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Advanced LV Distribution Network Monitoring and Enabled Applications

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SUMMARY

Aging of LV distribution network assets, penetration of Distributed Energy Resources (DERs), and increasing regulatory requirements are driving a need to consider LV network monitoring for asset monitoring/management, planning stage, power quality and reliability monitoring/enhancements, etc. The important of LV network monitoring with rise of DERs has already been recognized by several major distribution utilities around world. However, the deployment of a monitoring system in LV network is limited due to several factors, such as lack of communication infrastructure, cost of installation/maintenance, space limitations close of assets, etc.

This paper focuses on LV distribution network monitoring and its applications. The proposed LV monitoring node with low power sensors is not only cost effective, but also easy to install and maintain. It can facilitate remote monitoring through GPRS/wireless radio by interfacing with DMS over standard protocols, e.g. DNP3, IEC 60870-5-104, etc; as well as local recording and control functions. Typical LV distribution network key applications discussed in this paper are: 1) Pad Mounted/Pole Top/Transformers- asset monitoring, load profile; 2) LV network switchgears-control with protection functions; 3) Cable in Vaults –faulty section location detection and loading; 4) End of Line at Utility/Industrial – power quality monitoring, volt/var control.

KEYWORDS

Advanced distribution automation, Low Voltage (LV) distribution network, pad mount transformers, rogowski coil, SCADA

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1. Introduction

1.1. Why LV network monitoring?

Up until recently, there is relatively less attention/investment paid to Low Voltage (LV) distribution network assets, e.g. pad-mount or pole-top transformer, switchgear/RMU (Ring Main Unit), underground cables, end-of-line, etc., as illustrated in Figure 1. On the other hand, rise in penetration of Distributed Energy Resources (DERs), such as solar (Photo-Voltaic), wind, Plugin Hybrid Electrical Vehicles (PHEV), etc. creates several new challenges that were not envisioned when LV network were originally designed before several decades, for example, power quality issues (THD, voltage sag/swell), network over-loading, unbalance network, protection device mis-coordination, etc.

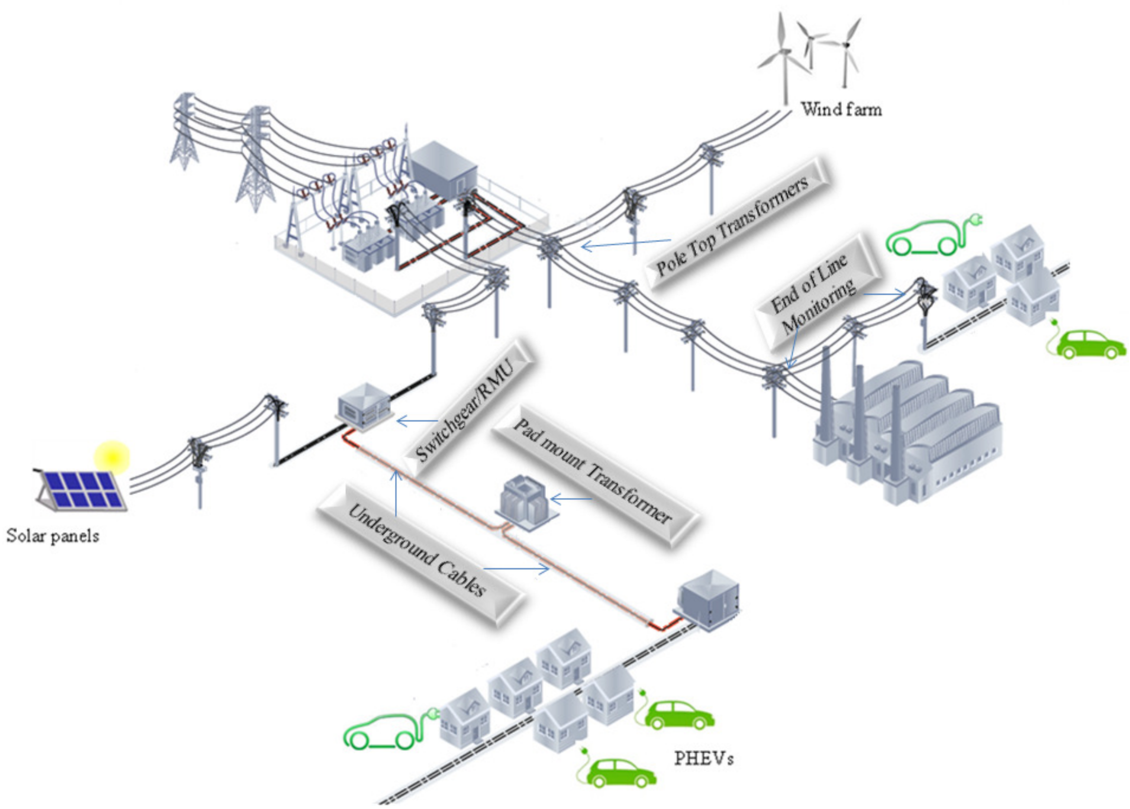


Figure 1 LV distribution network assets with DERs

There is an increasing need to improve visibility of distribution substation to make well informed Low Voltage (LV) network planning and operational decisions.

1.2. Challenges on applying LV Monitoring

Up until now, major LV distribution assets (pad-mount/ pole-top transformers, switchgears, underground cables) are not actively monitored, mainly due to various challenges discussed as follows:

i. Lack communication infrastructure: Communication infrastructure is required to facilitate information exchange between LV monitoring nodes and DMS system. Installing and maintaining dedicated private communication infrastructure may not be feasible for LV distribution automation.

ii. Protocol converters to integrate with existing DMS system: If communication infrastructure made available at LV network level, the next challenge faced is to integrate these devices into the DMS/SCADA. If LV network monitors does not have facilitated standard protocols of DMS/SCADA, it may require protocol converters which may add to cost and data latency.
iii. Costs of Installation: due to limited investment, the LV monitoring node should be cost-effective (justify cost-benefits).
iv. Space constraint for CTs & VTs: Cost and space to install current and voltage sensors to measure feeder/transformer currents and voltages is challenging especially for retrofit.
v. Undesired outage during installation/retrofit: If LV monitoring nodes with its sensors are not selected appropriately, it may require to schedule outage for installation of sensors/CT/VT. This is undesired for critical loads.

Recent advancements in the technology can address most of the above mentioned challenges, and enables a business case to install LV network monitoring for various applications, as discussed in the following topics.

2. LV MONITORING NODE (LVMN) ARCHITECTURE

2.1. Communication infrastructure: One of the possible option is to use public Cellular (GPRS/3G) network considering security aspects, which is available around major urban LV systems. If deploying communication infrastructure is too expensive for a distribution utility, low range radio or local storage in the device can used. It should also be possible for a typical LV monitoring digital device to record the important statistics which can be retrieved easily via local device interface.

2.2. Standard protocols to integrate with existing DMS system: The quantities measured at LV distribution network needs to be integrated into the existing or retrofit DMS infrastructure. Due to proprietary protocols, this can be only achieved with protocol converters which add undesired high cost and data latencies. With prioritization of several smart grid activities in various international and regional standard organizations, the focus is given to develop communication standards to integrate/interoperate various systems/devices with DMS from mutli-vendors. DNP3, IEC 60870-5-104, IEC 61850 are some of the examples of standard protocols suitable for LV monitoring/automation device to DMS.

2.3. Easy to install sensors: With advancements in sensor technologies (e.g. rogowski coil, Low Energy Analog (LEA), etc.), it possible to achieve low cost and easy to install sensors. Rogowski coils can be installed without load interruptions, and it can measure current ranging from mA to 100kA, with frequency up to 20 kHz.

The proposed LV network monitoring node is shown in Figure 2. The LV network monitoring node is a digital device which can be easily installed with distribution asset, e.g.pad-mounted or pole-top transformer/switchgear, underground cables, etc. The multiple feeder currents with bus voltage are measured by LV sensors. This device performs monitoring, control, and alarm/protection functions on these measured quantities, and drives local control/alarm through contact outputs, as well as remote control/alarm over communications (e.g. Cellular-GPRS, wireless radio). This information can be mapped to existing DMS/SCADA system using standard communication protocols (e.g. DNP3, IEC 60870-5-105 etc.).

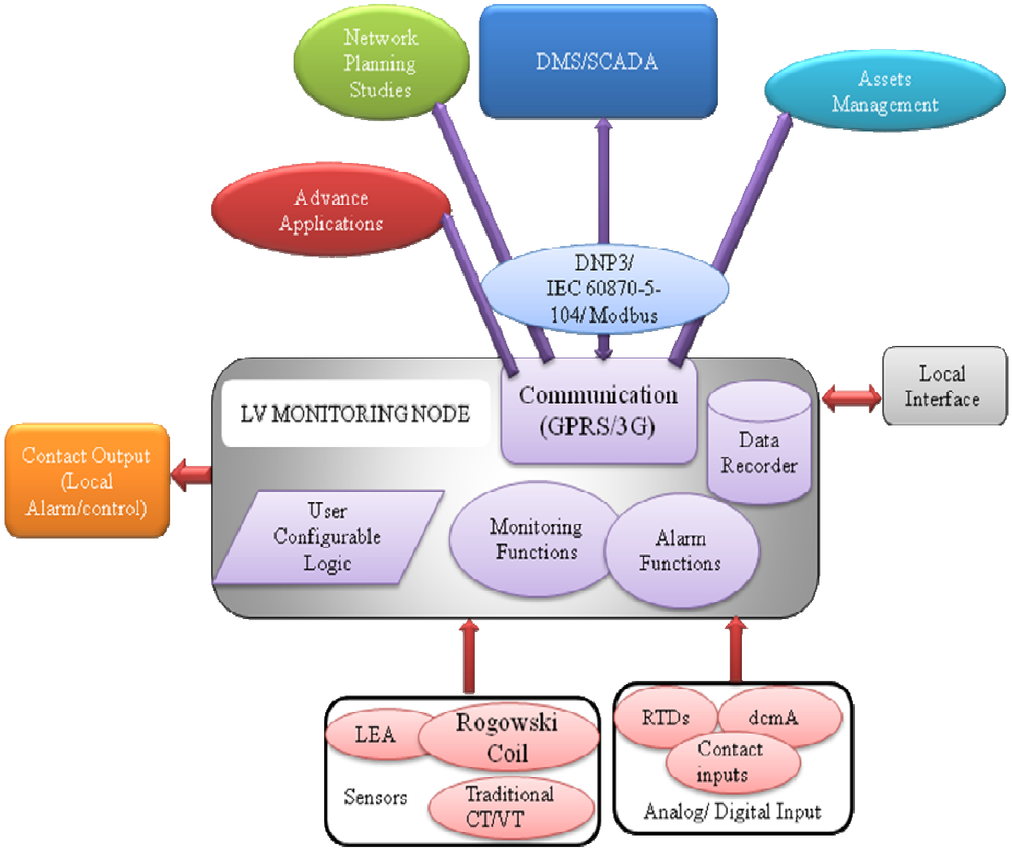


Figure 2 LV Monitoring Node (LVMN) Architecture

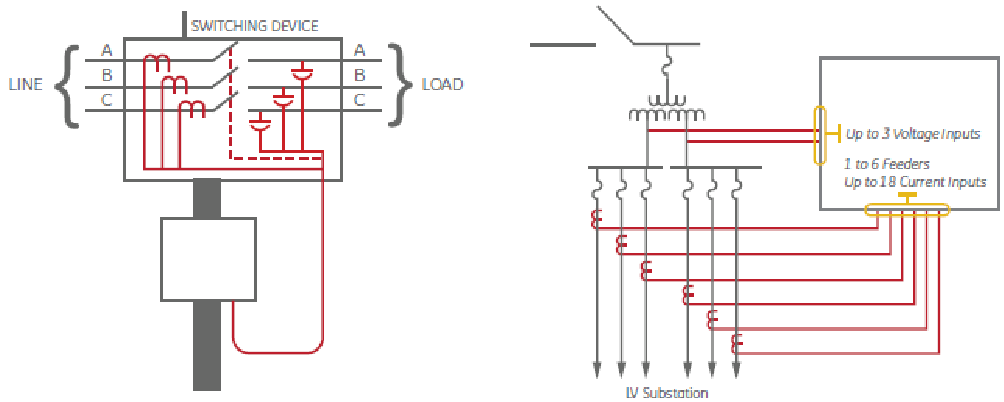
3. ADVANCE LV DISTRIBUTION NETWROK APPLICATIONS

Typically, the proposed LV monitoring nodes are installed close to pad-mounted or pole-top transformers or switchgear compartments. Availability of communication infrastructure, penetration of DERs in the community, and critical loads are some of the key factors considered during the node allocation. This section discusses some of the applications which can be achieved after deploying LV monitoring nodes in to the network.

3.1. Pad Mounted/Pole-Top Transformers and Switchgear

LV monitoring node can be installed in pad mounted or pole top switchgear, as shown in Figures 3 (a) below. Rogowski coil and LEA sensors are installed within the available space due to their low form factor. This enables the monitoring of the load profile of all connected feeders, and provides protection functions with remote control of the switchgear.

The LV monitoring node can be installed close to pad-mounted or pole-top transformers as shown in Figure 3(b). The installed sensors measures voltage and currents of the transformers, and also enables some key applications like, Enhanced transformer monitoring i.e. life span, outage time of the network; Transformer load profile monitoring, Peak demand statistics recording; improved load flow/planning studies; Transformer condition monitoring: oil and winding temperature monitoring through dcmA and RTD sensors; Energy monitoring and logging to help theft detection.

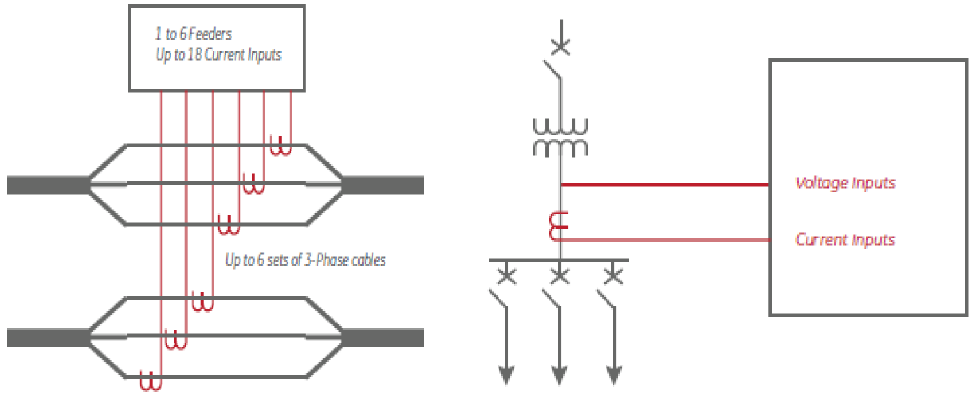


(a) (b)

Figure 3: (a) Pole Top Switchgear and (b) Transformer Monitoring Applications

3.2. Cable in Vaults

Deployment of the LV monitoring device can be carried out at strategic locations along cable paths in the vaults as shown in Figure 4(a). Rogowski coil allows retrofit installation in space-limited locations and to reduce the need for outages. These coils are installed at every possible cable section over the path. This enables faster fault detection/ faulty section location; and early warning on overload and alarms for fault detection with per phase overcurrent (50, 51) protection for each feeder to reduce feeder downtime.



(a) (b)

Figure 4: (a) Cable in Vault and (b) End of Line Monitoring Applications

3.3. End of Line – Utility/Industrial

Utility and industrial end of line monitoring for Volt/VAr control schemes play an important role in voltage optimization by ensuring the end customer is being provided with the proper voltage level. Further, Figure 4(b) shows the deployment of monitoring node at end of line locations which enables application like, end of line voltage and current measurements to help in short term and long term operational planning; energy monitoring and logging to help non-technical loss applications; Power quality monitoring.

4. LV MONITORING NODE INSTALLATION AT SCOTTISH AND SOUTHERN ENERGY (SSE)

New Thames valley vision (NTVV)- 5 years projects form the Scottish and southern energy power distribution company is leading UK and Ireland customers. One of the focus of this project is to trial, demonstrate and evaluate the potential of retrofitted monitoring node on 11kV LV distribution substations with embedded DG and PHEV charging points and hence to demonstrate the benefits of LV network monitoring on the operation of the Distribution System. More than 200 units are deployed at various pad mount and pole top transformers and switchgear locations. Figure below shows picture of actual installation sights with LV monitoring node using Rogowski coils. key functionality of LV monitoring nodes are: suitable for retrofit deployment of all indoor and outdoor substation location, monitoring and recording of 6 feeder data simultaneously, compatibility to use existing 3G/GPRS communication infrastructure facility, and facility to remotely upload software and setting changes.

Figure 5 LV Monitoring node installation at distribution substation [Courtesy: SSEPD]

Metered values data (i.e Current, voltage, energy, power quality metering) is communicated using establish GPRS communication network using DNP3 Protocol to DMS software. The data is retrieved; stored for display, alarm and future analysis purpose. Figure 6 below shows the typical snap shot of DMS software screen.

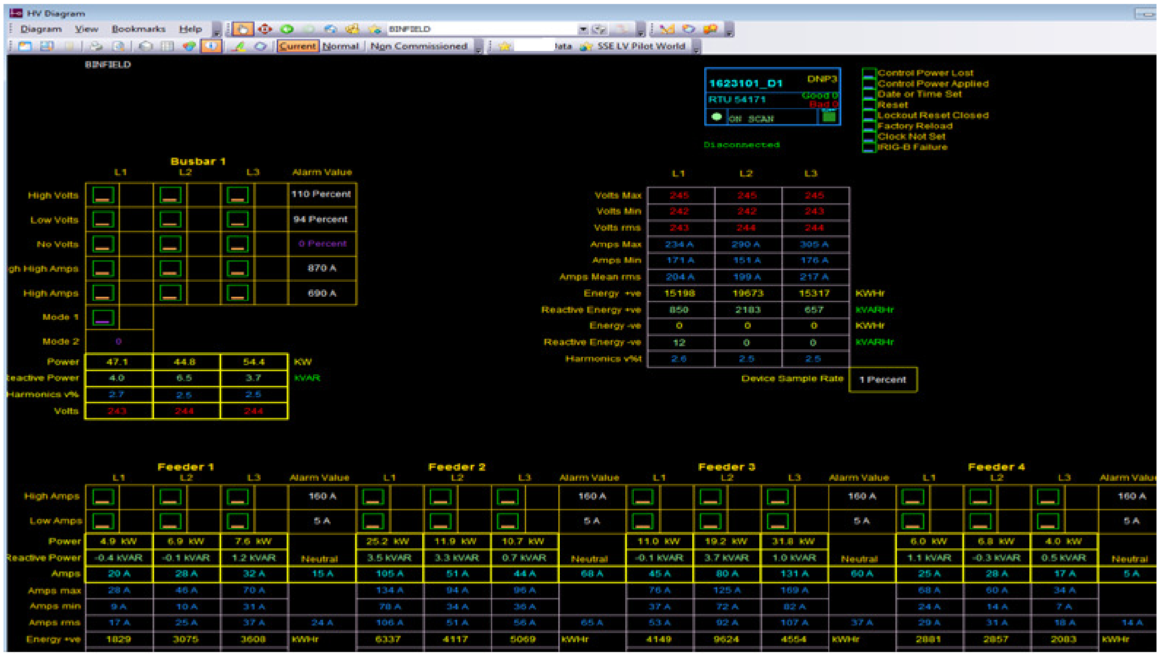


Figure 6 Snapshot of the distribution management software [Courtesy: SSEPD]

CONCLUSION

The important of LV network monitoring with penetration of DERs has already been recognised by several major distribution utilities. Further, with the advancement in the communication infrastructure, sensor technologies and cost effective LV monitoring device describe in this paper, provides retrofit solution for the monitoring of pad mount/pole top transformer/switchgears, and underground cable location. This will in turn improves visibility of LV distribution network to make well informed Low Voltage (LV) network planning and operational decisions.

BIBLIOGRAPHY

[1] P.Parikh, J.Concejo “Implementing LV Distribution monitoring System: Lessons learned and enabled applications” Distributech 2014, San Antonio, Texas.

[2] New Thames Valley Vision, Project Progress Repost, Scottish and Southern Energy Power Distribution, 2013.

[3] IEEE Power System Relaying Committee: “Practical Aspects of Rogowski Coil Applications to Relaying, Sept. 2010.

[4] Value of distribution automation applications, PIER Final Project Report, April 2007.

[5] G. Mauthe, V. Lohmann and F. Frey, "Enhanced customer value achieved by integrated protection, monitoring and control concepts", 1995, CIRED95 Conference publication.