SMART COMPACT SECONDARY SUBSTATIONS – METHOD FOR EVALUATION OF FUNCTIONALITY FOR UTILITIES

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ABSTRACT

Smart Grid technology manifests itself within all levels of electric energy supply. One of the levels where the benefits can be of greatest value is within Medium Voltage (MV) distribution level. The Compact Secondary Substation (CSS) will be a key node here. The MV distribution network consists of a large number of components over a wide area from various manufacturers. For a typical Utility, the present situation is that the control and monitoring of faults and operating conditions on the distribution network are very scarce and far from what is available on higher voltage levels. For instance, fault localization is often based on reports from customers and manual supervision.

A manufacturer of Smart CSS focuses on the technological aspects and functionality which can be provided based on assumed customer benefits. Such assumptions will not always match the expectations coming from the Utilities. A Utility must evaluate all investments in new technology in relation to a wide range of criteria which will have different level of importance for the individual Utility. This paper will discuss such criteria definition and show how it has been applied by Skagerak Nett AS, the second largest Utility in Norway, when evaluating investments in Smart CSS.

Such functionality mapping for a Utility gives valuable information and guidance for the Utility when classifying the CSSs in their network, as well as to the supplier industry to secure correct products and solutions fitting the Smart CSS applications.

INTRODUCTION

The rapid research and development within Information and Communication Technology (ICT) and sensor technology during the last years have provided new opportunities in almost any areas related to automation. Also within the power Utility sector, ICT has led to new solutions and new products, often referred to as Smart Grid technology.

Smart Grid is often referred to as functionality for remote monitoring of vital parts of the MV distribution network via sensors, and functionality for remote control of switches and breakers in strategic important key nodes in the network. These solutions have been a part of the power distribution network for quite some time, but mostly on the higher voltage levels and especially in power generation plants and transmission networks. Recently some of this functionality has also been introduced in the low voltage distribution levels in the various Smart Metering systems.

On the MV level, Smart Grid functionality has not been implemented to any great extent yet. However, this will not be the case in the future. The rapid increase in renewable power generation, often connected directly to the MV network, puts new demands on the operation of the network. Intermittent renewable energy sources such as wind and solar lead to a much more complex energy flow. A modern society is also ever more dependent on a reliable power supply. More extreme weather conditions and aging electrical infrastructure represent a challenge. In order to secure a reliable power supply under all conditions, Smart Grid technology will be important also in MV distribution networks.

To be prepared for upgrading existing MV distribution networks to become Smart, as well as new installations, the Utility must analyse the sensitivity in their network weighed towards the end users connected to the network. Skagerak Nett AS has done a classification of their CSSs to better understand how and where to automate the network. To do so, five performance criteria have been defined and will be elaborated in Table 1.

THE COMPACT SECONDARY SUBSTATION – VITAL FOR SMART GRID

A Utility has a significant number of CSSs, geographically spread over its entire supply area. This has traditionally led to relatively long response times for outage recovery and scarce overview in the operating conditions in a large distribution network. But through the CSS the Utility has good access to the infrastructure for implementing advanced functionality, opposed to smart meters, which often is inaccessible after installation as they typically are placed in private houses in Norway.

New patterns of power usage, new consumer products and increased dependency on reliable power supply, is reflected in new government regulations where monitoring and documentation of vital parameters are important. Aging infrastructure, out-of-date dimensioning of components and more extreme climate will be challenges that the Utilities must handle to secure high quality of electricity supplied.

Functionality for monitoring and control of the MV distribution network will be vital for the Utility to be able to provide a reliable and cost-effective power supply. The CSS will be the key node to be utilized, particularly because of easy access and full right of property.

More complex use of CSSs has been seen over the last years. One of many drivers is implementation of distributed generation to support the overall targets of utilizing more renewable energy [1]. This makes protection schemes to secure a reliable and stable energy supply more complicated. Another driver is the cost of energy not delivered to the end users, which in a lot of markets must be compensated by the Utility. This requires more monitoring as well as control of the CSS to change the supply path in the MV network in case of a failure. This classifies the CSS as a very critical network node to be automated in a future reliable MV distribution network.

Figure 1 shows a traditional CSS with Ring Main Unit (RMU), transformer and Low Voltage (LV) switchboard [1].

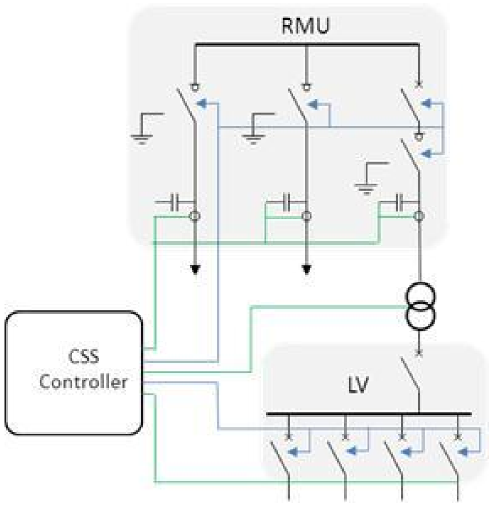

Figure 1: Smart CSS

Each feeder in the RMU has been equipped with measuring sensors providing both current and voltage signals to the RMU controller, which is then communicating with a SCADA system and other systems for particular information. The position indication of each switch and breaker in the RMU is monitored and communicated as well to the SCADA system via the controller. This is the basic function to be offered for enabling reconfiguration of the network in case of failures.

However, a Smart CSS will take it one step further. By utilizing more information from the CSS, early warning alarms can be provided to identify a potential failure before it happens. This will prevent failures and loss of energy in parts of the MV network and directly be a saving for the Utility. Then more monitoring will be required also taking the transformer, LV switchboard as well as the CSS housing itself into account related to a wide range of possible events.

Each CSS with its components can from a technology point of view be monitored in detail. However, the cost and amount of data to be collected and transferred to the SCADA system will not justify implementing 100% monitoring of all CSSs in the MV distribution network. The definition of a critical CSS as well as critical data to be transferred cannot be defined by the CSS supplier. Each Utility must do a CSS classification based on the customer profile as well as network topology based on a set of criteria as shown in Table 1.

CSS CLASSIFICATION

The challenge of investing in a Smart CSS is that the supplier of a CSS with internal components can offer monitoring and control of all items therein, but the value for the Utility will vary from a CSS to the next based on customer profile and network topology. All CSSs are not critical, and should then not have the same automation level. To optimize the level of investments for automation in the MV distribution network, a classification of the CSS's is required to define which signals to be collected and what to be controlled in each CSS.

New technologies and new products increase the possibilities and decrease the costs for installing new functionality in MV substations. Functionality that earlier was available for higher rated voltages is now available for MV networks at a cost that should not be a showstopper in most cases. This is in particular the case for functionality like remote monitoring and remote control. Smart Grid functionality has for a long time been used in transmission networks (300 – 420 kV) and regional networks (66 – 132 kV). During the past years distribution networks also sometimes have Smart Grid functionality. This occurs due to decreasing costs for electronic devices and communication devices as well as rapid development in ICT and sensor technology.

For a CSS manufacturer it is important to be able to supply the correct and valuable functionality to the Utilities. Functionality that is not required will make the CSS more complicated and increases the costs for installation and future maintenance although the component costs are low. Functionality that is not available will disqualify a particular product / solution when the functionality is a requirement, ref Table 1.

The challenge is to judge offered functionality towards the Utility requirements in such a way that the most appropriate solutions are developed and later on installed.

Skagerak Nett AS has developed a method to do such evaluation of various Smart Grid-functionality available on the market. The first step is to define the performance criteria relevant for the specific Utility. Both relevant functionality and criteria might vary in between countries and even Utilities in the same country based on the customer profile and network topology. For Skagerak Nett AS, the defined performance criterias are:

- Governmental regulations
- Health, safety and environment (HSE)
- Economy
- Operation, maintenance and future development of the Network
- Public reputation

Table 1 - Functionality versus performance criteria

Performance criteria / *Functionality*	*Governmental regulations*	*Health, safety and environment*	*Economy*	*Network operation, maintenance and development*	*Public reputation*
1. Power consumption	(x)	(x)	X	X	-
2. Transformer load	-	X	(x)	X	(x)
3. Power quality	X	X	(x)	X	X
4. Disneuter monitoring	X	X	(x)	-	X
5. Short-circuit indication	-	X	X	X	X
6. Open door alarm	X	X	-	-	(x)
7. Earth fault alarm	X	X	X	X	X
8. Phase failure	-	X	-	-	X
9. Temperature monitoring	-	X	(x)	X	-
10. Water intrusion monitoring	-	X	(x)	-	X
11. Outage monitoring	(x)	X	X	X	X
12. Remote control of switches	-	X	X	X	X
13. Switch position monitoring	-	X	X	X	-
14. Switch status	-	X	X	X	-

From Table 1, a list of functionalities defined by Skagerak Nett AS can be seen and how they relate to the performance criteria defined. Each function has then been evaluated relative to each performance criterion. Score “X” is Vital, “(x)” is Relevant and “-“ is Not relevant.

This score is based on a more thorough evaluation of each of the functionalities defined. Examples of such functionality evaluation are shown in Table 2 and Table 3 for respectively “Water intrusion monitoring” and “Remote control of switches”.

Table 2 – 10. Water intrusion monitoring

Performance criteria	*Description*
Government regulations	
Health, safety and environment	- Reduce risk for short circuit and damage to equipment - Increase personnel safety for on-site work
Economy	- Warning when water detected - Possibility for preventive maintenance - Averting outages will reduce outage fees
Grip operation, maintenance and development	- Reduce humidity in the secondary substation - Preventive measures to maintain asset condition
Public reputation	- Utility is able to avoid or minimize outages due to water intrusion

Table 3 – 12. Remote control of switches

Performance criteria	*Description*
Government regulations	
Health, safety and environment	- Reduce required local presence of personnel when switching - Increased security in communication is necessary
Economy	- Remote sectioning of the grid can lead to reduced outage fees - Less need for personnel
Grid operation, maintenance and development	- Remote sectioning of the grid - Shorter outages - Avoid test switching - More options for sectioning of the grid - Automated outage analysis and reporting - Reduce losses due to more options for optimal load-flow configurations of the grid
Public reputation	- Shorter outages will have a positive effect

The above presented functionality mapping is a tool used by Skagerak Nett AS to evaluate offered functionality related to the network requirement. Next step in such a process is then to define CSS classifications and classify each CSS in the MV distribution network under the responsibility of the Utility to a certain level of Smart CSS. Such classification might give several levels from no Smart functions all the way to fully automated and controlled.

CONCLUSION

Automation of MV distribution network is now becoming a real approach for Utilities in many countries. Skagerak Nett, a Utility in Norway, has also started to prepare for automation of their MV distribution network. This paper shows how the different technical features are evaluated to give values to the overall operation of the Utility. Such a mapping is crucial for a Utility to be able to define where to invest and how to invest in automation in an economical optimum way.

The paper also discussed the supplier side of the automation of CSS. Technology development is moving rapidly in a wide range of monitoring and control applications in different industrial areas. However, for automation of the distribution network, it is important that the supplier industry is fully aware of the values and need of a Utility to develop and qualify the best technology suitable for such type of Smart CSS applications. This paper has then presented a structured approach on how such a functionality mapping can be done. By sharing such information with the supplier industry, the correct automation components and solutions can then be developed and qualified for Smart CSS applications. The supplier industry will then be in a position to further develop and optimize the devices with regards to functionality required by the Utility segment.

REFERENCES

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