Reference Example
Opole Power Plant, Block 3, 360 MW
Protection and Control of the Primary Electrical Plant

ABB Network Partner
Overall advantages of the Opole Power Block Control System

- It integrates advanced functions for the protection of the generator, of transformers, line and motor feeders as well as for the control and supervision of the switchgear in one homogeneous system.
- It provides powerful automation functions with high requirements regarding safety and operational efficiency.
- Clear and exact registration and protocolling of all events during normal operation and under emergency conditions.
- Easy reading of all values and setting of all limits, including setting of protections.
- Higher reliability due to self-supervision and use of fibre optics.
- Highly reduced cabling and marshalling due to serial communication.
- Easy communication with other parts of the plant or network possible.
- Supervision of the primary equipment as a basis for maintenance.

The System fulfills the following tasks

- Protection and control of the generator
- Protection and control of the step-up transformer incl. cooling supervision
- Protection and control of auxiliary service transformer incl. cooling supervision and tap changer control
- Protection and control of 6 kV feeders for auxiliary supply
- Protection and supervision of 6 kV motor feeders
- Control and supervision of 0.4 kV supply feeders
- Generator synchronizing
- High-speed busbar transfer for 6 kV motor feeding busbars
- Supervision of the 400 kV bay
- Measuring
- Disturbance recording and evaluation
- Serial integration of the generator controller and operating facilities on station level

Commissioning

November/December 1995
Opole is an industrial centre in a highly industrialised region in Upper Silesia, Poland. There is an enormous demand for electrical energy. Environment constraints are heavy due to inheritances of the past.

Therefore 9 km to the north of the town Opole a power plant is under construction which finally will have 6 steam turbine-generator blocks of 360 MW each. The plant, Elektrownia Opole S.A., contains equipment in accordance with the highest standards of environmental protection, e.g. filters reducing emission to a minimum, purification plants for all water and oil circuits, a plant mixing the ash with water to an “emulgate” (patent of the power plant company) used to fill old coal mines and becoming hard like rock, thus reactivating these abandoned mines.

The whole power plant is scheduled to generate 14 millions kWh of power during 6500 h per year and 4700 TJ heat, extracted from turbine 5 and 6. In full service the plant will use 23 kt coal per day.

Block 3 is connected directly to the 400 kV station “Dobrzen” in the near vicinity. A large 6 kV system is used for all auxiliaries of the block and all environment-conserving equipment in such a way, that each block has its own supply for the auxiliaries, but in emergency cases there is a fast busbar transfer to another (undisturbed) part of this 6 kV network. Fig. 1 shows the 400/22 kV single line diagram with 22/6 kV auxiliary transformer.

22 kV, 360 MW, 426 MVA
The Generator has a rating of 22 kV, 360 MW, 426 MVA. The static excitation is fed by 3 single-phase transformers of 22/0.72 kV and 1.1 MVA. The 22/400 kV, 426 MVA step-up transformer is connected to the generator via a generator breaker, giving highest flexibility during service and clear zones for the protection. With this arrangement the auxiliaries of the generator may be fed from the generator voltage via 6 kV (normal case), the 400 kV (start) or another 6 kV bus in an emergency.

The primary electrical plant of Block 3 comprises the following equipment:

- generator
- 22 kV switching devices
- step-up transformer
- 400 kV bay (collection of status information only)
- auxiliary transformer
- excitation equipment
- 6 kV and 0.4 kV switchgear for the auxiliary supply.

All in the opposite listed equipment need to be controlled, protected and supervised. The Sub-
Tasks of the Opole PBCS

- Protection and control of the generator
- Protection and control of the step-up transformer incl. cooling supervision
- Protection and control of auxiliary service transformer incl. cooling supervision and tap changer control
- Protection and control of 6 kV feeders for auxiliary supply
- Protection and supervision of 6 kV motor feeders
- Control and supervision of 0.4 kV supply feeders
- Generator synchronizing
- High-speed busbar transfer for 6 kV motor feeding busbars
- Supervision of the 400 kV bay
- Measuring
- Disturbance recording and evaluation
- Serial integration of the generator controller and operating facilities on station level

The system can be divided into two levels

- The power plant level, referred to as “station level”
- The bay level (22 kV, 6 kV, 0.4 kV)
Station Level
On station level there is the operator’s console, a desk located in the control room with the station computer and two monitors, from where the primary electrical plant of Block 3 is controlled and supervised. In addition, there is an SMS (Station Monitoring System) workplace in a separate room for disturbance analysis, i.e. evaluation of disturbance records, event list and protection parameter handling.

Bay Level
On bay level there are the bay control, protection and data acquisition units. They are combined in cubicles or directly built into the switchgear panels. Station and bay level are linked by a fibre optic communication network.

FUNCTIONS
Protection of the generator, step-up transformer, auxiliary and excitation transformer
Two generator protection units type REG216 with functional redundancy are in charge of these functions. The duplicated arrangement is ABB standard for highest reliability. The functions are allocated to the two REG216 units in such a way that each one gives full protection even if one system is out of service.

Separate mounting, power supply, communication link, etc., together with self-supervision, guarantee highest availability and reliability for the individual units and thus for the whole power block.

Modular hardware, selectable functions, fully numerical system, continuous self-monitoring and communication facilities to the PBCS result in extreme flexibility with the possibility of a multitude of applications. Settings of parameters, display of measured values and events, recording and testing can be made on site by means of a PC or via the PBCS.

One unit contains the full complete protection of a 360 MVA generator such as:

<table>
<thead>
<tr>
<th>Protection Type</th>
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<tbody>
<tr>
<td>generator differential</td>
</tr>
<tr>
<td>transformer earth fault</td>
</tr>
<tr>
<td>100% stator earth fault</td>
</tr>
<tr>
<td>block differential</td>
</tr>
<tr>
<td>reverse power</td>
</tr>
<tr>
<td>aux. transf. differential</td>
</tr>
<tr>
<td>negative sequence, 3 steps</td>
</tr>
<tr>
<td>22 kV earth fault</td>
</tr>
<tr>
<td>overload</td>
</tr>
<tr>
<td>95% stator earth fault</td>
</tr>
<tr>
<td>frequency</td>
</tr>
<tr>
<td>rotor earth fault, 2 steps</td>
</tr>
</tbody>
</table>

Besides breaker back-up protection and thermal overload protection there are many other protection and logic functions included. Application specific logic functions are generated by the built-in FUPLA, a graphic method to combine digital signal processing functions for binary and analog quantities on the basis of function plans.

Remote control of excitation equipment
The generator voltage resp. cos \( \phi \) or reactive power is controlled by a static excitation equipment type ABB UNITROL P. Its voltage controller is con-

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Fig. 3, Generator excitation control
22 kV power terminal.
Bay control and protection for 6 kV and 0.4 kV

Control and protection for the 6 kV bays (4 feeding bays, 8 transformer bays and 35 motor bays) are realised by SPACOM units where, besides the control and interlock functions, overcurrent (instantaneous and delayed), thermal, earth fault protection functions and autoreclosing as well as measuring are performed.

For motor bays an extended protection program with start-up supervision, phase unbalance and much more are provided. This ensures that the auxiliaries of the main generator are protected by a similar reliability class as the block itself.

The 0.4 kV infeed bays are supervised and controlled by control units type SPOC. Signals from the protection integrated in the 0.4 kV circuit breakers are also collected by the control units.

Fig. 3 shows the single line diagram of the 6 kV and 0.4 kV level (without motor feeders).

22 kV power terminal

The generator breaker and the associated disconnector and earthing switches on 22 kV level are controlled and supervised by a REC316*4 bay control unit. These units perform all interlocks (isolator against generator breaker, earthing switches, etc.) and the measurement for current, voltage, reactive and active power and frequency. The REC316*4 is programmed with the help of the above mentioned function chart programming tool FUPLA.

Generator synchronizing

The REC316 used for the 22 kV power terminal also controls the selection of the right voltages and the allocation of the closing command for the synchronisation of the generator to the power grid. The operator can choose one out of three breakers for synchronising, the generator breaker or one of the two 400 kV breakers.

The synchronizing device issuing the frequency and voltage control pulses and the closing command is an ABB Synchrotact 4 in a double channel scheme.

Voltage control of tapped auxiliary transformer

Back-loop control of the voltage including limiting and protection functions is provided by a TCS110 voltage controller (Maschinenfabrik Reinhausen). Status and measurand indication as well as the modification of set points and the manual tap-changer control are available locally or via the PBCS.

High-speed busbar transfer (HBT) system on 6 kV bus

This equipment ensures that the power supply for the auxiliary service equipment of Block 3 is maintained even in case of a disturbance in the feeding circuit. A protection trip e.g. initiates an automatic transfer of the motor feeding bus from the affected feeder to a back-up feeder (see Fig. 4 “SZR”). The interruption time is very short, and the re-connection to the healthy infeed is phase angle controlled so that torque peaks endangering the shafts or gears are avoided and all drives remain in service.

Connected to the PBCS by means of a serial fibre optical link running the ANSI X3.28 protocol. Supervision (measurands, status signals, events), remote control and the modification of set-point values is thus achieved from the operator’s workplace, Fig. 3.
The high-speed hange-over may also be initiat-
ed manually from the operator’s console. The high-
speed busbar transfer function on the 6 kV bus is
realised by REC316*4 units.

Transformer cooling system control
The transformers of the block have cooling circuits
with oil pumps and fans. The control of this equip-
ment is performed in the PBCS and is initiated by
temperature setpoints. The protective part of the
functions, i.e. switching on additional cooling
groups upon temperature rise, is realized in the
generator protection unit REG216. Functions for
maintenance optimization as well as supervision
and manual control are implemented in the station
level PC.

Image of associated 400 kV bay
The 1½ breaker type 400 kV switchyard, where the
power plant is feeding in, belongs to another
company. Therefore the status image of the bay
allocated to Block 3 is collected only and displayed
in the PBCS.

Mimic board
In addition to the process image presented on the
operator’s monitors a passive mimic board with
status and measurand indications is installed in the
main control room of Block 3. This mimic board is
controlled by a RTU200 connected to the PBCS by
means of a RS232 link.

OPERATOR’S WORKPLACE
The operator’s workplace in the control room is a
desk with 2 monitors, each with mouse and key-
board and the station computer. From this desk the
primary electrical plant of Block 3 is controlled via
a menu-structured hierarchical user’s surface. Also
picture engineering and programming are done at
this place.

The system server containing the process data
base is an industrial PC mounted in a small panel
under the control desk. The bus masters SRI0500
reside in a separate cubicle in the SMS room. The
PTCS is time synchronized by a radio clock signal
(DCF77) received by a clock card in the system
server. A communication processor (NET) pro-
vides the system server with 8 serial ports capable
of utilizing a number of different protocols. The
additional X-Terminal accesses the system server via
an Ethernet LAN running the TCP/IP protocol.

The application is established with the
MicroSCADA system from ABB running under
UNIX. The pictures on the monitors are full graph-
ic based on OSF/Motif standards.

The system features four authorisation levels,
starting from a mere process overview without con-
trol rights up to all functions including the adding
and removal of users.

SMS WORKPLACE
This is the working place for the protection or
maintenance engineer. The work may include verifi-
cation and modification of protection settings, the
evaluation of disturbances using the sequence of
events list and the evaluation program REVAL, or
the elimination of failures showing up from persist-
ent alarms.

The REVAL program allows the generation of
fault diagrams for the time before, during and after
a fault with flexible scales, modes of presentation
and exact time marking.

This workplace in the SMS room has a desktop
PC with MS-Windows, a color printer and an event
logger. The PC gets all data via the Ethernet LAN.
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