POWER QUALITY MONITORING USING TRANSIENT ANALYSIS IN LV POWER DISTRIBUTION NETWORK – A CASE STUDY

by

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BACKGROUND

The power distribution network is becoming increasingly congested due to volatile renewable energy (RE) connections from photovoltaic (PV), wind and battery energy sources. The maximum impact of RE connections are felt by the DISCOM who operate the low voltage (LV) network in the region of high renewable energy concentration. There are concerns regarding adverse impact on power quality (PQ) parameters mainly voltage quality index, total harmonic distortions (THD) and voltage transients, as RE connections also result in voltage surges, flickers and switching transients. The impact of these PQ disturbances on technical losses and carbon footprint has led the DISCOM to devise ways of monitoring its LV network in real-time. ***The objective is to have a better situational awareness 24x7 of the PQ parameters, based on which informed decisions can be taken to minimize their adverse impact, leading to outage reduction and potential savings in network operation.***

Scottish and Southern Energy Power Distribution (SSEPD), under a pilot project partly funded by the Low Carbon Network Fund (LCNF) instituted by OFGEM – the UK Electricity Regulator, decided to monitor the impact of PQ disturbances due to renewable energy injection. Though monitoring of LV networks is common among many power distribution utilities of the world, ***this was the first time on-line, real-time measurements to monitor PQ disturbances induced from unpredictable RE sources was being attempted anywhere in the world.*** For the pilot project, it was decided to monitor the impact of transients on the LV network, in one of the most vulnerable sections with a history of tripping due to sudden voltage overshoot or transient. ***The scope of this project was to demonstrate that with appropriate PQ monitoring, it was possible to take informed proactive actions to mitigate PQ threshold violations, prevent costly outages and retrospectively inform the RE generator to apply appropriate power quality controls, to prevent adverse impact on the distribution grid.***

This case study is equally relevant to Indian DISCOMs given that the country has set an ambitious target to connect renewable energy capacity of 175 GW by 2022, of which about 100 GW is planned from solar, 60 GW from wind and 15 GW from hydro, biomass, etc. ***The Indian Forum of Regulators (FOR), represented by CERC and State electricity regulatory commissions having recognized the economic and environmental impact of power quality have released a report on "Power Quality of Electricity Supply to the Consumers", for compliance by DISCOMs to improve power quality and stability of the Indian electricity grid*** (*Ref. https://apqi.org/power-quality-of-electricity-supply-to-the-consumers/*).

OVERVIEW

The pilot project focussed on monitoring of the electrical transients often resulting from one or more RE generators connecting to the grid at the point of common coupling (PCC). ***These transients result from the imbalance created due to sudden supply vs demand gap and inverter switching operations during connections or disconnections of the RE generators, which is dependent upon meteorological factors.***

The historical time-series analysis of previous tripping incidents showed a correlation between the time of overvoltage protection relay operation and that of RE connection/ disconnection. Even though the DISCOM had installed load forecasting software integrated with meteorological data, the latter was not fully accurate because of spatial diversity, latency and weather unpredictability. ***The DISCOM therefore chose to do online transient monitoring, in 'near' real-time, to be forewarned on any emerging PQ violations, which will allow the DISCOM to take appropriate action for PQ mitigation by using load balancing or load control techniques, reactive power compensation or passive/ active filtering.*** The PQ data was analyzed with the help of a software application which monitored the network waveform at the PCC, at user-selectable intervals, varying from every 5 minutes to 30 minutes. The smaller the time interval, the more were the data samples for PQ analysis and the better was the accuracy of prediction.

Figure 1: Transient waveform analysis during PQ monitoring

SOLUTION

The primary concern was to be able to install the transient monitoring sensor at the Point of common coupling (PCC) safely and efficiently without taking downtime. This is crucial if large scale deployment of transient sensors have to be implemented without power disruption to the customers. Another critical requirement for the success of the project was sourcing of the transient sensors which could be installed non-invasively on the network, can be integrated with the transient monitoring system and allow the DISCOM to interact with the network in real-time for complete network analysis and visualization of any emerging transients, which could be potentially harmful if allowed to persist. ***The real-time transient measurement and the results of the analysis were displayed on the DISCOM information dashboard, based on which proactive action could be taken to control PQ violations due to the effect of transients.***

The transient sensors had to be chosen such that it can transmit data to the transient monitoring system in 'near' real-time for which mainstream GPRS communication was used. The sensor used for the project was ***Rogowski coil sensors***, with clamp on facility to attach to the three phases of the LV network. On the LV side of Distribution transformer (11KV/ 415V), the Rogowski sensors were clamped on each of the phase, safely and securely inside the Disconnect box (DB). This overcame the challenge of safety in live installation, without causing any supply disruption.

The sensors were connected to a ***master control unit (MCU) or a data concentrator*** to match the system accuracy and time interval adjustments as per the project expectations. The remote transient monitoring system at the DISCOM control center was configured to receive data at pre-selected intervals from the MCU or data concentrator. The connection was established from the MCU to the remote analytics application using GPRS.

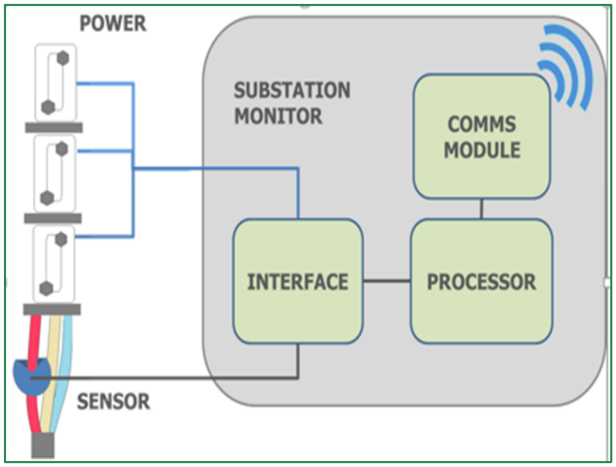

Figure 2: Master Control Unit (MCU) for PQ data communication

The remote analytics application was integrated with the transformer smart metering system, through the ***meter data management system*** to capture instantaneous values of voltage, current, active/ reactive power, active/ reactive energy, system frequency, power factor and harmonic content. ***The time series data obtained was analyzed for any PQ violations in terms of voltage surges, phase imbalance, reactive power overflows, harmonics and transients.*** Any PQ breach from the established norms as set by IEEE 519, EN 50160 or other regulatory standards of performance triggered an alarm, which was displayed on the visualization dashboard.

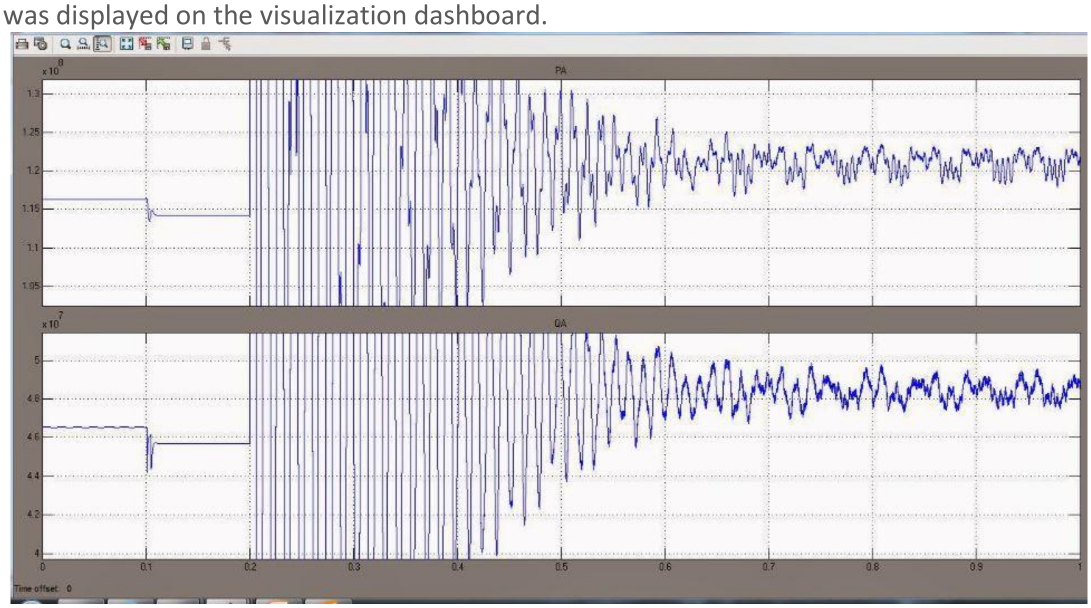

Figure 3: Time series analysis of Power Quality disturbances

RESULTS

The pilot demonstrated successfully the prospect of scaling up PQ monitoring by this method for monitoring and analyzing transients which have potentially debilitating impact on network reliability and asset life. ***The transient monitoring application and analytics dashboard can be integrated with the transformer smart metering infrastructure to analyze other PQ parameters like voltage quality, phase imbalance and harmonics.*** The analytics dashboard was able to display real-time network information, with specific instances of PQ violations displayed with time stamp and alarm notifications, allowing DISCOM operators to take proactive action to prevent major network failures. The project was demonstrated to be scalable by increasing data collection frequency at the concentrator which improved accuracy of the analysis and prediction of the network behaviour more accurately.

Figure 4: Installing Rogowski sensors (blue color) for PQ monitoring

LIMITATIONS

Transient monitoring using this method is a data-driven application. For higher accuracy, the data sampling frequency has to be increased to every 5 minutes or even lesser interval at every 1-minute interval. However, this will generate 60 x 24-hour x 3 phase = 4320 samples for all the phases for every PQ parameter measured, not just the transient, multiplied by the number of similar installations at various transformer locations spread across the DISCOM area of operations. The GPRS communication system should be robust and reliable to be able to manage huge 24x7 throughput volume, at an affordable cost. Another issue is GPRS connectivity and at remote rural or semi-urban locations where connectivity is intermittent or frequently drops, the data may not be sufficient for accurate analysis and prediction of the network conditions. Location and weather can also prove to be a hindrance in GPRS communication. Where conditions are not conducive for GPRS, alternative options e.g. RF mesh communication, WiMax or any other technology suitable for the particular geography may be explored, which however may also add to the cost of the project. The selection of Rogowski sensors is based on consideration of gain, response time, precision and interoperability standards, and is crucial for the success of the project. Rogowski coil sensors are not suitable for outdoor mounting, however, it can be installed inside weather-proof enclosure such as Disconnect box, in the present case.

In the context of Indian DISCOMs, this system can be effective for transient data monitoring in urban or semi-urban electrical locations, where GPRS signal strength is consistent and of relatively good quality. However, in remote rural areas, where GPRS signal strength is weak, the system may not work. In such case, the option of RF mesh or WiMax communication may be explored, which may add to the implementation cost. Also, it is recommended to include Power Quality monitoring and analysis as a separate training module during internal capacity building programs of Indian DISCOMs. This will give DISCOM engineers the ability to use new methods and tools for monitoring power quality, prevent threshold violations and enforce grid discipline, in compliance with CERC model PQ regulations in India.

CONCLUSION

Voltage transient is an important PQ parameter which needs to be monitored continuously in the most vulnerable sections of the LV Distribution network, which come under the risk of failure due to the vagaries of intermittent RE connections. ***The transients are a result of sudden capacitive switching, voltage surges, reactive power injection and arcing during volatile RE connections.*** The purpose of this use case implementation was to demonstrate the benefits of power quality monitoring using transient analysis. The pilot implementation of Rogowski sensor-based transient monitoring system provided an improved situational awareness of the network. The analytics dashboard at the DISCOM control center enabled the operators monitor the real-time display of transients and other instantaneous electrical parameters of the LV network. ***Integrated with smart metering data management system, apart from voltage transients, the analytics dashboard can monitor other PQ parameters e.g. voltage quality index, power factor and total harmonic distortion (THD).***

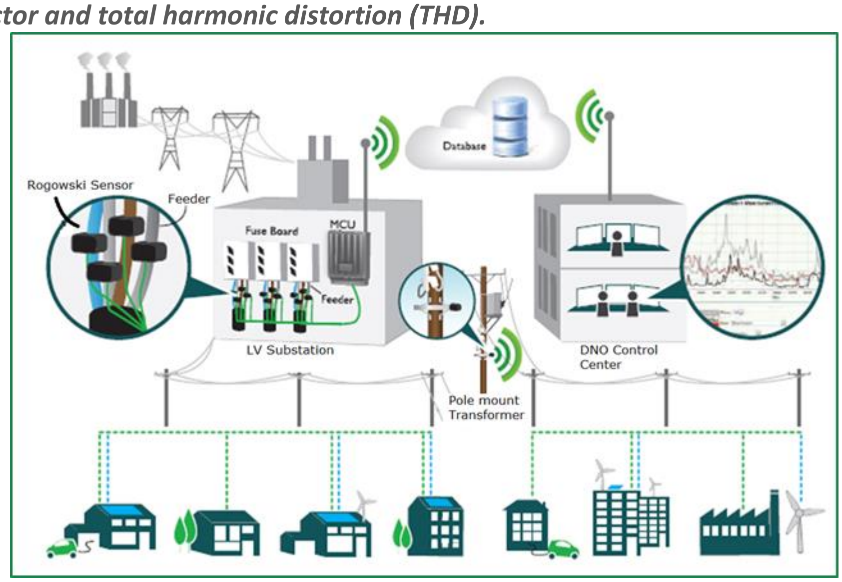

Figure 5: Schematic layout of PQ monitoring using transient analysis

The solution is scalable, with analytics dashboard at the DISCOM Control Center monitoring transients and other PQ parameters from various LV sections of the network, selected for measurement. The following tangible benefits were demonstrated as a result of this pilot project implementation:

1. Reduction in maintenance cost of the network, through preventive actions
2. Improvement in reliability indices CI/ CML (Customer interruptions/ Customer minutes lost)
3. Safeguarding electrical asset against arcing / partial discharge/ overheating caused by transients
4. Better compliance of regulatory norms and avoidance of penalties due to PQ violations