DISTRIBUTION AUTOMATION BY INTEGRATED WIRELESS COMMUNICATIONS AND INTELLIGENT NETWORKS

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1. INTRODUCTION

The demands on today's electrical distribution networks are higher than ever before. Customers and authorities urge for a distribution with as few and as short interruptions as possible. To achieve this, modern communication systems are required to provide a base for improved monitoring and management all the way down in the hierarchy of the distribution network. However, many utilities only tend to equip objects at high levels like substations and more important network points with communication/automation features. This is often due to a capacity problem in the communication networks. This capacity problem can easily be solved if a modern event triggered radio network is used. Event triggered radio networks can handle very large number of units even during avalanche conditions if an advanced collision avoidance system is utilized. Packaged together with a distribution automation dedicated radio protocol, rapid communication can be achieved without compromising safety.

To meet these requirements, both the communication system and the automation system should be fully integrated and from the start thoroughly designed to interact. The system shall be built for its purpose as well as being a part of an integrated system. If different types of equipment which, from beginning, are not built to interact with each other, (i.e. switchgear, actuators, intelligent units, communication devices etc.) are mixed, there is always a compromise in speed, accessibility, safety and functionality. Often the MTBF (*Mean Time Before Failure*) figures are lower and health check routines of equipment are more complex to carry out due to a non centralized supervision of the units.

Another vital issue is the purpose for which the equipment is actually designed to do. The question "Is the equipment designed for distribution automation?" should always be raised. Normally, general purpose equipment contains a lot of functionality that cannot be utilized, bringing a lot of compromises regarding the intended performance.

If control, monitoring, automation and communication functions are fully integrated and designed together to interact as one single powerful unit, then the true objectives for a modern distribution automation system is reached.

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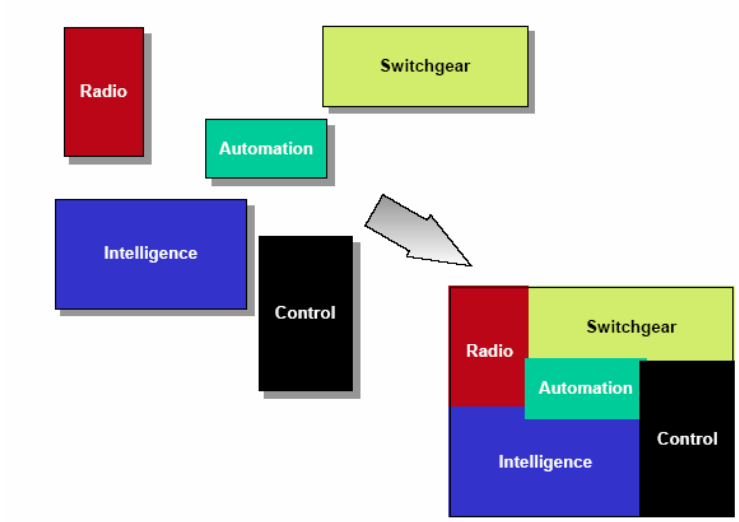

Figure 1. A fully integrated system is the key for the ever growing demands for effective distribution automation.

2. COMMUNICATION

The two key issue requirements for a communication system are speed and safety. Speed is important for advanced automation sequences and to keep SCADA (*Supervisory Control And Data Acquisition*) operators "in charge" of their system even during avalanche situations. Experience shows that SCADA operators a loss of the real-time aspect when command delays over three seconds occurs. To be able to make the correct decisions and operations, data from all levels must be updated immediately and in the correct sequence. To achieve the required performance, the communication system must be designed for its purpose and be very efficient.
The most important issue to bear in mind is to choose the right communication media, protocol and integration level to face future demands also regarding the always important safety aspects.

2.1. Communication media

One of the most suitable communication solutions for distribution automation is low power digital radio networks. They give the speed and safety required, whilst being extremely competitive when it comes to financial as well as operational benefits.
The choice of communication media is often regarded as a matter of second importance for investors of distribution automation communication equipment. Nevertheless it is perhaps one of the most important issues. There are several methods of transferring information in a distribution network. Nowadays, signal cables for communication in distribution automation systems is a method of the past and cannot, today, be considered as a realistic alternative. PLC (*Power Line Carrier*) systems is used at transmission levels and can be used at distribution levels, but brings speed and continuity difficulties. Remaining – radio.
There are though a vast range of different radio types and systems to choose between. Again it is important that the system is designed for its purpose, in this case: distribution automation. Public radio networks like GSM (*Global System for Mobile communications*) and TETRA (*TErrestrial Trunked RAdio*) unfortunately have several disadvantages regarding data transmission. They are rather expensive to use because there is a cost involved in every transmission (and sometimes reception). Another weakness is that the investor has to rely on another organization; if there is a fault in the public radio network, there is nothing to be done to speed up the fault location. The major problem with public radio network is however – speed. All public radio networks lack the speed needed for efficient distribution automation. Everybody can recognize that you have to move a few meters while talking to a cellular phone but unfortunately RMUs (*Ring-Main Units*), sectionalizes and reclosers cannot move to avoid poor signal strength circumstances. The human mind can also manage to recognize and interpret speech and differences, even on a disturbed GSM connection. Units interpreting data signals are, however, in need of bit error free telegrams to operate rapidly and securely. The mobile phone operators' coverage maps do not always tell the whole truth when it

comes to cover specific square meters zones far out in rural areas. Public radio networks offers good coverage in dense populated areas but not in sparse remote regions and are therefore not built for data communication.

Using traditional analogue voice communication systems (e.g. trunked radio), is another way to build up a radio network for communication to both new and existing distribution automation devices. However, this kind of system is designed for voice communication only and not for data transfer and the use of SDMs (*Short Data Messages*) is limited. The possibilities to build in intelligent functions and/or complex and effective communication networks are very limited. Another fact that contradicts voice communication systems is that when there are disturbances and outages in the distribution network and communication for monitoring and control is really needed, the frequencies are occupied by the service crews organizing the fault isolating and restoration work. Due to the often older kinds of technology, traditional analogue repeaters also amplify and transmit not only the signal in question but also the noise. This means that data transmitted through an analogue repeater runs the risk of becoming distorted and therefore cannot transmit the correct data. In voice communication this is not a big problem but can be disastrous for data communication.

To achieve rapid and secure communication which works under all possible conditions, the solution is to use a private digital radio network. The advantages are obvious: There is no cost involved in transmission and reception. No compromises have to be done regarding the traffic amount. There is only the initial investment to be considered. One major argument for private digital radio network is speed. An event triggered private low power digital radio network is the most rapid and safe communication infrastructure also compared to its investment.

2.2. Protocol and network topology

It is of vital importance to choose the most efficient communication protocol to transfer information in a digital radio network. Unfortunately this choice is often made without analyzing the distribution and communication needs deeply enough. The most common process is to start at the SCADA and analyze what protocol(s) are available. This is correct but it does not give the answer to what protocol is to be utilized in the distribution automation network. High level SCADA protocols are excellent for complex communication in the upper half of the SCADA hierarchy. However, for rapid and effective communication in distribution and feeder automation systems, a digital radio system is the key (see Figure 2).

To achieve the most suitable system integration, feeder and distribution automation communication systems should be linked to Radio Network Concentrators. These, in turn, connect the lower level digital radio networks to the SCADA using standard high level SCADA protocols. This allows the use of a, “fit for purpose”, specially designed radio protocol to meet the more and more complex automation functions in the distribution networks.

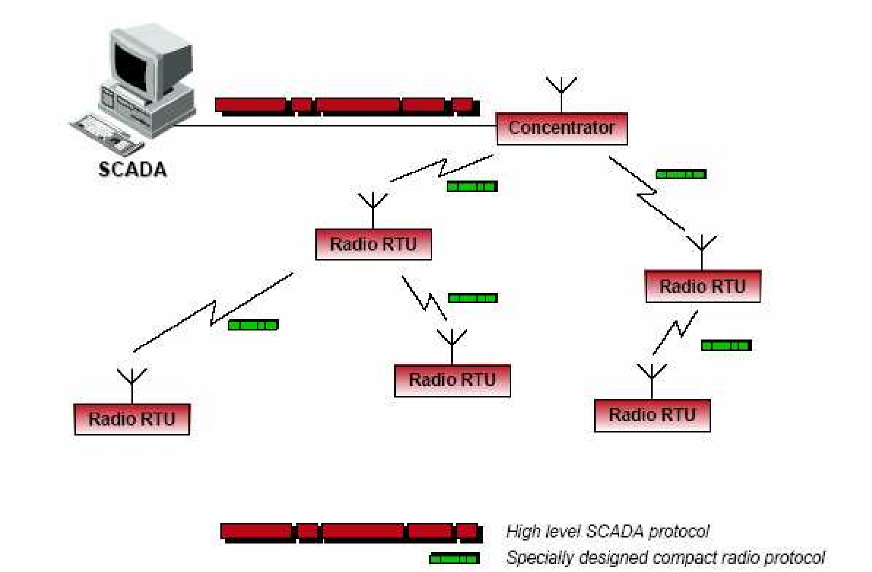

Figure 2. A specially designed digital radio protocol is the key for rapid and secure communication in distribution automation networks. Radio network concentrators communicate with SCADA systems using high level protocols.

A distribution automation radio network protocol should be designed with the following features:

- Event triggered hierarchy
- Multiple access
- Collision detection
- Collision avoidance
- Store and forward repeater capabilities
- Variable message length
- Error detection
- Automatic re-transmissions
- System and object addressing

The protocol shall be designed for the distribution automation equipment utilized. High level SCADA protocols are not suitable to use all the way out to the furthest outstations in the distribution automation network due to the protocols' lack of networking functionality. The protocol shall, for example, be designed for the amounts of data, effective re-transmission functionality time requirements etc. Protocols containing long overhead sequences, large data flows and irrelevant data transfer are, for example, more sensitive to noise and other disturbances. Apart from slowing down communication speed dramatically, this also makes the communication structure vulnerable and unstable.

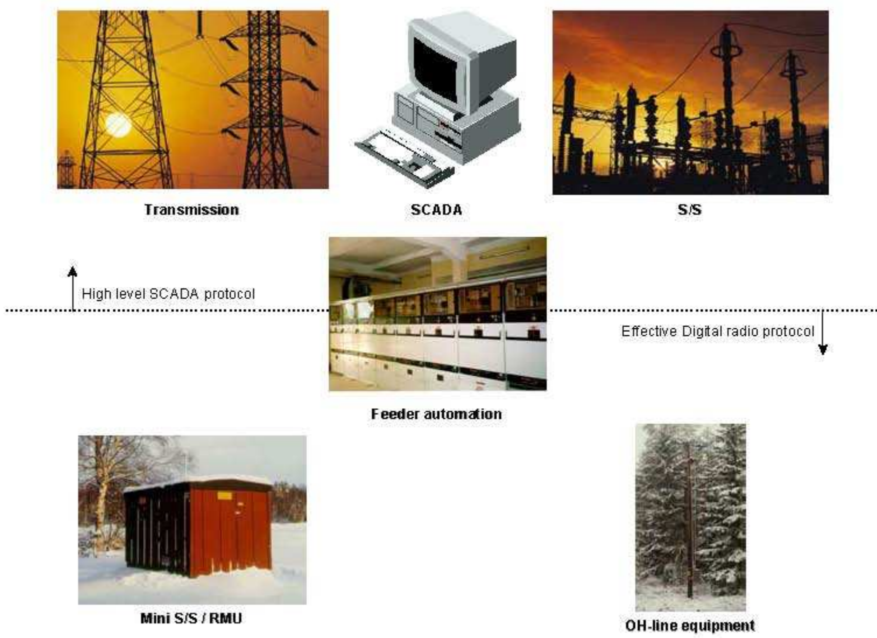

Figure 3. An adjusted communication structure vouches for safe, effective and rapid data transmission at all levels in multi-level SCADA hierarchy.

A private digital radio network shall have advanced network functionality to be efficient. Every unit in the radio network needs the capability of repeating messages using store and forward technology. With this feature, vast and remote areas difficult to access or areas with extremely rough terrain can be covered without the need of additional repeaters, costly mast and antenna installations or an expensive network of advanced base stations.

More and more radio systems appear on the market today: everything from remote controlled gates and car locks to high capacity micro-wave links and satellite systems. This fact, of course, narrows the radio systems' operating bandwidth and raises higher demands on event triggered communication. More and more countries discard polled systems due to the continuously increasing radio traffic. Event triggered communication also enables real time aspects in distribution automation systems. Operators and intelligent sectionalizing and restoration functions demand immediate response on commands and requests. A polled system cannot meet the continuously raising demands on a rapid data radio communication.

3. AUTOMATION

The distribution automation of today utilizes auto-sectionalizing and reclosing devices which can increase the level of service when faults occur. When distribution networks are linked together through a Normally Open Point, which can be “moved” towards the fault, a minimization of the distribution loss is achieved. Normally open points are today often moved manually on site or by remote control. This is though far from an optimal use of the distribution network.

If an advanced distribution automation system is used, the urge to achieve SCADA interface and full automatic restoration after fault location in the same system will be met. The answer is a distribution automation system with built-in local intelligence, centralized database with central intelligence and an integrated digital radio communications system. When these features are combined and fully integrated within the same system, faults can automatically be isolated and the distribution network restored to minimize the distribution loss. The combination of centralized and distributed intelligence is the key to flexible and effective distribution automation systems. In its most basic configuration, automation systems can provide auto-sectionalizing based on Loss Of Voltage (LOV) in the distribution network and pre-set timers. No communications between any devices are required for operation. This operation is most suited for non-loop systems but even in more advanced operating modes, this is the backbone functionality that will handle a fault situation even during communication loss.

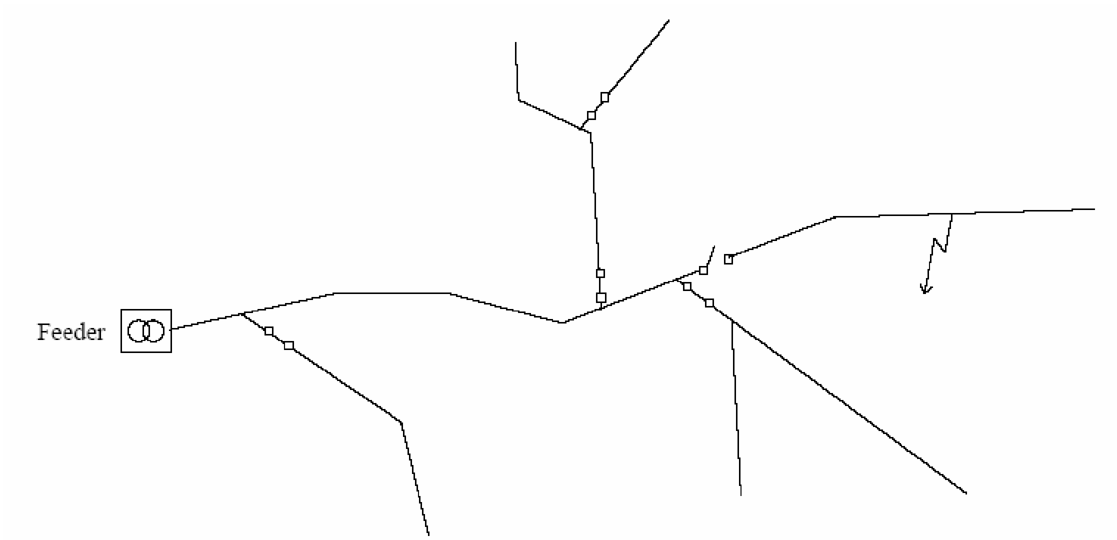

Figure 4. Fault isolation based on Loss Of Voltage (LOV) is the basic, but still efficient, method to isolate faults and in electrical distribution networks.

By integrating radio modules in the RTUs (*Radio-Terminal Units*) controlling switchgears, reclosers etc. and adding a radio network concentrator to the automation system, user control and a more intelligent performance is obtained. Integrated FPIs (*Fault Passage Indicators*) also give the opportunity to improve the sectionalizing process. The faulty section can be identified during the first LOV and no extra reclosing of the feeder circuit breaker is needed. Together, intelligent RTUs, directional sensitive FPIs and a powerful communication media bring distribution automation one step further into the future. With the early knowledge of fault location, the concentrator remotely isolates it by opening suitable switches. The intelligent restoration process then begins and feeds downstream sections from alternative feeders. The concentrator’s primary purpose is to provide a SCADA interface which gives the user full control over the distribution networks as well as the transmission networks and the substations. Using the distributed intelligence, making auto-sectionalizing and fault isolation possible, SCADA-operators only have to be concerned about the networks’ condition and make decisions about further action after the automation sequence is completed. In complex networks manual intervention in the automation functions should be as low as possible. Radio RTUs with built-in intelligence accompanied by the concentrator (and SCADA) also make it possible to achieve intelligent auto-restoration functionality. In a loop network, for example, this increases the level of service by isolating any permanent fault to the smallest line section possible.

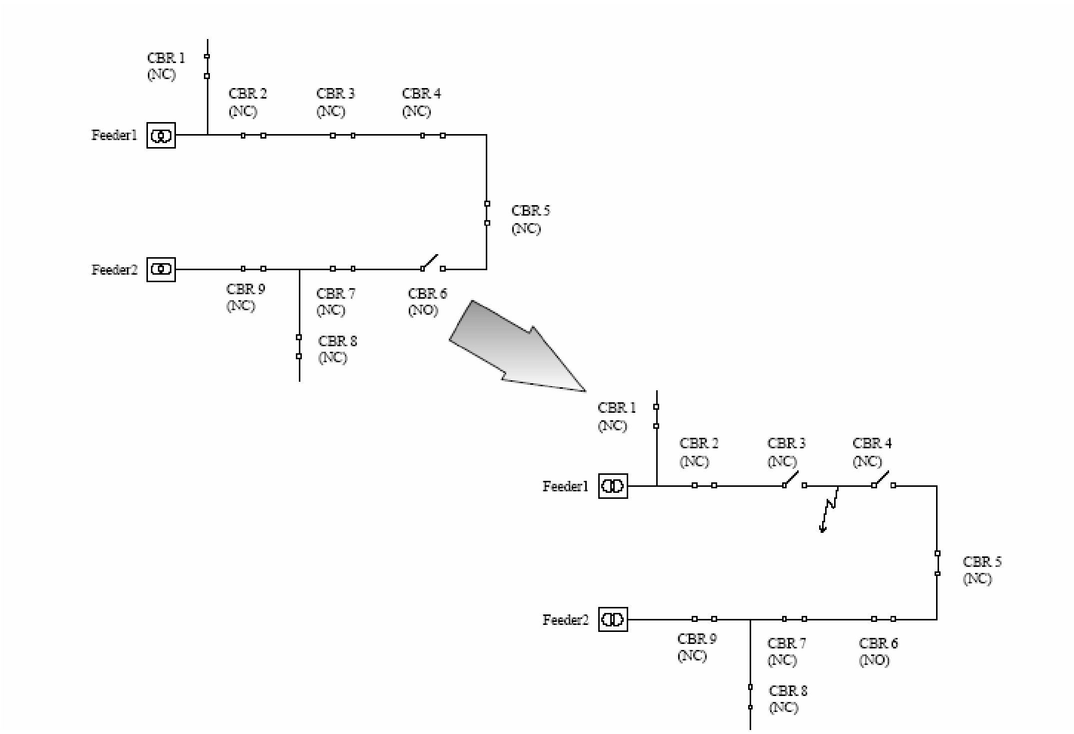

Figure 5. A loop auto-sectionalizing and network restoration sequence without the intervening by a SCADA operator.

To accomplish the most efficient restoration, it is vital to have complete information about the distribution network structure. All such network data should be configured in the concentrator which handles the restoration process. By using the concentrator as the central unit for this information, maintenance, network expansion and alteration, are hereby made easier. A stand alone system can for instance be upgraded to an auto-restoration system by just adding and configuring a concentrator, still no need for a SCADA system. It is of vital importance SCADA is used for its basic purposes. As far as possible, sectionalizing and restoration functions should therefore be integrated independently from the SCADA and not intervene with and slow down SCADA functions. The intelligent restoration sequence can use information about the load for the restoration to protect alternative feeders from exceeding its maximum load. This information can be configured as typical values in the concentrator or, based on actual readings in the distribution network if this has the necessary equipment. In its most sophisticated mode, the automation system is capable of a fast location and isolation of a fault, followed by an intelligent restoration process that restores service to a maximum number of customers around a loop without subjecting otherwise unaffected customers to interruptions from closing into faults. At the same time, the automation system offers simple system expansion and reconfiguration due to the centralized control in the concentrator.

SUMMARY

To meet the ever increasing demands on the electrical distribution where even the shortest outages involves everything from irate householders to big industries' production losses, modern communication systems are required to provide a base for improved monitoring and management all the way down in the hierarchy of the distribution network. To meet the requirements, both the communication system and the automation system should be fully integrated and from the start thoroughly designed to interact. If not, compromises regarding functionality, speed and safety inevitably have to be done. Control, monitoring, automation and communication functions shall be fully integrated and designed together to interact as one single powerful unit.

The choice of communication media is often regarded as a matter of second importance but is in reality perhaps one of the most important issues. One of the most suitable communication solutions for distribution automation is low power digital radio networks. They give the speed and safety required, still being extremely competitive when it comes to financial as well as operational benefits.

Public radio networks like GSM and TETRA unfortunately have several disadvantages regarding data transmission. Except from the fact that they are rather expensive, all public radio networks lack the speed needed for efficient distribution automation.

Public radio networks offer good coverage in densely populated areas but not in sparse remote regions which are of interest in distribution networks. Traditional analogue voice communication systems (e.g. trunked radio could theoretically be used but these systems are designed for voice communication only and not for data transfer. The possibilities to build in intelligent functions and/or complex and effective communication networks are very limited.

To attain effective and secure communication, an integrated protocol is of vital importance. High level SCADA protocols, for example, are not suitable to use on all levels in a transmission- and DA-network due to the fact that these protocols among other features contains long overhead sequences, large data flows and irrelevant data transfer. Except from being slow and ineffective, the data transfer also becomes sensitive to noise and other disturbances. The protocol shall be designed for the amounts of data, effective re-transmission functionality time requirements etc.

By integrating digital radio modules in the RTUs controlling switchgears, reclosers etc. and adding a radio network concentrator to the automation system, user control and a more intelligent sectionalizing and reclosing performance is obtained. Integrated Fault Passage Indicators (FPIs) further improve the automation process.

Sectionalizing and reclosing equipment equipped with intelligent RTUs using an effective and powerful digital radio as communication media will bring distribution automation one step further into the future.