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SPECIAL REPORT FOR SC B3
(Substations)

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Special Reporter

Substations are the backbone of the power supply worldwide independent from the country or region, where they are located. All these substations however are built on different levels: Developed countries with lower growth rates have high quality demands, while in lower developed countries a higher level of needs is driven by large growth rates.

For all substations in common all developments of this industry have a tremendous impact on the design, size, location, service behaviour, efficiency and availability, whether they still exist, being changed or replaced or newly planned. Criteria to satisfy the basic needs are reliability, affordability, sustainability and acceptability from the technical, economical and environmental surrounding.

Another driver for building of new substations is the growing age of the existing equipment. For HV equipment, some of which has been in service for 40 years, residual life is becoming a more and more important issue. Some of the key drivers that may influence the residual life of a substation can be summarised as follows:

- Equipment Factors like equipment condition / reliability but also maintenance or repair costs, knowledge about the switchgear, availability of consumable spares for repair/extension
- Changing System Requirements like availability & cost of outages, requirements for higher level of technical performance (e.g. rated current / short circuit current) or for extension or reconfiguration
- And last but not least External Factors like changes of the asset management strategy of the user, changing legal requirements, changing environmental/ecological demands or changing health and safety regulations.

Consequently the Preferential Subjects for the Session 2010 followed these different needs and developments and were chosen under three main topics as follows:

PS1 : New techniques/new design of substations:
- Substations in case of stronger constraints with respect to footprint and environment (severe climatic conditions and public amenity)
- EHV/UHV substations
- Design and construction of substations for offshore wind farms
- Design of GIL for bulk power transmission

PS2 : Existing substations, new challenges :

- Residual life estimation – Risk assessment, replacement or refurbishment options
- Uprating of substations and existing equipment to increase network capacity
- Technical solutions for extension of substations on already existing footprint
- Reducing the impact of substations on the environment and vice versa

PS3 : New secondary system challenges in substations :

- Experience with the shorter lifetime of secondary equipment compared with primary equipment
- Impact of distributed generation on substation design
- Implication of IEC 61850 on substation design and performance

A total of 25 papers addressing these 3 Preferential Subjects of 2010 have been selected for the session. These interesting papers and contributions on quite different aspects to the CIGRE Session 2010 make a valuable contribution to the active work of Study Committee B3. The significant efforts expended by the authors in producing these papers are truly appreciated.

The papers quite often address more than one preferential subject, so that it is quite difficult to organise the questions according to the different subtitles. On the other side, some papers address the same topic, so that they are considered together and covered just by one question. The following questions have been derived accordingly:

PS1: New techniques/new design of substations:

Substation design and technologies are at the state of the art. However the average age of a substation is approaching 40 years and more, so that new developments seem to be appropriate. The improvement of availability is therefore an important aspect for the operator. Real new developments are presented on UHV levels.

In some countries like China, India or South Africa, where generation and load centres have to be connected over large distances but also between regional power grids new large scale interconnections on UHV level have been developed some years ago or are planned now. We received two papers B3-101 and B3-102 with contributions about UHV equipment and systems technologies of 1100 kV AC and 800 kV HVDC substations.

In the first paper the development of a composite post line insulator for a 800 kV HVDC. This was considered to be necessary, for no optimized products were available for such a system and up scaling of an existing product not feasible. Tests have been successfully done on all designed systems according to the relevant standards. However here is not only the voltage level DC a challenge, also the expected life time of about 50 years might be a challenge for the composite post insulator.

Question 1.1: What can be said to the long term behaviour of such 800 kV DC insulator, what on the material subjected to 800 kV DC continuously? Are there already field experiences? What is the impact of hydrophobic behaviour and pollution?

Paper B3-102 describes the design features and field requirements of a 1200 kV substation project. It is stated, that the successful realization and operation of such UHV AC transmission system must be based on the close cooperation between transmission companies and equipment manufacturers. Testing of main components has been a real challenge, for parallel to the products the appropriate test equipment must be developed as well.

Question 1.2: What are the experiences of testing such high voltage levels? Does testing reach the limits of realization? Are there already experiences for the safe handling

during manufacturing, transportation and installation of UHV substation components?

Energy transmission is an important link between generation and consumer. While transmission lines have to face more and more environmental concerns cable connections are limited to load capacities. GIL, with its high transmission capacities and multiple achievable configurations is an advanced technological answer to the demanding criteria of safety, high service continuity and environmental efficiency since more than almost 40 years.

Papers B3-103 and B3-104 report about design features, experiences and a project study. The different layouts for GIL have definitely an impact on the economics as well as on service accessibility. GIL can be installed above ground, in a tunnel system and as a buried transmission line. After so many years of different kind of application, a summary of achieved service experiences must be possible.

Question 1.3: Which impact has the installation on maintenance? Which activities are in which intervals necessary if any? Which failure detection methods have to be applied, in particular for buried GIL?

The concentration in load centres like megacities makes it difficult to build a substation. Local requirements will lead to local solutions. Therefore examples like this project described in paper B3-105 cannot be taken as a general suggestion for other applications. However it gives information and describes the several technical requirements to be considered during the planning stage and implementation experiences in building a cutting-edge megacity underground substation. For this application typically GIS and GIT is selected, last but not least for safety reasons. In this regard this paper is useful for the planning of underground substations and addresses the non-conventional perspective for the construction in the future.

Other examples of urban underground substations are already in service for a long time.

Question 1.4: What are the experiences with underground substation so far? What are the measures after failures, if there were any? Which particular precautions have to be considered for urban underground substations?

PS2 : Existing substations, new challenges :

Besides building new substations the conditioning of existing substations has also an important impact. Decisions between replacement or refurbishment are not the only options, also uprating of substations and existing equipment to increase network capacity is quite often considered. Using existing substation footprint for new, more compact equipment is another approach. With increasing importance since years the impact of substations on the environment and vice versa has to be reduced.
Different papers like B3-201 and B3:202 report experiences about the improvement of transmission capacities by embedding series compensation in existing interconnected systems or by uprating the voltage levels. This is a commonly used procedure, so fare the safety margins of the installed system or equipment is able to allow this. Quite often the achieved solutions end up with individual solutions or not standardised values.

Question 2.1: What about the cost-effectiveness of such projects? Changing nominal values requires new type tests, how is this issue handled? Are there other projects like this?

Growing attention in particular to environmental issues causes electricity companies to find solutions to meet the new requirements and constraints as much as possible, without jeopardizing the security and the quality of supply. The strategic infrastructure as part of a development plan has to be subjected quite often to local authority’s specifications. However the technical solutions inevitably imply an increase in the complexity of the system and in costs. Paper B3-203 describes such a case where due to such reasons the visual impact of overhead lines has to be reduced and underground cables have been adopted. Consequently a new selection and separation system for a very fast recovery of this hybrid power link must be installed.

Question 2.2: Are there further examples or different solutions already practised? Is there a new trend in substation going underground, independently of possible consequences?

As already noticed uprating and upgrading of substations are an option to extend the lifetime of already older equipment. Uprating can be done on voltage, continuous current or short circuit breaking capacity. Power network are expanding and substation equipment, which was installed during the high economic growth period, has already reached up to 40 years of age. Paper B3-204 presents practical application examples in Japan which might be useful for uprating and upgrading of substations around the world. While the improvement with individual consideration for each component of the equipment must be done, it should not be forgotten that a previous type testing is no longer valid any more for such equipment. The repetition of a complete type test might have a tremendous impact on the economical evaluation of the life cycle cost.

Another paper B3-210 describes the exchange of the type of conductor and considers that all aspects of the complete substation must be regarded for uprating and optimization. So uprating of the continuous current of switchgear has to be checked on bus ducts as well as one all other contact connections of the substation.

Question 2.3: What are the drivers of uprating/upgrading vs. replacement? Is the impact of type testing considered in this evaluation? How can the increase of pressure values, current values and forces and temperatures be handled for existing materials/ sealings/ housings etc?

Asset management includes a wide range of activities. Three functional levels of asset management were differentiated as operational, tactical and strategic as recently published in an invited paper in ELECTRA. These functions define asset management responsibilities over the short- medium- and long-term. In consequence life cycle assessment LCA has to be considered as well.

Paper B3-205 reports about such an approach, investigating the impact of different substation technologies on environmental issues. Any change on an existing substation must be considered carefully. Besides technical necessities for the improvement of the equipment, also environmental requirements can be the reason for a change. Both manufacturers and users have to develop environmental awareness. The structural evaluation is described of the impact of selected switchgear designs on 16 environmental parameters. The results were weighted according to the relative importance of the environmental issues for the local conditions to determine which solution is the best. Finally it delivers a subjective result. Unfortunately in this comparison Mixed Technologies Switchgear MTS is not considered.

CIGRE Brochure 390 “Evaluation of Different Switchgear Technologies (AIS, MTS, GIS) for Rated Voltages of 52 kV and above” gives more information how to evaluate it.

Question 2.4: Are there other examples of utilities for such an evaluation? How valid is the result to check only on environmental and not also technical and economical parameters?

For the availability of a substation the reliability of all components down to parts and peaces is of importance. The improvement of existing components is used by utilities and results are therefore limited to individual conditions. However it makes sense to look on these results and to check whether they might be useful for others too. Furthermore the procedure might be helpful also for own investigations. Papers B3-206 reports on such investigations.

Question 2.5: Are these results also representative for other utilities? Are there experiences with other solutions?

The support insulator is another substation component, which is continuously stressed during operation, in some cases even under severe service conditions. Due to the electric properties the long term behaviour of the surface must remain unchanged over time. Results with an acoustic live-line diagnostic method to detect changes in service are described in paper B3-207.

Severe environmental conditions may lead to moisture penetration and further freezing in the micro pores in the porcelain followed by the development of cracks. It is concluded, that cracks can probably propagate towards the porcelain body and finally the porcelain will break. However porcelain is a brittle material and has no specified yield strength, so sudden breaks might happen without any sign before.

Question 2.6. Are there other experiences with acoustic test methods on porcelain insulators? How can the acoustic background noise of the operation/surrounding be excluded? How is the basic noise value defined?

Paper B3-209 informs about the long term experience of a real time system for detection and location of partial discharges in substations. Faults in the insulation of high voltage substation equipment are generally initiated by small low energy discharges which grow in amplitude until the degradation reaches a level that a breakdown can occur.

Tools to check on these effects are on the market for a long time. Systems are used mainly for the on-site testing but also for diagnostics. The sensitivity of such PDM systems is depending on the measurement principle; the highest level can be reached by using ultra high frequency antennas. The application can be used for periodic or continuous monitoring and is quite often deployed on higher voltage levels. The information is very detailed to the user of such systems and has to be evaluated in short times, which is quite often not easy and might also lead to wrong decisions. Detailed expertise is necessary.

Question 2.7: What are the experiences with PDM measurement systems so far? What is more used – singular measurement or trend analysis? Are there results on checking the further life expectancy? What are the economical benefits?

Since 2008 the majority of mankind is living in cities, a lot of them in so called megacities. The continuity of reliable power supply of such load centres is a big challenge for each utility. The management of assets of such a fast growing net with a mix of aged and supplemented by new components is according to paper B3-211 being handled through adoption of latest techniques of condition monitoring, residual life assessment, refurbishments and preventive maintenance programmes. The analysis of the results from the above techniques enables the evaluation of a time frame for activities and resulted in an optimised replacement strategy.

Another paper B3-214 reports about the application of new asset management methods to sub-transmission networks. Extensive technical systems like the electrical energy supply system require appropriate maintenance and replacement measures to be applied on the separate equipment components in order to maintain the desired technical performance levels. However, available resources are limited – the efficiency in maintaining and operating the systems has to improve constantly. In this context, explicit and comprehensive asset management methods are developed and implemented with electricity network operators worldwide, aiming at deepening the insight into relevant correlations between economical and technical performance and at providing better and more detailed data for decision support.

Question 2.8: Are there any new maintenance approaches or asset management strategies to be reported? Are there experiences with outsourcing of such activities?

Paper B3-212 informs about a case study in an area, where industrial pollution can create a lot of problems, mainly on air insulated insulators. In this study a 230 kV substation is located at a vicinity of a steel mill factory, where wind drives magnetite airborne contaminant particles onto the insulator surfaces. The reliable supply of power for such plant is essential, so that all precautions have to be taken, in order to avoid any disturbance.

As action for an improvement an insulator creepage extension has been applied. Obviously the replacement of the insulator by another one having a greater dielectric strength is not possible due to the economical situation. This might be an acceptable approach under these special conditions; however it is questionable, whether this solution is ready for a long-term service.

Question 2.9: Do other utilities have experiences with this or other similar solutions? Are there experiences about the long-term behavior? What about ageing of this solution?

The paper B3-213 gives a view on the development of the transmission network with regard to substation uprating to the 63 kA level and upgrading in a context of "unified" assets where the major existing design criteria should be kept as much as possible. Market liberalization and new power plants projects require a continuous effort of coordination to get new proposals in line with the transmission system development plan. Preconditions of existing substation equipment must be considered as well as economical consequences of the solutions.

Question 2.10: Does the decision making process compare all options besides uprating like Mixed Technologies Switchgear MTS and its advantages? Does the cost for the obviously extended tests be considered in the economical evaluation? Are there other experiences of other users?

The combination of major maintenance after 25 years with uprating the equipment of substations and the extension of the service lifetime seems to be a solution for those countries, which still use the first generation of switchgear. Paper B3-215 reports, that the main transmission power system will no longer be based on 110 kV, but on 220 kV. It means that many of 110 kV substations will be changed to 220 kV substations, if the built in safety margins allow. In this situation prolongation of residual life of old 110 kV substations to the short-term and middle-term period seems to be the optimum decision.

Question 2.11: Does there exist a cost comparison of uprating vs. new equipment? Is uprating the optimum approach in regard to the life cycle cost? What happens to all the other components of the substation? Are there similar solutions?

PS3: New secondary system challenges in substations

Substations consist of primary equipment and last but not least of secondary equipment, needed for operation, control and protection. The primary equipment, previously designed for a lifetime of 25 years, is approaching average almost 40 years of service time. The secondary equipment has in comparison to this a much shorter life expectation, ain average 10 years. In the meantime there must be some experience with the shorter lifetime of secondary equipment compared with primary equipment?

Furthermore changes in the surrounding of substations and technical progress in communication system lead also the development steps. Impact of distributed generation and the implication of IEC 61850 have also an impact on substation design and performance.

The implementation of IEC 61850 is the topic of B3 Sessions since 2006. The start was slowly, a controversy discussion was the result. An interesting paper B3-301 tries to summarize the experiences with an application of IEC 61850 on a smart grid project. In this substation already existing power transformers and its related bays were equipped with this new process bus technology in parallel to existing active substation automation system. Two nonconventional CTs/VTs were added to the primary equipment. Conventional instrument transformers using the 100V/1A interface may also communicate over the merging unit of a standardized digital interface of an instrument transformer. This seems to end up with mixed technology on the secondary side.

Advantages compared to parallel wiring usually still installed today are according to this contribution redistributing an enormous quantity of information with digital communication. The large amount of data in a monitoring unit can be integrated in the substation automation system. The required transmission capacity, transmission speed, and reliability place is greater than the demands on communication systems compared with station busses alone.

Question 3.1: Is this amount of data necessary and can it still be handled, e.g. in case of emergency? Is a human decision still accepted? What are the consequences of regular software updates or replacement of components? Are there finally economical benefits left?

In paper B3-302 an environmental friendly and intelligent compact substation of power distribution is presented. The substation unit is not only able to communicate & control but also monitor the conditions of the equipment using multiple sensors. Detailed information on the operating status is available, enabled by specific sensors and early detection of potential accident caused by electricity in a public surrounding.

Paper B3-303 is also addressing IEC 61850, but the focus is more on commissioning and maintenance test procedures. In practice few of the available test, simulation and blocking indications have been consistently implemented in the first generation of IEC 61850 devices. It is considered therefore necessary to move to a more interoperable but not standardized approach as described in the paper.

An update of the IEC 61850 standard can be used to integrate more efficient and standardized testing methods.

Question 3.2: Which improvements are recommended according to the experiences until now? What are the requirements for a new issue of IEC 61850? Are there experiences to be used for improvements?

Different automation products from different manufacturers require a standardized protocol to optimize the communication infrastructure in a substation. This was one of the reasons why IEC 61850 was introduced. It offers advantages such as interoperability, free configuration, and simple architecture and as stated in paper B3-304 cost savings in the substation. In consequence actions have been taken to manage problems such as upgrading control centers, producing equivalent company standards and developing telecommunication infrastructure using only optical fiber medium.

Paper B3-306 is considering the impact of the IEC 61850 process bus on the substation design and describes its advantages for the user.

Smart grids will have a major impact in the future on the interoperability of substations. In particular various organizations are involved and finally all has to fit with the standardizing smart grid technology.

Question 3.3: Are there other substation automation approaches, which can be taken as standard for other utilities? Is an overall substation automation standard in general possible? Is it considering the smart grid interoperability standards roadmap?

Paper B3-305 is talking about the consequences on the secondary equipment, not only when applying IEC 61850 but also in consequence of deregulation. Organizational changes in the transmission grid introduced new transaction points between the network operators. At these points the existing current transformers mainly have protection and operational measurement cores and in most cases no voltage transformers are installed at these connections. It would require a major primary retrofit of instrument transformers to cater for the new challenge of revenue metering. Besides the gigantic cost of the retrofit it would impact system availability and reliability during the retrofit period as well.

This paper presents the investigation of an alternative for a complete retrofit using corrections for existing instrument transformers in combination with an intelligent metering system. The approach is based on an intelligent voltage and current sensor system with software based correction capabilities.

Question 3.4: Are there other examples of adaption of substation automation triggered by the deregulation? How do other utilities solve these problems? What are the experiences with life-line work?