SWITCHGEAR WITH ADVANCED SURGE PROTECTION IN 40 KV NETWORK

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ABSTRACT

In order to optimize future investments in the Swedish 40 kV distribution network, Vattenfall Distribution decided to investigate the possibility to lower the insulation level of substation equipment by advanced surge protection.

Historically, Vattenfall's 40 kV substations in Sweden have the rated voltage 52 kV which is a rare voltage. As equipment for 36 kV and 40.5 kV is more frequently used, Vattenfall wanted to know the possibility to use equipment for these voltages in the network and, if so, identify necessary adaptions.

Insulation studies have been performed with positive result. Substations with switchgears of new design were built and are successful in operation.

INTRODUCTION

Many of the Swedish distribution substations are old and soon in need of replacement. In Sweden, Vattenfall operates a network with rated voltage 52 kV. As this voltage is rare, it is difficult to find relevant equipment. Existing substations are mainly of outdoor design.

In beginning of the 1990s, a general study to reduce the insulation levels in the Swedish networks was performed. It was found possible to reduce the insulation level of 40 kV substations by introducing optimized surge protection. This idea has now been verified by a new study also describing necessary adaptions of switchgear and lines.

Substations with new type of switchgears have been developed, tested and delivered by two manufacturers. The costs for 40 kV switchgear and additional equipment were reduced with 30 % compared to the old design.

Figure 1: New substation delivered by ABB

INSULATION COORDINATION STUDY

In the beginning of the 1990s, Vattenfall developed the idea to reduce the insulation levels of substations for different rated voltages in a study on design of future substations: "Substation 2010" [1]. STRI (Swedish Transmission Research Institute AB) performed general studies verifying the possibility for reduction by optimizing the surge protection.

As Vattenfall Distribution now stands in front of large reinvestments of substations in the 40 kV network, the insulation coordination of substations was suggested to be updated.
More detailed studies for relevant voltage were performed by STRI. Over-voltages phase-phase, phase-earth and over open circuit breaker as well as the energy stress in surge arresters were investigated.

Normally, indoor substations are connected to overhead-lines via cables. In the calculations a cable length of 100 m between the enclosed switchgear and the line is foreseen. The highest over-voltages occur at direct lightning on the line. When the over-voltage wave enters the end of line, the voltage will be limited by flash-over at the insulators with earthed attachments. The voltage will then be reduced further when the wave hits the surge-arrester protecting the cable. The risk for insulation faults should be minimized to an acceptable level by reducing the over-voltage compared to the insulation strength of substation. The risk for faults in different parts of system was evaluated. A flash-over in the incoming part of line is locally transient, a fault in a cable is permanent until repaired and a flash-over in the switchgear is also permanent and will probably affect the whole substation. Faults in the switchgear and at cables should be avoided. An MTBF (mean time between failures) of 400 years for a permanent fault is assumed to be acceptable.

The insulation level phase-phase and phase-earth is 170 kV for rated voltage 36 kV and 185 kV for 40.5 kV. Insulation coordination studies were made without surge arresters in switchgear, with surge arresters at switchgear bus-bar and with surge arresters at the bus-bar and in the bays. It was found necessary to install surge arresters both at bus-bar and in incoming and outgoing bays to keep the over-voltages within limits. The maximal voltage between phase and earth is below the limit. However the voltage phase-phase is higher than stipulated and special requirement for earthing of the poles of incoming lines are needed. To reduce the over-voltage and strain on surge arresters, spark-gaps in the last four poles of incoming lines and an earth-wire along end of line are installed.

As a result of the study it was decided to adapt the new philosophy for switchgear in two substations.

SWITCHGEAR DEVELOPMENT

Substations with new type of 40 kV switchgears were ordered from two manufacturers in open bid, ABB and AREVA T&D (nowadays Schneider). Two different suppliers were selected to get competition in delivery.
Coincidently, the selected insulation level for 40.5 kV switchgears in China is the same as requested for the new type of switchgear. The design was also suitable for our purpose. The manufacturers therefore modified existing 40.5 kV switchgears to fit. The existing types of switchgears are manufactured in China in accordance with Chinese and IEC standards. After the switchgears were modified and surge arresters installed, they were tested in accordance with IEC 62271-200. For example new tests with internal fault (arc test) in switchgears with pressure relief channels were performed.

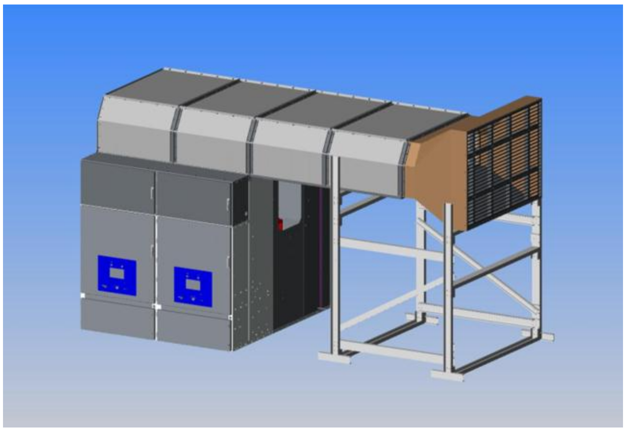

Figure 2: Equipment for IAC with pressure relief channel

An advantage of the new switchgears is the use of vacuum circuit breakers. Vattenfall has a policy to reduce the use of SF_6 when an alternative is forehand. As the highest operating voltage in the network is 46 kV, circuit breakers shall manage to break faults at this voltage. Existing vacuum breakers made for 40.5 kV were already tested in accordance with IEC 62271-100. However new breaking tests were required at 46 kV. The tests were successfully performed at KEMA. The following additional tests were done:

- Terminal fault test 100% Isc (symmetrical)
- Terminal fault test 100% Isc (assymetrical)
- Terminal fault test 60% Isc
- Terminal fault test 30% Isc
- Terminal fault test 10 % Isc
- Double earth fault test
- Short-time withstand current and peak withstand current test
- Cable charging test, class C2

INSTALLATION

After the type tests were finalized, ABB delivered switchgears from their factory in China. Schneider decided to move their manufacturing to Turkey. Three switchgears of this new type are now installed in new substations in west and mid Sweden. The installation at site was mainly without problems except that the distance for the cable connection was too small as cables were rated 52 kV and the general design of switchgear is for 40.5 kV. The distance for the cable connections was increased as the bottom of switchgear was lowered. The switchgears are successfully in operation.

Figure 3: Newly installed switchgear

SWITCHGEAR DATA

The highest data available:

Rated voltage	48 kV
Rated current	1250 A
Short circuit current.	31.5 kA, 3 sec
Internal fault, cl. IAC AFLR	31.5 kA, 1 sec.
Insulation level LIWL-PfWL	185-95 kV
“ over open disconnector	215-118 kV
Breaking capacity CB, class S2	20 kA

DEVIATION FROM STANDARD

Power installations in Sweden shall be designed and built in accordance with valid safety codes in order to be safe for person and property. One way to follow the code is to use equipment made in accordance to Swedish Standard, generally the same as relevant IEC-publication. However, deviations are allowed if the safety is verified and documented.

For this type of new switchgear there are two deviations from the standard.

For the first, the Lightning Withstand Level (LIWL) 185 kV has been selected instead of 250 kV given in the standard. Insulation coordination studies have shown that this is possible as the switchgear is well protected by surge arresters. The insulation on lines is coordinated by introducing spark-gaps on line-insulators and earth-conductors are laid along line-entrances.

Secondly, the highest voltage equipment should withstand is selected to be the highest operating voltage in Vattenfall’s 40kV network, 46 kV, instead of 52 kV given in the standard. The circuit-breakers are therefore tested for breaking at 46 kV.

COSTS

Before assignment of development project, cost for an indoor substation with the new type of switchgear were compared with cost for an outdoor substation and an indoor with gas-insulated switchgear. The cost for 46 kV switchgear plus additional costs were found to be reduced with 30 % compared to the old design. After installation the cost reduction was verified and found to be comparable.

SUMMARY AND CONCLUSION

The conclusion from insulating coordination studies is that there are good margins to reduce insulation levels by at least one step for substations rated up to 145 kV. Decision of application is based on economic conditions and the possibility to make suppliers interested.

In 2005, STRI performed a more detailed insulation coordination study for the 40 kV network verifying possibility for reduction of the insulation in substations. This makes the use of more common equipment for rated voltage 36-40.5 kV possible, instead of rare 52 kV equipment.

By open bid, two suppliers have been selected to develop a new type of indoor switchgear with optimized surge protection. The switchgears are adapted to the relevant operating voltage of 46 kV. Tests in accordance with IEC 62271 have been performed on both switchgears and circuit breakers.

New switchgears have been installed in three substations and are successfully operating. In spite of costs for additional arrangements at incoming lines, such as introduction of spark gaps and longitudinal earth conductors, the total cost is reduced with 30% for switchgear plus additional costs. An advantage is the use of vacuum circuit breakers instead of gas-insulated. Vattenfall has a general policy to avoid SF_6-gas when possible. As up to now the experience is positive general use of the new switchgear type is recommended.

Figure 4: New substation delivered by Schneider

REFERENCES

[1] F Brändström, W Lord, 2009, “The future substation – Reflection about design”, 20th CIRED, paper 0517

[2] J Lundquist, M Häger , STRI AB, 2005, Report R05-243 “Using 36-40.5 kV equipment in Vattenfall´s 40 kV stations” (only in Swedish)