Station Automation and Protection includes control, monitoring, and protection for power plant, transmission, and distribution applications. Solutions range from single function protection and control units to fully integrated, comprehensive, high-performance substation automation systems.

Panorama Substation Automation system in substation Tveiten, Norway
Statnett is responsible for building and operating the "highways" for the Norwegian power transmission. The main power grid in Norway consists of 400 kV and 300 kV AC transmission power lines. Statnett owns 8700 km of power lines, 59 substations with transformers, 15 substations without transformers and 5 reactive power compensation stations. In addition Statnett owns and operates the HVDC-installations for power exchange with Denmark. Total revenues for 1997 was 10500 MNOK. (1350 MUSD).

Statnett works systematically and with high focus on effective use of the main power network, where modernizing of the control and protection systems in the substations is a key issue. Statnett has a modernization program to update a number of high voltage substations.

Statnett decided to modernize the total protection and control system for substation Tveiten in conjunction with the exchange of the 66 kV switchgear. Statnett wanted to achieve better availability and supervision in addition to a flexible system. ABB was selected as supplier, both with reference to compliance with the technical requirements, and a cost effective solution.

The substation Tveiten is one of the larger substations in Norway. It is connected to the 300kV power grid, with 2 power lines. Tveiten is located in the south of Norway, and supplies power to both industry, farms and households in this region of Norway called Vestfold. Totally there is 4 power transformers in the substation and totally 5 voltage levels, 400 kV, 300 kV, 132 kV, 66 kV and 17 kV, see figure 1.

As the existing control and protection system was installed 1966, the need for refurbishment arised. ABB was selected as supplier with the brand new Panorama concept in autumn 1996.

The existing outdoor 66 kV switchgear was exchanged with an indoor airinsulated concept, also controlled by the new system.

The following describes the protection and control system, designed by ABB Kraft in Norway.

The system is based on modern microprocessor technique from ABB Network Partner in Sweden and ABB Transmit in Finland. The level of integration between protection and control, various functions etc. was an issue in this project. However, specific customer demands on redundancy prevented complete integration on the hardware level, even if the modern technique in principal makes it possible. Anyway, the level of integration is much higher than in any other substation delivered in Norway on transmission level.

Figure 1: Single line diagram, substation Tveiten
The Power generation in this region of Norway, called Vestfold, is limited. The largest Hydro Power Plants in southern Norway are located quite far away in the western part of southern Norway. Thus, the 300 kV power lines in Tveiten are extremely important for the local power supply in the region Vestfold.

Total installed transformer capacity is 500 MW. The owner of the substation, Statnett, delivers electrical power to a local company called Vestfold Kraft at 132/66 kV. Vestfold Kraft distributes the power on lower voltage levels, like 22 kV, 400 V and 230 V. The power supply from Statnett to Vestfold Kraft must have a very high availability. Statnett pays the local company a fine based on not delivered energy measured in kWh. This agreement made the installation of the new protection and control system more complicated, as the substation was in operation all the time. The installation of new control and protection cubicles must be performed sequentially, bay by bay, without interrupting other bays. This is the reason for the long commissioning period, lasting for approximately 9 months.

Also new protection and control functions, which where not finalized when the terminals were delivered from the factory had to be installed at the end of the project. This worked out successfully, and shows the flexibility of the new terminals, and its configuration tools.
System description

The system was designed according to customer demands, which required a high degree of independence, as shown in figure 2. Each line bay should have a dedicated controller. Also the protection terminals are dedicated bay units, and on 300 kV and 400 kV the distance protections should be duplicated, and not of the same type.

All the control terminals, REC 561 as well as the 300 kV distance protection REL 531 are communicating via LON-bus. In addition, the SPAU 341 for tap changer control are interfaced to the LON Network via gateways. The SPAU 341’s does only support SPABUS in the basic design. To be able to apply the minimizing circulating current method LON-bus is required. Then the circulating currents can be exchanged between the different regulators. In this application Transformer 1 and 2 operates in parallel (300/132 kV) and Transformer 3 and 4 operates in parallel (300/66 kV). At a maximum 3 transformers can operate in parallel with the SPAU 341. With a computerized control system also set point, tap changer position and different parameters are exchanged with the fulgraphic MMI via LON-bus.

The control and protection terminals were separated in two different rooms, because the 66 kV indoor switchgear was located 250 meters away from the main control room. By decentralized location of the 66 kV control cubicles, the amount of copper wires was significantly reduced.

All data between the 66 kV switchgear and the main control room is exchanged via optical fibers. One of the 3 LON star couplers was placed together with the 66 kV control cubicles. Between the star coupler and the REC 561, plastic opto fibers were used, while the rest of the LON-system in the main control room is made with glass opto fibers. Plastic opto fibers are recommended for distances not longer than 30 meter and glass opto fibers for distances up to 500 meters. By combining glass fibers and plastic fibers, a cost-effective solution is achieved.

The control of the switchgear can be performed from several locations. The highest level is the dispatch center. In substation Tveiten both the Network Control Center (NCC) and a Regional Control Center (RCC) has responsibilities for the control. 400 kV, 300 kV and the 4 transformers are controlled by NCC, while RCC controls 132 kV and 66 kV. Additionally NCC has responsibilities for the reactive power compensation and the auxiliary power supply system.

Figure 3. Configuration of communication and terminals for protection and control.
The second operator place is the station MMI, which includes a standard PC with Windows NT and integrated communication interface boards. The communication interfaces are all based on optical fibers, which results in extremely high compatibility against electromagnetic noise (EMC). The station MMI includes multiple monitors and also acts as a gateway between the local communication protocols SPABUS / LON and the remote control protocol RP 570. The database of the MMI acts as interface for addressing data in both directions.

Additionally a separate monitoring MMI is included for direct access to the protections. This is customer standard, because it covers both conventional and computer controlled substations.

In the future we expect this interface to be redundant, as the TCP/IP interface towards the station MMI is capable of handling the same information. There are several advantages in such a solution. The major ones are the higher data transmission rate, and the simplification of the internal data network in the substation.

**Technical aspects**

Since remote control was introduced in the 70’s, automatic synchro-check and phasing equipment for operation of the circuit breaker’s in asynchronous network’s has been a requirement.

The reason why the phasing function, and not only synchro-check is required in Norway is the topology of the network. Parts of the power network can under normal configurations become asynchronous, especially on the connection between East/West and North/South.

To be able to cover this functionality in the installed terminals a new system functionality for phasing (called IKA-function in Norway) was developed in cooperation between Statnett, ABB Kraft AS, Norway and ABB Network Partner AB, Sweden.

This development also included functionality for 1-phase and 3-phase autorecloasing, as well as earth fault detection in both direct earthed and isolated networks.

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Extremely high demands on the accuracy of time tagging events was fulfilled. The requirement was 1 ms maximum deviation between different terminals. This was achieved by combining serial synchronization telegrams with minute pulses broadcasted from a GPS receiver, see figure 6.
**Highlights**

- Maximum control functionality within bay controllers, including interlocking. Providing minimal external circuitry.

- Medium level of functional integration. Autoreclosing and synchro-check/phasing are integrated, but protections are separated.

- Extremely complex erection, with exchange of only one control cubicle at a time. The whole substation was in operation all the time.

- More than 60 terminals interfaced via serial bus to the local MMI and the remote control centers.

- 2 dispatch centers operator stations and one remote workstation additional to the local MMI and backup panels.

- Decentralized control system, with one control terminal per bay.

- Field upgrade of system software in control terminals was performed after the system was commissioned, with the complete substation in service.

- The project was performed as a turnkey delivery.

- In other similar substations the customer does the erection on site himself, based on ABB documentation and prefabricated cubicles.

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*Figure 7: Computer aided tool (CAP 531) for Configuration*
Panorama is the standard for a comprehensive range of integrated solutions for the efficient and reliable management of power networks. Using innovative information technology, Panorama delivers total control of the power process, from generation to consumption. The Panorama standard covers six application areas, each offering specific solutions.