Advanced energy management system for a Swiss utility

Bernische Kraftwerke (BKW) is a major Swiss utility supplying electrical energy to more than a million people. Recently, it took into operation a new, advanced energy management system called S.P.I.D.E.R. EMS from ABB. The system, the first of its kind to be installed in Switzerland, has features that include a user-friendly interface and innovative grid security functions giving access to operational information, such as power flow and load forecasts, as well as facilities for fault analysis. The dispatchers can be trained on a simulator that allows all the main functions to be manipulated in a realistic power system environment.

BKW Energie AG (BKW) supplies electrical energy to a large part of central and north-western Switzerland 1. More than a million people – some 15 percent of the total Swiss population – live in the area served by the utility.

BKW owns and operates seven hydroelectric power plants on the rivers Kander and Aare as well as the Mühleberg nuclear power plant near Berne. In addition, it co-owns several other power stations. The total installed power rating of BKW's own plants is 500 MW; the figure for the stations of which it is co-owner is approximately 1,500 MW.

In 1994, the electrical power supplied via BKW's network was 6,089 GWh, the maximum load over the period being 1,929 MW. 58 percent of the energy was generated by nuclear power plants, 11 percent by run-of-river plants and 31 percent by pumped-storage plants.

The utility operates about 5,000 km of overhead line at voltage levels between 380 and 16 kV. The network is served by 29 substations rated from 380 to 132 kV and 62 substations for voltages from 50 to 16 kV. Numerous tie lines link the BKW network at different voltage levels to the Swiss and European grids.

In the past, the load dispatching center in Mühleberg, near Berne, was mainly responsible for supervision and coordination, only the regional control stations being able to authorize switching. The utility's network control system, which dated from 1972, was recently replaced by an advanced energy management system to improve the reliability and utilization of BKW's installations. At the same time, network control was concentrated in a new operations control center in Mühleberg. The network control itself has also been considerably refined and now boasts the very latest security functions and control software, etc.

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Demands made on the EMS are high

Efficient, reliable control of a complex power system comprising many different production plants, lines, transformer substations and switchyards, makes huge demands on an energy management system. S.P.I.D.E.R. EMS was installed to help with decision-making and provide other task-related support as well as to relieve the operating staff of routine work.

The primary task of energy management, however, is to ensure reliable and safe operation of the power system, particularly when disturbances occur or equipment fails. In performing this task, it also has to ensure a stable power system voltage and frequency.

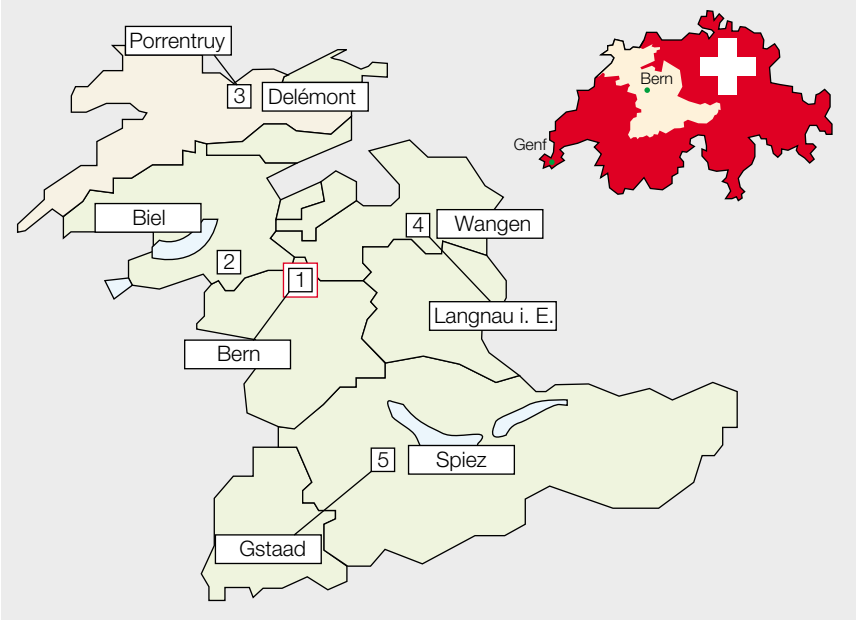
There are also economic aspects to consider, for example the optimum deployment of production and transmission plant and the exchange of energy with other utilities. Due to the complexity of these tasks, the management system has to offer a comprehensive range of functions.

S.P.I.D.E.R. EMS from ABB Network Partner AG satisfies the requirements of modern energy management in full. The system installed in BKW's control center in Mühleberg is responsible for overall management of the utility's transmission network. In this capacity it has the following main functions:

- Control and supervision of the network
- Load-frequency control
- Network security
- Training, with the help of a simulator

With its open system architecture and modular hardware and software, S.P.I.D.E.R. EMS can be easily modified to suit new requirements. Front-end processors handle the heavy communications workload by preprocessing and compressing the information for the mainframe computer, thereby freeing it for other processing duties 2.

Standardized interfaces allow the integration of non-ABB systems. Thanks to this feature, information can be exchanged with the existing system for controlling the energy interchange. It is via this system that the power plant scheduling as well as monitoring and energy billing take place. In addition, there are links to BKW's network planning system in Berne and two telecontrol systems (non-ABB front-end processors belonging to the old network control system), which will remain in operation until the old RTUs in the substations have been replaced by RTU 200s from ABB.



Geographical overview of BKW's new energy management system in Switzerland, with the operations control center and regional center in Mühleberg (1) as well as regional centers in Aarberg (2), Bassecourt (3), Bickigen (4) and Wimmis (5) **1**

System configuration

BKW's transmission network control system functions on two hierarchical levels. The operations control center in Mühleberg is responsible for supervision and remote control of the voltage levels from 380 to 132 kV, while five regional control stations monitor, and in some cases also control, the 50-kV and 16-kV networks. One of these regional control stations is located close to the operations control center, the other four being in key substations **1**. For historical reasons, the equipment in the regional control stations and the telecontrol equipment in the substations are from different vendors.

The new energy management system makes use of a double-computer configuration based on the DEC VAX 6000, which has a large-capacity main memory and mass storage unit **2**. Also duplicated is the local area network (Ethernet), the front-end processors and the communications links connected to them. A total of 60 remote terminal units of type S.P.I.D.E.R. RTU 200 communicate with the regional control stations, some of which have a local logging facility. 41 of the RTUs are installed in substations belonging to BKW; the other 19 are located in the stations in which the utility shares ownership. Data is transmitted to the RTUs (with partial redundancy) via radio relay, fiber optic or cable links at either 600 or 1,200 bauds, and between the regional front-end processors and the local area network (with full redundancy) at 9,600 bits/s.

For the load-frequency control functions, the energy management system is linked to the network control center in Laufenburg (EGL), which is responsible for overall load-frequency control in Switzerland, as well as to the control system of the utility Oberhasli Kraftwerke (KWO).

The installed S.P.I.D.E.R. EMS system has 16 workstations (WS 300), each with two or three full-graphics VDUs. Eight workstations, authorized to perform a range of duties, are in the Mühleberg operations control center, and another five are divided among the five regional centers **2**. A further two workstations are located in BKW's head office in Berne for tasks such as medium-term operations planning, power system studies, analyses and statistics.

The department responsible for maintenance of BKW's information systems is located in Nidau. Since it will also service the new energy management system, it has its own workstation for accessing the EMS. Authorization to use the workstations is strictly controlled. The maintenance department is further equipped with a S.P.I.D.E.R. test system, which is integrated in the computer network, and a data engineering system.

The man-machine interface is particularly user-friendly **3**, consisting of high-resolution VDUs, a function keyboard specially modified for this project, and a trackball/mouse. Numerous display options are offered by the use of the windows technique, with either single or combined presentations specially tailored to the actual operating situations. A large mimic board with switching states updated on-line, line load indicators and freely selectable digital displays showing actual measured values, provide an excellent overview of the network and production plant **4**.

Supervision and control

S.P.I.D.E.R. EMS includes a SCADA package for the basic supervisory and control functions. Two workstations in the Mühleberg control center are reserved for these duties.

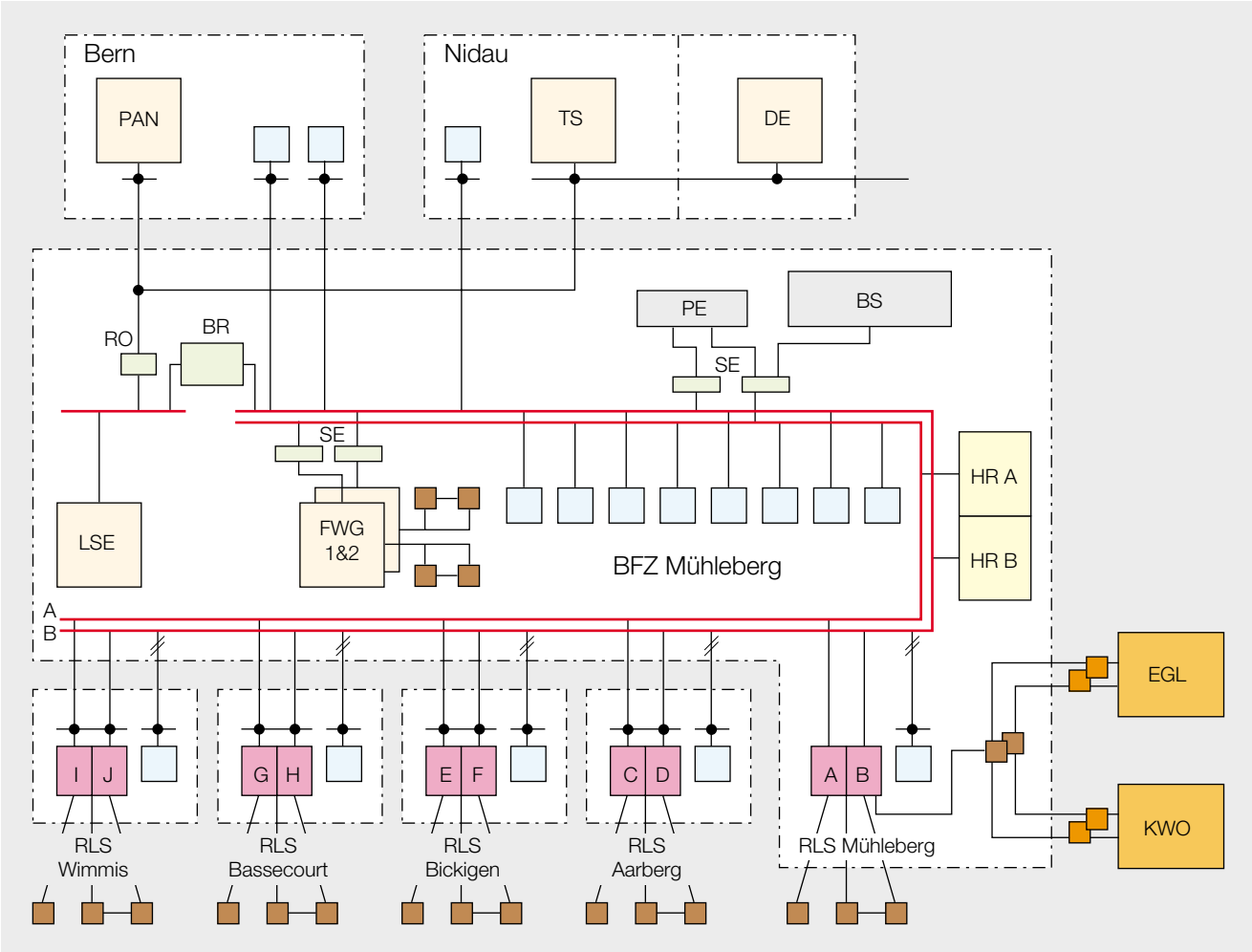
One of SCADA's principal tasks is to process and present in a concise form the data arriving from the remote stations **5**. In BKW's new energy management system, the data acquisition covers 100 busbars, 120 lines and 110 transformers, adding up to some 15,000 messages, 1,500 measured values and 600 meter readings in all. In addition, manually updated measured values and status signals are received from the utilities with which BKW cooperates.

Another task of the SCADA function package is to record, in chronological order, the changes in status and identify them as either events or alarms. Process values are calculated from the transmitted data; data logs, extracts from alarm lists as well as statistics, etc, also have to be prepared **6**.

The SCADA package is further responsible for the remote control of the different grid elements, circuit-breakers and transformer tapchangers, while another of its tasks is to systematically check the data validity, especially before control commands are executed. A special package

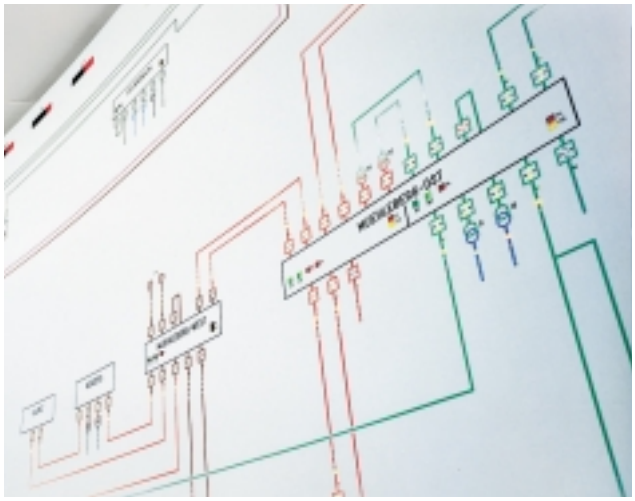
S.P.I.D.E.R. EMS configuration, as installed for BKW **2**

BFZ	*Operations control center*	
RLS	*Regional control center*	
BS	*Mimic display*	
PE	*Peripheral*	
HR	*Central computer*	
Light-red	*Distributed front-end processors*	
Red	*Local area network*	
Blue	*Workstations, with VDUs*	
Green	*LAN interfaces*	
	RO	*Router*
	SE	*Server*
	BR	*Bridge*
Dark-brown	*BKW's own telecontrol equipment*	
Light-brown	*BKW's own systems*	
	TS	*Test system*
	DE	*Data engineering system*
	LSE	*Energy interchange control system*
	FWG 1&2	*Front-end processors of previous system (will be replaced later)*
	PAN	*Network planning system*
Orange	*Non-ABB telecontrol equipment*	
Light-orange	*Non-ABB systems*	
	EGL	*Swiss load-frequency controller in Laufenburg*
	KWO	*Hydropower regulating system, Kraftwerke Oberhasli*

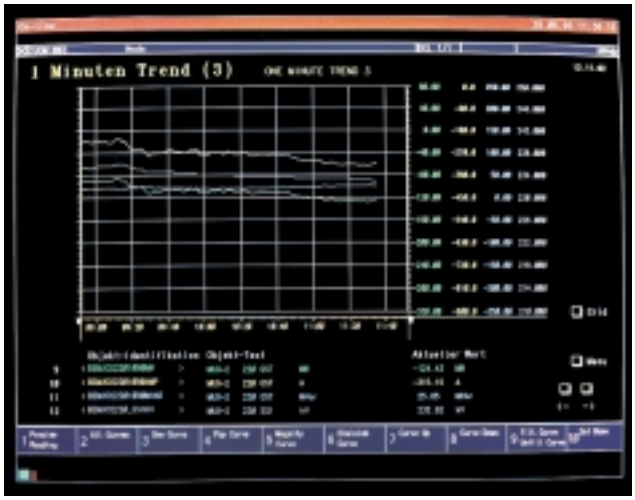


Operations control center in Mühleberg **3**

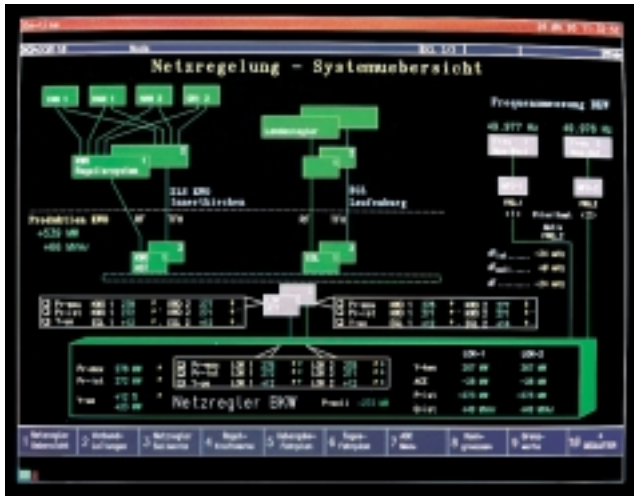
Part of the mimic board showing the Mühleberg-Ost substation **4**



Overview of the network status in the Mühleberg-Ost substation **5**



Load trend on the 220-kV line between Mühleberg and Gstaad **6**



Overview of the load-frequency control system **7**

allows sequential control of the switching, thereby freeing the dispatchers for other work. For example, sequential control programs are prepared off-line for repetitive operations (eg, bus transfers with line switching). Every time switching is requested, a software interpreter runs through one of these programs, checking each step for plausibility. The sequential controls are key tools, helping the dispatcher to work more efficiently and reducing the risk of switching errors.

Load-frequency control

The nuclear power stations and run-of-river plants, the output of which is largely predetermined by the water flow, together meet the base-load demand. Short-time fluctuations are compensated for by a hydropower system operated by Kraftwerke Oberhasli.

BKW's energy interchange control system informs the load-frequency controller one day in advance (in the case of alterations, on-line), of the daily schedule for the interchange powers. The load-frequency controller also takes into account the BKW participation requested by the Swiss load-frequency controller in Laufenburg in order to compensate for the system deviation that exists between the Swiss and the European grids. The sum of the scheduled interchange powers is compared with the measured interchange powers, and the difference transmitted together with a power-weighted frequency deviation to a PI-controller, which sends the request for power to the KWO's hydropower system **7**. The dispatcher can achieve the required conditions by making corrections as necessary. The load-frequency control data are exchanged between the energy management system and KWO every 5 seconds.

Since the frequency in the European grid fluctuates only slightly, the load-frequency control's priority is to maintain the interchange power levels. Deviations from the nominal frequency and scheduled interchange powers require correction by the load-frequency controller **8**. This control loop becomes very important in the event of major production downtimes or disconnection from the grid.

Network security functions support network evaluation

The network security functions are used mainly to determine, on the basis of status messages and measured values, whether the network is currently in a safe, critical or disturbed state. For a reliable evaluation of the situation, it is important to have precise information about the network conditions.

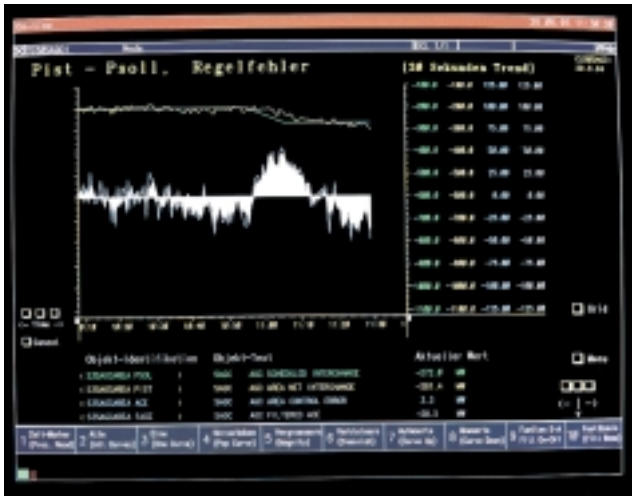
State estimations are performed for sections of the network providing enough data (measured values) are available from those sections. If not enough measured values are received from certain sections, pseudo-values are generated and a pseudo-estimation is made of their states.

Deviations between the measured values and the estimated values are recorded statistically. The statistics allow measured-value errors to be identified and also provide information about the accuracy of the measured values recorded.

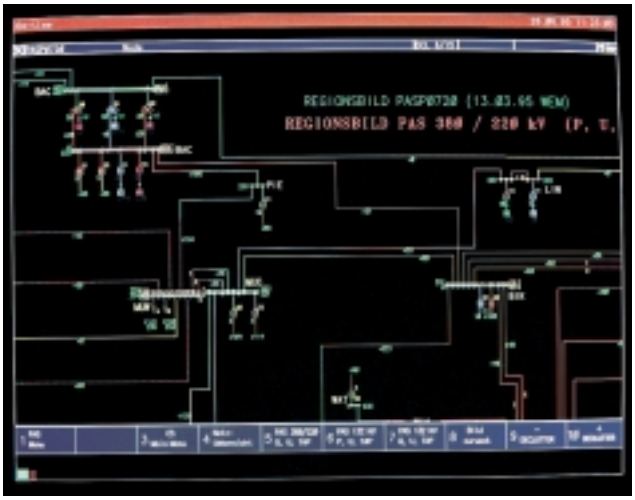
Based on the actual, instantaneous network status, failure of power system elements can be simulated and the new network status evaluated by means of load-flow analysis **9**. This gives the operator an overview of potential weaknesses in the network in its present configuration, allowing appropriate precautionary measures to be taken or, if necessary, action to be taken to restore safe and reliable operation. The same information can also be used to plan a strategy for the network's optimization or for operations planning.

Network security function blocks are provided for:

- Dynamic network colouring
- Topology modelling, observability, analysis, limit-value monitoring
- Determination of topology and measured-value errors



Example of the interchange power control characteristic 8



Extract from the network overview, with load-flow analysis 9

- State estimation for observable and non-observable sections of the network
- Forecasts of busbar loads
- Load-flow analysis
- Failure and short-circuit analysis

Simulator for training dispatchers

A Dispatcher Training Simulator (DTS) integrated in S.P.I.D.E.R. EMS offers valuable support in training dispatchers. A feature of the DTS is that it makes use of as many of the network security function blocks as possible. The introduction to the EMS functions and training in network control are made easier by this, since trainees work in an environment that is similar to the real world and use the same functions and user-interfaces.

Use of the DTS is based on the latest as well as historical network data supplied by the SCADA package; real-life operation, however, cannot be influenced through the DTS in any way. The package simulates the actual behaviour of the network and the telecontrol system and has access to consistent process data records. Simulated changes in the state of network elements affect the simulated network status in dynamic mode. Without actually influencing the operation of the network, dispatchers learn in this way how to respond to changes in the network configuration as well as to possible disturbances, plus how to restore the network to a safe and reliable state. Events are simulated through the use of prepared scenarios and/or interactively by an instructor. The results of the simulation are presented to the operator in exactly the same way as in a real-world process environment, thus giving trainees the impression that they are actually controlling the BKW network.

Two-stage introduction of S.P.I.D.E.R. EMS

The S.P.I.D.E.R. EMS energy management system was introduced in two stages: first the SCADA part with the load-frequency controller was installed and then the network security functions with the simulator for dispatcher training. Over the course of the project BKW's engineers were trained extensively in the use of the system and will be able to maintain and further develop it later on their own. For example, BKW specialists were given responsibility for engineering the process data and display graphics as well as for transferring them to the system. In addition, they produced the individual programs for the sequential control of the switching operations.

S.P.I.D.E.R. EMS, which in the meantime is operating successfully with several utilities, is a future-oriented energy management system with considerable potential for expansion. The deeper understanding of network behaviour and safe, reliable power system operation it allows, even under extreme conditions, are essential for the efficient and profitable operation of electric utilities.

Reference

[1] M. Benahmed, F. Rohr: Modernste Netzleittechnik für das Uebertragungsnetz der BKW. SEV/VSE Bulletin 22/95, 47–51.

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