A NOVEL RETROFIT CONCEPT FOR ENABLING SMART SECONDARY SUBSTATIONS

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ABSTRACT

Dominating driving forces for increasing automation in all levels of distribution network are the need to improve the reliability of the supply and the quality of the voltage, as well as the requirement to improve the operational efficiency of the network company. In addition, the increased deployment of distributed energy resources makes network operations harder to manage. In this scenario, smart secondary substations will provide a useful approach for planning and upgrading distribution networks. The paper presents a systematic approach to increase automation by introducing retrofit approaches in existing secondary substations cost-effectively and future-proof manner. Three such retrofit approaches are have been presented in this paper.

INTRODUCTION

The starting point for the retrofit concept is the manually operated Ring Main Unit (RMU) that is a part of the Gas Insulated Switchgear (GIS), which is typically located in the Compact Secondary Substation. An RMU can have some local intelligence in the form of a fault passage indicator device with local indications and manual operation of the load break switches.

Typically, secondary substations are unmanned and within several minutes of driving distance for the power utility’s service personnel. In an open ring type of distribution network, fault location, fault isolation and power restoration to the healthy parts of the power network requires operation of several RMUs and this is the main reason for the power interruption times to be in tens of minutes.

Until now, adding accurate indications medium voltage (MV) side measurements and communication capabilities to a secondary substation has, in practice, meant the replacement of the entire switchgear. The concept presented in this paper demonstrates the technical solution to accomplish the above actions as a retrofit installation by utilizing existing public communication network in a secure manner with minimum outage time.

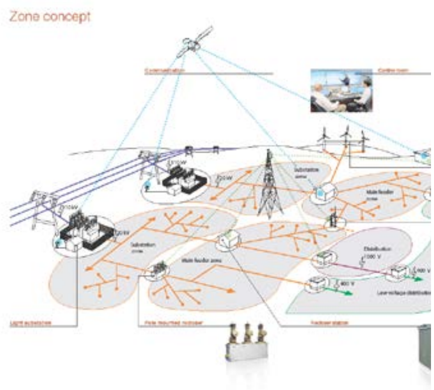

Figure 1. Main principle of the Zone Concept

ZONE CONCEPT AND AUTOMATION LEVELS

The Zone Concept in the distribution network automation is to divide the network into smaller zones. The required automation level in a zone is defined by the differences in fault vulnerability between the current zone and another zones and priority of the loads in that zone. Each zone should be equipped with communication for transfer of status indications, measurements, control commands etc. as required by the secondary distribution application.

In general, automation of the Smart Secondary Substations can be classified into four different levels that reflect the needed functional requirements of the different zones. The four levels are: Situational Awareness, Fault Isolation, Power Flow Management and Protection Selectivity. Each level is an incremental step from the preceding one.

Level 1: Situational Awareness

In the first level of automation in the Smart Secondary Substation, connections to fault location information and position indication signals of the load break switch are established. The level can also include low accuracy MV measurements and connections to the low voltage metering and measurement devices. The level provides vertical communication from the lower network levels to the upper levels, e.g. Substation Automation Systems (SAS) in primary substations or SCADA systems in District or Regional Control Centers. This level is considered to be minimum level of the Zone Concept

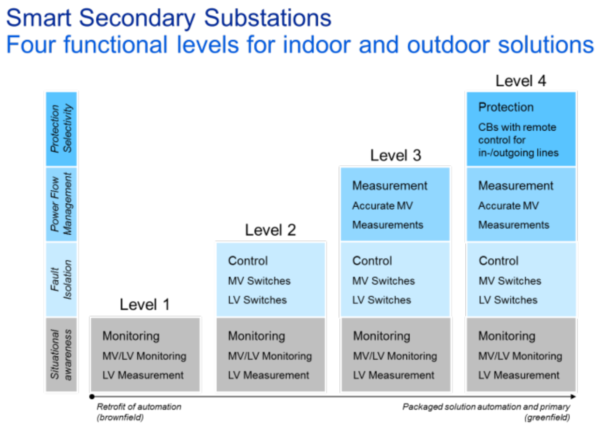

Figure 2. Four levels of the automation of the Smart Secondary Substations

Level 2 : Fault Isolation

The Fault Isolation level provides remote control of the primary equipment in the secondary substation. Automation provided in the upstream SAS or Network Control Centre (NCC) SCADA together with local intelligence in the secondary station enables isolation of the in a short duration of time and thereby not allowing the faults to persist and affect more zones . The isolation is partly based on the information provided in the Situational Awareness level. This level functionality is needed for the creation of the control zone in the Zone Concept.

Level 3 : Power Flow Management

This level adds accurate energy measurements to the existing secondary substation. The high-accuracy energy measurements enable a detailed power flow analysis of the distribution network in the higher level automation systems. Traditionally, data for power details have been based on calculations and predefined models that have not reflected the exact status of the power network in every situation. When entering into the Power flow management level smart secondary substations become a real part of the distribution network by presenting of the accurate details that particular MV network in every operation situation.

Level 4 : Protection Selectivity

The Protection Selectivity level adds full protection functionality to the Smart Secondary Substation. A pre-requisite for enabling level 4 in a secondary substation is the presence of circuit breakers. In most cases, this would necessitate replacement of the switchgear or installation of the pole mounted breakers and thus is not considered in this paper as a retrofit case.

In the Zone Concept, a level 4 enabled zones is called protection zone.

RETROFIT OF THE AUTOMATION LEVELS

An increasing number of distributed generation have been added by distribution network companies and hence the situation necessitates the deployment of automation in secondary substations in very short timeframe. On the other side, increasing demands on operational profitability are causing high pressures for cost effectiveness. These are the main reasons for the consideration of secure utilization of the publicly available communication infrastructure as a serious and viable option.

According to the GSM Association, the geographical coverage of 2G networks in Europe was 98% in e November 2011. In other words, communication network based on 2G technology can be utilized almost everywhere in Europe. While the 2G network is public, utilization of the well proven VPN technology together with the company networks and firewalls makes it possible to transfer data in a secure manner over the mobile communication network. The architecture of communication method is visible in the figure 3.

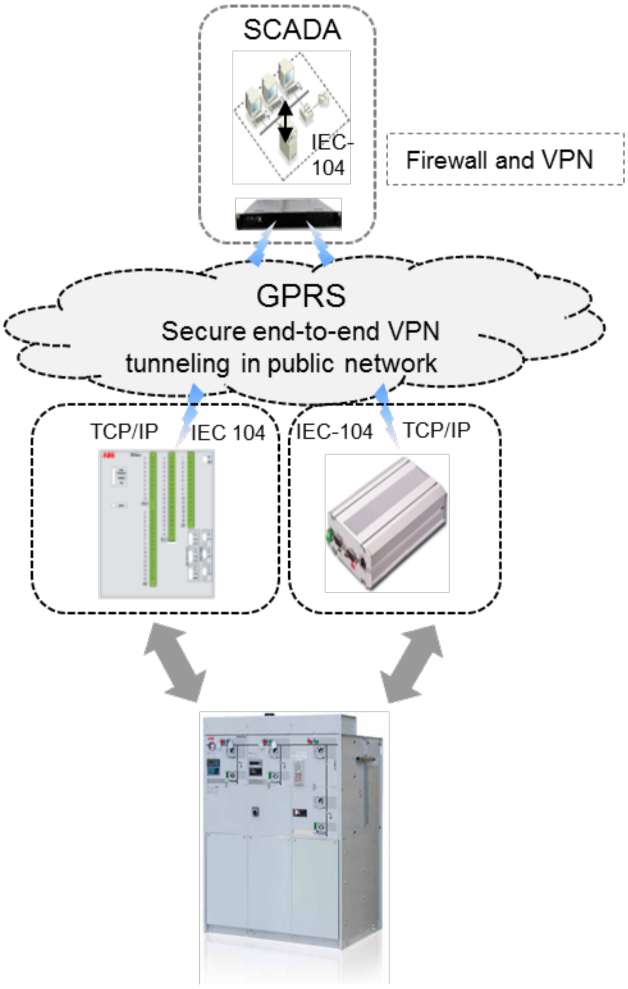

Figure 3. Communication Structure of the Smart Secondary substations

Retrofit concept for the Situational Awarness and Fault Isolation

As mention earlier, the lowest level of the smart secondary substation automation and Zone Concept is to have communication and status indications from the secondary switchgear. In this concept, the communication facility is created by utilizing devices having very minimal installation space requirements and with the ability to utilize the existing 2G mobile communication network. Such a device would be able to utilize the 2G network from any network provider available and can be configured to create a secure VPN based connectivity to the NCC with minimal effort. The communication device also provides methods to connect the possible fault passage indicators and metering devices from the low voltage side.

Retrofit to enable remote control of the existing RMU can be done if it is equipped with spring or motor operated load break switches. There are also techniques available to retrofit motors to RMUs, if factory installed motors are not available. Utilization of the publicly available communication together of these control methods will enable also the remote control with low establishment costs.

Retrofit concept for Power Flow Management

The key elements to accomplish the Power Flow Management level are the high accuracy measurements. For factory installation of secondary GIS, a very compact combined sensor can be deployed to replace original bushings. Apart from the 'bushing' functionality, the combined sensor also enables voltage and current measurements, and voltage based indication in a single enclosure.

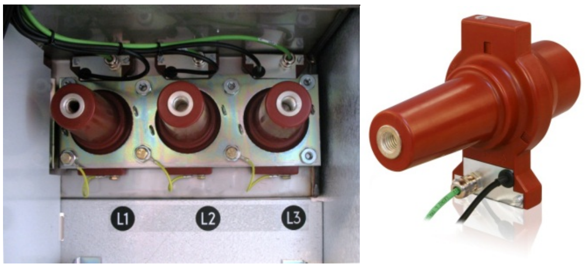

Figure 4. Factory installed combined voltage and current sensor replacing the bushings

However, it is not possible to upgrade an-already installed switchgear with this combined bushing type sensor. Considering the huge installed base of secondary GIS and requirements for accurate current and voltage measurements in MV systems, a new solution is required that can be additionally installed into the exiting switchgear. The key requirement for such a solution would be for fast and easy installation that would enable to minimize shutdown of the panel.

New sensors have been specifically developed for retrofit purposes of secondary GIS, precisely to meet the practical challenges mentioned earlier. The optimized design of the sensors enables installation of these sensors in a very short time period. The current sensors have been designed to be placed on the cable connectors and due to the flexible mounting system it can be assembled on many types of shielded cable connectors.

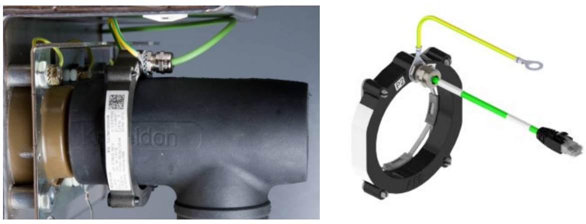

Figure 5. Retrofitting of the current sensor

The voltage sensors have been designed to be placed into the cable connector instead of the cable plug and different variants of the sensors to be compatible with various connector types.

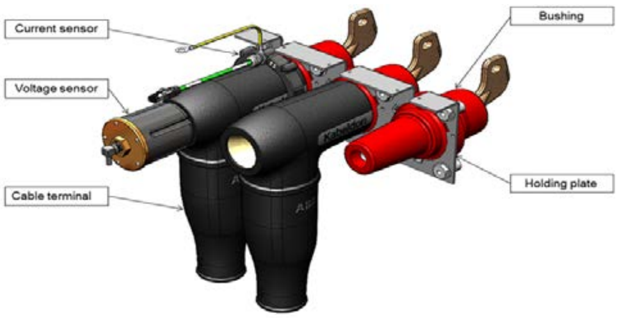

Figure 6. Retrofitting the Current and Voltage sensors

The new sensors utilize non-conventional principles such as Rogowski coil or voltage dividers that bring many advantages for both the user and secondary distribution application perspective. The construction of the sensors is done without use of any ferromagnetic core and therefore the behavior of the sensors is not influenced by the non-linearity and width of the hysteresis curve.

This fact results in the linear and highly accurate sensor characteristic in the full operating range that brings various benefits. The design of the voltage sensor is done in such a way that the sensor can remain connected during DC tests of the power cable and therefore disconnection can be avoided, as in case of conventional voltage transformers. This aspect reduces the outage time of the switchgear and simplifies the testing procedures.

CONCLUSION

With the secure utilization of the publicly available communication networks for the benefits of the remote monitoring and control of the secondary distribution network, different elements of the grid automation can be applied with small cost-efficient steps. This allows distribution utilities to develop their network automation level in several steps and without being forced to replace their existing equipment. Also by utilizing the existing public communication network, the distribution utilities can avoid huge investments in establishing and maintenance of their own private communication networks.

The new sensors represent an optimal retrofit solution where it is necessary to have needed infrastructure for power flow information measurement in an existing secondary GIS.

This solution cannot be achieved using conventional CTs and VTs within the limited space available in secondary GIS. Therefore, presented sensors exhibit the only solution optimized for such application and combined together with utilization of the communication with means of the publicly available networks sensors creates solutions that will enable the smart grids with acceptable establishment costs.

All these combined benefits make this concept cost-efficient and enable an easy step-wise approach towards 'smart' secondary substations.

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