Tianhuangping Pumped Storage Power Station

The Tianhuangping Pumped Storage Power Station was built in Anji County of Zhejiang Province, 175 km southwest of Shanghai, which includes the upper reservoir, lower reservoir, headrace tunnel, underground powerhouse caverns and switch station. The power station, with an installed capacity of 1800 MW, is equipped with six 300 MW reversible Francis pump turbines. Water is conveyed through two headrace tunnels of 7 m diameters each, which branch in front of the powerhouse into three penstocks with a diameter of 3.2 m each. The six tailrace tunnels have a diameters of 4.4 m each. Power is fed into the network via a switchyard on the left bank of the lower reservoir.

The lower reservoir is formed by a CFRD dam of 95m high, with an overall storage volume of 8.6 million m^3, a catchment area of 24.2 km^2 and average annual runoff of 27.6 million m^3. The design maximum pool level of the lower reservoir is 344.5 m. The construction of the CFRD dam commenced in October of 1993, and was completed in 1997.

The upper reservoir is at an elevation approximately 600 m higher, in a natural valley basin where the only opening is closed by a 72 m high rockfill dam, so as to maintain the 2315 m long crest constantly at elevation of 908 m. Four smaller saddle dams have been constructed to form the reservoir. The maximum depth of the reservoir is 50 m. The slope and bottom of the upper reservoir have an asphalt concrete lining, which is best suited to absorb the settlements and deformations in the reservoir without becoming permeable to water. The lining areas amount to 104,000 m^2 for the reservoir bottom and 182,000 m^2 for the reservoir slope, with a slope inclination of 1V:2~2.4H.

The substructure consists of a drainage layer made of crushed rock, the thickness of which is 90 cm on the slope and 60 cm on the bottom. Bituminous emulsion was sprayed to stabilize the substructure surface and to achieve a better bond with the asphalt binder layer.

The asphaltic binder layer is 10 cm thick on the slope and 8 cm on the bottom. The thickness of the impervious asphalt concrete layer is 10 cm in both cases. In order to protect the asphalt concrete against ageing as a result of ultra-violet radiation associated with oxygen in the air, the slope and the bottom are provided with an asphalt mastic seal coating. In the curve between the slope and the bottom and at the connections to the concrete structures, a 5 cm thick protective layer of asphalt concrete is applied, together with the polyester mesh reinforcement. Domestic bitumen products, of which several types were carefully examined, had been ruled out due to their excessive paraffin content, which impairs the bonding characteristics of bitumen.

Tianhuangping Pumped Storage Project is the first large scale project of its kind in China, and STRABAG Tiefbau GmbH was awarded the contract to implement the asphalt concrete lining. During construction, a site laboratory was set up, and nearly all the tests within the suitability testing were also carried out at site and not only (as is mostly the case abroad) at the central laboratory of STRABAG in Germany. The construction of the asphaltic lining was completed in 1997.

In 1998, the first unit was put into power generation. According to a recent inspection of the reservoir, the operation of the power station was very well, with leakage nearly to be zero. In 2004, the Tianhuangping Pumped Storage Project was awarded the state Twin-Golden Prize of both project reconnaissance and project design.

The project features are shown in the following table.

Table.1 Main features of Tianhuangping Pumped Storage Power Station

No. and names	Unit	Amount	No. and names	Unit	Amount
Hydrology			Dam height/crest length	m	72/577
Catchment area			2. Lower reservoir		
Upper reservoir dam	km^2	0.327	Storage level		
Lower reservoir dam	km^2	24.2	Design maximum	m	344.5
Mean annual runoff (Lower reservoir)	$\times 10^4$ m^3	2760	Design minimum	m	295.0
Typical discharge (Lower reservoir)			Design flood (P=1%)	m	347.3
Mean yearly	m^3/s	0.876	Check flood (P=0.1%)	m	348.3
Design flood (P=1%)	m^3/s	536	PMF	m	349.3
Check flood (P=0.1%)	m^3/s	859	Reservoir storage capacity		
PMF	m^3/s	1280	Total (design max. level)	$\times 10^4$ m^3	859.56
Sediment (Lower reservoir)			Normal power capacity	$\times 10^4$ m^3	676.76
Mean annual concentration	$\times 10^4$ ton	0.83	Standby capacity	$\times 10^4$ m^3	125.32
Mean annual load	kg/m^3	0.192	Dead storage capacity	$\times 10^4$ m^3	57.48
Pumping and power generation features			Dam		
Installed capacity	MW	1800	Type: CFRD		
Effective storage capacity			Elevation of Crest/parapet wall	m	350.2/351.5
Normal power output	$\times 10^4$ m^3	676.76	Dam height/crest length	m	92/225.11
Standby output	$\times 10^4$ m^3	125.32	Spillway		
Reserve for downstream consumption	$\times 10^4$ m^3	30	Type: side weir without gate		
Peak and valley modulation			Discharge (design/check/PMF)	m^3/s	536/859/1280/
Mean annual output	$\times 10^8$ kW.h	30.14	Energy dissipation: ski-jump		
Mean annual input	$\times 10^8$ kW.h	41.04	3. Headrace system		
Main structures			Upper intake		
1. Upper reservoir			Type: Bank shaft		
Storage level			Num. of inlet		2
Design maximum	m	905.2	Size (wide/height)	m	23.9/10.0
Design minimum	m	863.0	Num. of plane gate		2
Storage capacity			Gate wide/height	m	6.0/7.03
Total of design max. level	$\times 10^4$ m^3	919.2	Penstocks		
Normal power capacity	$\times 10^4$ m^3	676.76	Type: embedded		
Standby capacity	$\times 10^4$ m^3	125.32	Main pipe		
Reserve of downstream consumption	$\times 10^4$ m^3	30	Number		2
Dead storage capacity	$\times 10^4$ m^3	37.97	Length / inner diameter	m	882.2/7.0
Basic earthquake intensity		Less than VI	Bifurcated pipe: concrete		
Seepage prevention of upper reservoir			Branch pipe		
Type: Asphalt lining			Numers		6
Area	$\times 10^4$ m^2	28.5	Inner diameter	m	3.2~2.0
Main dam			Length	m	229.9~314.7
Type	asphalt concrete face rockfill dam		Steel lining length	m	184.5~232.7
Elevation of crest/parapet wall	m	907.5/908.8	Max. dynamic head	m	887

No. and names	Unit	Amount	No. and names	Unit	Amount
Tailrace tunnel			Pump lift (max./min.)	m	610.2/518.5
Number		6	2. Generator and motor		
Length/inner diameter	m	229~247/4.4	Type: 3 phase/vertical shaft		
Intake of upper reservoir			Number		6
Type: Bank slope inlet			Rated capacity:		
Numer		6	Engine (cosφ=0.90 lag)	MVA	333
Outlet size (wide/height)	m	10.9/7.0	Motor (cosφ>0.975)	MVA	336
Emergency gate type: plane, high pressure			Rated voltage	kV	18
			Initiate mode: frequency convert		
Number/size(wide/height) of emergency gate	-/(m/m)	6/(3.6/4.4)	3. Other equipment		
Bulkhead gate type: plane, sliding			Inlet spherical valve		
Number of bulkhead gate		3	Numer		6
Bulkhead gate size (wide/height)	m	4.4/4.92	Inner diameter	m	2.0
4. Underground powerhouse and switch station			Design pressure	MPa	8.7
Size of underground caverns (long/wide/height)			Bridge crane		
Power cavern	m/m/m	198.7/21/47.7	Number	-	2
			Lift capacity	ton	250/50/10
Main transformer cavern	m	180.9/18/24.7	SFC		
			Number	-	2
			Capacity	MW	22
			Rated voltage	kV	18
Six bus bar caverns	m/m/m	Long: 33.5 Wide/height= 6.2/6.5 8.2/9.5	Rated direct current	A	1300
			Frequency	Hz	0~52.5
			Main transformer		
			Type: indoor, 3 phase, oil dipped, double coils		
Tailrace emergency gate cavern	m	147.5/7.2/15.1			
Access tunnel	m	695.7/8.2/8.45	Cooling: OFWF		
Gravity drainage tunnel	m	1624/3.0/2.8	Number	-	6
Erection elevation of units	m	225	Rated capacity	MVA	360
Generator floor elevation	m	239.3	Rated voltage	kV	515±8×1.25%/18
500kV Switch station			500kV Cable		
Area (long/wide)	m	208/35	Type: XLPE dry		
Elevation	M	350.2	Rated voltage (V_0/V)	kV	298/515
Main machinery and electric apparatus			Max. work current	A	890
1. Pump turbine			Cross section/ material	-	800mm^2/copper
Type: vertical shaft, single grade			Number	-	3
Number	-	6	500 kV GIS		
Rated output	MW	306	Rated voltage	kV	550
Maximum input	MW	<336	Rated current	A	3150
Turbine gross head (max/min)	m	610.2/518.5	Rated withstand current/ duration	kA/s	50/3
Turbine rated head	m	526	Rated peak withstand current	kA	125
Turbine rated discharge	m^3/s	67.6			

Fig. 1 Bird view of Tianhuangping Power Station