1. Nuclear Power Plant Dukovany

1.1 Reactor Unit Scheme with identified main components

NPP Dukovany reactor unit scheme is shown in the Fig. 1-1. Following main components are identified:

PRIMARY CIRCUIT

1. Reactor
2. Steam generator
3. Pressuriser
4. Spent-fuel storage pool
5. Refueling pit
6. Refueling machine
7. Main coolant pump
8. Pressure relief tower
9. HVAC system
10. Ventilation chimney
11. Main crane

SECONDARY CIRCUIT

12. High-pressure turbine stage
13. Low-pressure turbine stage
14. Generator
15. Condenser
16. Separator-reheater
17. Regenerative heaters
18. Feedwater tank with degasifier
19. Steam piping into turbine
20. Cooling circulation circuit piping
21. Insulated cables for generator power outlet
22. High-voltage transformer 400 kV
23. House transformer 6 kV
24. Manipulation crane

1.2 NPP technical parameters

Number of reactor units	4
Reactor Type	Pressurised water reactor VVER 440/213

Output parameters of one unit

Nominal thermal output	1375 MWt
Generator output	440 MWe
Net electrical output	388 MWe
Own consumption	52 MWe

Reactor technical parameters

Reactor height	23.67 m
Pressure vessel inner diameter	3.542 m
Cylindrical part wall thickness	340 mm
Thickness of pressure vessel cladding	9 mm
Empty pressure vessel weight	215.15 t
Reactor weight	395 t

Reactor core

Number of fuel assemblies	312
Number of fuel elements per assembly	126
Number of control assemblies	37
Core height	2.5 m
Core diameter	2.88 m
Fuel enrichment	1.6/2.4/3.82* % U 235
Core loading (UO_2)	42 t
Fuel cycle	four years with partly transition to five years

* with profiled enrichment

Reactor cooling system

Number of cooling loops	6
Inner diameter of main cooling piping	500 mm
Volume of coolant in primary circuit	209 m^3
Primary circuit working pressure	12.25 MPa
Inlet coolant temperature	approx. 267 ^oC
Outlet coolant temperature	approx. 297 ^oC
Reactor coolant flow	42 000 m^3 per hour

Steam-generator

Number per unit	6
Steam production per SG	452 t. p h.
Steam output pressure	4,61 MPa
Steam output temperature	260.0 ^{o} C
Steam generator weight	approx. 165 t
Steam generator body diameter	3.21 m
Steam generator body length	11.80m

Main coolant pump

Number per unit	6
Nominal power consumption	1.6 MW
Operational capacity	approx. 7000 m^3 per hour
Rotor speed	1500 r.p.m.
Pump weight	approx. 48 t

Turbine

Number of high-pressure sections	1
Number of low-pressure sections	2
Nominal rotor speed	3000 r.p.m.
Inlet steam temperature	256 ^oC
Inlet steam pressure	4.3 MPa

Generator

Rated power	220 MW
Output voltage	15.75 kV
Nominal frequency	50 Hz
Cooling media	hydrogen - water

Condenser

Number per turbine	1
Number of pipes per condenser	approx. 31 716
Water flow	35 000 m^3/hour
Pipe material	titanium

Cooling towers

Number per unit	2
Height	125 m
Diameter in top of the tower	59.49 m
Foot diameter	87.94 m
Wall thickness	0.6-0.15 m
Water flow (one tower)	approx. 10.55 m^3/s
Volume of evaporated steam from one tower	max. 0.15 m^3/s

1.3 Modernization activities already carried out in Dukovany NPP

A) Activities carried out within the "Back-fitting of NPP Dukovany"

1. A7 Main coolant pump control algorithms modification
2. A8 Steam generator level measurement reliability improvement
3. A12 Hydrogen recombination system within hermetic zone installation
4. A21 High-pressure compressors replacement
5. A23 Addition of redundant back-up to the category one power supplies No. 4
6. A30 Teledosimetric system installation
7. A32 Grab tank on Skryje stream installation
8. B1 Cooling system installation for the machine halls roof steel structure
9. B5 Stationary fire extinguishing equipment installation for central oil system
10. B7 Unit electrical fire detection system upgrade
11. B10 Stationary halon fire extinguishing system installation for unit electrical equipment

B) Activities carried out within the "Modernization of NPP Dukovany"

1.	ZL 1702	Installation of electrical fire detection system at water pump station "Jihlava"
2.	ZL 2180	Modernization of system for public warning during accidents
3.	ZL 2374	Construction of interim spent fuel storage facility
4.	ZL 3103	0.4 kV switchgears upgrade
5.	ZL 3582	TH 10 valves control
6.	ZL 3664	32/16/16 MVA back-up transformer installation
7.	ZL 3701	Pressure measurement in the OG box
8.	ZL 3704	Reconstruction of the protection actuated by "HPK break" signal.
9.	ZL 3818	EDU surroundings teledosimetric system. RA control data transfer
10.	ZL 3863	Fire-proof spraying of critical and important cable rooms
11.	ZL 4290	PV KO keys modification
12.	P590	AKOBOJE Automated Physical Protection System Optimization
13.	P591	Freon replacement in SZCH
14.	P598	Water treatment station modernization
15.	P602	MCR simulator
16.	P606	Roof flats construction for the EDU employees
17.	S150	Condenser reconstruction
18.	S357	Post-emergency hydrogen recombination
19.	S439	Replacement feeding water line for the SKŘ sensors flushing system
20.	S568	TQ sumps protection
21.	S675	Water and Oil coolers replacement in the diesel generator I station
22.	S765	Condensate treatment system modernization
23.	S776	Diesel generators electrical system reconstruction
24.	S952	Construction of intermediate floor in the PPR and SD rooms
25.	T130	Construction of new telephone switchboard
26.	T248	PV KO (relief valve) node reconstruction
27.	T263	HNČ replacement
28.	T317	Water and Oil cooler replacement for diesel generator II station
29.	T370	Replacement of TG pumps by a sealess type

30.	T547	First category power supplies system No. 4 batteries replacement
31.	T556	Control room diesel generator annunciation upgrade
32.	T703	SHNČ section collector displacement
33.	T764	SO continuous measurement system installation
34.	T802	Section switchboards service inlets of selected consumers reconstruction
35.	T982	Fire protection barriers
36.	T983	Fire protection barriers
37.	T984	Fire protection barriers

2. Nuclear power plant Timelines

2.1 Reactor Unit Scheme with identified main components

NPP Temelín scheme is shown on Fig. 2-1. Following main components are identified:

1. Reactor
2. Primary circuit piping
3. Main coolant pump
4. Pressuriser
5. Steam generator
6. Polar Crane
7. Spent-fuel pool
8. Refueling machine
9. Hydro-accumulators
10. Containment
11. Ventilation stack
12. Emergency core cooling system
13. Diesel generator station
14. Machine hall
15. Feed-water tank
16. Main steam piping
17. High-pressure turbine stage
18. Low-pressure turbine stage
19. Generator
20. Exciter
21. Separator
22. Condenser
23. Heat exchanger
24. Coolant inlet and outlet
25. Pumping station
26. Cooling water pump
27. Cooling tower
28. Generator power output
29. Transformer
30. Power output
31. Distillate reservoirs

2.2 NPP technical parameters

Number of units	2
Reactor Type	PWR VVER 1000

Unit parameters

Nominal thermal output	3000 MWt
Generator output	981 MWe
Net electrical output	912 MWe
Own consumption	69 MWe

Reactor technical parameters

Reactor height	10.9 m
Pressure vessel inner diameter	4.5 m
Cylindrical part wall thickness	193 mm
Thickness of pressure vessel cladding	7 – 18 mm
Reactor weight without coolant	approx. 800 t
Pressure vessel weight	322 t

Reactor core

Number of fuel assemblies	163
Number of fuel elements per assembly	312
Number of control rods	61
Height of active core	3.6 m
Core height	3.1 m
Fuel enrichment	max. 5 % U 235
Core loading (UO_2)	92 t
Fuel cycle	four years

Reactor cooling system

Number of cooling loops	4
Inner diameter of main Cooling piping	850 mm
Volume of coolant in primary circuit	337 m^3
Primary circuit working pressure	15.7 MPa
Inlet coolant temperature	approx. 290^o C
Outlet coolant temperature	approx. 320^o C
Coolant flow	84 800 m^3/hour

Steam-generator

Number per unit	4
Steam quantity produced in one steam generator	1470 t/hour
Outlet steam pressure	6.3 MPa
Outlet steam temperature	278.5^o C
Steam generator weight	approx. 416 t
Steam generator body diameter	4,2 m
Steam generator body length	14,5 m

Main coolant pump

Number per unit	4
Nominal power consumption	5.1 – 6.8 MW
Operational capacity	approx. 21 200 m^3 p. hour
Rotor speed	1000 r.p.m.
Pump weight	approx. 156 t

Containment system

Height of cylindrical part	38 m
Inner diameter of cylindrical part	45 m
Wall thickness	1.2 m
Thickness of stainless steel liner	8 mm

Turbine

Number of high-pressure sections	1
Number of low-pressure sections	3
Rotor speed	3000 r.p.m.
High-pressure section weight	206 t
Low-pressure section weight	480 t

Generator

Rated apparent power	1111 MW
Power factor	0.9
Output voltage	24 kV
Nominal frequency	50 Hz
Cooling media	hydrogen – water
Weight	564 t

Condenser

Number per turbine	3
Number of pipes per condenser	approx. 32 000
Pipe length	12 m
Pipe material	titanium

Cooling tower

Number per unit	2
Height	154.8 m
Diameter in top of the tower	82.6 m
Foot diameter	130.7 m
Wall thickness	0.9 – 0.18 m
Number of askew columns	112
Water flow (one tower)	approx. 17.2 m^3/s
Volume of evaporated steam from one tower	max. 0.4 m^3/s

2.3 Design changes performed at Temelín NPP

ITEM No.	ITEM	REASON	COMMENT
1	I&C Systems replacement	1,3	Unit 1 and 2 I&C. The replacement does not concern common and auxiliary I&C systems
2	Nuclear fuel, control rods (lifetime)	1,3	New nuclear fuel brings significant nuclear safety improvement, radioactive wastes and operational costs reduction
3	Radiation monitoring system (RMS)	3,2	Original design of RMS did meet neither technical nor legislative requirements
4	Primary circuit diagnostic system (TMDS)	4,1	Original design of primary circuit diagnostic system was not completely solved
5	Sipping	2,3	Original (Russian) system did not meet new legislation and western standard requirements
6	Bitumination system	1	Requirement for radioactive wastes reduction defined by PRE-OSART mission
7	Refueling machine I&C system replacement	3	Replacement of the original GANZ system with the system supplied by the ANSALDO company
8	Installation of compact grid in the spent fuel pool	4	New compact grid enables significant increase of spent fuel pool capacity
9	Simulator	1,2	provision for the operational personnel training
10	Technical support center	1	Fulfillment of the recommendations accepted after the TMI emergency
11	Inverters, rectifiers (AEG)	3	Replacement of the original (Russian) electrical instrumentation ABP (ANN) of safety systems power supplies was initiated by the requirement for nuclear safety improvement
12	Penetrations (Škoda+ISTC Company)	3	Provision for safe hermetic penetration
13	Replacement of J2UX circuit breakers	3	Initiated by negative operating experience at Bohunice and Dukovany NPPs (fires, etc.)
14	Unit transformer penetrations (Passoni Villa bushings)	3	Replacement of original (Russian) penetrations because of negative operating experience at other Czech power plants
15	Addition of back-up power supply for reactor building No. 2	1	Requirement for separation of power supplies for each unit
16	Addition of a common back-up diesel generator station (DGS)	1,4	Addition of another back-up emergency power supply source for safety related systems for the reason of provision of this power supply type for important and costly equipment
17	Increase of accumulator batteries capacity	1	Replacement of original accumulator batteries because of negative operating experience and with the intent to increase their operational capacity in case of total station blackout
18	Implementation of "reserve electrical protections" and provision for full selectivity in 6 kV radial electrical networks	4	Fully selective scheme providing for the elimination of failures in the electric part of the individual units (short-circuits, problems with grounding, etc.).
19	Pressuriser electrical heaters continuous control	1	The intent is to decrease ageing of primary circuit components
20	Installation of hydrogen recombination system	1	Elimination of hydrogen in the containment during accidents
21	Post-accident hydrogen monitoring system	1	Monitoring of hydrogen concentration during and after accident.
22	Replacement of selected valves	3	Replacement of unreliable valves
23	Reconstruction of stabile fire extinguishing system for outdoor power transformers	1	Inclusion of automatic activation; installation of additional barriers; installation of additional nozzles
24	Introduction of secondary load follow regulation	4	Technical requirements of ČEZ, a.s. defined in connection with the preparation of the operation with UCPTE

ITEM No.	ITEM	REASON	COMMENT
25	Construction of plant terminal (TELETE)	4	Technical requirements of ČEZ, a.s. defined in connection with the preparation of the operation with UCPTE
26	Modification of the TVD and TVN water systems	4	Initiated by results of new hydraulic calculations to assure full system functionality in all operating modes
27	Replacement of pumps	3	Liquidation of manufacturers, unsuitable characteristics
28	Modification of containment cesspool system	1	Modifications based on results of tests performed in Russia
29	Containment venting (single failure)	1	Sheathing of first closing valve and corresponding piping under the containment
30	Titanium condenser pipes installation	4	Increase of pipes lifetime with the transition to a more effective chemistry regime (by increasing pH)
31	Control rod drives replacement	3	Increase of the lifetime and reliability using innovated drives manufactured by ŠKODA
32	Introduction of new chemistry control	4	Increased quality of the chemical control enables to reach longer lifetime of important components, in particular the steam-generator
33	New safety analysis	1,2	Reworking of safety analyses in connection with the fuel and I&C replacement
34	ATWS analyses	1	Reworking of safety analysis in relation to latest findings in nuclear power engineering
35	PSA level 1 and 2 development project	1	level 1 – solves the probability of core damage level 2 – solves the probability of releases due to core damage
36	Severe accidents analysis	1	Studies of selected severe (beyond design basis) accidents
37	SW independent verification & validation project (IV&V)	2	Independent verification and validation of safety critical SW
38	Leak Before Break	1	Assessment of primary circuit integrity securing level (prevention against LOCA)
39	EOP development project	4,1	Symptom based emergency procedures development (prevention of accidents)
40	SAMG development project	1,4	Guidelines for liquidation of accidents (logically linked with EOP)- accident mitigation
41	Fire safety, cables, electronic fire detection system	2,4	Replacement of original cabling with fire-poof and fire non-propagating ones; installation of electronic fire detection system manufactured by CERBERUS.
42	Seismic analyses	1	Re-assessment of Temelín design against newly defined seismic loading - 0.1 g; calculation of response spectra for each floor, rep. building; seismic re-qualification
43	Completion of documentation	2	Project for amendment and completion of required documentation related to safety related equipment (strength, lifetime, seismicity).
44	ISE project	4,1	Installation of computer based information system
45	Modification of SG inner parts	4	Modification of the feeding node and SG separation (lifetime improvement)
46	Addition of new SG water level measurement	2	Project assure separations of safety divisions
47	I&C system for polar crane replacement	3	Replacement of the original ROBOTRON system with a new one, more reliable and enabling addition of functionality
48	Filtration system for emergency control room	1	Addition of filters in HVAC system will enable use of MCR even during accidents
49	Modification of main control room venting system	1	Assuring the main control room environment according to standards (temperature, noisiness, etc.)

ITEM No.	ITEM	REASON	COMMENT
50	Installation of GERB absorbers	2	Fulfillment of seismic requirements
51	Addition of drench fire extinguishing system for main coolant pumps	2	Reaction to regulatory body requirements
52	Addition of radioactive waste treatment system for liquid wastes liquidation after accidents	1	Lowering of radioactive wastes volume
53	Addition of system for collection of boric water and system for separation	1	Lowering of radioactive wastes volume
54	Replacement of asbestos sealing	4,2	Replacement with Teflon provides for increased technological equipment lifetime
55	Installation of new heat-exchangers of active engineered safety systems	3	Low quality of original heat-exchangers
56	Addition of relief valve to pressuriser system	1	Prevention of false actions of pressuriser safety valves
57	Replacement of steam generator steam pipes quick-acting valves	3	Protection of important and costly components
58	Modernization of main coolant pumps	4,1	Provision for required coolant flow through the core, fixation of the impeller, rotor balancing
59	Organized depository of high activity wastes	2	Change of original radioactive waste depository concept
60	Replacement of freon in cooling systems	2	Reconstruction of cooling station with use of absorber units

Legend : Reason for design change:

1 – recommendation of individual missions and audits (IAEA, NUS Halliburton, TUV, etc.)
2 – requirement coming from regulatory body or/and from new legislation
3 – replacement of components because of low quality of original ones, loss of supplier, etc.
4 – ČEZ own decision