A SUBSTATION CONCEPT FOR CHANGEABLE LOAD CONDITIONS

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INTRODUCTION

In this paper a new type of substation is presented. A need for faster installation and dismantling of distribution substations has been identified. Vattenfall, a Swedish utility, has developed a concept for a new type of indoor 52/24(12) kV substation, easy to install and dismantle with a minimum of work at site. Based on this concept a substation was designed in cooperation with ABB Power Technologies AB. The first substation delivered by ABB has now successfully been in operation for one and a half year and a second one is just commissioned.

The substation consists of modules that are pre-assembled and factory-tested. The station therefore demands a minimum of time at site for erection and test. Cables prepared for rapid connection connect the different modules. By bolted switchgear modules on the frame of transformer enclosure, the ground preparation for substation is minimized. An indoor substation is more reliable than an outdoor and the maintenance work is facilitated and reduced. The substation is remote operated from the dispatch centre. All advantages developed reduce the cost for distribution of power.

1. BACKGROUND

The load conditions in some parts of northern Sweden are changing. The amount of inhabitants in inland areas decreases. Young people often move from the region to more populated areas near the coast. However in some areas new mines starts and new wind power plants opens.

The existing substations are mostly old and today often wrongly placed. Therefore new substations are necessary to be built where new load appears. The optimal solution to meet the variation in load conditions is a substation easy to build.

52 kV distribution substations in Sweden are until now often of outdoor design, normally built at site. At installation a lot of fitters and testers working locally are needed. As the substation locations often are in remote areas, the staff is normally away from home for long periods. Nowadays this is not acceptable.

Until now substations often have been provided with two transformers of full capacity. One of these is normally spare for automatic connection at fault on the operating one i.e. full transformer redundancy. The cost for this redundancy is high. In the future it is suggested to use mobile substations as spare. Therefore only one transformer is foreseen in the new concept for the distribution substation.

To optimize future investments Vattenfall raised some questions:
- Can similar methods be used for building substations as for building of modern living houses i.e. use of prefabricated modules put together at site?
- How to design a substation which is easy to move when the conditions are changed?
- How to minimize the ground area for the substation?
- Can the environmental influence be reduced i.e. use of oil and SF6-gas should be minimized.
- Can costs for operation and maintenance be limited?
- Is it possible to lower the costs for administration in projects?
- How to design a substation to be well adapted to urban areas and nature?
- How to guarantee the public safety?

By answering these questions the northern region of the Swedish utility Vattenfall, (Vattenfall Eldistribution AB) developed a concept for a modularized indoor installation for 52/24(12) kV. Based on this concept a new type of distribution substation was designed in cooperation with ABB Power Technologies AB.

The first substation delivered by ABB has now being operated for one and a half year and a second one is just commissioned.
2. SUBSTATION DESCRIPTION

A new type of distribution substation, called MALTE, has been developed, easy and quick to install and dismantle. MALTE is a small 52/24(12) kV radial fed transformer station with a maximum transformer size of 12.5 MVA. Due to a cost effective design, standardization and remote control the total cost for installation has been reduced.

The space required for the substation is reduced to around 100 m², which is less than 30% compared to a conventional outdoor substation.

An indoor installation was chosen as the environmental conditions during winter in the north of Sweden are tough, with a lot of snow and temperatures down to minus 40°C. By having all electrical equipment indoor higher reliability and better work conditions for personnel are achieved. See figure 1.

As it is an indoor substation no fence is required. However the substation is strengthened to withstand possible attempt of burglary.

The substation consists of modules that are pre-assembled and factory-tested. The station therefore demands a minimum of time at site for erection and test. Cables prepared for rapid connection are used for connecting the different modules. The modules can then also be quickly replaced if a major fault occurs on high-voltage equipment.

On the secondary side the voltage can in an easy manner be changed between 24 and 12 kV. The transformer can either be supplied with a change over switch or the transformer can be exchanged. On the transformer there is an auxiliary winding of 100 kVA.

The primary side has normally only one bay equipped with a conventional circuit breaker. If there is a need of more 52 kV bays, a gas-insulated switchgear can be considered. The secondary side is normally equipped with one incoming and five outgoing panels. The circuit breakers are here of vacuum type. See Single Line diagram, figure 2.

In the secondary switchgear room are also relay and control panels and the auxiliary system located. The substation is normally unmanned and is remote controlled from a dispatch centre, from where also changing of relay settings are possible. For communication different systems, which meet the users specific operational mode, can be used, for example ABB’s PCU 400 gateway. On the neutral side the station can be equipped with a control unit for detection of high impedance fault on each outgoing MV-feeder.

3. RATINGS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum transformer power</td>
<td>12.5 MVA</td>
</tr>
<tr>
<td>Cooling type</td>
<td>ONAN/ONAF</td>
</tr>
<tr>
<td>Maximum ambient temperature</td>
<td>40°C</td>
</tr>
<tr>
<td>Minimum ambient temperature Indoor</td>
<td>-25°C</td>
</tr>
<tr>
<td>Minimum ambient temperature Outdoor</td>
<td>-50°C</td>
</tr>
<tr>
<td>(After a shut down it shall be possible to operate the 52 kV circuit-breaker at the outdoor ambient temperature.)</td>
<td></td>
</tr>
</tbody>
</table>

3.1 Primary

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest voltage of equipment</td>
<td>52 kV</td>
</tr>
<tr>
<td>Rated lightning impulse withstand voltage (LIWV)</td>
<td>250 kV</td>
</tr>
<tr>
<td>Rated short duration power frequency withstand voltage</td>
<td>95 kV</td>
</tr>
<tr>
<td>Frequency</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Short-circuit current 1 sec.</td>
<td>12.5 kA</td>
</tr>
<tr>
<td>Rated current, switchgear bay</td>
<td>300 A</td>
</tr>
</tbody>
</table>
3.2 Secondary

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest voltage of equipment</td>
<td>24/12 kV</td>
</tr>
<tr>
<td>Rated lightning impulse withstand voltage (LIWV)</td>
<td>125/75 kV</td>
</tr>
<tr>
<td>Rated short duration power frequency withstand voltage</td>
<td>50/28 kV</td>
</tr>
<tr>
<td>Frequency</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Short-circuit current 1 sec.</td>
<td>20 kA</td>
</tr>
<tr>
<td>Rated current, transformer bay</td>
<td>1250 A</td>
</tr>
<tr>
<td>Rated current, feeder bay</td>
<td>630 A</td>
</tr>
</tbody>
</table>

4. MODULES

The substation consists of three modules that are pre-assembled in factory.
- One transformer enclosure.
- One switchgear module where the 52 kV bay and neutral earthing reactor/resistor are placed.
- One switchgear module for 24(12) kV switchgear cubicles where also the auxiliary system and relay and control panels are located.

The modules for 52 kV and for 24/12 kV switchgears are bolted to the transformer enclosure. See figure 3. If more 24 kV switchgear bays or higher transformer capacity are locally required, more modules can be added to the standardized substation.

4.1 Transformer enclosure

The transformer enclosure is assembled at site. The bottom is a factory made concrete oil pit. The pit is placed on a prepared sand bed and serves also as foundation for the whole substation. Other parts of the transformer enclosure are packed in the oil pit during transport from factory to site. The pit will at site be provided with a gravel layer for oil fire extinguishing.

The roof over the transformer is assembled from a few prefabricated pieces. They are easy to dismantle for exchange of the transformer.

The modules for 52 kV and for 24/12 kV are used as walls for the transformer enclosure. The other two walls consist of cassettes with ventilation louvers. The louvers have protection class IP23D and can only be dismantled from the inside of the assembled enclosure. There is a door on each side for access to the transformer.

The enclosure is equipped with indoor lighting.

4.2 Module for 52 kV bay and neutral equipment

The electrical equipment is installed in an enclosure, prefabricated with steel frame and walls of sandwich elements. The elements consist of steel sheets and mineral wool. Wall panels are not possible to dismantle from outside.

The enclosure of fire resistance class EI 60 is dimensioned to withstand an internal arc fault and is arranged for pressure relief. As the enclosure is bolted to the transformer enclosure no separate foundation is needed. However the enclosure can also be located on the ground as a solitary enclosure on a sand bed or on separate foundation. The enclosure is equipped with lighting, heater and ventilation to avoid condensation.

The enclosure is divided in two parts. Between the circuit breaker and the neutral equipment there is a wire mesh screen with a degree of protection of IP2X. Therefore each end of the enclosure is equipped with doors. Under the reactor there is an oil pit.

The circuit breaker of SF₆-type is disconnectable and can easily be removed for service or maintenance. Therefore also the control cables to the circuit breaker are connected with plug-in.

All control cable connections to other modules are made with pre-fabricated plug in connectors tested in the factory. After test they are disconnected for transport and then easily once again connected at site demanding no further tests. The same procedure is possible if the substation in the future shall be moved.

All power cables to the transformer are fire sealed and prefabricated for quick connection at site.
4.3 Module for 24 kV switchgear, Auxiliary system, Relay and control

Also here the electrical equipment is placed in an enclosure, prefabricated in the same way as described above in clause 4.2. The main part of the enclosure is of fire resistance class EI 60 but the wall towards the transformer has fire resistance class REI90. The enclosure is equipped with lighting, heater and ventilation.

The enclosure is after test of all electrical equipment at factory, transported to site and bolted to the transformer foundation and the steel frame of the transformer enclosure. Alternatively it can be located on ground as a solitary enclosure or on separate foundation.

All control cable connections to other modules are made with pre-fabricated plug in connectors tested in the factory. Power cables to the transformer are fire sealed and prefabricated for quick connection at site. Outgoing cables from the switchgear are connected from the bottom of the enclosure.

5. ERECTION

The substation is assembled on a prepared sand bed with insulating material. Space for handling the modules and transformer enclosure with a crane shall be available in the substation area.

The material is transported to the site on two lorries with trailers. The transformer is separately transported.

The oil pit is put on the ground and act as foundation for the whole substation.

The transformer is then lift on the pit. Frame and roof of the transformer enclosure are installed. The switchgear modules are bolted to the transformer oil pit and the steel frame. The walls are erected and the prefabricated cables connected. The estimated time for installation is five days. Then the switchgears are connected to the networks and the final commissioning starts.

6. SUMMARY AND CONCLUSION

A new type of distribution substation has been developed, easy and quick to install and dismantle. Due to a cost effective design, standardization and factory assembling the total cost for installation has been reduced.

The load conditions in some parts of northern Sweden are changing. The existing substations are mostly old and today wrongly placed. Therefore new substations are necessary to be built where new load appears.

The optimal solution to meet the variation in load conditions is a substation easy to build and move. Vattenfall Eldistribution AB has developed a concept for a new type of modularised indoor installation for 52/24 (12) kV. The first substation delivered by ABB has been in operation for one and a half year and a second one is commissioned.

An indoor installation was chosen as the environmental conditions during winter in the north of Sweden are tough, with a lot of snow and temperatures below minus 40°C. As the sites for substations often are in remote areas, the local work shall be reduced as much as possible. Therefore the substation is split in modules with the electrical equipment placed in enclosures easy to transport from factory to site. The complete substation will be transported with three lorries.

The civil work at site is reduced to drainage, hardening of a small area for transformer foundation and mobile crane and ditching for cables.

An innovation is the formation of the building. The whole substation is erected on the prefabricated foundation/oilpit which also is used as transport-base for the walls and roof of the building. The electrical equipment is placed in two enclosures standing on brackets fixed to the transformer-foundation.

Erection of the substation starts by placing the prefabricated transformer foundation on the earlier prepared ground. After that the walls and steel-frame of building are erected. The transformer is lifted in and the roof above can be placed in position. Then the two enclosures with electrical equipment such as 52 kV circuit breaker, neutral components, 24 kV switchgear and control and auxiliary panels are hanged on. Installation of the prepared cabling can start directly afterwards and be quickly finished. The Substation is planned to be ready for commissioning within three weeks.

The standardized substation has one 52 kV single line connection with a conventional circuit-breaker. If needed, space can be provided for more line-bays by use of a gas-insulated switchgear. There is space for six outgoing 24 kV metal-clad switchgear bays.

Normally Vattenfall have two transformers in each substation, of which one act as spare. Investments today have to be reduced as much as possible. Therefore future low loaded substations are suggested to have only one transformer. Redundancy at transformer fault or bigger maintenance work in the substation will be provided with a mobile station. Eight substations are in the near future served by one such mobile station. New substations shall be prepared for quick connection of this unit. The save of investment cost for new transformers will with this new philosophy be considerable.

A lot of distribution substations are old and should be
refurbished. Within ten years hundreds of substations in Sweden can be replaced with this new type of installation. The concept can also be used for quick permanent installation abroad for example after a catastrophe.