COMPACT SECONDARY SUBSTATION IN A FUTURE MEDIUM VOLTAGE DISTRIBUTION NETWORK

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ABSTRACT

Due to high focus on the global climate change situation, most countries have committed to support initiatives to cut emissions in different areas. The introduction of renewable power generation is one of the key elements to reduce global warming, which will influence the Medium Voltage (MV) distribution network. Environmental energy targets will change the Distribution network to also become a receiver of energy from different renewable sources. To secure high quality of energy supplies to the consumers, new network concepts and automated solutions must be provided. This paper will present the Zone concept for MV distribution networks. To utilize the Zone concept in a future MV distribution network, the Compact Secondary Substation (CSS) becomes key nodes. The intelligent Ring Main Unit (RMU) will play an important role in the future MV distribution network as a provider of plug-and-play solution with easy SCADA or DMS connectivity. The automated capabilities of Intelligent Electronic Devices (IED), such as measurement, monitoring, control, and communications functions, makes it possible to provide all required information for implementing automated fault identification, fault isolation, and power restoration. As a result, the power outage duration and the system reliability can be improved significantly.

INTROUDCTION

This paper will discuss the shift from a manually operated distribution system towards a distribution system where more intelligence is built into the RMU as well as the CSS. Such a technology shift is driven by national regulators to secure high quality of energy supplied to the end consumers. Due to this, a technology shift is already ongoing in some markets, in other markets it will happen in the near future, whilst in some other markets no indication is visible that such a technology shift will ever happen.

Increased focus on power quality in the distribution network can already be seen. This is because the distribution network with its key nodes represents the connections point for a wide range of different loads as well as unpredictable renewable power generation fed into the network. The traditional energy flow can be totally changed. Introduction of distributed generation in distribution networks requires development of protection and control systems which can reliably locate and isolate the fault. In addition, connection to SCADA or DMS systems would be the preferred solution in order to balance between supply and demand.

To handle more complex distribution network installations and the upgrade of existing ones to achieve high quality of energy supplied, new solution for network operations as well as components will be required.

MARKET

Traditional operation of the Distribution network

Cable distribution networks have traditionally been operated as open Ring (Figure 1) or Radial (Figure 2) feed network configurations.

Both network topologies are based on network components with basic protection functionality which is presented by a fuse, and with limited or no automation possibilities built in. Distribution System Operators (DSOs) are today not fully aware of events that occur behind the primary substation. This in combination with large distribution networks consisting of a high number of supply points gives a challenging environment for providing a stable energy supply.

For both Ring and Radial networks, time consuming manual work has been required to locate and restore supply after a fault has occurred. Typically is the DSOs not aware of faults in secondary distribution network until customers reports that they are without power. This could potentially lead to long outage times for the end users causing various impact based on the type of costumer affected.

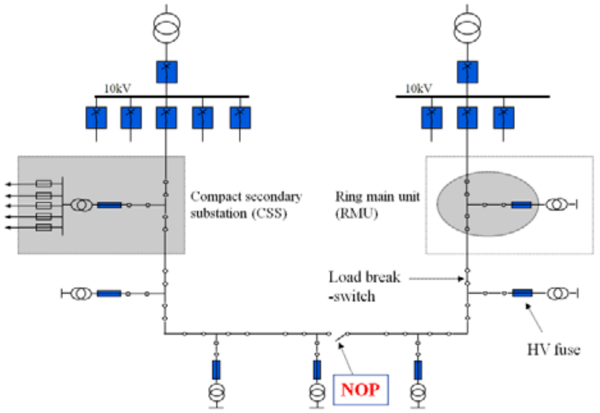

Figure 1: Traditional Distribution Ring Network

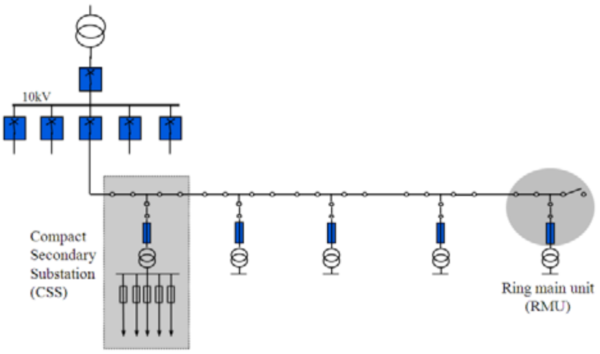

Figure 2: Traditional Distribution Radial Network

Solutions to automate distribution networks have been available for some years, but this is usually done by combining loose and independent elements into systems. The price/benefit of such systems has, in most cases, not supported a full scale investment decision.

A combination of reduction in manpower available for network maintenance and implementation of new energy sources are creating a challenging environment for the future distribution networks like

- Increased focus on power quality due to integration of renewable energy sources
- Penalty systems for loss of energy supply
- Fused protection lead to manual resources for fuse replacement in case of a failure
- How to get the needed monitoring and automation functions integrated at an acceptable cost

Future operation of MV Distribution network

The distribution network has during the least years become more complex. One of the drivers is the introduction of distributed generation, which influences directly the energy flow in the distribution network as well as the electrical parameters used for the protection schemes. New approaches of protection principles will be introduced in order to properly protect the complete system and mainly the principals which will be independent on network topology, as well as amount of power generations point currently available. Cost effective line differential protection systems seems to be appropriate for the future of distribution systems to utilize closed ring network with changing energy flow.

In order to control renewable energy sources connected to secondary distribution in an efficient way, new elements to the network will be introduced. Small energy storages up to 2 MW could play an important role, in order to balance peaks of supply and demand as well as contribute to quality of energy. They may efficiently control voltage, power factor or reduce harmonics. This will however need the connectivity to DMS systems, which will need intelligence to be able to calculate the required demand of Active Power (P) and/or Reactive Power (Q) depending on the actual situation in the network and available P and/or Q in energy storages. In case that systems with renewables will be properly designed from the protection, control and monitoring point of views there might be a solution on how to address increased demand on energy and reduce CO2 emissions in the same time.

Reliability of the energy supply is the next important element which will change practices on how to control the distribution network. To reduce the risk of failures and long periods without energy supply, national regulators have, in some countries implemented penalties for non delivered energy. These penalties vary across counties as well as being dependant upon the duration of the lack supply.

To increase the quality of energy supplied in a more complex MV distribution network, Smart CSS with remote monitoring and control will be required in selected key nodes in the network. To have a Smart CSS in a future distribution network, signal collection, processing and communication must be done in a simple and cost efficient way. There will also be required to optimize the overall control of the distribution network to simplify the reconfiguration of the network after a failure.

The intelligent RMU will play an important role in the future MV distribution network as a provider of plug-and-play solution with easy DMS connectivity. The automated capabilities of Intelligent Electronic Devices (IED), such as measurement, monitoring, control, and communications functions, makes it possible to provide all required information for implementing automated fault identification, fault isolation, and power restoration. As a result, the power outage duration and the system reliability can be improved significantly.

The typical RMU in the distribution network has today Load Break Switches (LBS). In a future network, it may be beneficial to operate the distribution ring without any open point to reduce power losses. Circuit Breakers (CB) must then be introduced instead of the traditionally LBS. This also opens the possibility of having fault handling with no customer impact.

CONCEPTS FOR THE FUTURE DISTRIBUTION NETWORK

The Zone concept

The Zone concept [1] provides a model for dividing distribution networks into zones, separated by active and intelligent components, in order to handle fault situations in an optimal way. Optimal in this context means as few affected consumers as possible, fast power restoration and, finally, as little need for personnel as possible. This is a new way of operating the network, which is divided into zones based on consumption criticality and the disturbance vulnerability. A Zone can include several traditional MV distribution rings or only parts of such rings. The Zones are divided by Circuit Breakers, Load Break Switches or Disconnectors with remote communication and various degrees of intelligence for protection, measurement and control.

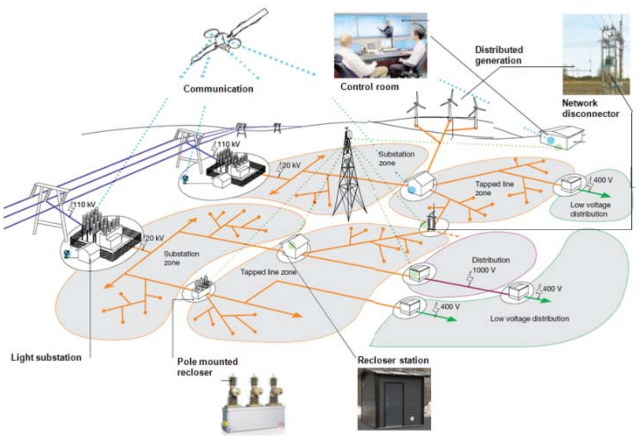

Figure 3: The Zone concept

Dominating driving forces today are the needs to improve the supply reliability and voltage quality as well as the requirement to improve the operational efficiency of the network company. Additionally the increased use of distributed energy resources complicates the network operation but it also provides additional means to secure the power supply. In such situation will the Zone concept provide a useful model for planning and upgrading of distribution networks.

The lay-out of the power distribution network is affected by the density of settlement, power consumption and its criticality, legislation, environmental concerns, weather conditions, philosophy of the distribution network owner.

In Figure 3, the various Zones below the substation are shown as shadowed areas. Between these Zones, are Zone dividers with protection and breaking/reclosing or only disconnecting capabilities. All Zone dividers are provided with facilities for remote communication for transfer of status indications, control commands, measurements, fault indication etc. as required by the application.

Depending on the capabilities of the Zone divider equipment, the Zone on the downside is either a protection or a control Zone. Needless to say that it is worthwhile to differentiate between areas with low fault probability from those with high fault risks. Another Zone divider criteria is the need to secure the supply to areas with substantial and/or critical consumption. The same criteria are used when determining whether a Zone shall become a protection Zone or control Zone.

Communication is a central part of the Zone concept, as it is essential to know the status of the Zone divider equipment and to control it. With the development of capable wireless communication it has become feasible to arrange communication to most of the nodes in a distribution network. This has been made possible by the development of public wireless networks like GPRS or 3G. In the selection of the communication methods not only communication features but also availability and security issues have to be addressed.

Smart CSS

In the Zone concept, the CSS with its built in technology becomes a key node and must act as a Smart CSS.

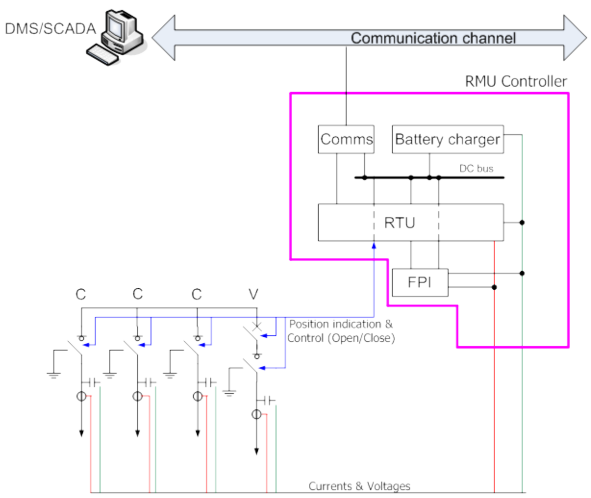

Figure 4: Remote monitoring and control of an RMU

Figure 4 shows a typical RMU configuration with three Cable switches (C) and one Vacuum Circuit Breaker (V). Each feeder in the RMU is equipped with measuring sensors providing both current and voltage for all three phases to the RMU controller, which is capable of measuring up to twelve current and twelve voltages.

The position indication of each switch and breaker in the RMU is connected to the RMU controller for local as well as remote (SCADA) monitoring and/or control. The RMU controller is sending Open/Close commands to each switch/breaker in the RMU, either locally or remotely from a SCADA system.

Traditionally, DSOs use the trouble call system to detect power outages in the distribution network. In case of a failure in the network, the affected customers must report the loss of power or power outage. The control center then sends a maintenance crew to the field. The fault location could then be identified manually. Switching scheme(s) to isolate the faulty part as well as reconfiguration of the network to achieve power restoration is then done manually. This traditional procedure for power restoration may take several hours to complete, depending on how fast customers report the power outage and the time required for the maintenance crew to locate the fault and to restore tower power. The automated capabilities of RMU controllers, such as measurement, monitoring, control and communication, makes it practical to implement automated fault identification, fault isolation, and power restoration. As a result, the power outage duration and the system reliability can be improved significantly. In Figure 4, the RMU controller uses a Fault Passage Indicator algorithm to detect the forward or reverse fault for a variety of earthing systems, such as isolated, solidly earthed, resistance earthed, resonant grounding, etc.

In the case of external power failure, a RMU controller must provide a backup power supply. This is achieved by using batteries that are monitored and charged by an integrated battery charger in the RMU controller.
As the RMU's are spread across distribution network, the challenge is how to provide the collected data to the SCADA system as well as control the RMU in an efficient way.

Different communication channels must be provided like cellular one such as GPRS, 3G, etc. Other communication options including wired (fiber optic) or other wireless technologies (radio etc) should be supported by the RMU controller.

The RMU controller must be easy to install and operate for both retrofit installations as well as for new installations. Compactness of RMU controller is also very important, different functionalities as depicted in Figure 4 are all available within one box and integrated in the RMU itself. Thus it tremendously reduce the time required and thereby the cost of installing such solution. This gives fewer components with interconnections, improved system reliability, less maintenance and finally reduced lifetime cost of the system.

Today, remote control and monitoring of a CSS means the RMU only. A Smart CSS will take it one step further and include the transformer as well as Low Voltage switchboard as can be seen in Figure 5.

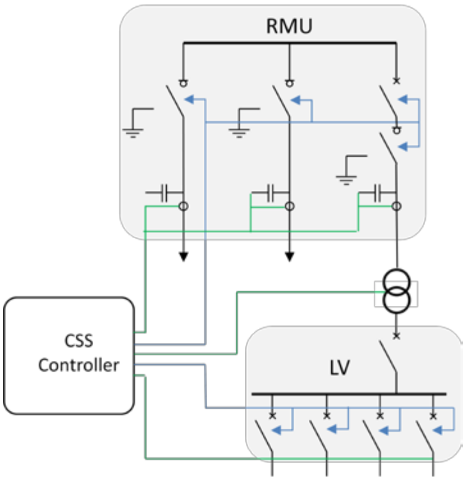

Figure 5: Smart CSS

Also these components in a CSS are critical for securing high quality of energy supplied.

CONCLUSION

The future distribution network will be influenced by the introduction of renewable power generation in combination with various type of critical loads.

To secure high quality of energy supplied, automation in the distribution network will be required. Smart CSS will be placed in key points in the network to monitor critical components as well as key parameters in the network. This will require simple and flexible RTU solutions fully integrated in the CSS. Solutions suitable for upgrading a traditional CSS to a Smart CSS must also be provided to be able to handle the future distribution network without a complete new MV installation.

A flexible communication to a DMS system will be required to process the data collected and define actions to be executed in case of network problems.

REFERENCES

[1] P. Manner, K. Koivuranta, A. Kostiainen, G. Wiklund, CIRED 2011, Towards self-healing power distribution by means of the zone concept, *21th International Conference on Electricity Distribution Proceedings*, Frankfurt, Germany, 6-9 June 2011