

Function:  
Time:  
Cost:

Optimized



## PS-1 substations

Staff report

**'A substation concept that cuts in half the typical delivery time for turnkey substations' – this was the ambitious goal ABB engineers set themselves when asked to develop a transformer substation that addresses today's energy market needs. Taking the overall substation functionality as a starting point, their response was to focus on reducing investment and operating costs through pre-engineering and integration of the right components. The result is a platform which, by speeding up every stage of a substation project, creates genuine competitive advantages for customers. PS-1 is a modern substation concept, based on air- as well as gas-insulated switchgear technology, for voltages up to 145 kV.**

**L**iberalization and deregulation of the electrical energy markets are rapidly changing the rules of power distribution, increasing cost pressure on utilities and network operators the world over. This, in turn, is putting pressure on

companies – ie, operators *and* substation suppliers – to find suitable means of reducing costs without sacrificing quality. One way is to simplify the processes involved in engineering, constructing and operating substations. Another is to

move away from the huge variety of traditional configurations and technologies and focus only on those that best fit the functions substations perform. The definition of their main function is simple: to connect different

networks and transfer electrical energy within and/or between networks with a good margin of safety. If, now, the technical realization of the functions is not defined in too much detail, and a 'functional specification' is provided instead, a considerable potential for cutting costs is freed up.

### Analyze and define

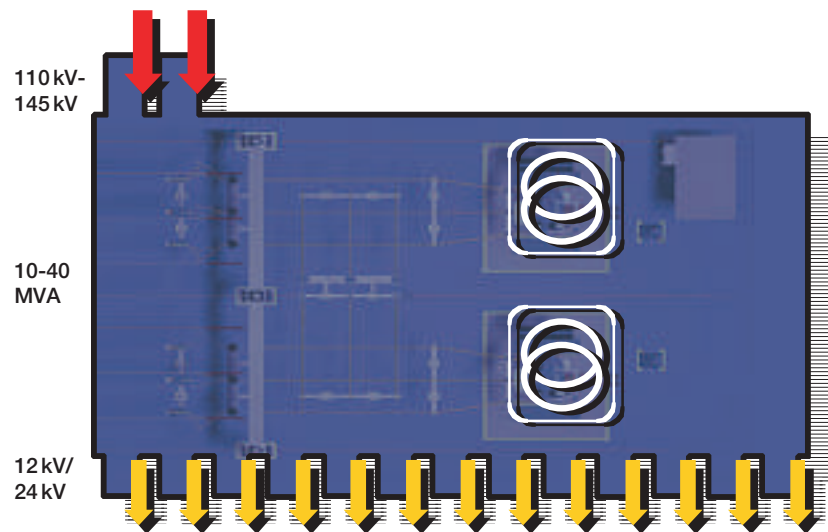
The general functional requirements of typical substations remain unaffected by the market changes now taking place. An analysis of these requirements by a multinational team put together by ABB, and interviews with customers to validate the results, showed that, for certain typical subtransmission and distribution applications, the substation can be depicted as a 'black box' in which voltage is transformed and power from an incoming network is distributed to a number of outgoing feeders.

Based on the analysis that was carried out, ABB has developed a totally new substation concept, called PS-1. PS-1 solutions define complete, pre-engineered transformer substations which are quick to install and commission, and which feature clear technical functionality, optimized for the specific task.

From the evaluation of the functional configurations of typical substations, ABB was able to define substations with the following basic technical functionality which could be realized with PS-1 **1**:

- Connection to the HV network with up to two lines (110–145 kV)

### **1** Basic functionality of PS-1 substation solutions



- Transformation with up to two power transformers (each 10–40 MVA)
- Connection to the MV network with up to 20 feeders (12/24 kV)

Additional requirements are possible; for example, requirements related to the substation site or environment that make it necessary to choose between air-insulated switchgear (AIS) and gas-insulated switchgear (GIS), or which dictate the basic insulation level (BIL) or the short-circuit current.

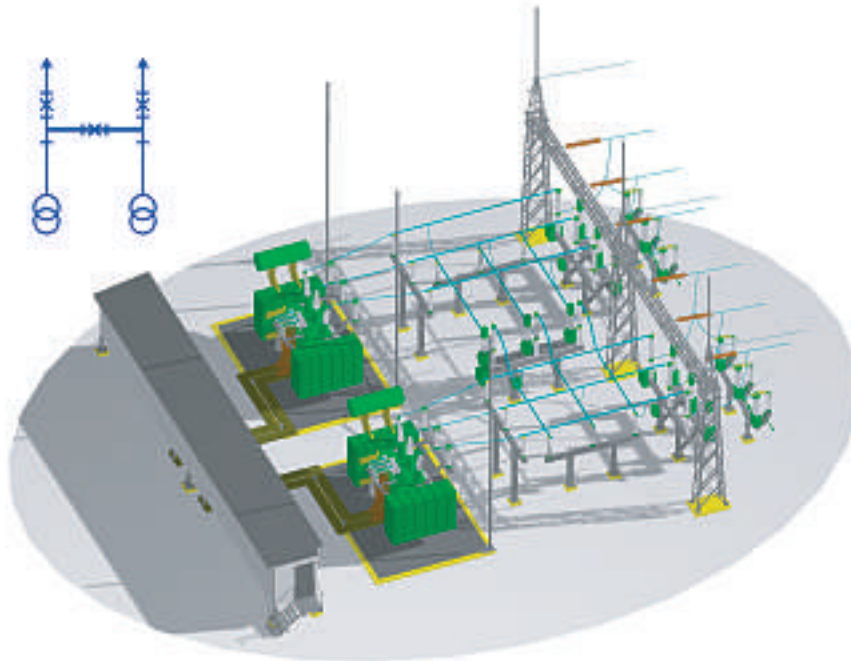
A factor that is always of relevance is the availability required of the substation. This is an essential parameter when evaluating the functions, and in turn the economy, of a substation, and therefore played a key role in the choice of configurations that are now part of the PS-1 substation portfolio.

### Pre-design and optimize

What the functional analysis showed was that it was possible to focus on a limited number of substation layouts. It was seen that this clear definition and limitation has advantages that span an entire substation project – from the initial planning to the detailed interface engineering, production, assembly and testing, right through to the civil works, transport, installation and commissioning. By standardizing all the process stages, material flows and transport paths, the entire process can be simplified, and thus optimized.



**2** Example of a PS-1 substation layout (AIS solution). Configuration for a substation which feeds into a medium-voltage network and has to maintain a moderate level of load transfer between the connected substations.



Operators, too, benefit from the process optimization, since it enables them to reduce their efforts in the areas of planning, supervision and maintenance.

Clear definition was thus given top priority, and underlay the entire approach to the PS-1 project. For instance, all the substation equipment is identified at the conceptual stage. And with the exception of some residual adaptation of external interfaces, for example for integrating the substation into the protection and control system of the connected grid, the project engineering is also finalized during the concept development phase. The internal design is based entirely on IEC/ANSI standards. Also defined in detail are the supply management, production processes, logistics and installation, significantly shortening the project cycle times usually needed for traditional substations.

### Substation configurations

A comprehensive availability analysis was carried out by ABB to determine the typical substation types and connections, and so allow a definition of the functional substation configurations for the PS-1 portfolio. The comprehensive study covered high-voltage AIS as well as high-voltage GIS technology (for the sake of simplicity only the results for GIS are considered in the following).

Based on this analysis, two types of substation were defined:

- *Main substations*, which have either an infeed from the transmission network or more than two connections to the sub-transmission network.
- *Transformer substations*, which are connected to the sub-transmission network on the HV side via one or two circuits. These fulfill mainly local supply functions, eg by acting as an infeed to

the distribution level at medium voltage (MV). They typically have one or two HV/MV transformers rated between 10 MVA and 80 MVA.

Of these two types, the transformer substations were identified for the PS-1 GIS *and* AIS portfolio. In the next step, the substations were divided according to their main function in the network, which in turn defines the type of connection:

- *Single-circuit or double-circuit radial connection*: These substations have only a *supply function*, ie they serve only to *feed* the network.
- *Loop connection*: Such substations interconnect other transformer or main substations. Apart from the supply function they also have a *transfer function*.

In each case, the substation availability was determined using the widely accepted and internationally validated probabilistic calculation method. This systematically considers the failure behavior of specific equipment parts and all relevant failure scenarios.

On the basis of the quantitative availability analysis and the cost of the respective equipment, four of the ten investigated configurations were chosen for a PS-1 GIS portfolio [1].

### PS-1 takes shape ...

While availability is key, there are also other parameters which are relevant when choosing a substation configuration. These, in turn, are affected

110/12-kV PS-1 substation, built for a utility in Estonia



by factors such as the operation of the substation or its maintenance strategy. A solution was developed for the HV parts of PS-1 substations – for AIS as well as for GIS – to allow a flexible response to the requirements of different application areas. For AIS, eight configurations were chosen, including the one shown in 2; for GIS, four configurations were picked.

### ...with state-of-the-art equipment

An important factor in the AIS as well as the GIS PS-1 substation is the role played by state-of-the-art equipment. For example, ABB's latest circuit-breaker equipment finds use in the AIS solution, while in the GIS solution, ABB's compact gas-insulated HV switchgear reduces the space required to a minimum.

To extend the application area, polymer insulators are used throughout PS-1. Low sensitivity to pollution is just one of this component's material-specific characteristics.

PS-1 is also the first integrated substation concept to encompass extensive standardization and optimization of the power transformers.

The medium-voltage switchgear that is used is equipped with advanced bay computers that perform safety, control, measurement and communications functions. In addition, all cubicles have active safety features such as an arc fault protection.

Worth mentioning, too, is the overall protection and control equipment. This is based on digital relay systems to allow easy integration of the



substation into the surrounding networks.

With all these advanced features, the PS-1 substation is well equipped to benefit from ABB's Industrial<sup>IT</sup> initiative, which has been developed to help companies achieve integrated, real-time solutions for automation and information across their enterprises. Seamless linking of substation automation, substation asset management and collaborative business systems in real time is the key to ensuring a more reliable and more efficient energy supply in the future.

### 'Start-to-finish' logistics

Everything about PS-1, from the definition of the project to final commissioning of the substation, has been optimized with that one ambitious goal in mind – 'to cut in half the typical delivery time for turnkey substations'.

For example, the project specifications are reduced to a functional description of the station and



clarification of external interfaces. The *PS-1 configurator* (a software tool) can be used to quickly collect functional parameters and convert them into a system layout – including the selection of suitable equipment and comprehensive documentation.

Planning is the next process to benefit: integration of the substation into the local network is limited to final adjustments, which are made simple by the standardized equipment interfaces.

Production, assembly and preliminary testing all proceed faster with PS-1. To save time on the actual site, important substation components are pre-assembled and have their functionality thoroughly checked before leaving our factories.

Pre-preparation of the equipment for site installation also has the advantage that it considerably shortens the time required for the civil works. The PS-1 components arrive on the site together and on time. Installation is completed much faster than with traditional projects.

Commissioning, too, progresses faster as a result of the pre-testing of parts in our factories.

Planning and supervision of the installation by the customer is also minimized thanks to the process optimization achieved with PS-1.

### Success breeds success

With the PS-1, ABB offers network operators and industry in general a substation concept designed especially for today's market environment. PS-1 is the successful answer to market demand for innovative substation solutions that cut costs without compromising quality or reliability. The success of the concept is already turning into a market success.

PS-1 substations have been delivered to very different customers for various applications in many parts of the world. Utilities in Brazil, Romania and Sweden, for instance, have installed them in their subtransmission and distribution networks. But not only utilities

appreciate the benefits of PS-1: customers in industry whose strategic goal is to have their own network access are also choosing PS-1. For example, PS-1 substations are already supplying electrical energy to oil exploration facilities, a paper mill and a large car factory.

Walgreens, the US drugstore retailer, has also chosen a PS-1 substation to supply the power for its new product distribution warehouse in Ohio. The substation will convert electricity at 115 kV to the required facility distribution voltage of 12.47 kV.

More recently, an independent power producer in Germany has decided in favor of PS-1 to feed energy from its new wind farm into the network of the local utility.

All of these customers have chosen PS-1 not only to take advantage of the speed with which the substations can be constructed and energized, but also in recognition of the fact that it sets new standards for the future. And, just as importantly, PS-1 does this without compromises, providing the same functionality and guaranteeing the same high reliability as traditional ABB substations. (ms)

---

## References

- [1] C. Payerl, G. Friberg: Functionality oriented design as response to requirements of liberalized electricity markets – the PS-1 substation concept. Paper CIRED 2001.
- [2] A. Osterholt, G. Friberg, P. Maurer: Reliability assessment as basis for new transformer substation concepts. 13<sup>th</sup> Conference of the Electric Power Supply Industry. CEPPI, Manila, Philippines, 2000.