for the start-up and shut-down procedures in the case of longer standstills. The diesel exhaust is fed into two turbochargers. A portion of the exhaust gases can be utilized in a waste-heat boiler producing steam for preheating the heavy fuel oil and those units at standby.

Silencers lower the exhaust sound to a level below the values stipulated by Greek and EU legislation. The system is supplied with fuel from fuel tanks, after being passed through a heavy fuel oil treatment plant with self-cleaning separators and filter systems. The oil sludge produced during the treatment is utilized in the incinerator for heat and steam generation.

Scope of supply of ABB Kraftwerke AG as specified by the turnkey contract for the Rhodes diesel power plant:

- Engineering, calculation, delivery, installation, commissioning, and acceptance tests
- Three 29-MVA generators
- Three 30-MVA main transformers
- Three 2.5-MVA auxiliary transformers
- MV switchgear units
- Digital DPC system with VDU-based process control, hardware and software, including data transfer to the load dispatcher on the island of Rhodes
- Central control room equipment
- Protection, instrumentation and metering equipment
- Training of the customer's operating and maintenance personnel, including documentation
- Performance of trial run in accordance with details agreed in the contract
- Assistance in operating plant during the semi-commercial and commercial operating phase
- Verification of the specified operating data

Rhodes diesel power plant, today with two 12-MW and three 24-MW units **1**

The diesel engines and generators are cooled in a primary cooling cycle that uses demineralized water. The cooling water is cooled in a secondary cooling cycle with heat-exchangers that make use of seawater. Treatment of the seawater is necessary to prevent the formation of algal vegetation. The operational wastewater from all areas of the power plant is collected and cleaned in the wastewater treatment plant before being discharged into the sea.

Process control tasks

The DPC system for the new 24-MW units 3, 4 and 5 has the following main process control tasks:

- Safe and cost-effective start-up and shut-down of the three units, with the shortest possible times for start-up
- Economical handling of changing load conditions on the basis of the power demands made on the local grid
- Automatic control and monitoring of the mechanical equipment, while en-

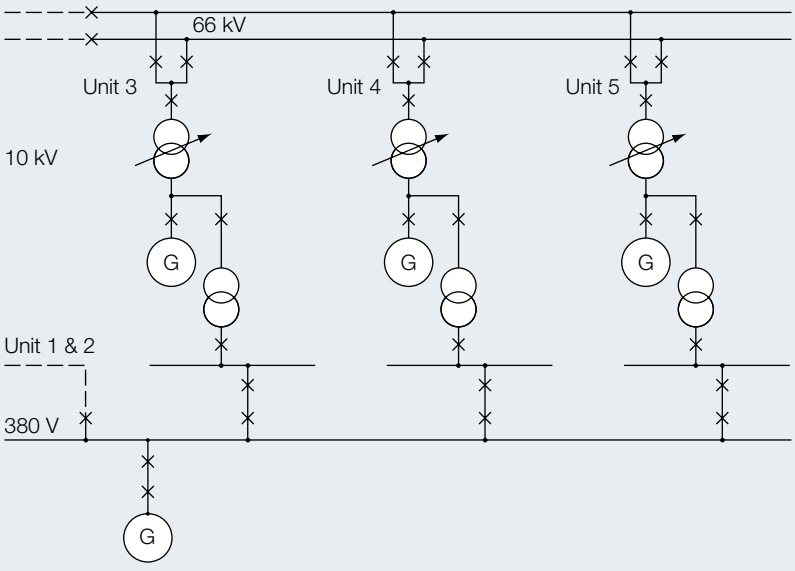
Table 1:
Technical data of units 3, 4 and 5 of the Rhodes diesel power plant

Main data	
Output per unit (MW_e)	23.411
Overall output (MW_e)	70.233
Diesel-generator set	
Diesel engine	
Supplier	SEMT Pielstick
Type	PC 4.2-B, four-stroke, 18 cylinders, 2 turbochargers
Output (MW)	23.85
Synchronous generator	
Supplier	ABB
Type	W 268/125/14
Output (MVA)	29.35
Power factor	0.8
Frequency (Hz)	50
Speed (rev/min)	428.6
Static excitation system	
Supplier	ABB
Output (kVA)	250
Main transformer	
Supplier	ABB
Output (MVA)	30
Voltage (kV/kV)	10/66
Type of cooling	ONAN/ONAF

suring the highest possible level of plant reliability and availability

- Protective measures to guard the plant from inadmissible operating conditions

Single-line diagram of the three new 24-MW units 3, 4 and 5 **2**



- Monitoring and control of power plant operation from the central control room
- Video display of process data in the control room, facilitating quick intervention by the operating personnel in the event of disturbances; in addition, essential process data is shown on a mosaic display panel and on an operator desk.

Process control concept

The customer specified high-quality process control features to ensure optimized plant operation. The installed system with its hardware and software components and a user-friendly man-machine communication interface is designed to meet the demands in full.

The digital stored-program control system is based on a hierarchical control concept with decentralized units. The data is transmitted over a high-speed data bus (Ethernet IEEE), providing real-time information at any point on the data bus **4** .

Monitoring and diagnostic functions are automatic, thus ensuring reliable fault detection at operator stations in the central control room for fast clearance of faults.

The power plant control and monitoring functions are assigned to three different control levels to ensure reliable and user-friendly operation and maintenance of the plant:

- Central unit control level
- Distributed system control level
- Drive control level

The high level of reliability of the DPC system is enhanced further by a redundant MB 300 bus. This bus is based on coaxial and fiber-optic cables providing links to the process computers for the diesel-generator sets as well as to the process computers in the vicinity of the

general auxiliary systems, such as the sea-water pumping station, heavy fuel oil treatment plant and the general equipment in the machine hall. The data bus also provides interfaces between the computers and the relay room, the recorder and mosaic display panel, the control desk and the information management system.

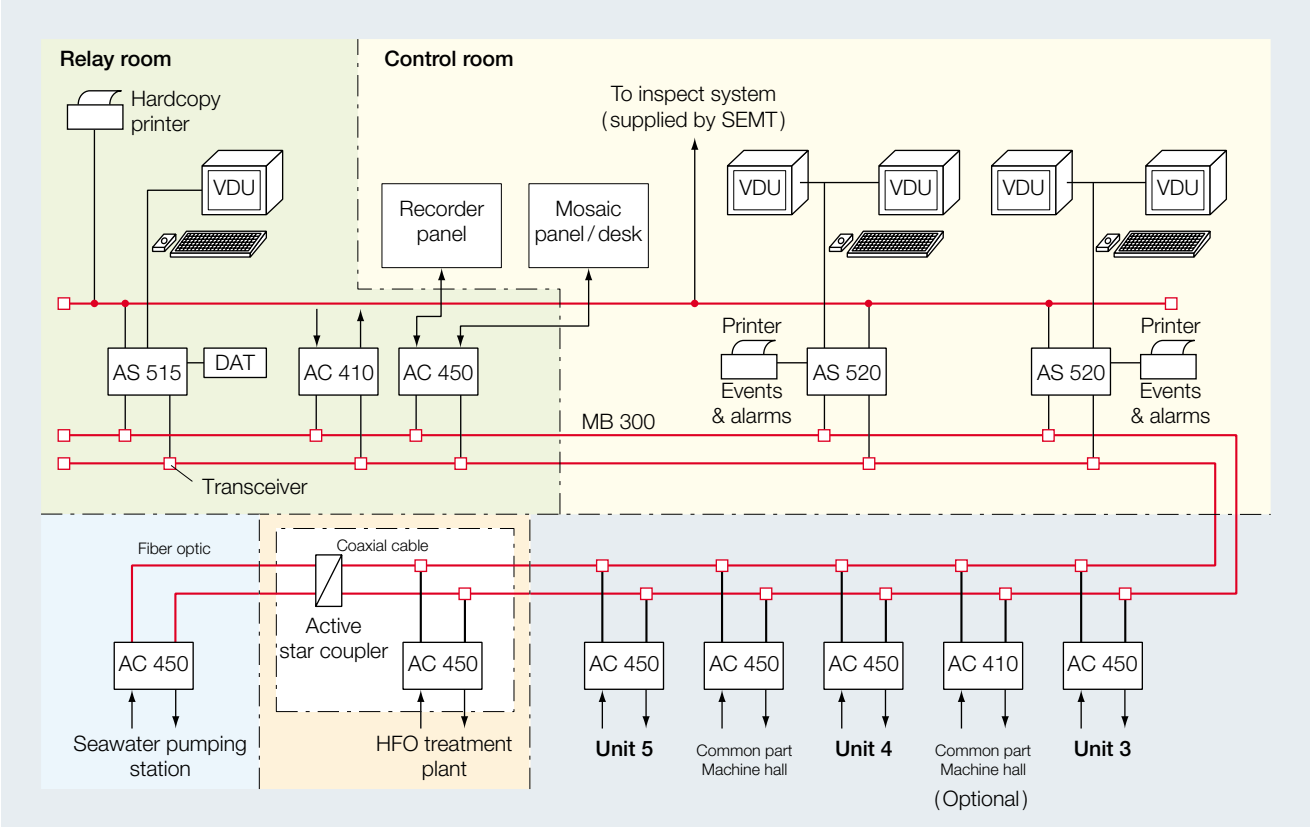
The functionality of the installed process control system provides for operational control and protective functions as well as database-related functions for historical data acquisition and the generation of trends and statistics:

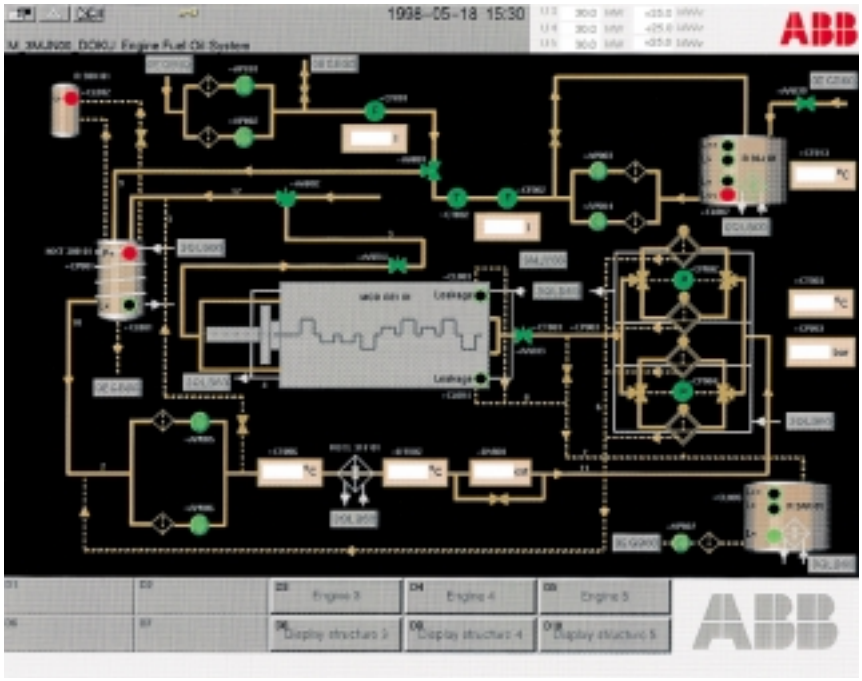
- Acquisition and sequenced processing of all operating data
- Monitoring and control of the three generator sets

One of the three 24-MW diesel-generator sets 3

Configuration of the Diesel Process Control (DPC) system for units 3, 4 and 5 4

AC *Decentralized process computer*
AS *Operator station computer*
DAT *Historical data storage (tape unit)*
VDU *Display unit in operator station*





Screenshot of the fuel system for the plant **5**

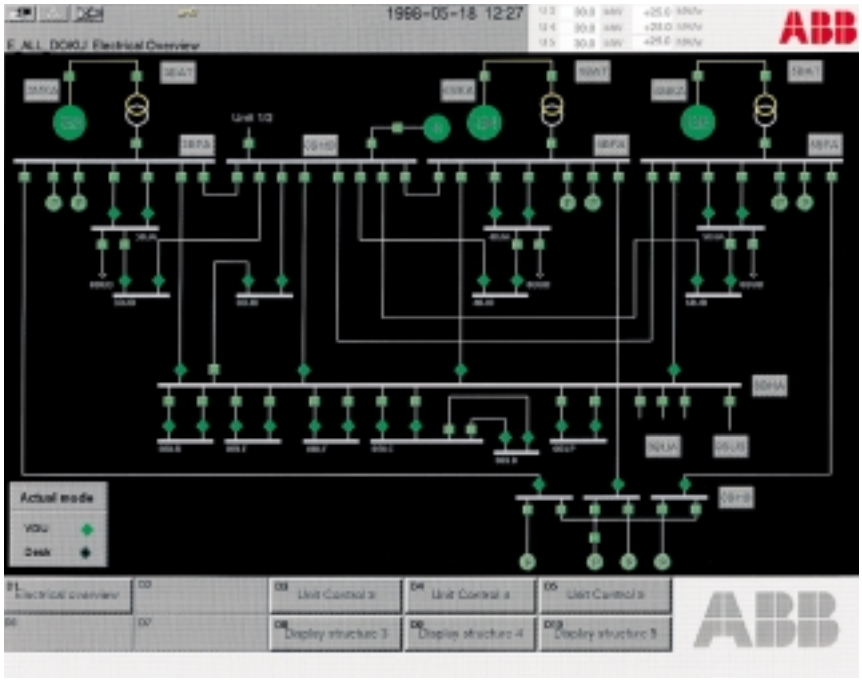
- Monitoring and control of the general and auxiliary systems
- Monitoring and control of the 66-kV switchyard
- Specification of the setpoints for automatic start-up and shut-down of the diesel-generator units
- Specification of the output and voltage control setpoints for the generators and the overall power plant
- Time synchronization for the entire process control system
- Transfer of information to the load dispatcher of the customer
- Information management system, including operator station, for operational statistics with historical data memory

The process variables are controlled and displayed at two operator stations, each with two VDUs. The DPC system processes all of the relevant process data:

- 4,740 digital inputs (status messages)
- 1,300 digital outputs (command outputs, signals)
- 700 analogue inputs (measured values, counter readings)
- 230 analogue outputs (indicators, recording devices)

The system can be easily extended for larger amounts of data. The process control equipment is supplied through an uninterruptible power supply system.

Screenshot of the electrical equipment, including the generators **6**



Components of the DPC system

The distributed process computer stations consist of the following main units:

- Process computer (AC400) including central processing units and I/O boards
- Interface for the MasterBus 300
- I/O interface between the stations and the process
- Power supply and distribution
- Transducers for electrical variables
- Synchronization equipment

The above components are housed in sheet-steel cabinets complying with protection class IP 42. The generator control functions also include control and monitoring of the power output and the speed of the machine. Values can be set for the voltage, speed and load, these being processed and maintained by the regulators

situated further downstream. The design of the control features allows isochronous load sharing, base loading and droop mode operation.

The generator sets are usually started up, shut down and controlled from the central control room. The operator can choose whether the diesel-generator sets are to be operated in manual or automatic mode. Operation of the auxiliary systems is fully automatic; all functions for pressure, level or other control, with either binary or analogue signals, are monitored. Every item of information about the power plant process is transmitted to the high-performance bus in real-time sequence, whereupon it is available to every station connected to the bus.

The operator stations include the following features:

- System monitoring
- Listing of alarms and events
- Graphic process images in real time 5
- Object displays 6
- Trend displays and curves
- Reports
- Security system for selected operator access to special system data and applications
- Network communication
- Clock synchronization via bus/network
- Windowing capabilities

The decentralized system configuration with a central control room gives the operator full access to all the process data and operational processes at all times. The control system philosophy is based on a large number of stand-alone control units, resulting in independent process sections.

The plant is operated from the operator stations in the control room as well as from manual controls at the control cabinets or local operating panels for the auxiliary systems or switchgear units.

The operator stations are incorporated in the central control desk 7. They comply with the standards applicable for industrial use and feature all the ergonomic qualities found in modern control room design.

Operator station in the central control room 7

Operating experience

The three new power plant units and the DPC system have been on-line since late 1997. The experience gained during commissioning and the first phase of operation shows that the new control technology meets the high expectations for the project in full.

The 8-day and 10-day load operations which were contractually specified showed that the overall plant is able to maintain its reliability standards during the semi-commercial and commercial operating phase. The specified operating data were verified in pre-defined performance test procedures that were conducted in mid-1998 in cooperation with independent experts appointed by the customer.

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