CABLING OF RURAL NETWORKS – FROM VISION TO PRACTICE

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ABSTRACT

Increasing reliability of rural distribution networks has been key driver in Finland for several years. Lot of distribution automation investments has been carried out in order to improve the existing networks and reliability analysis tool has been developed and taken into use in order to study the effect of investments beforehand. Vattenfall Finland has taken a new step by deciding to use cabling as the only network construction also in MV-level in rural area. After that, the focus in the research and development is in developing cable network more cost efficient and reliable. Examples of such work are development of cabling in rocky soil and condition monitoring of cable network.

INTRODUCTION

The development of power distribution is quite challenging nowadays in Finland as well as in other Nordic countries. The ageing of existing networks force to big investments during coming years. The primary network solutions used nowadays are partially old-fashioned and should not be used in coming re-investments. Aging of existing network, increased quality requirements and the threat of major disturbances due to storms are the key drivers to be taken into account in network planning. Due to the fact that reliability is today part of economic regulation via outage costs, optimization of quality of supply is important part of business planning.

In Finland, extensive research and development work has been carried out in order to improve the reliability of supply. On the other hand this has meant development of new planning methods and on the other hand developing of new technology [1, 2].

In Sweden the major disturbances led to situation that cabling was more or less ordered by law, which can be seen as good solution from reliability point of view but not necessarily from business point of view [3].

In Finland the development has been slightly different. The major disturbances in 2001 led to standard compensations as well as to regulation model in which customer outage costs are part of business. This has been the base for the optimization studies, which has been carried out during past years. One result of the studies has been such that by using the existing reference cabling cost as an input in the studies cabling in MV-level is not beneficial in rural areas. In order to be beneficial the cabling cost should be remarkable lower than the reference value. It should be noticed that the reference value was based on the history in which there was no rural cabling. Furthermore the vulnerability of overhead lines to major disturbances is not typically taken into account in the studies.

In Vattenfall Finland a big investment program to improve distribution reliability was carried out during years 2006-2010 [2]. The investments included:

- network circuit breakers
- new remote controlled disconnectors
- modular substations
- centralized Petersen coils
- Improved animal and over voltage protection

As part of the development process using reliability analysis tool was established. By using the tool the effect of the investments to reliability could be analyzed beforehand, which means very cost effective reliability improvement [2].

Another side of improvement dealt with customer communication in fault situations including [4]:

- sharing fault information in web service
- fault information as SMS-messages
- AMR-based fault indication for low voltage network

A special step in the strategic reliability-driven development was publication of commitment that outage time shall not exceed 6 hours. For customers that meant compensation in the case of longer outages.

As part of the reliability improvement a new idea was arisen some years ago. The idea was to study, weather it were beneficial to change the paradigm: Would it be reasonable to build all the rural networks (including MV) as cable. There were couple of pilot project during 2006-2008 in order to develop the cabling methods and in order to find out if it would be reasonable decision. The atmosphere were optimistic, because during the piloting phase (2007) it was decided that all the MV/LV substations will be pad mounted and all the LV networks should be cabled. This can be seen as predictive decision along the way to full cable network.

After successful piloting phase the company was ready to big decision: In 2009 Vattenfall Finland published a decision that from now on cabling is the primary network construction method in MV level also in rural areas. After that decision there is no need to study case by case is ti beneficial to use cable or not, but use the planning resource to optimize the order of network renovation.

Another important factor which provided good basis for the decision is the existence of service market to be used in network construction. In Vattenfall Finland network construction has been outsourced several years ago, which means that there is nowadays established service market available to be used also in cabling.

During the development process the cooperation between Vattenfall and Tampere University of Technology has been quite active. For example, the development of reliability analysis tool and cable installation testing are based on the cooperation [2, 5].

The next chapter presents briefly the principles how rural cabling is carried out today in Vattenfall. After that examples of research and development tasks are presented: Cabling in rocky soil and condition monitoring of cable networks.

CABLING TODAY

Based on the development process and strategic decision presented above the current practice in Vattenfall Finland is nowadays using cable in MV-level also in rural areas. The cabling is based on the following principles:

- the number of used cable types is limited in order to have benefit on big volumes
- the standard cable is suitable for ploughing, but not for using in poles
- all the installation work and today also field planning is done by construction companies, which have quite free hands to develop the working methods
- network construction is made quite big projects, which gives good basis for service market
- the installation and commissioning testing procedure is well defined in order to ensure the quality of installations
- in the case of rocky soil, concrete is used instead of blasting (putting cable in poles is sometimes used)
- decentralized earth fault compensation is used in cable network in parallel with centralized

Using the above principles the cost level is reasonable. The experience on the reliability is so far limited, because there is only a few hundreds of kilometres new cable network so far. However, there is continuous process to evaluate the existing methods and improve the whole concept as well as reduce the total lifetime costs.

CABLING IN ROCKY SOIL

The existing solutions used in the case of rocky soil are expensive. The primary method today is using concrete, which is in line with the standard [6, 7]. Putting cable in poles increases costs because it requires poles and special cable. However there is not exact standard for the working methods and quality of concrete. Thus civil engineering department of TUT was asked to participate in the research work. The following questions were arisen to be studied:

- How good solution using concrete is from the whole life cycle point of view?
- How concrete exploiting methods can be developed?
- Are there any new alternatives to be used instead of concrete?

Today cable installation has been done by laying cable on rock surface and a half pipe shelter on it. The final product is finished by a concrete layer without any steel reinforcements or anchors. Before the cable installation the rock surface is cleared and base trimmed and filled by excavator. The final product is seen on figure 1. Desirable life cycle for structures is 50 years but there is no reference on this kind of installation. The oldest installations are only some years old and there are worries about sustainability of this type of cabling shelter structure.

Figure 1. Cable shelter structure on the rock surface.

The biggest worries consider concretes durability because it is dependent of the concrete mix and methods of work. In addition there is an open slot between the concrete layer and the rock surface, because the concrete cracks easily by external loads. These external loads can occur for example from forestry machinery, excavator, ATVs, snowmobiles and animals. Fracturing of the structure can be significantly reduced by steel reinforcement. That causes challenges to cover installation on the rock surface. Nowadays best know structure is cable with shelter pipe or channel and reinforced concrete casting. The casting process results in material loss, which increases the cost because the concrete casting is one of the main cost components of this installation technique.

Development possibilities

Nowadays concrete cover structure is problematic. It is just a lump of concrete on top of the cable. Therefore, one cannot be sure about this cable shelters lifecycle. The cable shelter needs some reinforcements, anchoring and a right concrete mix to achieve the intended 50 years lifecycle.

Reducing the usage of concrete has the best influence on the cost. The current cost of concrete shelter defines the cost limits to the other methods. This can be done by using the cable molding system. It´s benefits are fast installation, little material usage and strong cover structure, but it however requires development. Another method of reducing the concrete usage is using a stiffer concrete mix because it would not slip away from the top of the cable. However, this is difficult to assess because each cast section is a unique and concrete mix will behave little differently in every situation. Clarifying this matter would require field test by various concrete mix.

The quality of the current cable shelter structure on rock is highly dependent on the contractor which installs the cable. Contractors do not have enough information to construct concrete shelter on rock surface and they would need additional guidance.

Alternative solutions

As one potential alternative to concrete is rock cutting. In Finland there is at least one contractor which is capable to do soil trenching. The machine is very rough. It weighs about 30 tons. However, it is showed that this kind of machines can not cut Finnish rock because of hardness of the rock material. In practice use of rip or break techniques is almost impossible if not fractured and loosened with drilling and blasting, which is rather expensive. It is also possible to use diamond cutters to loosen the rock surface, but it is also expensive.

Due to the fact that excavating bedrock is difficult or impossible, the installation right on top of the surface of the rock is preferred. The main emphasis must be on coming up with a feasible and economical concrete casting solution. Hence the two main routes of future research should consider developing a suitable molding system and regulating the concrete mix fluidity.

Figure 2. Trencher excavates frozen soil fast, but it cannot cut Finnish granite rock surface.

CONDITION MONITORING

Extensive cabling increases the need for effective preventive maintenance. This can only be realized when reliable information about the current condition of the cable system is available. The key factors on producing this kind of information are the measurements conducted in cable system. With preventive maintenance outage costs can be reduced and on the other hand condition information can be used to optimize the life time of a cable system, thus minimizing the total life time costs. Five different stages can be separated from the life cycle of a cable system: construction, commissioning test, operation, faults and end of life. In figure 1 cable system life cycle management process with its main tasks on each stage is proposed. This should be constantly progressing process and feedback from other stages should be used in the first stage to construct even more reliable and cost effective systems.

Today, Vattenfall installs only third generation XLPE insulated cables. With these cables it is assumed that water treeing is not as much of a problem as before. It is noticed that the most fault prone parts in new cable systems are joints and terminations. Partial discharge measurements can detect deteriorated joints and terminations which makes it an attractive tool for condition monitoring of cable systems. Other benefits of partial discharge measurements are the fact that when conducted correctly it causes no further deterioration and the measurement can also be done on-line, in the best case without any interruption. Other possible measurements are dielectric response measurements for instance tan δ measurements.

When applied correctly partial discharge detection is a well-known and proven way to detect weak spots in the insulation material of high-voltage equipment. It should be noted that accurate evaluation of remaining life time is not possible with these measurements. Off-line partial discharge measurements in cable systems have already proven their efficiency but they are expensive and laborious. On-line partial discharge detection and location systems for medium voltage cables have been commercially available for only few years. HVPD Ltd and KEMA Nederland B.V. are some of the pioneers in this field. Promising results about the capabilities of these measurement systems have been published by both organizations [8, 9]. But more information is still needed to reveal the true capability of this new technology and how to use it effectively. Continuous on-line partial discharge monitoring of cable systems is likely to increase in future once the technology is fully developed and has become cost effective.

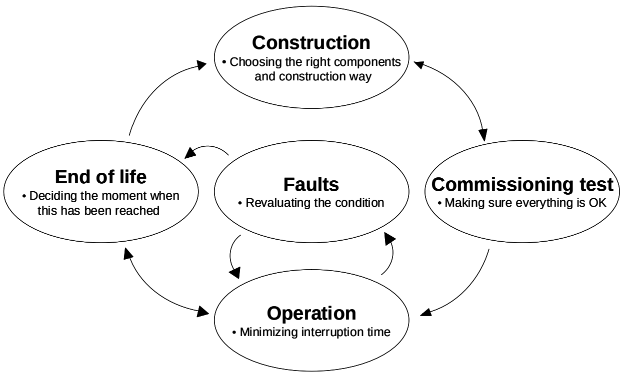

Figure 1. Cable system life cycle management process

Partial discharge measurements could be used in every stage of cable system life cycle. At construction stage it is important to use only cables that have passed partial discharge tests after manufacturing. In commissioning test an off-line partial discharge measurement is recommended. During cable operation interruption time can be minimized with the help of continuous and periodic on-line partial discharge measurements. When fault occurs this opens the possibility for off-line partial discharge measurements which are also beneficial in deciding when a cable system has reached its end of life stage.

Dielectric response measurements could be used in three stages: commissioning test, faults and end of life. In commissioning test measurement base value is obtained and later measurements can be compared to this. These measurements can be used to help making the decision when the cable system has reached its end of life.

The main objective of ongoing research and development is to find answers on questions:

- what should be measured in commissioning test to improve the quality control of joints and terminations
- how on-line partial discharge measurements can be used most effectively (periodic or continuous depending on the priority of cable)
- how the measurements should be done in practice (including sensors and data management) and what kinds of limitations there are
- to develop the condition monitoring data management (including the commissioning tests and other condition related data sources)

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