IMPROVEMENT OF THE SUPPLY QUALITY BY INTRODUCTION OF A NEW CONCEPT FOR MODULIZED DISTRIBUTION NETWORKS IN RURAL AREAS OF SWEDEN

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ABSTRACT

In connection with a large-scale program for improvement of supply security, new technology has been developed and will be introduced. The technology, which is adapted for rural areas, will be built in modules and consist of simple and straightforward technical solutions reducing the number of components to a minimum. Cable technology will secure for low failure rate due to external impact. The approach has also lead to new technical phenomenon that has been dealt with accordingly, e.g. compensation of capacitive ground currents. The approach will also lead to improvement of personnel safety and lower maintenance need.

INTRODUCTION

The demands and expectations on electricity supply security from the society and customers on better supply quality, has accelerated during the last years and increased faster than the improvement of the electricity network. The distribution systems (10-20 kV) in rural areas have mostly consisted of overhead lines, which means that the network is exposed to weather related disturbances. Typically disturbances are from storms and snow that results in trees falling over the lines.

Therefore a large-scale project has been launched to refurbish the entire distribution system (10-20 kV). The major approach is to make the system weather robust by replacing overhead lines by underground cables. To some extent also other technique will be used.

The conversion to a ground cable network in combination with substation modules will also improve the working environment and security for the field personnel. Fieldwork for fault location and repair during hard weather condition will be reduced significantly.

The personnel safety will be improved by connection of cables directly to the apparatus by insulated plug in connections. The network stations are built as modules, which simplify the work in field. The entire network station module (10/0,4 kV) will easily be replacing during a possible fault.

In view of the actual conditions (legislation, ground conditions, system design etc), certain attention has been paid for the compensation for earth fault currents. Hence, a new technical design has been developed in cooperation with manufacturers.

The design of the simple and straightforward future power distribution network in the rural parts of Sweden will result in less maintenance, simplified network structure, new modular technique and less use of resources. Though the investment cost may be higher than for a conventional overhead line system, the overall cost over time taking all aspects into account will be on the same level or lower.

DRIVING FORCES, OVERALL PHILOSOPHY

The MV-systems in rural areas have historically been built as overhead lines, typically with a large share of line routings in forest areas.

At the time for erection of the existing MV-system, the power industry was organised in a great number of smaller utilities with local establishment. Later on the power industry has gradually been reorganised to lager utilities and centralised locations. The overall organisation has also been rationalised. In certain parts of the network this has led to longer access time for fault repair.

More important, however, are the customer's increasing-, and changing demand on electricity. The use of electricity changes in character: e.g. of more computerized systems and equipment in the society, small companies and private sector as well.

The aspects above have led to a gap between expected and actual quality level and has also been the main trigger for launching a large-scale program for rehabilitation of the MV-system. The fault statistics and target level is illustrated in figure 1.

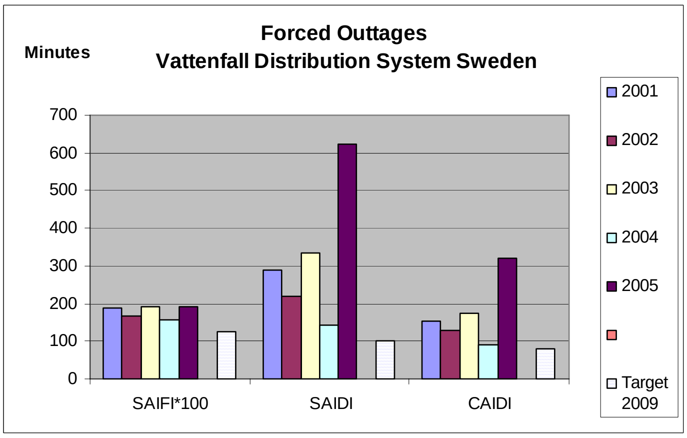

Figure 1. Fault statistics and target 2009

There is also a focus in media on power supply security,

leading to a well-pronounced awareness among all customers. Hence, also non-affected customers are well aware of the shortage in supply security, which leads to bad reputation also among non-affected customers.
The repair work following a big storm often means hard filed work involving large amount of service personnel simultaneously.
The cost for maintenance and repair is fairly high and should be possible to affect by new technology.
The aspects mentioned above can be summarized in the following driving forces for the implementation of a new concept:

- Unacceptable supply security due to weather related disturbances
- Increasing and changing customer demand
- High repair and maintenance cost
- Focus in media affecting brand mark
- Hard and bad field work environment
- New technique is available

DESCRIPTION OF THE SYSTEM

Network topology

The distribution network should be built in a simple (non-complicated) manner with as few components as possible in order to reach in high availability and low costs. Basically there are three kinds of modules, namely *transformer-, switch-, and branch module.* To allow for compensation of ground fault currents there is a variant of the transformer module including a Petersen-coil.

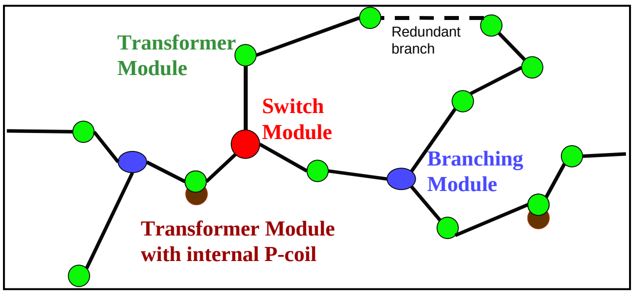

Figure 2. Topology of a distribution system

The branches in between the modules should typically be performed as ground cables, giving low failure rate.Normally, the rural distribution grids are radial. However, for certain sections it may be preferable to arrange for redundant feeding during fault conditions (see figure 2.)

Equipment and Modules

Transformer module (Substation)
The transformer module includes a transformer and a cable cabinet in one unit. The transformer has internal fuses on the MV-side and three phase disconnection for internal faults and flashover in low voltage winding to ground. The MV fuses and the isolating circuit breaker are enclosed within the transformer. The cables are connected with touch-proof connectors. Some of the transformer modules conclude P-coil enclosed in transformer tank. The transformer module is mounted on a concrete plate or concrete foundation. That allows for fast and simple installation and removal by one man and truck-mounted mobile crane.

Figure 3. Transformer module (with or without internal P-coil)

Switching/ coupling modul
In a similar manner as the other modules, the switch module is compact, has touch-proof parts and it is easy to install and operate.
Functionally, the switch module should have the ability to open and close on load current, which will allow for reconnection in the grid during normal operation. The device should be possible for manual operation in field and with the option for remote control in certain specific locations.

Figure 4. Switching/coupling module.

Branching module

The branching module consists of a touch-proof cable cabinet (630 A, 12-24 kV) and is used to connect three branches. The cable connectors are touch-proof and are equipped with a capacitive test point (voltage test). The modules also include the possibility for grounding and easy disconnection of a branch.

Figure 5. Branching module

Cable

The cost of laying cables is a big part of the total investment cost, which calls for cost-effective techniques laying techniques. The cable should have an appropriate design to withstand tough installation conditions in air, ground or water. The cable should be easy to bend and particularly suitable for installation by plough, which is a less expensive method.

Figure 6. Double PE-sheathed cable.

Protection and fault clearance

A special concern has been to achieve proper functionality regarding ground faults. The Swedish legislation put certain requirements on maximum ground-fault currents and touch voltages. The comprehensive use of ground cable in the rural distribution network leads to increased problems related to ground fault currents, especially for mixed networks comprising both cable and overhead lines. In order to secure for proper selectivity and sensitivity for ground faults, analyses have shown it necessary to compensate for the capacitive currents locally in the network. Hence, there should be a combination of compensation devices placed in feeding station and locally in the 10/0,4 stations as well. In order to give proper performance, the compensation devices have to fulfil certain electrical requirements such as low ratio $[R/X]$ and linear voltage-current characteristic. The specified requirements have been verified by type test.

The distributed Petersen coil (in the 10/0,4 kV station) is enclosed in the transformer tank, which is part of the Transformer Module.

The transformer Module is equipped with fuses on the low voltage side to protect for transformer overload and for clearance of external faults and. There are also fuses on the MV side with the task to disconnect internal faults in the transformer. These fuses are located in the transformer tank. Any possible faults in the MV system will be disconnected entirely from the feeding station.

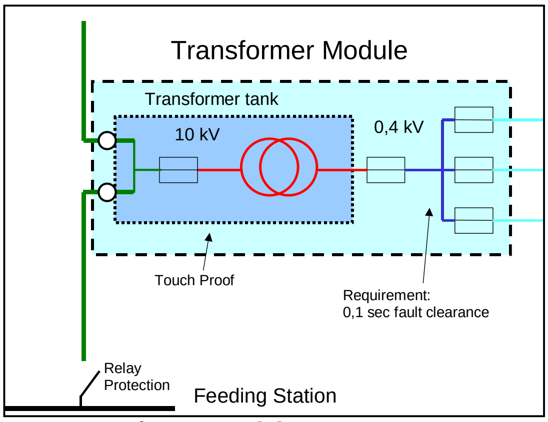

Fig 7. Transformer Module, protection arrangement

ECONOMY

For a certain distribution network, different network schemes have been compared and evaluated by means of LCC (Life Cycle Cost) analysis.

The studied alternatives are:

A. Existing overhead power lines
B. Covered conductors overhead line (BLL)
C. Ground cable and traditional technique
D. Ground cable and traditional technique (variant with no disconnecting switch)
E. Ground cable and new technique and with the today's price.
F. Ground cable and new technique and with future cable prize.

The economic analysis shows that cable network is beneficial given that the *customer costs* are considered. The possible use of the new substation technique will not significantly affect the overall economy. However, in the analysis it has been conservatively assumed that the cost for the new substations technique is equal to conventional technique. In view of the simplified approach in the new technique there are reasons to assume there is a significant potential for cost reductions of the modular components when competition improves. (Disturbance cost refers to direct costs for the network owner, whereas customer costs refer to the costs for the customer.)

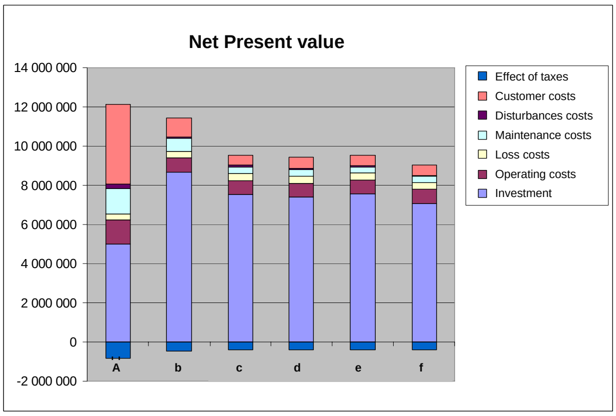

Figure 8. Life cycle cost analysis.

The technical concept described also brings other benefits. The module approach with less number of components will reduce the maintenance need through longer inspection intervals and less number of remarks after inspections, see figure 8.

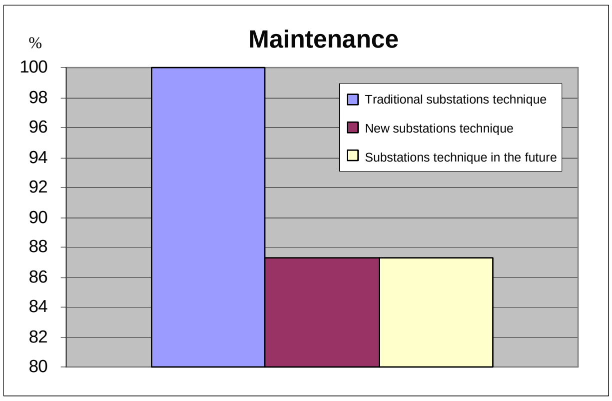

Figure 9. Maintenance.

The less number of components and straightforward technique will lead to fewer substation faults and higher availability. Also the personnel safety (own personnel and third person) will be substantially improved.

OPERATION

The described system requires almost no measures during operation. The actions to be taken are following a possible fault. The Branching- and Switch Modules plays a central role for fast location of the fault as well as limiting the consequence of a fault to as few customers as possible.
Repair of a possible Transformer fault is performed by simply replacement of the Transformer Module. The replacement is an easy and fast procedure thanks to standardised snap-on connections, non-complicated mechanical mounting on concrete foundation and the use of standard mobile mounted crane.
In spite of the design with touch proof connectors, a special tool will be used to snap off and on the cable connectors in order to even more improve the personnel safety.

PILOT INSTALLATIONS

Two pilot projects have been launched in an early stage in order to gradually develop the concept and test the theoretical approach. Two different manufacturers are involved, one for each project. The projects are of the same size and include about 25 substations each. The experiences have been very good so far.
There have been no problems regarding the substation and modular technique. Thanks to the conversion from overhead line to cable network the availability has been improved substantially (from SAIDI 1400 minutes to 70 minutes in one of the projects).

One of the projects is referred to as Värmlandsnäs, see figure 10.

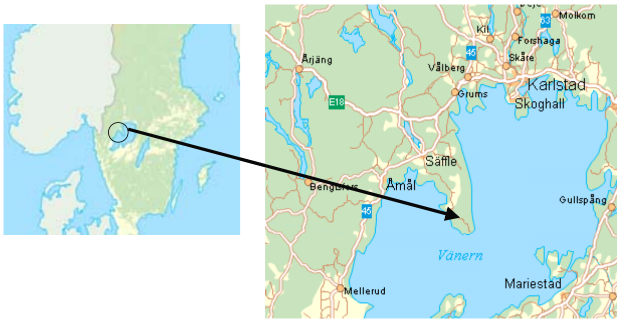

Figure 10. Location of the Värmlandsnäs pilot project.

Overhead cable has been used in a small part of the project due to rocky terrain. An existing overhead line with isolated conductors (BLL) has been kept in order to demonstrate mixed networks, e.g. concerning grounding arrangements and overvoltages from lightning.

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