INTRODUCTION

Distribution Automation is increasingly being introduced by Croatian distribution utilities in order to be prepared for the forthcoming process of energy market opening in Croatia.

First, we have tried to define a term “Distribution Automation” that is often related only to MV network remote monitoring and control. Distribution Automation comprises a number of functions, as shown in the paper that should help distribution utility to survive in the deregulated environment.

Furthermore, paper gives an overview of applied technical solutions (most of them are systems developed by domestic companies) in the field of MV network remote monitoring and control as well as the perspectives of Distribution Automation in Croatia.

Also, new solutions for measuring current and voltage are presented – sensor technology, which in practice rules out conventional instrument transformers because of their large size and higher costs. Due to their characteristics, current and voltage sensors become the standard equipment in MV switchgear automation process.

The communication system, selected for data transmission, has a direct bearing on the success of a Distribution Automation project. This part of the paper reviews the types of communication systems suitable for MV network remote monitoring and control as seen from distribution utilities in Croatia.

DISTRIBUTION AUTOMATION DEFINITION

Many distribution utilities tend to view both Supervisory Control and Data Acquisition (SCADA) and Distribution Automation (DA) systems only as remote control and status indication tools. DA does more than that. On Fig.1, we can see five main Distribution Automation function groups and related functions.

Distribution utilities must shift their focus from conservative “reliability at all costs” emphasis to a more efficient and economic emphasis. That means that future decisions or calculations regarding investments should be based on both technical and economic studies. Therefore, additional “filter” in assessing DA function process is cost-benefit analysis that should be done resulting with DA functions that should be adopted by distribution utility. Therefore, Distribution Automation is not only technical issue, rather commercial approach – valuing what to do, where and in what scope.

This paper deals just with the MV network monitoring and control with the special review of technical solutions applied in Croatia. We must say that MV automation level (there we are referring to automation architecture, not number of switchgear remotely controlled) in Croatia is low due to the fact that all decisions regarding any interventions are left to operator(s) in control center(s).

In the next chapter, we have tried to present some technical solutions applied in Croatia, related to MV network monitoring and control. Primary and secondary equipment are stressed.
Here, we are talking about pole mounted switch disconnectors or pole mounted switchgears remote monitoring and control. On Fig.2, conventional system is shown, with the classic switch disconnector connected with the drive motor (in cubicle down the pole) with the lever.

Recently, new generation of pole mounted switch disconnectors (Fig.3) has become very popular. They made overhead network remote control systems more efficient and reliable in terms of installation and maintenance. Price and characteristics listed below; practically roles out “conventional” systems with the conventional disconector and related systems:

- The sealed enclosure eliminates risks from environmental hazards and increases the reliability of electrical distribution systems,
- the enclosure of stainless steal is hermetically sealed and corrosion resistant,
- Motor drive, for switch remote control, is mounted directly on switch axle,
- The switch inside the sealed tank in an inert SF₆ gas atmosphere is insensitive to outside pressure changes.
Function realized:
- Fast fault detection, localization and power supply restoration
- Fast connection of alternative supply direction
Due to the price on the one hand and Croatian distribution utilities strategy regarding automation architecture on the other, reclosers and sectionalizers weren’t widely applied in Croatia.

**MV underground network**

Croatian electric utilities starting underground network automation adopt a “puzzle” principle. That means that first MV switchgear should be replaced with modern ones, which is prepared for remote monitoring and control. Than, RTU with the communication equipment comes with the supply (usually 48VDC). That is all needed for MV/LV transformer station remote monitoring and control. But problem occurs later on when, as a system extension, fault indicators have to be installed, or measuring equipment. Than we have a problems regarding available space, installation problem, etc. Manufactures have been reacting very quickly, and nowadays, trend is integration of all equipment required, that will be installed now or later on, in compact switchgear or at least we have situation where primary and secondary equipment are in separate cubicles. (Fig.4).

**Secondary equipment**

Systems explained are based on the following secondary equipment:
- Compact RTU’s (shown on Fig. 5.) developed by domestic company with following characteristics:
  - MICRO RTU DSR 100 (pole disconnectors): 8DI, 1DO, 6AI, special algorithms, “store and forward”, RS232 interface, IEC 101 protocol
  - MINI RTU DSSN 200 (other MV switchgears): 64DI, 8AI, 16DO, “store and forward”, RS 232 interface, IEC 101 protocol
- Power supply: 24VDC (pole switch disconnectors) or 48VDC (MV/LV transformer stations), batteries with charger AC/DC.
- Communication equipment: as explained in last chapter
- Fault detector KonLOK 100 for overhead MV network as a part of mentioned systems or mounted as a self-standing unit powered by solar sells.
- Fault detector KI 20 for underground MV network

**SENSOR TECHNOLOGY – NEW MEASUREMENT TECHNOLOGY**

Real time analogue voltages and currents are required to achieve most effective DA schemes. Conventional current and voltage transformers are not the best solution for application in MV switchgears. The main force in the development of new measurement technology based on current and voltage sensors (Fig. 6.), has been need to standardize and optimize the MV switchgear design and manufacturing.

The current sensors are based on the Rogowski coil in which the iron coil has been replaced by non-magnetic material. The measuring principle for voltage measurement is based on a resistive or capacitive voltage divider, which results in a wide dynamic range and high linearity. Of course, mentioned principles are well known, but sensors as new measuring equipment have become technically feasible due to the introduction of microprocessors in the secondary equipment. Equipment that can use the required accurate low signals received from a sensor has been available on the market for some years.
Technology summary:

- One of the long-term trends in MV switchgear design has been towards smaller size. In conventional switchgear, current transformer (CT) and voltage transformer (VT) takes a significant part of the total volume of the cubicle. The volume of the sensors is less than 1/3 of the volume of the conventional transformer.

- Another trend in the switchgear industry is aim for shorter delivery times. Here the complicated logistics of conventional CT’s and VT’s is a major problem. To specify transformer, lot of information must be known (load current, secondary burdens, accuracy classes). Result is a transformer manufactured individually, according to order. The new sensors, on the other hand, have a very wide linearity range. The result is, that for rated currents 40…1250A, and for rated voltages 7,2….24kV only one model is needed.

- The nonlinearity of magnetic cores in the CT’s and VT’s sets inevitable physical limitations on the measurement range and accuracy. Therefore, these novel sensors give benefits that are not achievable with conventional technologies like:
  - large measuring range and high accuracy
  - integration of protection and measurement functions using the same sensors for both.

- The sensors have a positive impact on the reliability of switchgear. Risk of damage by human error is reduced by the use of the sensors due to the:
  - easy installation
  - no direct damage caused by incorrect wiring
  - small output voltages
  - safe opening and short-circuiting of the sensor secondary circuits possible without over voltages and overheating

As a conclusion it can be said that, Croatian distribution utilities have recognized sensors together with modern protection and control RTU’s as a safe and cost-effective solution that will support MV switchgears automation process.

COMMUNICATION SYSTEMS FOR MV NETWORK REMOTE CONTROL – CROATIAN CASE

The communication system, selected for data transmission, has a direct bearing on the success of a distribution automation project. This part of the paper reviews the types of communication systems suitable for MV network remote monitoring and control. But before that, we should take a look on some basic facts:

- Number of transformer stations or pole switch disconnectors to be remotely controlled is relatively very high,
- Transformer stations or pole switch disconnectors are very disperse, geographically speaking,
- Data transfer should be safe and reliable

Here are the most common communication options available:

- Telephone lines - owned
  Very reliable media. Exploitation costs for this type are the least, but it could be applied only if cable, used for other utility needs, passes near switchgear to be remotely controlled. Obviously, it is suitable only for automation of the network in the town.

- Telephone lines - leased
  Same as above, but in the cases of line fault or damage, utility doesn't have impact on repair time. In addition, leasing price isn't really acceptable, especially in the town area. This type of media (owned or leased) is definitely not suitable for urban network automation.

- Fiber-Optics
  Optics system provides the highest quality transmission, and transport extremely large amounts of information. Being made of glass, the fiber cable is non-conduction, and is not susceptible to noise or ground potential problems. However, the question is whether are these characteristics really needed for MV switchgears automation. In addition, the price of terminal equipment (installation cost) is still very high and it may take some time before utilities will start using fiber optic links installed along the MV distribution network.

- Wireless - GSM, GPRS
  Implementation is very simple: you buy terminal devices and make a contract with the provider. These solutions did not meet expectations (Croatia case) due to the limited coverage (mostly in urban areas), unavailability during disturbances, still high monthly fees and service unavailability. Maybe, situation would be different with more competition on the field.

- DLC (Distribution Line Carrier)
  DLC system injects a low frequency radio signal over the distribution lines. Field devices are coupled to the conductors to receive communications from the SCADA master station. Communication cannot be maintained while a disturbance, such a damaged poles or broken power lines, is in progress in the distribution network. Technical and reliability problems limit these systems.
- Conventional radio systems

Dedicated conventional radio systems, based on licensed channels, are very suitable for Distribution Automation. If the system is properly designed, these channels are available when needed.

However, many countries suffer from the shortage of available frequencies in the VHF/UHF bands, forcing utilities to use the same frequencies for both voice and data transmission. In this case possibility of constant interference between voice and data transmission is very high. Still, this solution is acceptable but only if number of stations to be controlled is not high and if it's a just temporary solution till utility builds up a radio system just for a data transmission. This is probably the best choice, not because of it's technical characteristics (although they are acceptable), but techno-economic ones. It has high flexibility, simple expansion and acceptable price. Practical experiences with this system in Croatia are very good. In order to achieve optimal coverage, telemetric equipment, installed in MV network, should be able to perform "store and forward" function with rules out additional costs due to the repeaters installation costs.

Communication systems summary

As we can see from the previous chapter, most communication system has at least one very "bad" characteristic that other positive one can't compensate. Those systems can be practically applied only if there are some special demands on technical characteristics possessed by one, and as a temporary solution. So, it is obvious that authors suggest radio system (built just for data transmission) as an optimal solution. It is must especially on the locations in the areas where wireless and fiber links are unavailable or not viable. Someone think that a communication response achieved using radio system is poor. Although fast response (update on the operator's screen) is always desirable, it is important to remember that performing functions, such as isolating a damaged portion of the network and restoring the power, can be done even after a delay of several seconds or even minutes. Using radio for these applications is therefore acceptable.

However, in distribution utilities in Croatia communication systems for data transmission participate in DA processes as follows:

- Conventional radio systems (UHF band) built just for data transmission - 60%
- Conventional radio systems (VHF band) used for both data transmission and voice communic. -30 %
- Telephone lines, owned - 3%
- Fiber-Optic - 4 %
- Digital radio systems (TETRA standard) - 3 %

CONCLUSION

In the paper we have presented first phase of Distribution Automation process started in Croatian utilities that included as follows:

- Distribution Automation definition – step by step approach,
- Automation architecture selection,
- Communication system selection,
- Selection of important points/switchgears in MV network to be remotely controlled,
- Selection of technical solutions/systems for remote monitoring and control,
- Modern technology adoption (new generation of primary equipment and sensor technology).

Experiences gain through first phase were great and they will be a drivers for second phase that should include:
- More MV switchgears and pole switch disconnectors remotely controled
- Main distribution control centers replacement (old SCADA systems) or upgrade with DMS functions,
- Structural preparation for market opening.

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