smart Grid in Indian Power System:

Drivers for Smart Grid in India are

T&D loss reduction and efficiency improvements: Transmission & Distribution network losses (including commercial) is around 27%

Access to energy for the masses: About 300 million people do not have access to power. Govt intend to electrify 100% households in next 5 years (microgrids, rooftop solar, DER….)

Renewable Integration to Grid: Central theme of 12th Five Year Plan (2012-17) is low carbon development. Several initiatives being taken to increase the share of renewable in energy mix.

Peak load management: Demand response for high volume consumers and Micro grids for groups of consumers with captive generation facilities that can island during peak hours; enhancement in energy efficiency and other demand side management programs

System improvements: Reduction in outages/power cuts, improvements in reliability and quality of supply, Improved customer service and “Prosumer enablement”, Infrastructure for Electric-mobility: 7 million EVs expected by 2020.

As the Renewable Energy has to be integrated to the Transmission or Distribution Grids, there is a need for reliable communication system for Real Time visualization of the Power Grids including all RE generation nodes. As per CERC Regulations also RLDCs/SLDCs need to know status of RE Sources to synchronize with the Power System. Optical Fibre cables on EHV Transmission System is widely used in India with about 55,000 kms network being operated by Power Grid (CTU). PMU based WAMS Project under execution by CTU is a great leap forward in EHV Transmission Smart Grid.

Wide Area Measurement System (WAMS) :

WAMS means Real Time, Synchronized Data Acquisition used to Dynamically Control, Monitor and Manage Power Grid Network. Present SCADA system is like “X-Ray Scan” with RTUs streaming Power system data samples every 4-8 seconds with time latency & skew due to various communication media like PLCC, Microwave & Optical fibre. In WAMS, PMUs (Phasor Measurement Units) stream Power System data at frequency of 25/50 samples per second on Optical Fibre network with very low latency & skew (in milliseconds). Thus SCADA System is able to provide more Granular picture of the Power System like a “CT Scan”. SCADA/EMS

Systems are gradually moving from present “State Estimation” to “Dynamic State Measurement” & Power System Control & Protection features can be made operational due to fast communication technologies. In view of above challenges, India needed a System which could provide Enhenced Situational Awareness to Control & Monitor the Health of Grid. Developments in Synchrophasor Technology worldwide were introduced & PMU Pilot projects were taken up to test & try this in Indian Grid.

PMUs are located at strategic nodes of the Power System with careful placement study & they stream dynamic Power System data to PDCs (Phasor Data Concentrators) located in State/Regional/National Control Centers for panoramic granular view & Grid Management.

Unified Real Time Dynamic State Measurement Scheme (URTDSM Project) :

WAMS Project named Unified Real Time Dynamic State Measurement Scheme was taken up by POWERGRID with an Objective to enhance situational awareness and visualisation of power system state on real time basis for improved operational and planning efficiency of the grid.

URTDSM Project execution is under progress since 2015 & around 900 PMUs have been installed so far which are being gradually integrated with PDCs getting installed at SLDCs/RLDCs. This WAMS Project is the Largest Synchrophasor PMUs deployment Project in the world. Success of the URTDSM Project largely depends on seamless integration of all PMUs with PDCs & deployment of the software (some are under validation) under development at IIT, Bombay.

Benefits to Indian Transmission system from WAMS Project: Indian Power System will benefit from WAMS Project as it will bring efficiency in Operation with Economy, will enable efficient calibration of measuring equipments, enable In-depth insight into Power System behavior & Elements, would facilitate integration of large quantum of intermittent and variable renewable generation into the grid, enables synchronous measurement of real time grid parameters across the widely spread grid with low latency in data transfer to control centers which would be very effective in reliable, secure and economical grid operation. It provides more intelligent/dynamic information to Special Protection Schemes which will be a step towards self-healing Grids. Further the WAMS Data shall be used for Power System Planning and will help in better planning of the Power System in the Country.

RE Integration to Distribution Grid:

The distribution sector is the revenue source for the entire power industry supply chain and therefore it is crucial to manage it most efficiently. Even though it is such a crucial component of the electricity system, large parts of the distribution network are currently unmonitored. Distribution networks are not able to effectively monitor their systems for technical and commercial losses, understand changing load profiles and control and adapt supply to meet the

changing demand. With the advent of Smart Grid technology, IoT and improved Big Data capabilities, distribution networks can address the need for better visibility and control over their networks at a low cost. OrxaGrid's online power sensors, innovative big data solutions including RE Integration solutions advise Distribution Grids what proactive actions they should take to reduce technical and commercial losses and increase grid efficiency. Difficulty in integrating RE sources into the grid due to uncertain availability of wind and solar sources creates the need of having a bi-directional communication network for sensing, supervising and dispersion of real time information on energy consumption and forecast modification.
OrxaGrid's achieves all objectives by focusing on Real Time individual Feeder-wise Monitoring, Instantaneous Fault Data Detection and Distribution Grid Optimization using the above data for improving overall power availability, power reliability, power loss monitoring, load management and overall system planning.

Conclusion:

The traditional electricity networks designed for unidirectional flow of electricity, revenue and information will have a paradigm shift to bidirectional flow of these elements. Before the advent of Smart Grids, communication networks were used to monitor and control power flow using Supervisory Control and Data Acquisition (SCADA)/Energy Management Systems (EMS). Control & monitoring is now reaching upto the end consumer. Secure, reliable, scalable, interoperable and cost effective communication networks is required for Smart metering, SCADA, Substation and Distribution Automation, Wide Area Monitoring System (WAMS) etc. It is believed that the grid will soon emerge as a **'Grid of Things'** just like the Internet has evolved as the **'Internet of Things'**.

The advanced Controlled Switching Devices available in the market currently not only perform the controlled Switching but also help in Online monitoring of Circuit Breaker, an added advantage of installing CSDs.

Switching strategies were adapted for different switching applications of Reactors and Power Transformers including residual flux compensation, switchable and non-switchable Shunt with experience gained Reactors and Shunt Capacitors banks and the best successful practices adopted. A big success story of collaborative approach between CTU & SCOPE while installing more than 300+ CSDs on various existing Reactor and Transformer Switching applications in Power Transmission network during last 3-4 years & strategies adapted for old & new EHV Circuit Breakers with different operating mechanisms.

The benefits of PMU / WAMS for the Smart Transmission Grid are substantial. These benefits will result from improvements in the key value areas of **Reliability** — by reducing the occurrence of interruptions and power quality disturbances and reducing the probability and consequences of widespread blackouts**, Economy** & **Efficiency** — Near capacity use of Elements & Grid**, Environmental** — by reducing emissions by enabling a larger penetration of renewable and improving efficiency of generation, delivery, and consumption In near future Wide Area Monitoring, Protection and Control (WAMPAC) System will be a reality for efficient Monitoring, Control and Protection of Indian National EHV Transmission Grid.

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