NEW DESIGN PHILOSOPHIES WITH COMPACT SECONDARY SUBSTATION

Jesper Gaard
ABB A/S - Denmark
jesper.gaard@dk.abb.com

Erik Hansen
ABB A/S - Denmark
erik.hansen@dk.abb.com

Steen Hansen
ABB A/S - Denmark
steen.hansen@dk.abb.com

Carsten Thrue
ABB A/S - Denmark
carsten.thrue@dk.abb.com

ABSTRACT

This paper will deal with the next generation of Compact Secondary Substations (CSS) and describe how new design philosophies can solve some of today's problems in a more efficient way compared to traditional solutions. The focus of the paper is on the complex CSS in the city centres and the requirements for this type of products.

INTRODUCTION

The next generation of CSS will not only have focus on the basic rating for transformation of energy and initial costs. Aspects like availability, safety, life cycle cost and environmental impact will be equally important for selection of the most suitable CSS solution.
Placing the CSS down town in the major cities becomes increasingly difficult.
Utilities are facing a number of challenges when they are planning an upgrade or new installation of CSS.
The necessary square meters for the footprint of a CSS and operation area in front of the doors are not available or becoming very expensive.
City architects do no longer accept the negative impact that traditional CSS generally has on the visual environment.
City administration does not accept blocking of roads and sidewalks for a longer period.

For surface mounted CSS application the introduction of a docking principle - as known from laptops - will give faster installation, less "on site"- work and easy up rating at a later stage.
An esthetical design of the enclosure in combination with an active noise reduction system will make it easier to find the needed space in the city centre

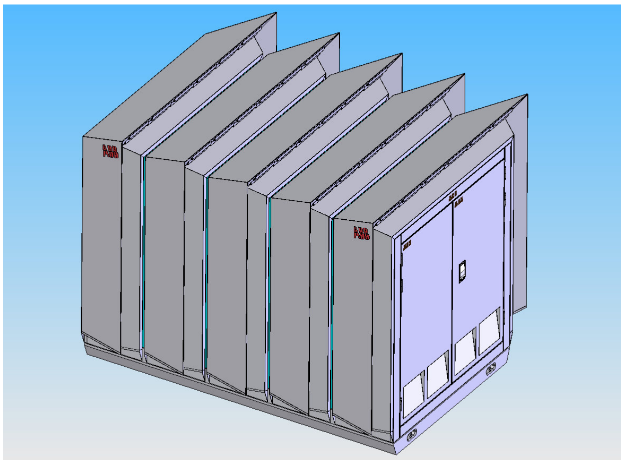
A new design philosophy for Underground CSS enables "install and forget". The underground enclosure will be completely sealed and cooling will replace the traditional ventilation system. This adds new requirements to the electrical design of the CSS, but at the same time gives new possibilities for selection of installation sites.

Use of type tested equipment will improve both availability and safety. It ensures the basic level of safety to general public and operators. Internal arc fault protection, both passive and active, is an integrated part of the design of the next generation of CSS.

SURFACE MOUNTED CSS

The surface mounted CSS can be truly internal arc fault proof. This means that it is protected against any fault that might occur anywhere inside the CSS.
This is done by using MV switchgear equipped with Arc Eliminator, which uses an ultra fast earthing switch as protection device. This switch is controlled by the local intelligence system, i.e. it monitors all compartments and switchboards.
The local intelligence system detects the influence that the fault has on the CSS configuration and, if possible, will restore the MV loop.

Design of CSS is a subjective matter which also relates to location and surroundings. The ABB proposal for a city centre design is shown below.



Surface mounted CSS

Areas for placing surface mounted CSS are scarce in major cities; hence the footprint of the CSS is of utmost importance. Time spent on repair or replacement of a CSS also has to be taken into consideration. This time can be reduced considerably by building the CSS based on docking principle:

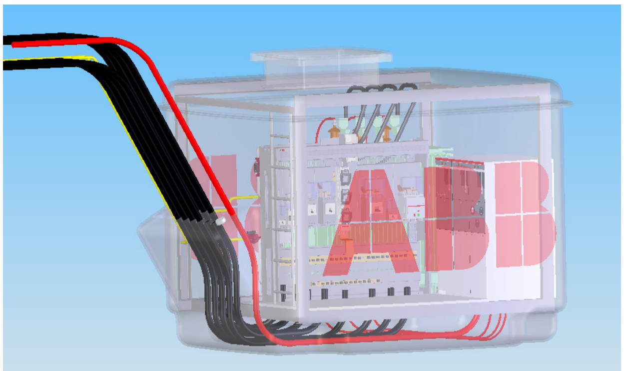
- Foundation build as "dock" including external cable connections
- Main components mounted on a frame
- Removable monocoque enclosure

The dock is the rigid base for the CSS without any electrical components. The dock is equipped with fixed contacts for

MV switchgear. All cable work will be done at site.
Main components and interconnections are factory assembled and routine tested on the frame. This is transported to installation site and placed on the dock by means of a crane and automatically connected to external cables through fixed contacts on the dock.
Finally the enclosure will be placed over the dock and frame as cover.
The use of the docking principle makes it much faster to upgrade the CSS or replace a damaged CSS with a new one thus reducing the downtime. Repair of a damaged CSS is done in utility workshop.
For upgrading purposes the docking principle CSS is designed in such a way that any rating of CSS can be installed on any dock. Free interchangeability between frame mounted CSS and dock is essential.

UNDERGROUND CSS

The ultimate answer to reduction of visual impact of a CSS is to install it completely underground.
These solutions are well known in the market, and are characterized by having an access hatch for entrance of operators of the CSS, as well as ventilation ducts for bringing in and out the needed ventilation air for cooling of transformer and switchgears.
Future CSSs may have no need for neither entrance hatches or ventilation ducts, if they are remote operated and have a closed loop heat exchanger based cooling system. This provision makes it possible to create a "sealed for life" CSS. The heat exchanger system does not require circulation of cooling air from outside resulting in improved climatic conditions inside the CSS.
The heat loss of the underground CSS is lead to the surrounding soil by means of the above indicated cooling system. In fact, this loss energy might be sold to neighbors as supplement to room and water heating, and so bring profit to the utility.



Underground CSS

The CSS is remote operated from either a console above ground, a utility control centre or even from a wireless terminal in the operator's truck.

Monitoring systems for recording of operational behavior, like temperature recording, current and voltage measurements, entering of water and leakage of transformer oil, etc., will make no need for regular inspection of the installation. Once put into service, the CSS will run on its own, and first at the instance, where one or more of the service parameters under continuous monitoring moves outside its defined service window, the CSS asks for attention. Depending on the speed of moving outside the service window, the priority of the action needed may vary.

AVAILABILITY

The increasing demands for a higher continuity of energy supplies will require distribution network to be controlled more intelligently.
Using directional short circuit indicators and motor operated RMUs will make the MV loop self-restoring in less than one minute in case of cable fault. This requires the presence of a local intelligence system in the CSS which also controls the Arc Eliminator inside the RMU. In case of an arc inside CSS the Arc Eliminator extinguishes it within milliseconds preventing damages to equipment inside the CSS.
This will only be possible with a fast and reliable communication throughout the MV loop and the primary circuit breakers.
The local intelligence system is comparing information from sensors in the CSS, like voltage, current, frequency, noise, pollution level, humidity, temperature, etc., with preset service values. Deviations outside the service window will be communicated to the SCADA system. Local and downstream incidents will be cleared immediately by the local intelligence system and communicated to the SCADA system.
By using motor operated breakers on both LV and MV side remote control is available.

SAFETY

Requirements for personnel safety increases, not only for operators, but also for general public.
The increased focus can be seen in the latest revisions of IEC 62271-200 and 62271-202, where safety aspects play a more central role in both standards than previously.

To ensure the basic level of safety it is essential to use type tested CSS. Compared to solutions based on individually acquired components, assembled at site by the utility or a local contractor, a type tested CSS according IEC 62271-202 increases the safety level.

IEC 62271-202 states that CSS, placed in locations accessible to the public, shall ensure protection to persons and environment, according to the specified service conditions.

The use of type tested components limits the number of CSS type tests to be performed. The IEC 62271-202 among others things requires that internal arc fault test and verification of sound level are performed.
Low frequency acoustic noise from the transformer and LV switchboard components may be amplified by the CSS enclosure. The level of amplification can be revealed in a test.

Due to the fact that pressure and gas flow from the freestanding switchgear differ considerably from the installation conditions inside CSS, internal arc fault test on complete installation has to be performed.
Two test series are to be passed, one series proving safety to general public and a second series proving safety to operators.

As the variety of types and lay-outs of CSS, ratings of network and combinations of components are numerous, it is not feasible to make type tests in all these possible combinations of a CSS.
The performance of any configuration may be substantiated by test data of comparable configurations, already having passed type tests with same type of MV switchgear.

However, the standard only defines passive protection measures. The level of protection may be further increased by using active measures, such as:

- Constant monitoring of service and operation conditions
- Truly internal arc fault proof CSS by using Arc Eliminator
- Voltage indicators in MV switchgear
- Fire extinguishing system in CSS
- Pre-warning measures
- Remote operation of switchgear, MV and LV

All the above mentioned measures are commercially available today.

LIFE CYCLE COST

The more technology installed in a CSS, the higher the initial cost. However, the true economic picture would be revealed when calculating the total life cycle cost.

Using surveillance technology like temperature measurement, real-time power measurement and climatic condition measurement lowers the risk for breakdowns, hence lowering costs for restoration and costs for none delivered kWh's (only valid in some markets). A self restoring network further decreases the downtime.

Remote control and surveillance lowers the number of routine service inspections. Savings are of course location dependent, but with a large number of CSS installed, considerable numbers of man-hours are used for service. The docking principle will allow faster, hence more economic upgrading of the CSS.

An economic advantage is the introduction of the heat exchanger based cooling system, permitting to sell this otherwise lost energy for heating purposes.
Measuring of climatic parameters, including pollution impact, could be developed into a sales product.

Sophisticated design might cost more than the ordinary engineering approach, but if the sophisticated design is a precondition for allowing a surface mounted CSS on behalf of the more expensive underground solution CSS, this additional cost is insignificant.

ENVIRONMENTAL IMPACT

Normally, when environmental impact is discussed, it is implicit that the discussion is focused on different chemicals and gasses. However, other kinds of environmental impact, such as design, acoustic noise and magnetic fields, have to be addressed as well.

Traditional design of the CSS is an "engineer's enclosure". During the normal design process high focus is on functionality and less focus on appearance. Generally this has the effect that the CSS "just looks OK".
By combining the traditional functionality with modern design it is possible to create a design that reduces the optical impact on the "city design" and it only adds very limited to the overall installation costs. On the other hand it makes it easier to get acceptance from the municipal administration that the CSS has to be placed visible in the city and so reduces the need for more expensive underground CSS. In fact, a beautiful enclosure design may improve the overall look of the area, surrounding the CSS.

A CSS emits low frequency acoustic noise, mainly due to the transformer and LV switchboard components. From an environmental point of view this low frequency noise is seen as additional background noise to the city environment. Hence the noise consists of 100Hz plus harmonics, it is very difficult to remove it with traditional, passive reduction methods. However, it can be reduced significantly by using a combination of transducers to create an inverted noise spectrum. These transducers are controlled by the local intelligence system of the CSS.

Another topic to be addressed is the Electro Magnetic Fields (EMF) outside the CSS. Increased ratings of installed transformer will increase the magnetic field around the CSS. The level of the field is depended on the distance, but also on the layout of the CSS. The lengths of the low voltage cables are important, but also the physical placement shall be considered. It is important to keep the current loop of

main circuit as little as possible to achieve the lowest possible values of magnetic fields.
Today this topic is not covered by any standard, but an IEC working group regarding standardization of EMF-measurement methods including CSS has been started.

One of the biggest risks of damage to the environment is leaking of transformer oil. Monitoring of the oil level can be handled by the intelligent system and reported to the upstream surveillance system if a leakage occurs. In combination with the supervision one can use high tech biodegradable oil - Biotemp - this almost removes the risk of oil pollution due to oil leaking. This makes it possible to skip the traditional oil pit obstructing the cooling airflow around transformer.

CONCLUSION

From stakeholder side increased focus will be on

- Availability
- Safety
- Life Cycle Cost
- Environment

This paper proposes a number of concept solutions to handle these topics in densely populated city areas.

Higher availability of the supply will be obtained by introducing local intelligence system in the CSS. Next generation of CSS will be truly arc proof, increasing the safety level substantially. The installation time will be reduced by using the docking principle resulting in an improved life cycle cost. Esthetical design and active sound reduction of the CSS results in less environmental impact.

In general stakeholders need to increase focus on choosing type tested CSS according to IEC 62271-202.

REFERENCES:

IEC 62271-200 AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV

IEC 62271-202 High-voltage/low-voltage prefabricated substations