Chapter 7 Conceptual Design of Priority PSPP

7.1 Study on Optimum Development Scale

To conduct a conceptual design and to estimate roughly project cost for the priority development candidate site, Altınkaya PSPP and Gökçekaya PSPP, the optimum development scale of each project was evaluated based on topographical maps of 1/5,000.

(1) Methodology of optimization of development scale

The economic efficiency evaluation of the optimum development scale of priority PSPP was conducted by B/C method applying GT thermal power plant as an alternative power source.

The B/C method calculates a ratio of total development cost and O&M cost of a gas turbine thermal power project (Benefit: B) to those of a PSPP project (Cost: C). The following equations are used for calculating Cost and Benefit:

$$C = C1 + C2$$
$$= P_P \times I_P \times a_P + P_P \times H \times F_P / \eta_P$$

C1 ; annual costs of PSPP generation
C2 ; annual costs for pumping
I_P ; construction unit costs of PSPP
a_P ; annual cost factor
P_P ; peak generation capacity
H ; annual equivalent hours for continuous peak generation (800 hours)
F_p ; fuel costs for pumping (coal thermal)
η_P ; total efficiency of PSPP generation (70%)

$$B = B1 + B2$$
$$= Y_A \times I_A \times a_A \times \alpha_1 + P_P \times H \times F_A \times \alpha_2$$

B1 ; kW values of alternative power plant
B2 ; kWh values of alternative power plant
Y_A ; effective generation capacity (installed capacity − unusable capacity)
I_A ; construction unit costs of alternative power plant (gas turbine)
α_1 ; kW adjustment coefficient (a parameter to adjust the difference of power supply reliability between PSPP and alternative. The difference comes from the duration of maintenance works, probability of forced outage, ratio of plant self-use, and T&D losses.) Here, 1.21 is used.
a_A ; annual cost factor of alternative power plant
H ; annual equivalent hours for continuous peak generation (800 hours)
F_A ; fuel costs of alternative power plant (gas turbine)
α_2 ; kWh adjustment coefficient (a parameter to adjust the difference of ratio of plant self-use and T&D losses). Here, 1.03 is used.

(2) Unusable capacity

A PSPP cannot always operate at its full capacity, since its daily operation is influenced by peak generation hours and generation capability for pumping during off-peak hours. Thus, when daily generation energy, which is determined by the volume of stored water for generation, is insufficient, full power operation cannot meet the operation hours required for demand and supply balance, and PSPP has to be operated at partial load. The reduction of output capacity caused by such a situation is generally called as "unusable capacity."

Since unusable capacity depends largely on required peak duration hours and pond storage capacity, the required peak duration hours were determined as 7 hours, which was calculated by the demand supply balance simulation (described in detail in Section 4.6.2), and the effective capacity was calculated with the following equation:

$Y_A = P_P \times h$ ／(required peak generation hours＝7 hours) (h ＜ 7 hours)

$= P_P$ (h ≧ 7 hours)

ここに、Y_A ; effective capacity（peak generation capacity－unusable capacity）

P_P ; peak generation capacity

h ; peak duration hours of PSPP（6, 7, 8 hours）

(3) Input parameters

Interest, depreciation, and O&M costs were taken as fixed costs, and fuel prices in 2020 were considered as variable costs in this economic analysis. For calculating fuel cost of pumping energy, fuel cost of imported coal thermal power plant and total efficiency of PSPP of 70% were also considered. Input parameters are shown in Table 7. 1.

Table 7. 1 Input Parameters

Power source	Construction cost	Life time	Annual O&M cost factor	Fuel cost
PSPP		40	1.0%	Coal thermal
GT thermal	500 USD/kW	20	5.0%	14.1 USC/kWh
Coal thermal	1,600 USD/kW	20	3.5%	3.6 USC/kWh

(4) Comparative study of the optimum development scale and the economic analysis results

(a) Altınkaya PSPP

Optimum development scale has been studied from the viewpoint of economical efficiency. The comparative study cases, whose main parameters are installed capacity and peak duration hours, are shown in Table 7. 2.

Table 7. 2 Comparative Study of the Optimum Development Scale（Altınkaya PSPP）

Max Capacity (MW)	Operation Hour (hr)	Active Storage (10^6m^3)	Effective Head (m)	Turbine Discharge (m^3/s)	Upper Dam		Lower Dam	Underground Structure		
					HWL LWL (EL.m)	Height (m)	HWL LWL (EL.m)	Tunnel Dia (m)	Penstock Dia. (m)	P.S Volume (10^3m^3)
1,000	6	4.5	592	206	817 800	67	190 160	6.5	3.7	162
	7	5.2	592	206	819 800	69				
	8	6.0	592	206	821 800	71				
1,400	6	6.1	604	280	822 801	72		7.5	4.3	215
	7	7.1	604	280	825 801	75				
	8	8.1	604	280	827 801	77				
1,800	6	7.6	611	350	827 802	77		8.4	4.8	266
	7	8.9	611	350	829 802	79				
	8	10.1	611	350	831 802	81				

The construction unit cost of each case is shown in Table 7. 3 and Figure 7. 1.

The construction unit costs vary between 663 USD and 946 USD, and the larger is the installed capacity, the lesser is the project cost due to scale economy. The difference of the construction unit costs by operation hour is not so remarkable, i.e., 2-5 USD/kW.

Table 7. 3 Construction Unit Cost of Each Case

Operating hr	6			7			8		
Output (MW)	1,000	1,400	1,800	1,000	1,400	1,800	1,000	1,400	1,800
Total project cost (×mil. USD)	942	1067	1,193	944	1,070	1,201	946	1,078	1,209
Construction unit cost (USD/kW)	942	762	663	944	765	667	946	770	671

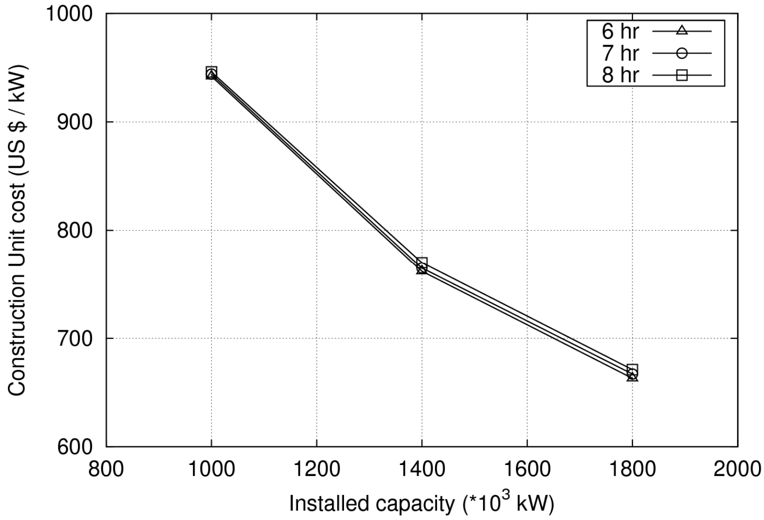


Figure 7. 1 Correlation between Installed Capacity and Construction Unit Cost

(b) Gökçekaya PSPP

The optimum development scale has been studied from the viewpoint of economical efficiency. The comparative study cases, whose main parameters are installed capacity and peak duration hours, are shown in Table 7. 4.

Table 7. 4 Comparative Study of the Optimum Development Scale（Gökçekaya PSPP）

Max Capacity (MW)	Operation Hour (hr)	Active Storage (10^6m^3)	Effective Head (m)	Turbine Discharge (m^3/s)	Upper Dam		Lower Dam	Underground Structure		
					HWL LWL (EL.m)	Height (m)	HWL LWL (EL.m)	Tunnel Dia (m)	Penstock Dia. (m)	P.S Volume (10^3m^3)
1,000	6	6.9	376.5	316	800 780	25	389 377.5	7.9	4.5	195
	7	8.0	376.5	316	800 778	27				
	8	9.2	376.5	316	800 775	30				
1,200	6	8.1	378.5	372	800 777	28		8.6	4.9	226
	7	9.4	378.5	372	800 774	31				
	8	10.8	378.5	372	800 770	35				
1,400	6	9.3	379.5	428	800 774	31		9.2	5.3	266
	7	10.8	379.5	428	800 770	34				
	8	12.4	379.5	428	- -	-				

*) The case of 1,400 MW and 8hrs cannot secure the amount of active storage of the upper dam due to the present topographical condition.

Construction unit cost of each case is shown in Table 7. 5 and Figure 7. 2.

The construction unit costs vary between 768 USD and 944 USD, and the larger is the installed capacity, the lesser is the project cost due to scale economy. The difference of the construction unit costs by operation hour is not so remarkable, i.e., 5-20 USD/kW.

Table 7. 5 Construction Unit Cost of Each Case

Operating hr	6hr			7hr			8hr		
Output (MW)	1,000	1,200	1,400	1,000	1,200	1,400	1,000	1,200	1,400
Total project cost (×mil. USD)	931	1,002	1,075	936	1,009	1,099	944	1,033	-
Construction unit cost (USD/kW)	931	835	768	936	841	785	944	861	-

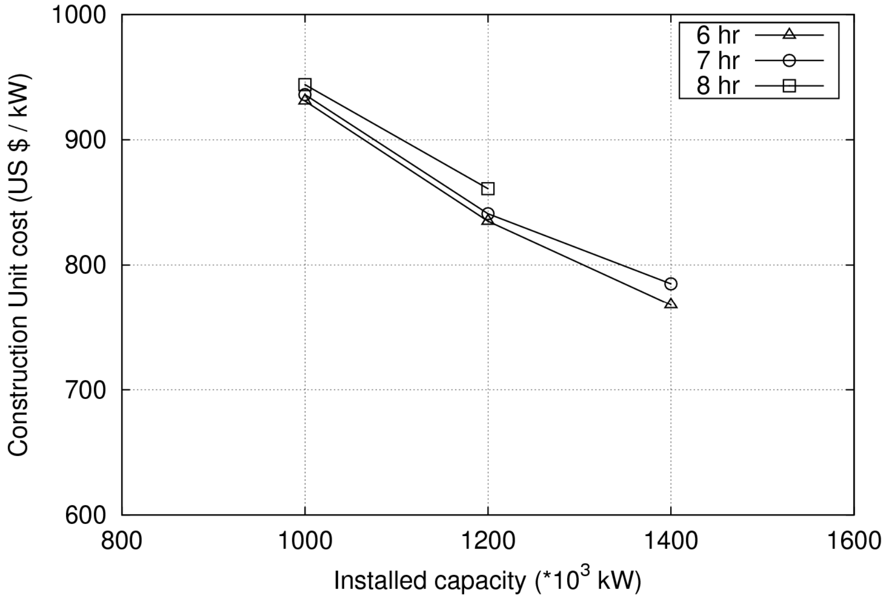


Figure 7. 2 Correlation between Installed Capacity and Construction Unit Cost

(5) Analysis results of optimum development scale

(a) Altınkaya PSPP

The project's (B/C) and (B-C) of each case are shown in Table 7. 6 and Figure 7. 3.

Table 7. 6 Analysis Results of the Optimum Development Scale

Unit : mil. USD

Peak Duration (hr)	6			7			8		
Output (MW)	1,000	1,400	1,800	1,000	1,400	1,800	1,000	1,400	1,800
Effective Output (MW)	857	1,200	1,543	1,000	1,400	1,800	1,000	1,400	1,800
Benefit (B)	203.1	284.3	365.5	217.5	304.5	391.5	217.5	304.5	391.5
Cost (C)	146.9	177.4	208.0	147.1	177.8	208.8	147.3	178.6	209.6
B/C	1.38	1.60	1.76	1.48	1.71	1.87	1.48	1.70	1.87
B-C	56.2	106.9	157.5	70.4	126.7	182.7	70.2	125.9	181.9

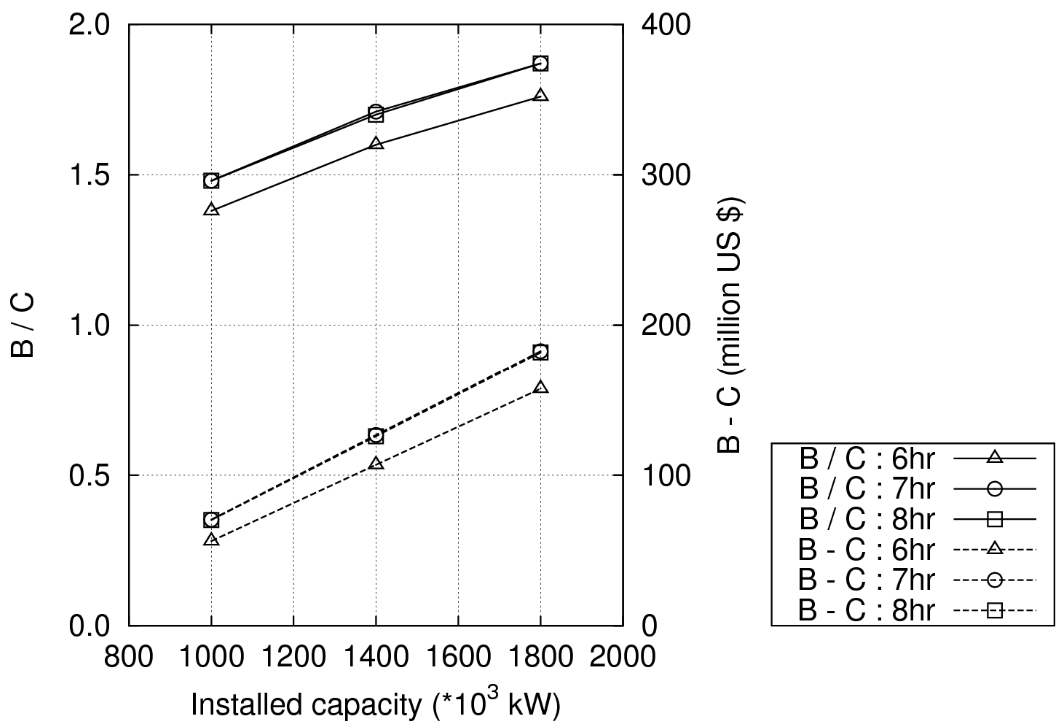


Figure 7. 3 Correlation between Installed Capacity and B/C, B-C

The case of installed capacity of 1,800 MW (450 MW × 4 units) and peak duration hours of 7 hours was selected as the optimum development scale for Altınkaya PSPP, since it has the maximum B/C value of 1.87.

(b) Gökçekaya PSPP

The project’s Benefit/Cost (B/C) ratio and Benefit- Cost (B-C) of each case are shown in Table 7. 7 and Figure 7. 4.

Table 7. 7 Results of the Optimum Development Scale

Unit : mil..USD

Peak Duration (hr)	6hr			7hr			8hr		
Output (MW)	1,000	1,200	1,400	1,000	1,200	1,400	1,000	1,200	1,400
Effective Output (MW)	857	1,029	1,200	1,000	1,200	1,400	1,000	1,200	1,400
Benefit (B)	203.1	243.7	284.3	217.5	261.0	304.5	217.5	261.0	
Cost (C)	145.7	161.9	178.3	146.2	162.7	181.0	147.1	165.4	
B/C	1.39	1.51	1.59	1.49	1.60	1.68	1.48	1.58	
B-C	57.4	81.8	106.0	71.3	98.4	123.5	70.4	95.7	

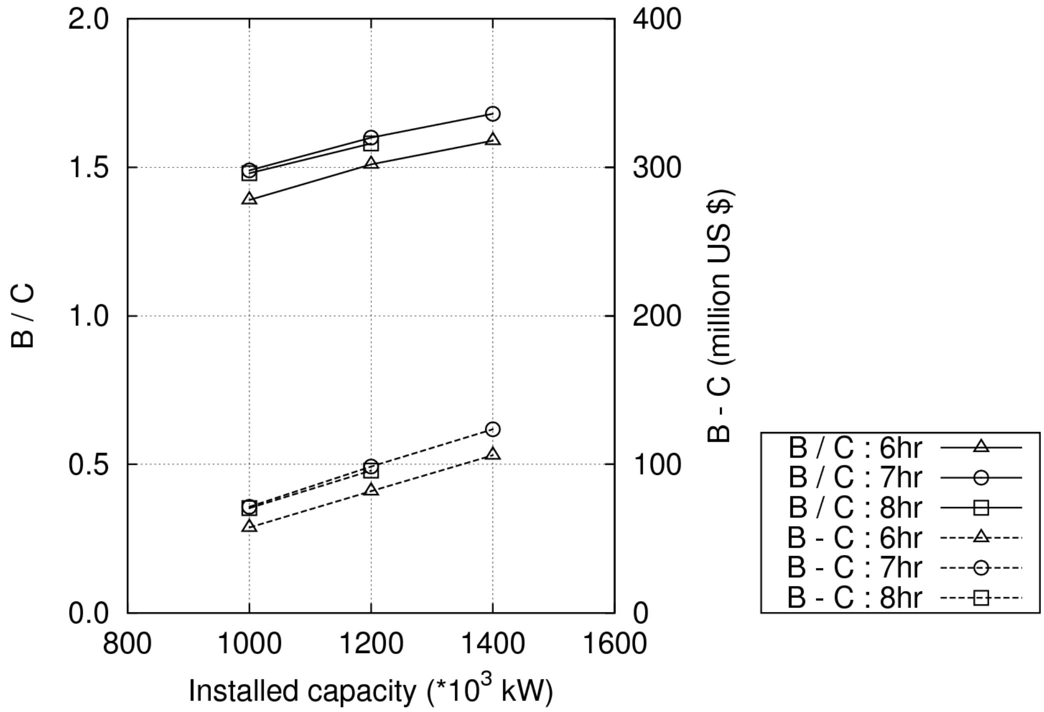


Figure 7. 4 Correlation between Installed Capacity and B/C, B-C

The case of installed capacity of 1,400 MW (350 MW × 4 units) and peak duration hours of 7 hours was selected as the optimum development scale for Gökçekaya PSPP, since it has the maximum B/C value of 1.68.

7.2 Conceptual Design of Altınkaya PSPP

As a result of the conceptual design of Altınkaya PSPP, the main features are shown in Table 7. 8 and structural drawings are presented in Figure 7. 5 and Figure 7. 6 and Appendix 7-2. The conceptual design of the site is as follows.

7.2.1 Design of Power Generation Plan

A power generation plan is an important matter in the design of a PSPP's facilities. However, many revisions are necessary to reach an optimum plan, since features of a power generation plan are also changed by the design of facilities.

The conceptual design was carried out according to the flowchart of Figure 7. 7 based on the topographical maps of 1/5,000. The main features of power generation plan were decided as shown in Table 7. 8.

Figure 7. 5   Altınkaya PSPP General Layout

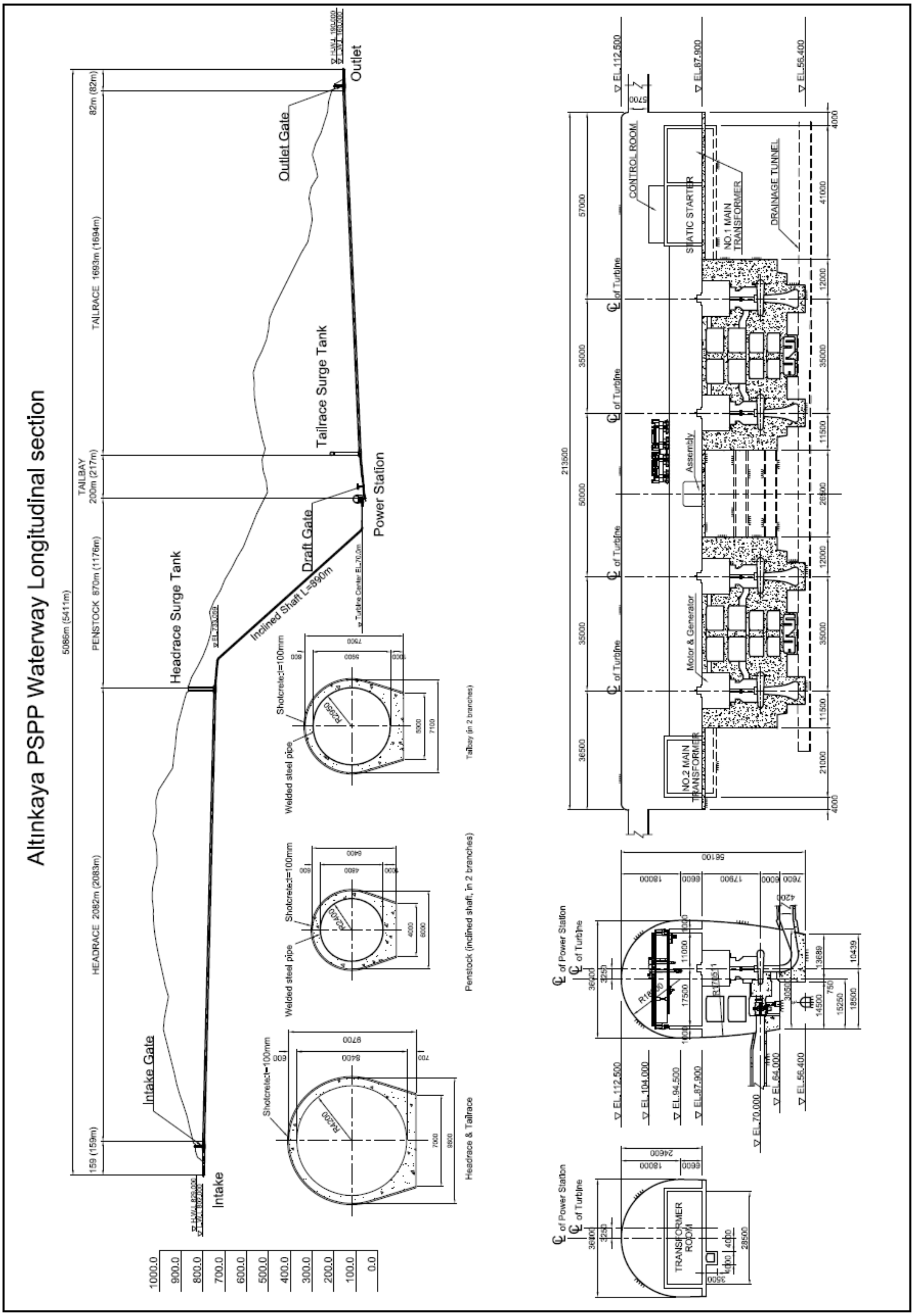


Figure 7. 6 Altınkaya PSPP Waterway Longitudinal Section

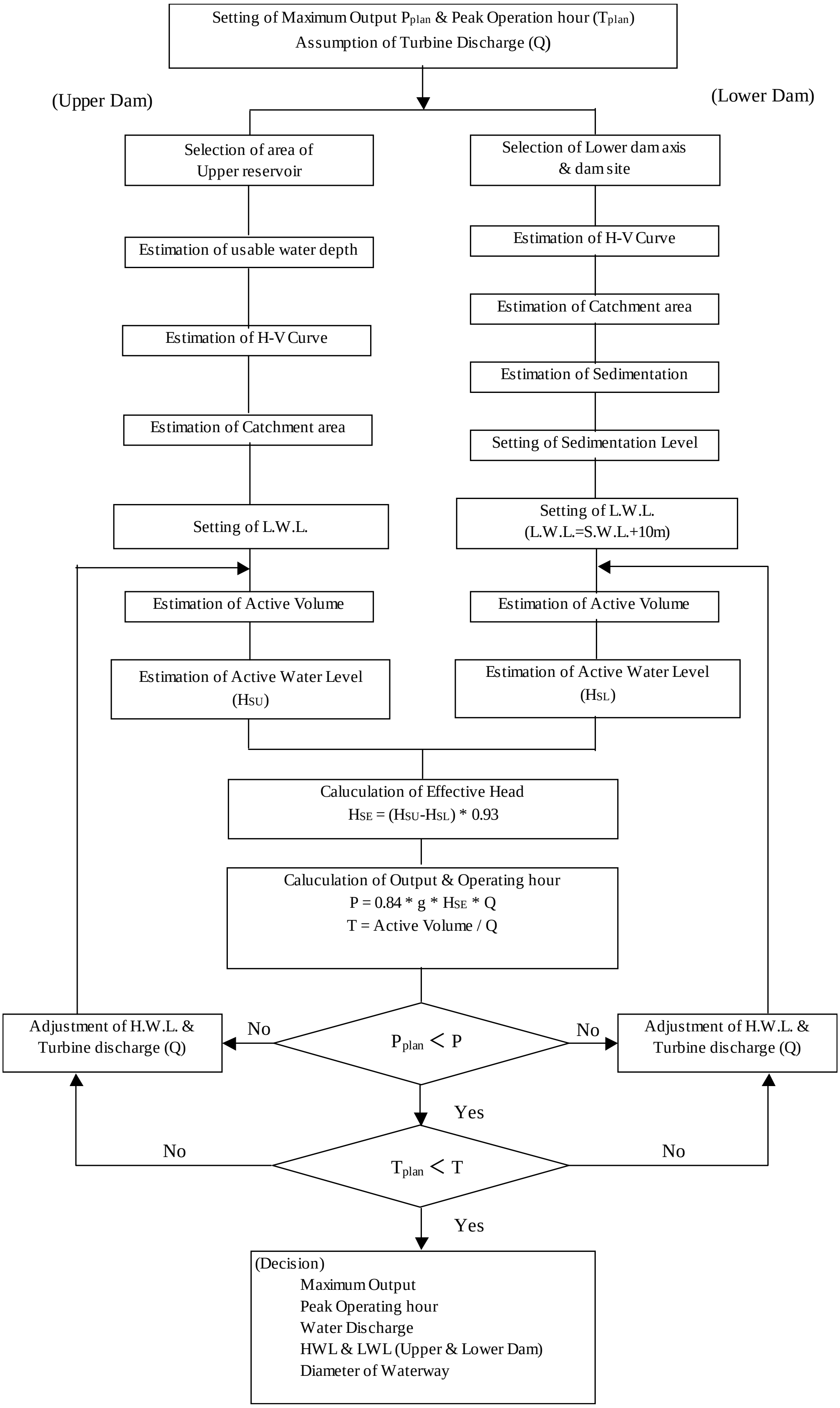


Figure 7. 7 Flowchart of Study on Power Generation Plan

Table 7. 8 Main Features of Altınkaya PSPP

	Description		Unit	Altınkaya PSPP
General	Installed Capacity	P	MW	1,800
	Designed Discharge	Qd	m^3/s	350
	Effective Head	Hd	m	611
	Peak Duration Time		hrs	7
Upper Dam and Reservoir	Type			Concrete Gravity Dam
	Height	H	m	79
	Crest Length	L	m	330
	Dam (Bank) Volume	V	m^3	467,000
	Excavation Volume	Ve	m^3	341,000
	Reservoir Area	Ra	km^2	0.5
	Catchment Area	Ca	km^2	60.6
	H.W.L		m	829
	L.W.L		m	802
	Usable Water Depth		m	27
	Effective Reservoir Capacity		$mil.m^3$	8.9
Lower Dam Reservoir	H.W.L		m	190
	L.W.L		m	160
	Usable Water Depth		m	30
	Effective Reservoir Capacity		$mil.m^3$	2,892
Waterway	Intake	L(m) x n	m	Open 60 x 1, Tunnel 99 x 1
	Headrace	L(m) x n	m	2,083 x 1
	Penstock	L(m) x n	m	1,066 x 2 , 110 x 4
	Tailbay	L(m) x n	m	105 x 4 , 112 x 2
	Tailrace	L(m) x n	m	1,694 x 1
	Outlet	L(m) x n	m	Tunnel 37 x 1, Open 45 x 1
	Total Length	Lt	m	5,411
Powerhouse	Type			Egg-shape (Underground)
	Overburden		m	437
	Height		m	56.1
	Width		m	36
	Length		m	213.5
	Cavern Volume		m^3	266,000
Turbine	Type			Single-Stage Francis
	Number		unit	4
	Unit generating capacity		MW	450

7.2.2 Design of the Main Structures and Equipment

(1) Design of civil structures

(a) Upper dam and reservoir

The upper dam was designed as a concrete gravity dam which requires small amount of rock, since it is unclear whether enough amount of rock as the construction material of dam is exploitable or not. A diversion tunnel is constructed for the dam construction, which has a discharge capacity for 30 years of probability flood flow of 80 m^3/s. Spillway gates, which have a discharge capacity of $500m^3/s$, and outlet gate, which has a discharge capacity of $50m^3/s$, are planned to be installed and discharge flood flow under operation.

The HWL of the reservoir is planned as 829 m and usable water depth is planned as 27 m to secure the required active storage capacity of 8.9 × 10^6 m^3. In addition, a disposal bank of 500,000 m^3 is planned inside the reservoir to dispose efficiently soil and rock brought about by excavation of dam and intake, and the soil and rock will be used for the construction material of cofferdam in the upper dam construction area.

The correlation between the utilization of water depth and the active storage capacity of the reservoir is shown in Figure 7. 8.

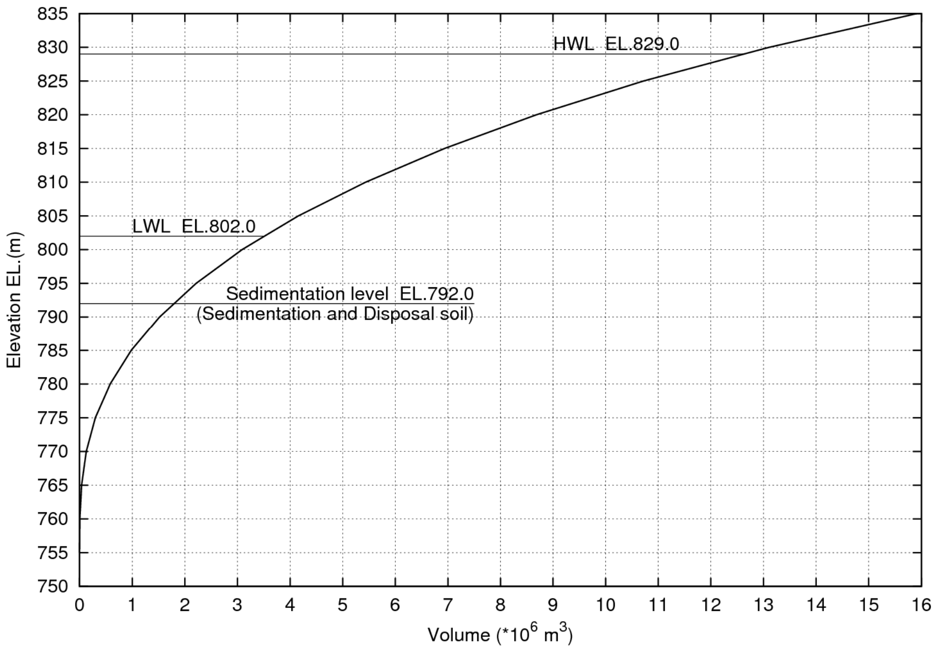


Figure 7. 8 Storage Capacity Curve of the Upper Reservoir

(b) Intake

Lateral type of intake is adopted, which is applied generally for the intake of PSPP. It is laid out in line with the ridge in the reservoir, and the mouths are designed to make the flow velocity at inlet of water less than 1 m/s. The bottom level of intake is set as 793 m, which is 1 m higher than the sedimentation level, and height of mouth is 8.4 m, which is the same as the height of the headrace tunnel. LWL is set as 802 m, which is 0.6 m higher than the top elevation of the mouth. In addition, 1.5 m height of anti-vortex girder is installed.

(c) Waterway and underground powerhouse

Generally, the shortest route shall be selected between the upper reservoir and the lower reservoir for the waterway alignment, based on the topographical and geological conditions. However, there are following constraints concerned in this project site.

- Waterway tunnel cannot be constructed under the village on the southeast of the intake.
- Outlet should be located in a cove of the lower reservoir, which is a suitable place to construct the cofferdam.

Therefore, waterway should be curved to meet the above requirements. The curves are planned to be located at the points which have a distance of 30*D* each from the intake and the outlet to prevent drift flow in the intake and outlet. As well, the curves' radiuses were designed as 300 m considering the workability of construction. Here, *D* is the internal diameter of headrace/tailrace tunnel.

The shape of waterway was designed as circular in order to prevent stress concentration.

1) Headrace

Reinforced concrete shall be placed for the headrace lining. The inner diameter is determined as 8.4 m under the condition of maximum velocity of 6.5 m/s based on the experiences in Japan. Detailed design of the headrace is as follows:

- The headrace tunnel length is approximately 2,100 m and the shape of excavation section is a horseshoe with height of 9.8 m.
- Reinforced concrete lining is constructed after excavation.
- Consolidation grouting is planned to improve permeability and deformation modulus of the area loosened by excavation, and to expect pre-stress effect on the concrete lining.

2) Headrace surge tank

Headrace surge tank is planned to place at the joint of headrace and penstock, and the top of the surge tank is on the ground surface of a ridge. Upper surge was estimated 40 m higher than HWL of the upper reservoir. Shaft diameter is set as 15 m, and port section diameter is set as 4.5 m according to the surging analysis. The waterway is bifurcated at the headrace surge tank.

3) Penstock

The penstock is designed as a 10% inclined tunnel from the headrace surge tank to the upper bending point, which has an overburden depth of more than 50 m, and as 48° inclined shaft, which degree is decided considering the repose angle of the excavated rock, from the upper bending point to the lower bending point at the elevation of pump-turbine center. Two penstocks are bifurcated to four branches in total in the lower horizontal part, and each branch is put together with the inlet valve. The maximum averaged flow velocity in the penstock is set as 10 m/s and that in the joint part is set as 20 m/s based on the experiences in Japan. A steel pipe is installed in the tunnel and shaft, after which the space is filled with concrete. The detailed design of penstock is as follows:

- The penstock tunnel and shaft of two-branch part is approximately 1070 m long with a horseshoe-shape excavation section of 6.5 m in height. The diameter of the steel pipe is 4.8 m.
- The penstock tunnel of the four-branch part is approximately 85 m long with a horseshoe-shape excavation section of 5.1 m in height. The diameter of the steel pipe is 3.4 m.
- The penstock tunnel of joint part is approximately 25 m long with a horse-shoe-shape excavation section of 4.1 m in height. The diameter of steel pipe is 2.4 m.

4) Underground powerhouse

Principally, the location and direction of the powerhouse caverns are determined after excavating the exploratory adits and investigating geological conditions, e.g., the initial ground pressure and rock mass properties such as by in-situ tests. At this stage, the location of the underground powerhouse is selected to make the waterway the shortest, and where its overburden depth is less than 500 m, which is the maximum value of the existing underground powerhouses.

An egg-shape type, which shape is pertinent for the surrounding rock of cavern to be the most stable mechanically, is selected. The scale of cavern is determined to secure the required space to install electrical equipment based on experiences. The main features are as follows:

Width	:	36.0 m
Height	:	56.1 m
Length	:	213.5 m
Volume	:	266,000 m^3

In addition, main tunnels around the underground powerhouse such as an equipment transportation tunnel 2,560 m long, a cable tunnel of 1580 m, a drainage tunnel of 1,350 m, etc., are planned based on the topographical maps of 1/5,000.

5) Tailbay

Tailbay is defined as waterway between the draft tube and the tailrace surge tank, and four draft gates chambers are installed at the side of the equipment transportation tunnel above the draft gates. Four-branched waterways are merged to two branches in the tailbay and connect to the tailrace surge tank. The detailed design is as follows:

- Tailbay of the four-branch part is approximately 105 m long with a horseshoe-shape excavation section of 5.9 m in height. The inner diameter of the branch tunnel is 4.2 m.
- The tailbay of the two-branch part is approximately 110 m long with a horseshoe-shape excavation section of 5.9 m in height. The inner diameter of the branch tunnel is 5.9 m.
- The inner steel pipes are installed to withstand the water hammer pressure.

6) Tailrace surge tank

A tailrace surge tank is constructed at the joint point of tailbay and tailrace, which has a port and an upper chamber because it is constructed underground. In line with that, the upper surge is not a constraint to decide the diameter of the shaft. Therefore, the inner diameter of the shaft of 10 m and the port diameter of 4.5 m are decided so that the water level of down surge is higher than the LWL of the lower reservoir minus 60 m by calculation of surging. The two branched tunnels are merged to one at the tailrace surge tank.

7) Tailrace

Reinforced concrete shall be placed for the tailrace lining. The inner diameter is determined as 8.4 m under the condition of maximum velocity of 6.5 m/s based on the experiences in Japan. Detailed design of the tailrace is as follows:

- The tailrace tunnel length is approximately 2,100 m and the shape of excavation section is a horseshoe with height of 9.8 m.
- Reinforced concrete lining is constructed after excavation.
- Consolidation grouting is planned to improve permeability and deformation modulus of the area loosened by excavation and to expect pre-stress effect on the concrete lining.

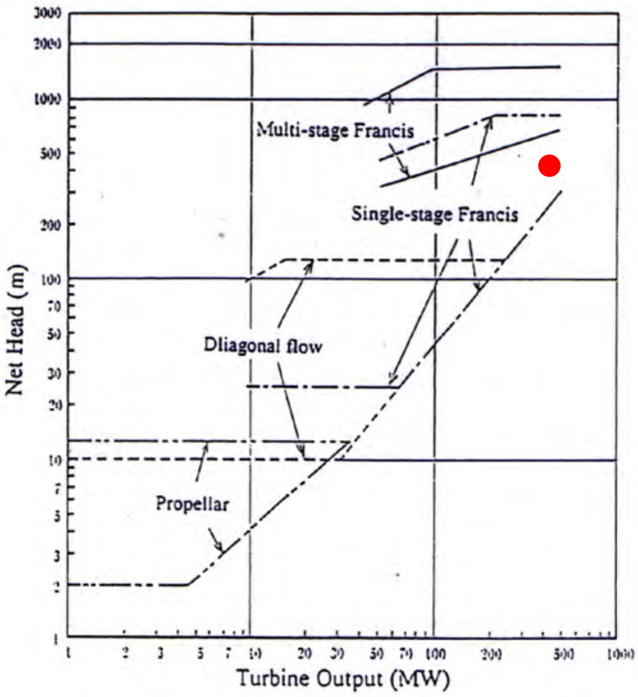
(d) Outlet

A lateral type of outlet is adopted, which is applied generally for outlets of a PSPP, and it is laid out in line with the ridge in the lower reservoir. Since the outlet is constructed in the existing reservoir, the size of outlet shall be small in order to make the cofferdam as small as possible. Although flow velocity at the opposite bank is generally the critical condition to decide the size of the mouth, in this case, the slope of the opposite bank is planned to be protected and the size of mouth is designed just so as to make averaged flow velocity at pumping operation less than 1 m/s. In addition, the top elevation of the mouth is set as 0.5 m lower than the LWL of the reservoir, and a 1.5-m-high anti-vortex girder is installed.

(2) Design of Electromechanical Equipment

(a) Pump-turbine

The applicable type of pump-turbine is restricted by the turbine output and net head as shown in Figure 7. 9. Francis-type single-stage pump-turbine is selected for the Altınkaya PSPP in consideration of this site condition consisting of 610 m effective head and 450 MW unit capacity, which was determined through the study of optimum development scale.



Reference;
Feasibility Study for the Upper Cisokan Pumped Storage Hydroelectric Power Development Project, JICA, March 1995.

Figure 7. 9 Standard of Pump-turbine Selection

The applicable rotating speed is restricted by fabrication limit as shown in Figure 7. 10. Rated rotating speed of 500 min^{-1} is adopted in consideration of this restriction and improvement of economic efficiency by downsizing.

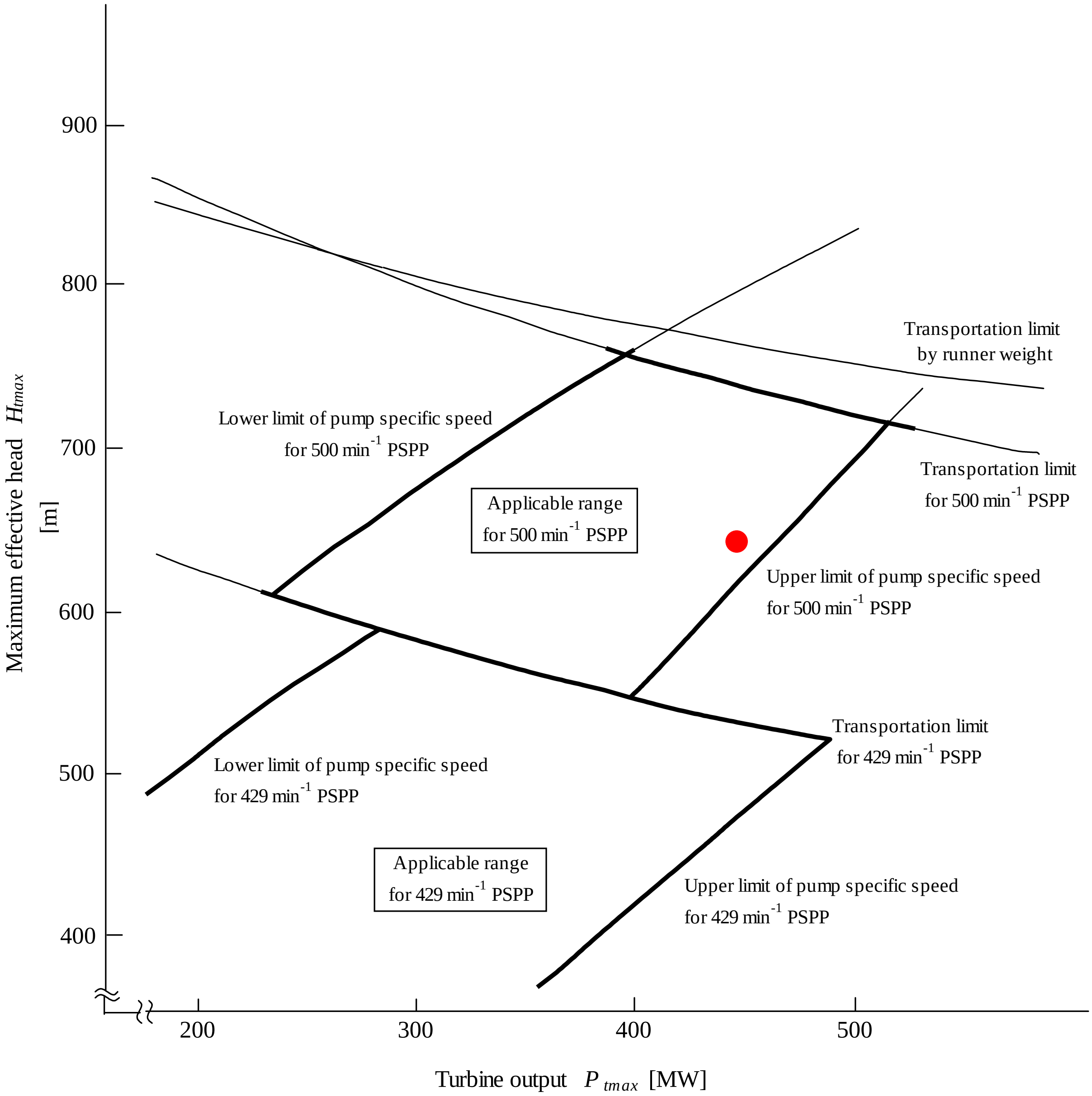


Figure 7. 10 Fabrication Limit of Pump-turbine

The main characteristics of a pump-turbine are designed as follows on the basis of design conditions such as water level of upper/lower reservoir and head loss:

1) Design conditions
   i) High water level of upper reservoir: *UHWL* [m]
   ii) Normal water level of upper reservoir: *UNWL* [m]
   iii) Low water level of upper reservoir: *ULWL* [m]
   iv) High water level of lower reservoir *LHWL* [m]
   v) Normal water level of lower reservoir: *LNWL* [m]
   vi) Low water level of lower reservoir: *LLWL* [m]
   vii) Head loss: H_L [m]

2) Gross head

i) Maximum gross head: $H_{stmax} = UHWL - LLWL$ [m]

ii) Normal gross head: $H_{stnor} = UNWL - LNWL$ [m]

iii) Minimum gross head: $H_{stmin} = ULWL - LHWL$ [m]

3) Basic specifications of reversible pump-turbine and generator-motor

i) Rated generator-motor capacity: P_{gu}

$$P_{gu} = \frac{P_{gmax}}{p_{fg}} \quad \text{[MVA]}$$

where

P_{gmax}: Maximum generator output [MW]

p_{fg}: Power factor of generator 90 [%] (given by the examples of TEPCO)

ii) Maximum turbine output: P_{tmax}

$$P_{tmax} = \frac{P_{gmax}}{\eta_{gmax}} \quad \text{[MW]}$$

where

η_{gmax}: Generator efficiency [%] (based on our experiences with 500 min^{-1} PSPPs)

iii) Maximum motor output: P_{mmax}

$$P_{mmax} = P_{gu} \times p_{fm} \times \eta_{mmax} \quad \text{[MW]}$$

where

p_{fm}: Power factor of motor 95 [%] (given by the examples of TEPCO)

η_{mmax}: Motor efficiency [%] (based on our experiences with 500 min^{-1} PSPPs)

iv) Maximum pump axial input: P_{pmax}

Maximum pump axial input takes a margin of 2.5% against maximum motor output.

$$P_{pmax} = P_{mmax} \times 0.975 \quad \text{[MW]}$$

v) Turbine discharge

Estimated values of normal effective head H'_{tnor} and turbine specific speed n_s are calculated as follows:

$$H'_{tnor} = H_{stnor} - H_L \quad \text{[m]}$$

$$n_s = N \times \frac{P_{tmax}^{\frac{1}{2}}}{H'^{\frac{5}{4}}_{tnor}}$$

The estimated value of turbine discharge at normal head Q'_{tnor} is calculated using turbine efficiency at H'_{tnor}, $\eta_{t(Htnor,Ptmax)}$, which is derived from $n_s - \eta_t$ characteristic of the existing PSPPs:

$$Q'_{tnor} = \frac{P_{tmax}}{9.8 \times H'_{tnor} \times \eta_{t(Htnor,Ptmax)}}$$

4) Reversible Pump-turbine characteristics

Each maximum, normal, and minimum value of effective head/pump head, turbine/pump discharge, output/axial input, and turbine/pump efficiency is calculated using basic specifications of reversible pump-turbine (which were calculated in (3)) and TEPCO's experiences.

5) Cavitation factor σ and suction head H_s

Pressure inside waterway becomes the lowest around runner outlet. When pressure decreases to the saturated vapor pressure, cavitation occurs inside runner. Net positive suction head (*NPSH*) defined by the following formula is used as a factor in judging potential to cause cavitation:

$$NPSH = (-H_s + \frac{v_2^2}{2g} + H_a - A) - H_v$$

where

H_s: Suction head [m]

A: Vertical difference between runner center and bottom edge of runner blade [m]

v_2: Sectional average velocity at draft tube outlet [m/s]

H_a: Atmospheric pressure [m]

H_v: Saturated vapor pressure [m]

The term in parentheses in the right-hand side of the above formula indicates the total pressure at runner outlet as absolute pressure. Accordingly, *NPSH* represents how much the total pressure at runner outlet has a margin against the saturated vapor pressure. *NPSH* per unit head defined by the following formula is called Thoma's cavitation factor:

$$\sigma = \frac{NPSH}{H} = \frac{(-H_s + \frac{v_2^2}{2g} + H_a - A) - H_v}{H}$$

Cavitation factor σ enlarges in line with decrease in the suction head H_s. As cavitation factor increases, the total pressure at the runner outlet has a larger margin against the saturated vapor pressure and cavitation is suppressed. Lowering the installation height of the turbine decreases the suction head, but it leads to increase in the amount of excavation and consequently the construction cost rises. Therefore, the suction head is decided in consideration of not only suppression of cavitation but also construction cost reduction. In the case of reversible pump-turbine, the study on suction head is conducted based on the conditions in pump mode because the most severe condition occurs in pump operation at maximum pump head.

In this study, cavitation factor of 0.142 is estimated based on n_{spo}-σ characteristic of the existing PSPPs and suction head of −90 m is calculated using maximum pump head H_{pmax}.

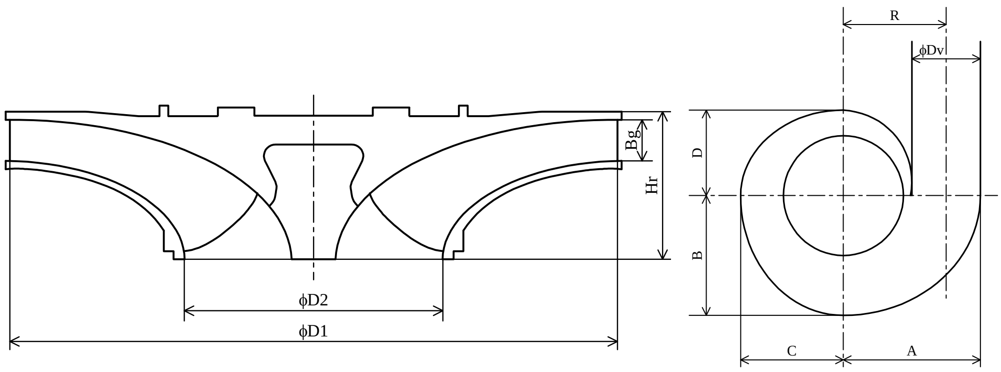
Main characteristics of reversible pump-turbine determined through the above study are shown in Table 7. 9 and Table 7. 10. These characteristics are designed in reflection of the past record of reversible pump-turbine efficiency in Japan, which has been improved through recent research and development. The efficiency of a reversible pump-turbine produced by manufacturers in Japan is a few percentages higher than that of a general pump-turbine, whose number of suppliers is not limited. The adoption of this high-efficiency reversible pump-turbine can make the whole of the project more compact and economical. It can be expected that the adoption of splitter runner (refer to Section 8.2) enables additional improvement of reversible pump-turbine efficiency and expansion of output adjustable range.

Table 7. 9 Main Characteristics of Reversible Pump-turbine (Altınkaya PSPP)

Item	Characteristic	
Type	Vertical shaft single runner single discharge spiral Francis type pump-turbine	
Maximum output [MW]	1,800	
Number of units	4	
Unit capacity [MW]	450	
Rotating speed [min^{-1}]	500 ± 20	
Turbine/Pump	Turbine	Pump
Effective head/Pump head [m] Maximum Normal Minimum	 640.4 611.0 579.4	 687.5 — 625.5
Discharge [m^3/s] at maximum head at normal head at minimum head	 81.9 87.5 82.7	 55.2 — 67.1
Output/Axial input [MW] at maximum head at normal head at minimum head	 464.2 464.2 415.5	 417.8 — 450.0
Efficiency [%] at maximum head at normal head at minimum head	 90.3 88.6 88.5	 89.0 — 89.3
Generator/Motor efficiency [%]	97.1	97.4
Total efficiency [%]	86.0	87.0
Power factor [%]	90	95
Pump specific speed	32.2	
Suction head H_s [m]	- 90	
Head change ratio (H_{pmax}／H_{tmin})	1.19	
Capacity of generator-motor [MVA]	525.0	

Table 7. 10 Main Dimension of Reversible Pump-turbine (Altınkaya PSPP)

Item	Dimension
Diameter of runner inlet: D_1 [m]	4.4
Diameter of runner outlet: D_2 [m]	2.4
Height of runner inlet: B_g [m]	0.39
Casing size: *A* [m]	5.8
Casing size :*B* [m]	5.4
Casing size: *C* [m]	5.1
Casing size: *D* [m]	4.6
Deviation from casing center to inlet center: *R* [m]	4.6
Diameter of inlet valve: D_v [m]	2.4



(b) Generator-motor

In the study on optimum development scale, a generator-motor was designed on condition that adjustable-speed pumped storage power system would be adopted. The adjustable-speed system was developed in order to secure frequency adjustment ability in power system during pumping operation and realize high-efficiency operation during generating operation.

1) Main feature of adjustable-speed pumped storage power system

The main feature of this system is to control the rotating speed of rotor during generating and pumping operation in line with adjusting slip with stator by exciting the cylindrical rotor’s three-winding with variable-frequency three-phase AC.

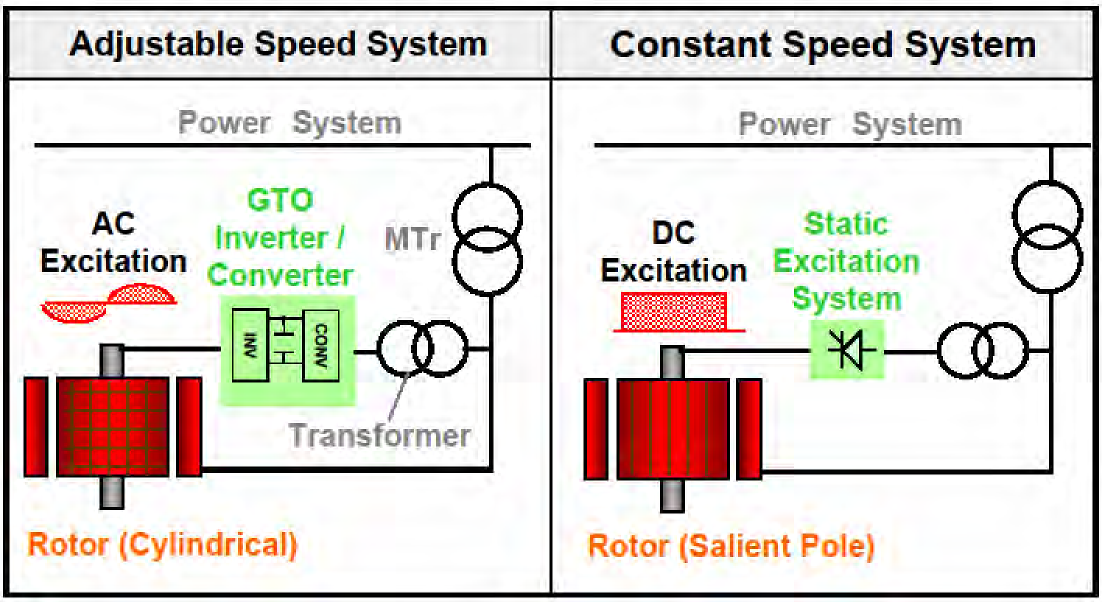


Figure 7. 11 Configuration of Adjustable Speed System

The merits of adopting this technology are as follows:

✓ Input power to motor during pumping operation can be adjusted because axial input power changes in proportion to the cube of the rotating speed of rotor, which can be adjusted within a certain range. As a result of this, frequency adjustment capacity of power system during low demand at night is expanded.

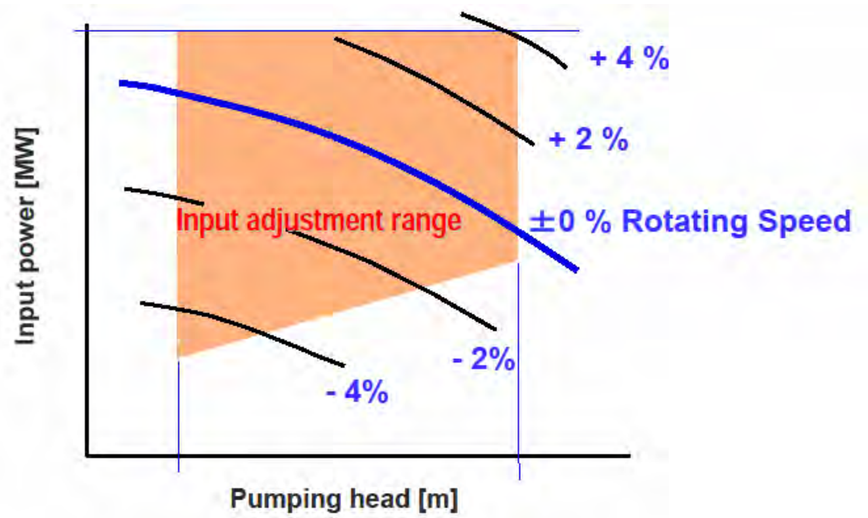


Figure 7. 12 Input Adjustment Range during Pumping Operation

✓ High-efficiency operation during generating operation can be realized by setting rotating speed to the most efficient point according to head and discharge, and consequently output adjustable range; in other words, frequency adjustment capacity during generating operation in the daytime is expanded by suppressing turbine oscillation and cavitation during low-head and low-load operation.

2) Determination of generator-motor capacity

In the case of adjustable-speed system, the active power input/output of motor-generator is divided proportionally between stator and rotor according to the rotating speed of rotor (slip with stator). Also, input power from power system to motor increases in proportion to the cube of rotating speed when increasing the rotating speed during pumping operation. Because the required stator capacity depends on the rotating speed in this way, appropriate stator capacity of adjustable-speed system should be determined in consideration of adjustable range of rotating speed. In this design, stator rated capacity of 525 MVA is calculated based on TEPCO's experiences of PSPPs, assuming that the adjustable range of rotating speed is ±4% of the synchronous speed.

3) Alternating-current exciter

There are two ways to generate the low-frequency three-phase AC current that is given to the three windings of the rotor. One is an inverter system, which rectifies AC to DC, and then converts to AC again. The other is a cycloconverter, which converts AC source to low-frequency AC directly. Adoption of the inverter system to alternating-current exciter is recommended because of the following advantages and benefits:

- ✓ To enable simplified system configuration by eliminating the need of a power-factor-correcting device such as a capacitor because the inverter system can improve the power factor at the input of the inverter.
- ✓ To enhance system reliability on power fluctuations, in case of an accident such as a lightning strike on a transmission line.

(3) Design of hydromechanical works

(a) Penstock and steel liner

The thickness of penstock and steel liner is calculated by the following formula:

$$t_0 = \frac{P(D_0 + \varepsilon)}{2\sigma_a \eta}(1 - \lambda) + \varepsilon$$

t_0	:	design thickness
P	:	design hydraulic pressure
D_0	:	internal diameter
σ_a	:	allowable stress
η	:	joint efficiency (=0.95)
ε	:	allowance thickness for corrosion and abrasion (=1.5 mm)
λ	:	sharing ratio of internal pressure by bedrock (=30%: inclined shaft part)

(b) Gate

In this project, spillway gate and outlet gate of the upper dam, stop log of the diversion tunnel, intake and outlet gates, and draft gate are planned to be installed. Radial gate and jetflow gate are applied for spillway and outlet, respectively, and slide gate is applied for the others.

(4) Access road

The newly built approach roads for approach/maintenance are estimated to be about 30 km long in total and the existing 30 km roads will be altered if necessary. A plan of roads for construction shall be prepared based on the study on detailed road specifications and construction schedule.

7.2.3 Rough Cost Estimate

Conceptual design is carried out based on the information and data obtained from the detailed site survey and the topographical maps of 1/5,000, and the quantity of each construction work is calculated. Cost of each construction work is estimated based on its quantity and its construction unit cost provided by EIE. The results of cost estimate are shown in Table 7. 11. The detailed method to estimate is described below.

Table 7. 11 Rough Cost Estimate of Altınkaya PSPP

Cost Items	Cost (10^6USD)	Remarks
A. Preparatory Works	90.0	
B. Construction Works	398.7	
Upper dam and reservoir	46.9	
Diversion	2.3	
Dam	44.6	
Lower reservoir	40.4	
Waterway	154.6	
Intake	5.2	
Headrace	34.9	
Headrace surge tank	6.4	
Penstock	26.8	
Draft gate chamber and shaft	2.9	
Tail bay	5.2	
Tailrace surge tank	6.0	
Tailrace	28.6	
Outlet	4.9	
Work adits	33.7	
Power house and switch yard	88.9	
Power house	87.0	
Switch yard	1.8	
Main tunnels	53.0	
Investigation and test	15.0	
C. Equipment	409.9	
Hydro-mechanical works	84.3	
Electro-mechanical works	310.0	
Building relations	15.5	Electro-mech*0.05
D. Engineering service	50.0	
E. Administrative expense	9.0	(A-C)*0.01
F. Land compensation and resettlement	9.0	A*0.1
G. Contingency	96.7	(A-F)*0.1
H. Price contingency	96.7	(A-F)*0.1
I. Custom duty	41.0	C*0.1
Total project cost	1,201	
Unit cost (USD/kW)	667	

(1) Construction cost

(a) Preparatory works

The construction cost of preparatory works is the construction cost of approach roads. The quantities of access roads are roughly estimated based on the 1/5000 topographical maps and site survey results.

(b) Civil works

The unit cost of each civil work provided by the counterpart of EIE is applied for calculating the cost of each civil work, but some unit costs are revised or added based on the experiences in Japan.

The quantities of excavation (soil, rock, and tunnel), concrete, re-bar, and so on, are roughly calculated for each main civil structure in line with the preliminary design drawing based on the topographical maps of 1/5,000 and the detailed site survey results. As a miscellaneous work cost, 10% for open work cost and 15% for tunnel work cost are added to each civil work cost. Taking into account the geological condition uncertainties, 30% is added for tunnel work cost as well.

Investigation and testing costs are estimated to be 15 million USD in total and categorized in civil works.

(c) Hydromechanical works

The precedents for other countries are applied for the price of the hydromechanical work such as steel pipe and gate. The installation costs are estimated as 15% of the above price.

(d) Electrical and mechanical equipment

The cost of electrical-mechanical equipment is estimated based on the experiences in Japan and overseas. The estimated cost includes price of the generator, transportation cost, price of auxiliary equipment, and installation cost.

(2) Engineering services

The costs of engineering services such as feasibility study, detailed design, bidding procedure, and construction supervision has been estimated to be 50 million USD in total.

(3) Administration expenses

Administration expenses of the project owner are also estimated, at 1.0% of the construction cost above.

(4) Land expropriation and resettlement compensation

Cost of land expropriation and resettlement compensation is estimated at 10% of the preparatory works.

(5) Custom duty

The mechanical and electrical equipments will be imported; therefore, 10% of the cost of electrical-mechanical equipment above is estimated as a custom duty.

(6) Physical contingency

Ten percent of (1)-(4) is estimated for physical contingency.

(7) Price contingency

Ten percent of (1)-(4) is estimated for price contingency.

7.2.4 Standard Development Schedule of PSPP Project

The standard development schedule of PSPP project is shown in Table 7. 12.

The entire implementation period of the project will take approximately 13 years in normal case after the start of the feasibility study. The sequence of activities leading to the commissioning of the project is as follows:

(1) Feasibility Study (FS)

Geological investigation work will take half year, then, topographical, geological, hydrological survey, evaluation of the above survey results, basic design, and economic-financial analysis will take approximately 1 year based on experiences in Japan and overseas. Thus, feasibility study will take 1.5 years in total.

Environmental investigation conducted in parallel with FS will take 1.25 years from site investigation to environmental evaluation.

(2) Environmental Impact Assessment (EIA)

A project owner is obliged to carry out EIA procedures according to Turkish EIA regulations. In case that the execution agency of EIA is the same as the project owner, EIA can be carried out during FS in parallel. However, in consideration of the situation in Turkey, since the execution agency and the project owner may be different, additional duration for EIA is required. It will take generally 1.5 years to carry out EIA procedures including duration of site investigation, acquisition of governmental approval on EIA report and public acceptance. Therefore, the above additional duration for EIA is assumed 1 year in consideration of utilizing the results of the environmental investigation during FS as mentioned above.

(3) Establishing Funding Plan

In the case where the project financing is sought from an international consortium, it will take approximately 1 year from the application to conclusion of Loan agreement.

(4) Bid tendering and selection of Consultant

Procurement of consultant for engineering services will take 0.5 year.

(5) Preparation of the Detailed Design and Tender Documents

Preparation of the detailed design and tender documents will take 1.5 years according to the guidelines for procurement of JICA. Duration of additional topographical and geological investigation is included in this period.

(6) Bidding and Contract with Contractor, Manufacturer

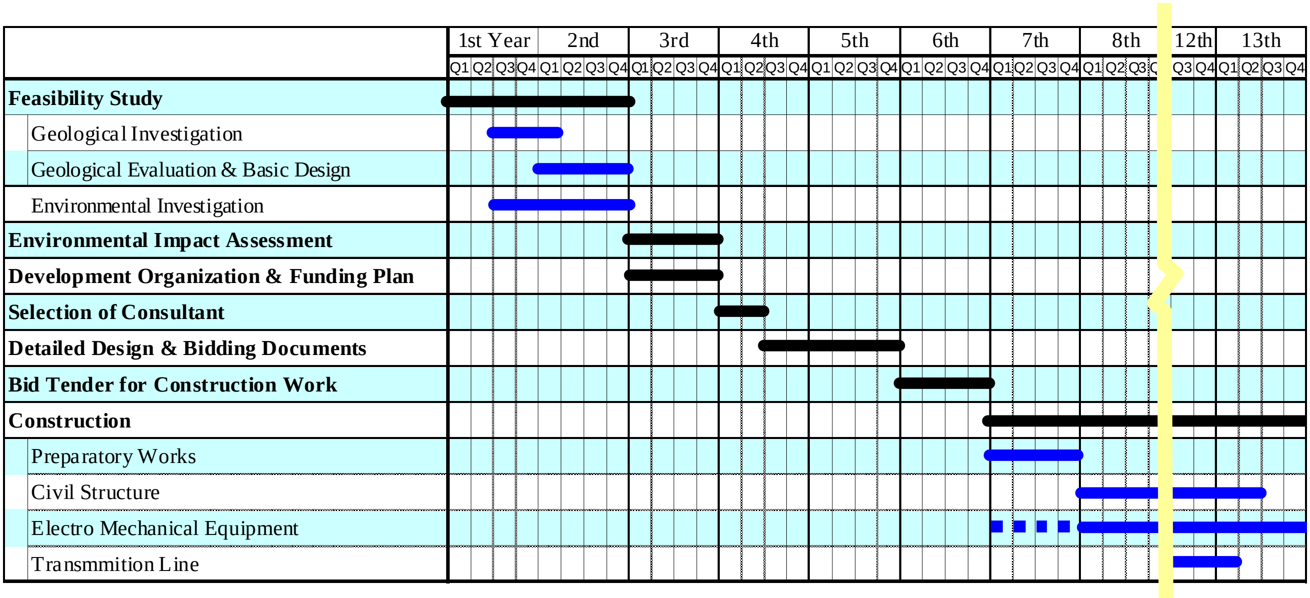
Bidding procedure, negotiation of contract with contractor for civil works and manufacturer for electrical mechanical equipment will take 1.0 year according to the guidelines for procurement of JICA.

(7) Construction Works

The period of construction work will take approximately 7.0 years including preparation works of 1.0 year according to the experiences in Japan and overseas.

Provided that the selection of consultant for the Feasibility Study will be started in 2011 following this master plan study, the commissioning of the first unit will be in 2024.

Table 7. 12 Standard Development Schedule（Altınkaya PSPP ）



7.3 Conceptual Design of Gökçekaya PSPP

As a result of the conceptual design of Gökçekaya SPP, the main features are shown in Table 7. 13 and structural drawings are presented in Figure 7. 13, Figure 7. 14 and Appendix 7-3. The conceptual design of the site is as follows.

7.3.1 Design of Power Generation Planning

A power generation plan is an important matter of design of the PSPP's facilities. However, many revisions are necessary to reach an optimum plan, since features of the power generation plan are also changed by design of the facilities.

The conceptual design was carried out according to the flowchart of Figure 7. 7, based on the topographical maps of 1/5,000. The main features of power generation plan were decided as shown in Table 7. 13.

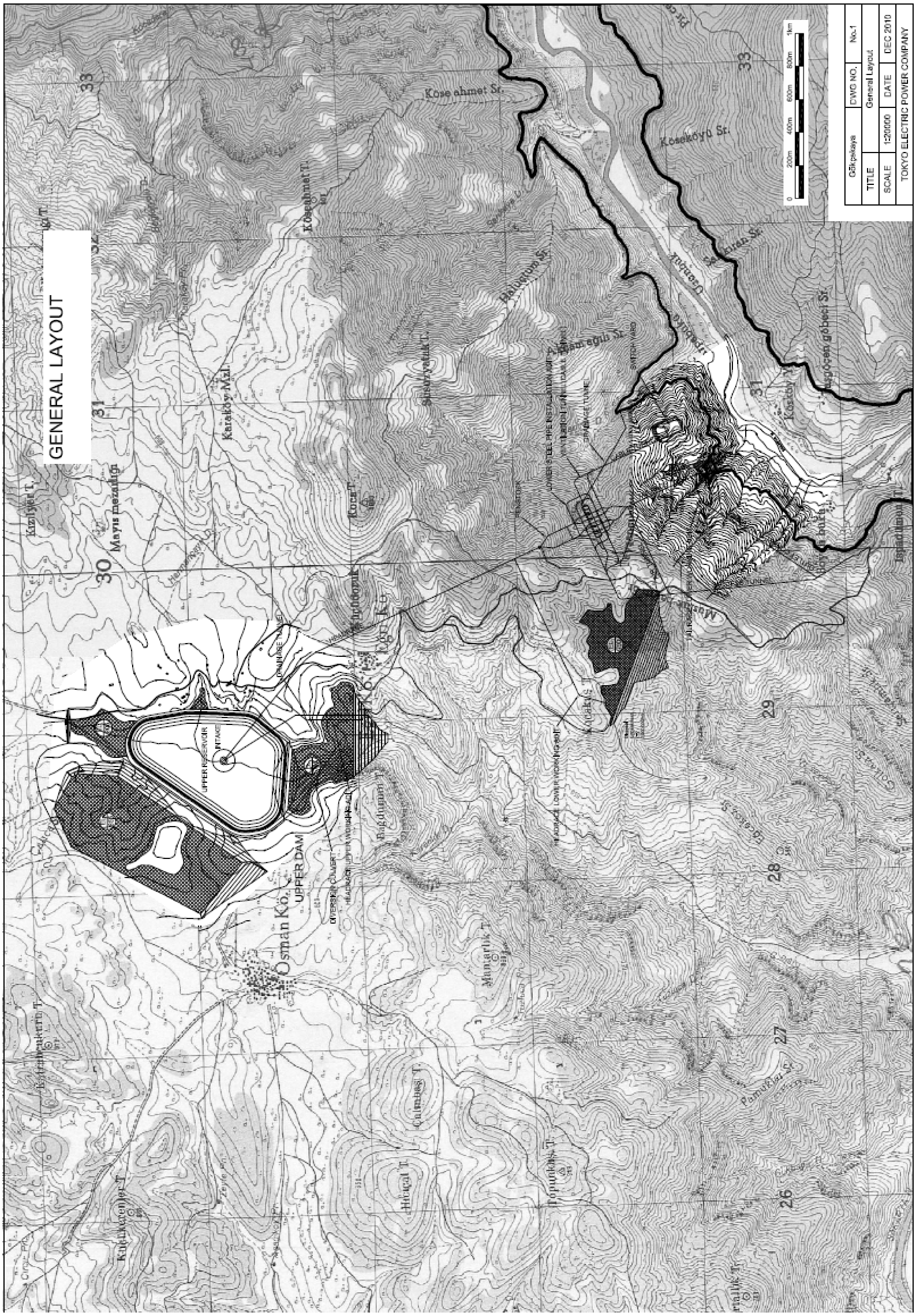


Figure 7. 13 Gökçekaya PSPP General Layout

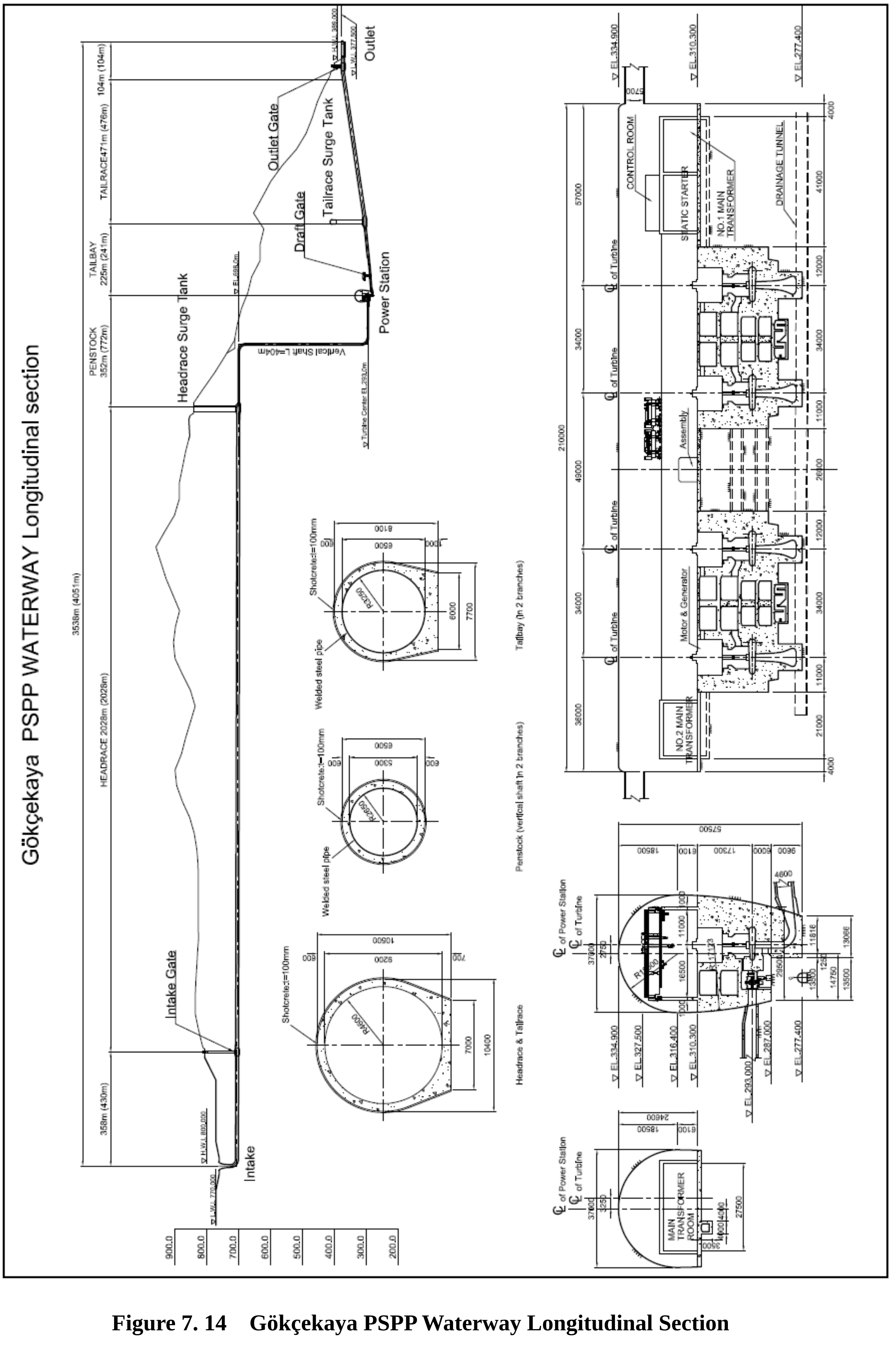


Figure 7. 14   Gökçekaya PSPP Waterway Longitudinal Section

Table 7. 13 Main Features of Gökçekaya PSPP

	Description		Unit	Gökçekaya PSPP
General	Installed Capacity	P	MW	1,400
	Designed Discharge	Qd	m^3/s	428
	Effective Head	Hd	m	379.5
	Peak Duration Time		hrs	7
Upper Dam and Reservoir	Type			Full Face Pond (Asphalt)
	Height	H	m	35
	Crest Length	L	m	2,700
	Dam (Bank) Volume	V	m^3	1,557,000
	Excavation Volume	Ve	m^3	10,310,000
	Reservoir Area	Ra	km^2	0.5
	Catchment Area	Ca	km^2	4.8
	H.W.L		m	800
	L.W.L		m	770
	Usable Water Depth		m	30
	Effective Reservoir Capacity		$mil.m^3$	10.8
Lower Dam Reservoir	H.W.L		m	389
	L.W.L		m	377.5
	Usable Water Depth		m	11.5
	Effective Reservoir Capacity		$mil.m^3$	214
Waterway	Intake	L(m) x n	m	Bellmouth 34 x 1, Tunnel 396 x 1
	Headrace	L(m) x n	m	2,028 x 1
	Penstock	L(m) x n	m	662 x 2 , 110 x 4
	Tailbay	L(m) x n	m	125 x 4 , 116 x 2
	Tailrace	L(m) x n	m	476 x 1
	Tailrace	L(m) x n	m	Tunnel 53 x 1, Open 51 x 1
	Total Length	Lt	m	4,051
Powerhouse	Type			Egg-shape (Underground)
	Overburden		m	365.0
	Height		m	57.5
	Width		m	37.0
	Length		m	210.0
	Cavern Volume		m^3	266,000
Turbine	Type			Single-Stage Francis
	Number		unit	4
	Unit generating capacity		MW	350

7.3.2 Design of the Main Structures and Equipment

(1) Design of civil structures

(a) Upper dam and reservoir

The site around the upper reservoir is comparatively flat and strong and hard rocks were observed. In addition, the width of the river is wider than that in the up- and downstream. The artificial excavation-type pond is suitable, judging from the above topographical conditions. The pond is planned to be fully faced with asphalt to prevent water leaking completely, since there are limestone outcrops around the pond. Besides, bypass channel is planned on the right bank of the pond, where there are no residents, since the pond segmentalizes the current river. The discharge capacity of the bypass channel is designed as 76 m^3/s.

Active storage capacity of the pond is 10.8 × 10^6 m^3, whose HWL is 800 m and usable water depth is 30 m. Disposal areas are planned on the right bank and downstream of the pond to manage a large amount of excavated rock and soil.

The relation between the usable water depth and active storage capacity of the pond is shown in Figure 7. 15.

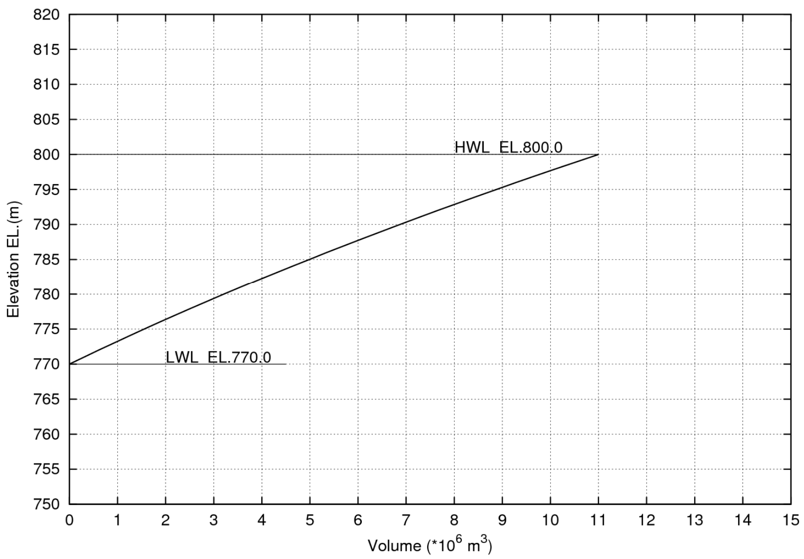


Figure 7. 15 Storage Capacity Curve of the Upper Reservoir

(b) Intake

Morning glory type of intake, which is reinforced concrete structure, is adopted and is constructed in the bottom of the pond in order to increase the efficiency of water storage, since the upper pond is full-face artificial excavation pond. The steel liner is installed in vertical shaft and tunnel part up to the intake gate in order to prevent water leakage.

The inflow velocity in front of the screen is designed less than 0.5 m/s, and the inflow velocity in the bell mouth is designed less than 0.7 m/s according to the experiences in Japan. Since the top elevation of the mouth is 0.5 m lower than the LWL of the pond, and the height is 8.5 m, the bottom of pond around intake is tapered.

(c) Waterway and powerhouse

Generally, the shortest route shall be selected between the upper reservoir and the lower reservoir for the waterway alignment, based on the topographical and geological conditions. However, in order to avoid construction under the village on the southeast of the upper pond, waterway should be curved. The curves are planned to be located at points which have a distance of 30*D* from the intake to prevent drift flow in the intake. As well, the curves' radiuses were designed as 300 m. The shape of waterway was designed as circular in order to prevent stress concentration.

1) Headrace

Reinforced concrete shall be placed for the headrace lining. The inner diameter is determined as 9.2 m under the condition of maximum velocity of 6.5 m/s based on the experiences in Japan. Detailed design of the headrace is as follows:

- The headrace tunnel length is approximately 2,000 m and the shape of excavation section is a horseshoe with height of 10.6 m.

- Reinforced concrete lining is constructed after excavation.
- Consolidation grouting is planned to improve permeability and deformation modulus of the area loosened by excavation and to expect pre-stress effect on the concrete lining.

2) Headrace surge tank

Headrace surge tank is planned to place at the joint of headrace and penstock, and the top of the surge tank is on the ground surface of a ridge. Upper surge was estimated 40 m higher than HWL of the upper reservoir. Shaft diameter is set as 17 m, and port section diameter is set as 5.0 m according to the surging analysis. The waterway is bifurcated at the headrace surge tank.

3) Penstock

The penstock is designed as a horizontal tunnel from the headrace surge tank to the upper bending point, where the overburden depth is of more than 50 m, and as vertical shaft from the upper bending point to the lower bending point at the elevation of the pump-turbine center. Two penstocks are bifurcated to four branches in total in the lower horizontal part, and each branch is put together with the inlet valve. The maximum averaged flow velocity in the penstock is set as 10 m/s and that in the joint part is set as 20 m/s based on the experiences in Japan. The steel pipe is installed in the tunnel and shaft, and after that the space is filled with concrete. The detailed design of penstock is as follows:

- The penstock tunnel and shaft of the two-branch part is approximately 660 m long with a horseshoe-shape excavation section of 7.0 m in height in the horizontal tunnel and circular-shape excavation section of diameter of 6.7 m in the vertical shaft. The diameter of steel pipe is 5.3 m.
- The penstock tunnel of the four-branch part is approximately 85 m long with a horseshoe-shape excavation section of 5.4 m in height. The diameter of steel pipe is 3.7 m.
- The penstock tunnel of joint part is approximately 25 m long with a horseshoe-shape excavation section of 5.4 m in height. The diameter of steel pipe is 2.7 m.

4) Underground powerhouse

Principally, the location and direction of the powerhouse cavern are determined after excavating the exploratory adits and investigating the geological condition, e.g., initial ground pressure and rock mass properties such as by in-situ tests. In this stage, the location of the underground powerhouse is selected to make the waterway the shortest, and where its overburden depth is less than 500 m, which is the maximum value of the existing underground powerhouses.

An egg-shape type, which shape is pertinent for the surrounding rock of cavern to be the most stable mechanically, is selected The scale of cavern is determined to secure the required space to install the electrical equipments based on the experiences. The main features are as follows:

Width	:	37.0 m
Height	:	57.5 m
Length	:	210.0 m
Volume	:	266,000 m^3

In addition, main tunnels around the underground powerhouse such as an equipment transportation tunnel 2,650 m long, a cable tunnel of 980 m, a drainage tunnel of 970 m, etc., are planned based on the topographical maps of 1/5000.

5) Tailbay

Tailbay is defined as the waterway between the draft tube and the tailrace surge tank, and four draft gate chambers are installed at the side of the equipment transportation tunnel above the draft gates. Four-branched waterways are merged to two branches in the tailbay and connect to the tailrace surge tank. The detailed design is as follows:

- The tailbay of the four-branch part is approximately 130 m long with a horseshoe-shape excavation section of 6.3 m in height. The inner diameter of the branch tunnel is 4.6 m.

- The tailbay of the two-branch part is approximately 120 m long with a horseshoe-shape excavation section of 8.2 m in height. The inner diameter of the branch tunnel is 6.5 m.
- The inner steel pipes are installed to withstand the surging pressure.

6) Tailrace surge tank

A tailrace surge tank is constructed at the joint point of tailbay and tailrace, which has a port and an upper chamber because it is constructed underground. In line with that, the upper surge is not a constraint to decide the diameter of the shaft. Therefore, the inner diameter of the shaft of 10 m and the port diameter of 5.5 m are decided so that the water level of down surge is higher than the LWL of the lower reservoir minus 40 m by calculation of surging. The two branched tunnels are merged to one at the tailrace surge tank.

7) Tailrace

Reinforced concrete shall be placed for the tailrace lining. The inner diameter is determined as 9.2 m under the condition of maximum velocity of 6.5 m/s based on the experiences in Japan. Detailed design of the tailrace is as follows:

- The tailrace tunnel length is approximately 480 m and the shape of excavation section is a horseshoe with height of 10.6 m.
- Reinforced concrete lining is constructed after excavation.
- Consolidation grouting is planned to improve permeability and deformation modulus of the area loosened by excavation and to expect pre-stress effect on the concrete lining.

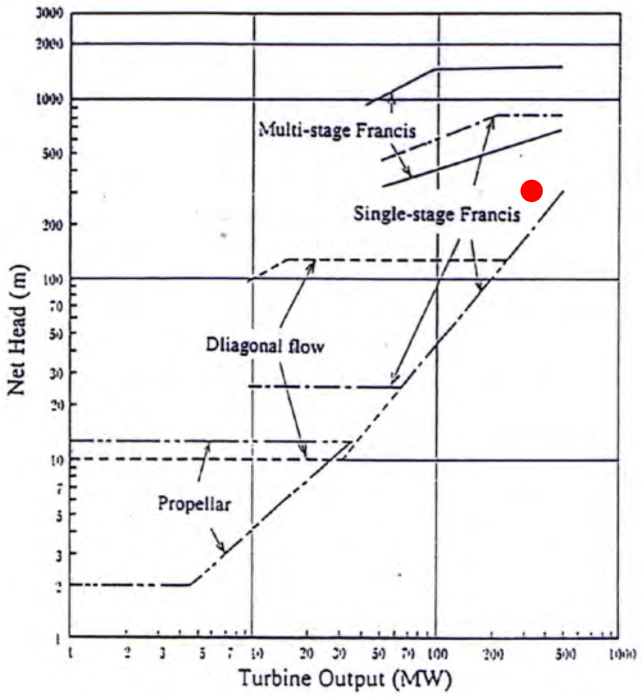
(d) Outlet

A lateral type of outlet is adopted, which is applied generally for outlet of PSPP. It is laid out in line with the ridge in the lower reservoir. Since the outlet is constructed in the existing reservoir, the size of outlet shall be small in order to make the cofferdam as small as possible. In the design of the outlet, flow velocity at the opposite bank and velocity of pumping were considered, but the distance to the slope of the opposite bank is long enough and the size of mouth is designed just so as to make the averaged flow velocity at pumping operation less than 1 m/s. In addition, the top elevation of the mouth is 0.5 m lower than the LWL of the reservoir, and a 1.5 m high anti-vortex girder is planned to be installed.

(2) Design of Electromechanical Equipment

(a) Pump-turbine

Applicable type of pump-turbine is restricted by turbine output and net head as shown in Figure 7. 16. A Francis-type single-stage pump-turbine is selected for the Gökçekaya PSPP in consideration of this site condition consisting of 380 m effective head and 350 MW unit capacity, which was determined through the study of optimum development scale.



Reference;
Feasibility Study for the Upper Cisokan Pumped Storage Hydroelectric Power Development Project, JICA, March 1995.

Figure 7. 16 Standard of Pump-turbine Selection

The applicable rotating speed is restricted by the fabrication limit, as shown in Figure 7. 17. Rated rotating speed of 429 min^{-1} is adopted in consideration of this restriction and improvement of economic efficiency by downsizing.

These characteristics are designed in reflection of the past record of reversible pump-turbine efficiency in Japan, which has been improved through recent research and development. The efficiency of reversible pump-turbine produced by manufacturers in Japan is a few percentages higher than that of a general pump-turbine, whose number of suppliers is not limited. It can be expected that the adoption of splitter runner (refer to Section 8.2) enables additional improvement of reversible pump-turbine efficiency and expansion of output adjustable range.

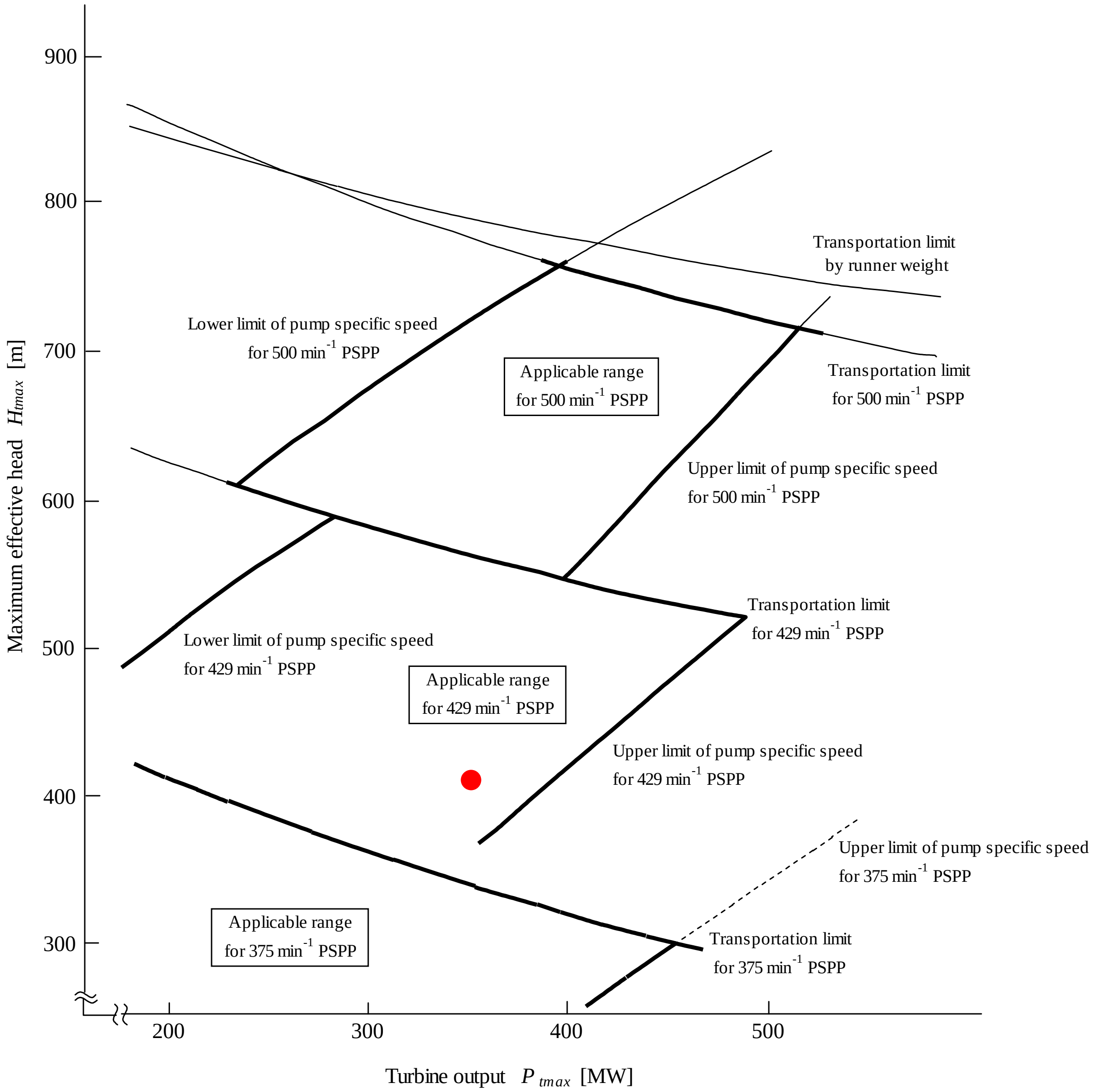


Figure 7. 17 Fabrication Limit of Pump-turbine

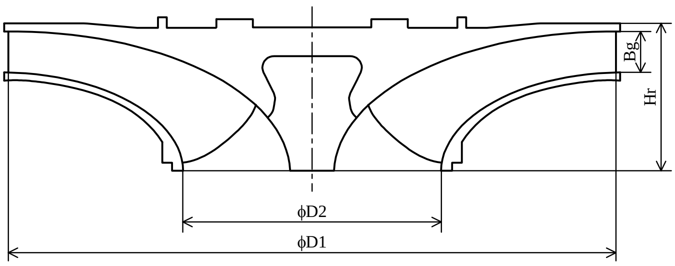
On the basis of Gökçekaya's design conditions consisting of water level of upper/lower reservoir and head loss, the main characteristics of reversible pump-turbine shown in Table 7. 14 and Table 7. 15 were determined through the same procedure as Altınkaya PSPP.

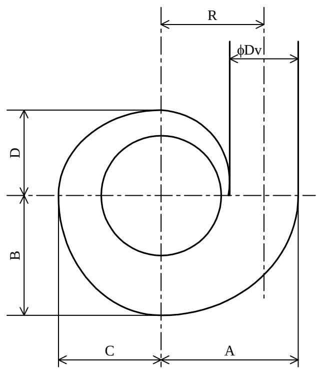
Table 7. 14 Main Characteristics of Reversible Pump-turbine (Gökçekaya PSPP)

Item	Characteristic	
Type	Vertical shaft single runner single discharge spiral Francis type pump-turbine	
Maximum output [MW]	1,400	
Number of units	4	
Unit capacity [MW]	350	
Rotating speed [min^{-1}]	429 ± 17	
Turbine/Pump	Turbine	Pump
Effective head/Pump head [m]		
Maximum	396.6	439.7
Normal	379.5	—
Minimum	353.2	398.5
Discharge [m^3/s]		
at maximum head	100.3	71.2
at normal head	107.0	—
at minimum head	103.8	82.0
Output/Axial input [MW]		
at maximum head	357.5	336.7
at normal head	357.5	—
at minimum head	320.4	353.9
Efficiency [%]		
at maximum head	91.7	91.1
at normal head	89.9	—
at minimum head	89.2	90.5
Generator/Motor efficiency [%]	97.9	98.3
Total efficiency [%]	88.0	89.0
Power factor [%]	90	95
Pump specific speed	43.5	
Suction head H_s [m]	-84.5	
Head change ratio (H_{pmax}／H_{tmin})	1.24	
Capacity of generator-motor [MVA]	410.0	

Table 7. 15 Main Dimension of Reversible Pump-turbine (Gökçekaya PSPP)

Item	Dimension
Diameter of runner inlet: D_1 [m]	4.4
Diameter of runner outlet: D_2 [m]	2.7
Height of runner inlet: B_g [m]	0.50
Casing size: *A* [m]	5.9
Casing size: *B* [m]	5.4
Casing size: *C* [m]	5.0
Casing size: *D* [m]	4.5
Deviation from casing center to inlet center: *R* [m]	4.6
Diameter of inlet valve: D_v [m]	2.6





(b) Generator-motor

A generator-motor was designed on the same condition as Altınkaya PSPP’s, that an adjustable-speed pumped storage power system be adopted. The adjustable-speed system was developed in order to secure the frequency adjustment ability in the power system during pumping operation and realize high-efficiency operation during generating operation. The benefits of adopting the adjustable-speed system are as mentioned in the section of Altınkaya PSPP’s generator-motor design.

(3) Design of hydromechanical works

(a) Penstock and steel liner

The thickness of penstock and steel liner is calculated by the following formula:

$$t_0 = \frac{P(D_0 + \varepsilon)}{2\sigma_a \eta}(1-\lambda) + \varepsilon$$

- t_0 : designed thickness
- P : hydraulic pressure at a place to determine stress
- D_0 : internal diameter
- σ_a : allowable stress
- η : joint efficiency (=0.95)
- ε : allowance thickness for corrosion and wear (=1.5 mm)
- λ : sharing ratio of internal pressure by bedrock (=30%: vertical shaft only)

(b) Gate

In this project, intake and outlet gates and draft gates are planned to be installed, which are slide gates.

(4) Access road

The newly built approach roads for approach/maintenance are estimated to be about 10 km long in total and the existing 5 km roads will be altered if necessary. A plan of roads for construction shall be prepared based on the study on detailed road specifications and construction schedule.

7.3.3 Preliminary Cost Estimation

Conceptual design is carried out based on the information and data obtained from the detailed site survey and the topographical maps of 1/5000, and the quantity of each construction work is calculated. Cost of each construction work is estimated based on its quantity and its construction unit cost provided by EIE. The results of cost estimate are shown in Table 7. 16. The detailed method for estimation is described below.

Table 7. 16 Cost Estimation of Gökçekaya PSPP Site

Cost Items	Cost (10^6USD)	Remarks
A. Preparatory Works	25.0	
B. Construction Works	418.0	
Upper dam and reservoir	136.4	
Diversion	1.3	
Dam	135.1	
Lower reservoir	26.2	
Waterway	125.3	
Intake	11.1	
Headrace	32.9	
Headrace surge tank	7.8	
Penstock	15.4	
Draft gate chamber and shaft	2.8	
Tail bay	5.7	
Tailrace surge tank	3.8	
Tailrace	7.9	
Outlet	4.1	
Work adits	33.7	
Power house and switch yard	76.2	
Power house	74.2	
Switch yard	2.0	
Main tunnels	39.0	
Investigation and test	15.0	
C. Equipment	377.7	
Hydro-mechanical works	64.4	
Electro-mechanical works	298.4	
Building relations	14.9	Electro-mech*0.05
D. Engineering service	50.0	
E. Administrative expense	8.2	(A-C)*0.01
F. Land compensation and resettlement	5.0	A*0.2
G. Contingency	88.4	(A-F)*0.1
H. Price contingency	88.4	(A-F)*0.1
I. Custom duty	37.8	C*0.1
Total project cost	1,098	
Unit cost (USD/kW)	785	

(1) Construction cost

(a) Preparatory works

The construction cost of preparatory works is the construction cost of approach roads. The quantities of access roads are roughly estimated based on the 1/5000 topographical maps and site survey results.

(b) Civil works

The unit cost of each civil work provided by the counterpart of EIE is applied for calculating the cost of each civil work, but some unit costs are revised or added based on the experiences in Japan.

The quantities of excavation (soil, rock, and tunnel), concrete, re-bar, and so on, are roughly calculated for each main civil structure in line with the preliminary design drawing based on the topographical maps of 1/5000 and the detailed site survey results. As a miscellaneous work cost, 10% for open work cost and 15% for tunnel work cost are added to each civil work cost. Taking into account the geological condition uncertainties, 15% is added for tunnel work cost as well.

Investigation and testing costs are estimated to be 15 million USD in total and categorized in civil works.

(c) Hydromechanical works

The precedents for other countries are applied for the price of the hydromechanical work such as steel pipe and gate. The installation costs are estimated as 15% of the above price.

(d) Electrical and mechanical equipment

The cost of electrical-mechanical equipment is estimated based on the experiences in Japan and overseas. The estimated cost includes price of the generator, transportation cost, price of auxiliary equipment, and installation cost.

(2) Engineering services

The costs of engineering services such as feasibility study, detailed design, bidding procedure, and construction supervision have been estimated to be 50 million USD in total.

(3) Administration expenses

Administration expenses of the project owner are also estimated, at 1.0% of the construction cost above.

(4) Land expropriation and resettlement compensation

Cost of land expropriation and resettlement compensation is estimated at 20% of preparatory works.

(5) Custom duty

The mechanical and electrical equipment will be imported; therefore, 10% of the cost of electrical-mechanical equipment above is estimated as a custom duty.

(6) Physical contingency

Ten percent of (1)-(4) is estimated for physical contingency.

(7) Price contingency

Ten percent of (1)-(4) is estimated for price contingency.

7.3.4 Standard Development Schedule of PSPP Project

The standard development schedule of PSPP project is shown in Table 7. 17.

The entire implementation period of the project will take approximately 12 years in normal case after the start of the feasibility study. The sequence of activities leading to the commissioning of the project is as follows:

(1) Feasibility study (FS)

Geological investigation work will take half a year; then, topographical, geological, and hydrological survey, evaluation of the above survey results, basic design, and economic-financial analysis will take approximately 1 year based on experiences in Japan and overseas. Thus, feasibility study will take 1.5 years in total.

Environmental investigation conducted in parallel with FS will take 1.25 years from site investigation to environmental evaluation.

(2) Environmental Impact Assessment (EIA)

A project owner is obliged to carry out EIA procedures according to Turkish EIA regulations. In case that the execution agency of EIA is the same as the project owner, EIA can be carried out during FS in parallel. However, in consideration of the situation in Turkey, since the execution agency and the project owner may be different, additional duration for EIA is required. It will take generally 1.5 years to carry out EIA procedures including duration of site investigation, acquisition of governmental approval on EIA report and public acceptance. Therefore, the above additional duration for EIA is assumed 1 year in consideration of utilizing the results of the environmental investigation during FS as mentioned above.

(3) Establishing funding plan

In the case where the project financing is sought from an international consortium, it will take approximately 1 year from the application to the conclusion of the loan agreement.

(4) Bid tendering and selection of consultant

The procurement of a consultant for engineering services will take 0.5 years.

(5) Preparation of the detailed design and tender documents

The preparation of detailed design and tender documents will take 1.5 years according to the guidelines for the procurement of JICA. The duration of additional topographical and geological investigation is included in this period.

(6) Bidding and contract with contractor and manufacturer

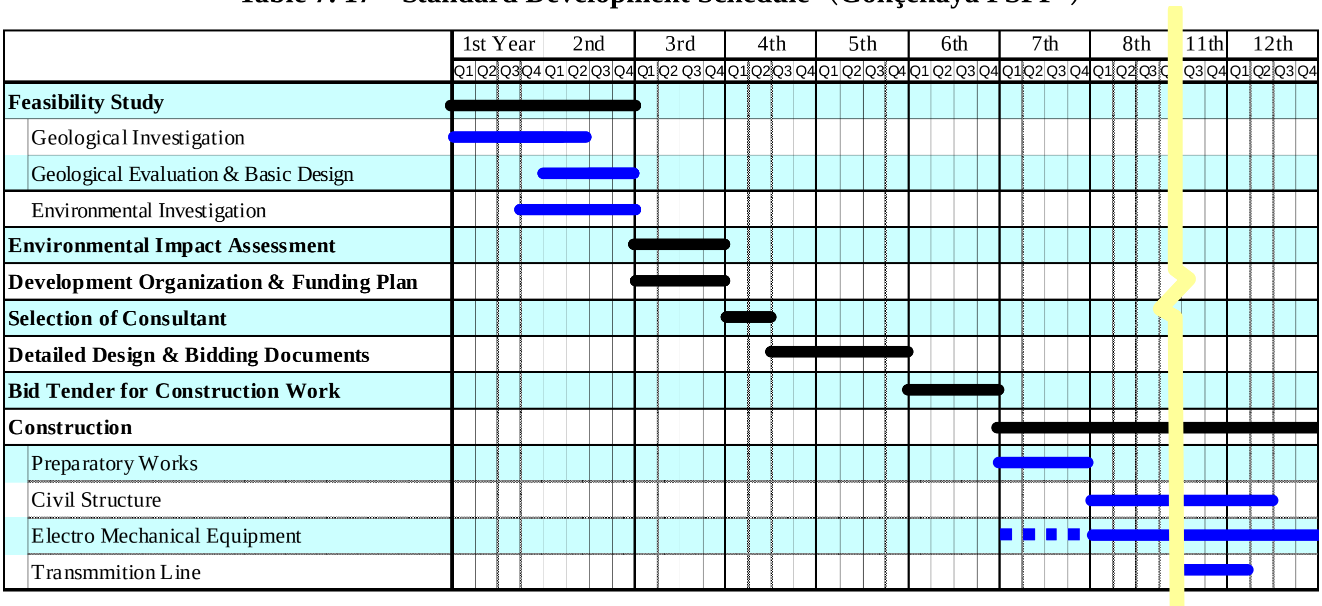
Bidding procedure and negotiation of contract with contractor for civil works and with manufacturer for electrical-mechanical equipment will take 1.0 year according to the guidelines for the procurement of JICA.

(7) Construction works

The period of construction work will take approximately 6.0 years including preparation works of 1.0 year according to experiences in Japan and overseas.

Provided that the selection of consultant for the feasibility study will be started in 2011 following this master plan study, the commissioning of the first unit will be in 2023.

Table 7. 17 Standard Development Schedule（Gökçekaya PSPP ）



7.4 Rough Cost Estimate of Transmission Facility

The route has been selected on the desk work based on the topographical map of the EIE offer for two selected PSPP sites. The selected line route alternatives were surveyed to evaluate their feasibility because a long tower span was assumed from the mountainous area condition for the Altınkaya PSPP. Moreover, construction cost has been estimated based on the length of the power line route planned on the basis of desk work and from the experience of Tokyo Electric Power Company in accordance with the design standard of TEIAS.

7.4.1 Design Standard of Transmission of TEIAS

The transmission line from the selected pumped storage power plant follows the design standard that TEIAS (Turkish Electric Transmission Company) provided. The design standard of TEIAS is as follows:

(1) Basic design condition

A basic condition is shown in the following.

(a) Outside temperature

- The maximum temperature 45℃
- -5℃ in lowest temperature

(b) Wind pressure

- Electric wire 68 kg/m^2
- 90 kg/m^2 when insulator ream is not iced up, 30 kg/m^2 when insulator ream is iced up
- Iron tower 90 kg/m^2

(c) Icing

- Icing coefficient 0.2 (Area Zone II)
- Icing density 0.6 g/cc

(2) Design of conductor and ground wire

(a) Conductor and ground line

EHSS galvanized steel (offer from Turkey), 96 mm^2, was applied. Table 7. 18 and Table 7. 19 show the specification of the conductor and the ground line.

Table 7. 18 Specification of Conductors

Conductor (Code word)	Pheasant
Stranding	Al: 54/3.899 mm St: 19/2.339 mm
Standards	ASTM B232
Size of Conductor	644.5 mm^2
Outside diameter	35.1 mm
Weight	2.433 kg/m
Minimum tension load	19,800 kgf
Equivalent Elasticity coefficient	7,952 kgf/mm^2
Linear Expansion coefficient	19.59×10^{-6}

Table 7. 19 Specification of Ground wires

Conductor (Code word)	EHSS galvanized steel
Size of Conductor	96 mm^2
Outside diameter	—
Weight	0.6 kg/m
Minimum tension load	—
Equivalent Elasticity coefficient	—
Linear Expansion coefficient	—

(b) Clearance and tension of ground wire

To avoid reverse flashover to the electric wire and direct stroke to the electric wire from the ground wire, clearance of the ground wire under the tension is always adjusted to 80% of the conductor clearance.

(c) Standard span length

The standard span between towers is assumed to be 450 m.

(d) About ground high (ground clearance)

a) Surface of water : 8.5 m
b) Road : 12 m
c) Forest : 8.0 m
d) Near : 8.7 m
e) Rail way : 10.5 m

(3) Insulator design

(a) Proof strength of insulator of tower

The proof strength of the insulator applied to 380 kV transmission line is as follows:

・Suspension tower type: 160 kN
・Tension tower type: 210 kN

(b) Number of insulators by a series

The number of insulators by a series is 20 insulators applied to 380 kV power line.

7.4.2 Rough Estimation of Transmission Line Construction

The construction cost of 380 kV line in the normal condition by unit length is 160,000 USD/km from a result of the interview with TEIAS. Moreover, the cost of the 500kV double circuit line was twice as the single line cost in the past Tokyo Electric Power Company experience. The cost of 380 kV double circuit is 320,000 USD/km, which is obtained as twice of 160,000 USD/km. This is the construction cost in the plain area. The target transmission line is located in mountain area. According to the cost of the transmission line that passes the mountain area being 1.25 times the cost in flatland as per Tokyo Electric Power Company, the cost of 380 kV double circuit transmission line in mountain area is roughly estimated to be 400,000 USD/km.

The transmission line construction unit price from the PSPP is assumed as shown in Table 7. 20.

Table 7. 20 Unit Construction Cost of 380kV Double Circuit Transmission Line

380kV Double circuit transmission line	400,000 USD/km

7.4.3 Rough Cost Estimate of Transmission Line of Altınkaya PSPP

Figure 7. 18 shows a transmission line route for the switch yard of Altınkaya PSPP to the nearest switch yard of the power grid of TEIAS, the switch yard of Altınkaya HES. Roughly estimated length of the transmission line of Altınkaya PSPP is 11.1 km; then, the construction cost is estimated roughly as 11.1 km × 0.4 million USD/km = 4.44 million USD.

Figure 7. 18 Transmission Line Route of Altınkaya PSPP

7.4.4 Rough Cost Estimate of Transmission Line of Gökçekaya PSPP

Roughly estimated length of the transmission line of Gökçekaya PSPP is 1.8 km; then, the construction cost is estimated roughly as 1.8 km × 0.4 million USD/km = 0.72 million USD.

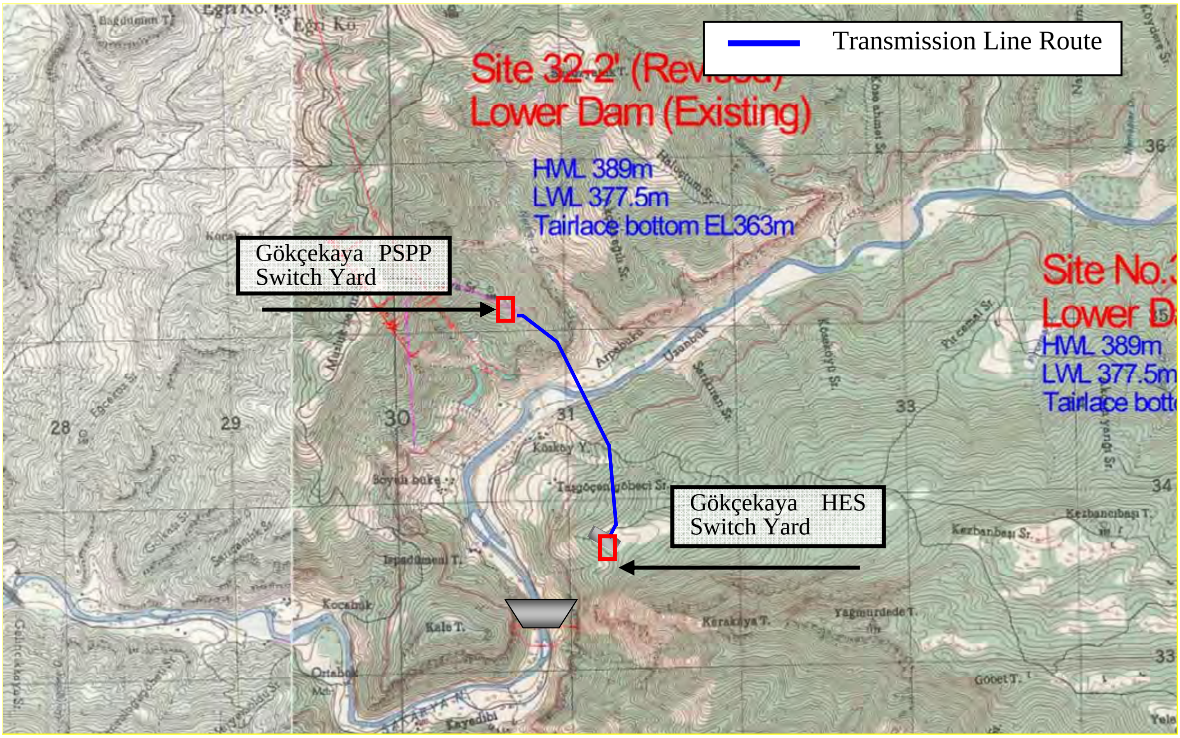


Figure 7. 19 Transmission Route of Gökçekaya PSPP

7.4.5 Status of Power Flow of 380 kV System with Operating PSPP

(1) Methodology of the Study

In this section, the status of power flow of 380 kV system is confirmed for the PSPP operation based on the power system model made by TEIAS about the peak power demand in 2015. The number of 380 kV transmission lines required for the PSPP operation is also estimated.

As mentioned earlier, power outputs of the existing hydropower stations are suppressed at 20-30% of their maximum levels in this analysis model by TEIAS and the new thermal power stations are partially stopped.

Here, the cases of the maximum power outputs of the hydropower plants/the new IPP thermal power plants are examined according to TEIAS' request. The base system model was created by studying the power network system containing the full-output hydropower stations in the northeast area and the east mountainous area and the new IPP power stations in the Black Sea coast area in Turkey whose power outputs have been suppressed in the previous obtained model as already mentioned. The increases in power generation outputs are assumed to be consumed by an increase in the system load by 15%.

Furthermore, the Study Team estimated the additional transmission lines required for the operation of each candidate of PSPP that was selected in the above study (Altınkaya PSPP or Gökçekaya PSPP) and compared the power transmission losses.

(2) Power Network System Reinforcement against Increase in Power Outputs of Generators in 2015

In case that all the power stations are fully operated in the system analysis model in 2015 obtained from TEIAS, the amount of load has to be increased to more than 30% of the total power demand and it would be difficult to analyze the model. Thus, the power stations whose outputs are increased are categorized into two groups: one is the group containing the power stations located in the Black Sea coast area and the other is the group containing the power stations located in the eastern mountainous area.

The following two generation patterns are set out:

Generation Pattern A: The case of increase in power generation outputs in the Black Sea coast area
Generation Pattern B: The case of increase in power generation outputs in the east mountainous area

The power stations assumed to be fully operated in Generation Pattern A are as follows:

- Hydropower stations: Altınkaya, Boyabat, Hasanugurlu, Borcke, Deriner, Artvinhe
- IPP thermal power stations: Amarsa, Cayli TES, Sinop TES, Gerze Termik
- Hydropower stations (commonly fully operated for Pattern A and B): Yusuferi, Gökçekaya
- IPP thermal power stations (commonly fully operated for Pattern A and B): Erentes, Cayrihan

The power stations assumed to be fully operated in Generation Pattern B are as follows:

- Hydropower stations: Beyhani, Pervari, Cetin, Keban, Birecic, Karakaya, Ataturk, Akdam
- Hydropower stations (commonly fully operated for Generation Pattern A and B): Yusuferi, Gökçekaya
- IPP thermal power stations (commonly fully operated for Generation Pattern A and B): Erentes, Cayrihan

Next, the following criteria are set out in accordance with the TEIAS' system planning criteria to find out the reinforcement of the transmission lines covering both of the Generation Patterns A and B about the power generation outputs using the model representing the 2015 system obtained from TEIAS.

Following are the criteria set out:

- To add circuits or transformers to avoid the overloaded conditions for 380/154 kV transformers and 154 kV system at normal operation.

- To make reinforcements of the system to avoid the overloaded conditions of the remaining circuits for 380 kV transmission lines when the N-1 fault occurs. The allowable capacities of 380 kV transmission lines when a single circuit occurs are set out as the values listed in Table 7. 21, which are described in the PSS/E data obtained from TEIAS. This study uses the values of Rate B, which corresponds to the summer season capacity.

Table 7. 21 Capacity of Transmission Lines described in the PSS/E Data obtained from TEIAS

	3B, Pheasant	3B, Cardinal	2B, Cardinal
Rate A (MVA)	1,921	1,589	1,057
Rate B (MVA)	1,604	1,334	889

* Rate A and Rate B indicate 105 % of the thermal capacity and the summer season capacity respectively.

From the results of the system analysis, it could be found out that the part of the 380/154 kV transformers and 154 kV system would have the overloaded conditions and some single-circuit faults led to the overloaded conditions of the part of 380 kV transmission lines when the power stations were operated following the Generation Patterns A or B. Thus, the circuits were added to the overloaded intervals to avoid the overloaded conditions.

Here, we call the system resulting from the above-mentioned way as “base system”. The base system has the ability to transmit the power in Generation Patterns A and B without overloaded conditions both at normal operation and single circuit faults in case of no PSPP operation.

The system losses in the base system are shown in Table 7. 22. There are no significant difference between both the cases, Generation Patterns A and B.

Table 7. 22 Transmission Loss Rate in Base System

	A: Case of Increase in Power Generation in the Black Sea Coast Area	B: Case of Increase in Power Generation in the East Mountainous Area
Power Generation	54,698.2 MW	54,697.2 MW
Load	53,302.8 MW	53,302.8 MW
Transmission Loss	1,395.3 MW	1,394.4 MW
Transmission Loss Rate	2.55%	2.55%

Figure 7. 20 and Figure 7. 21 show the results of the power flow calculation for the base system. Each figure indicates the location of the PSPPs; however, those PSPPs are not operated.

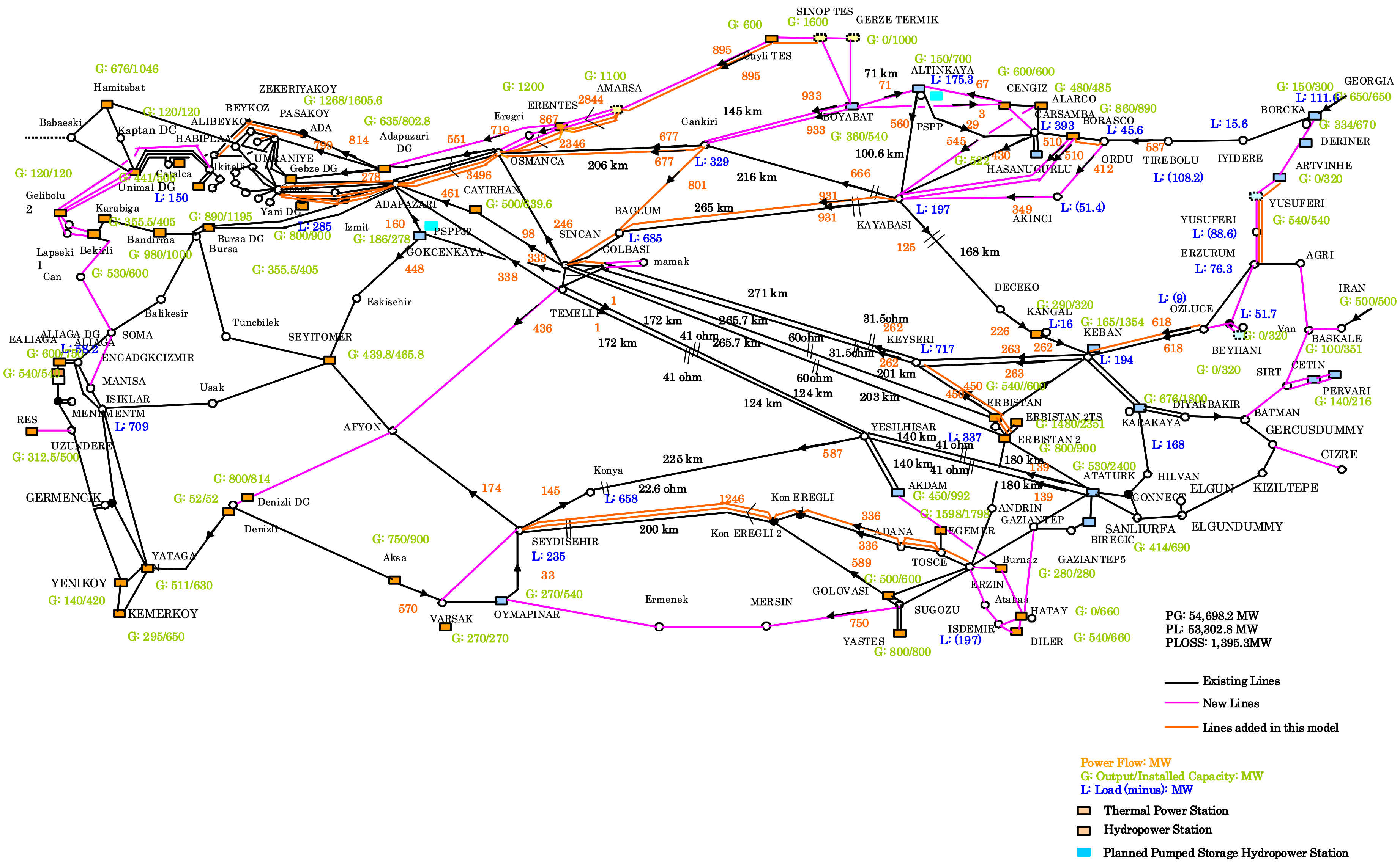


Figure 7. 20 The Results of the Power Flow Calculation for Base System (Generation Pattern A)

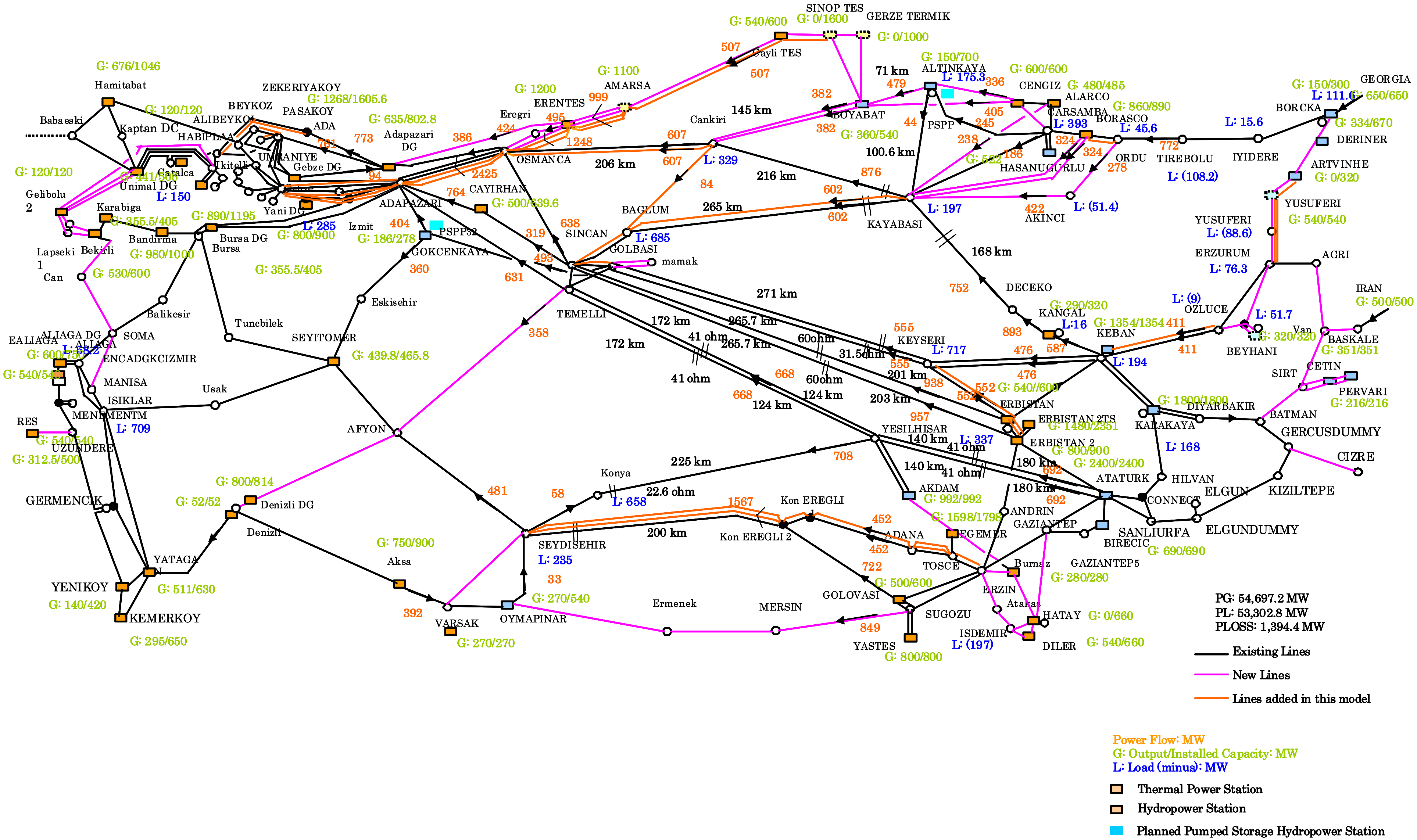


Figure 7. 21 The Results of the Power Flow Calculation for Base System (Generation Pattern B)

(3) Required circuits of the transmission lines for PSPP operation

The PSPP is connected to the base system and the required circuits of the 380 kV transmission lines for PSPP operation are estimated according to the system criteria set out in the previous section.

(a) Required circuits of the transmission lines for Altınkaya PSPP operation

The required circuits of the 380 kV transmission lines for Altınkaya PSPP operation were estimated in the base system. Altınkaya PSPP was assumed to be connected to the Altınkaya hydropower station by the double circuits of 380 kV transmission lines.

When the Altınkaya PSPP is operated following Generation Pattern A, the 380 kV system would not have any overloaded circuits in the normal operation. However, the intervals of Altınkaya–Kayabasi–Baglum–Sincan and that of Boyabat–Cankiri become overloaded when a single circuit fault occurs at some other circuits.

When the Altınkaya PSPP is operated following Generation Pattern B, the 380 kV system would not have any overloaded circuits in the normal operation and when a single circuit fault occurs at some other circuits.

Thus, the following circuits are to be added so that the system becomes compatible with Generation Pattern A when the Altınkaya PSPP is operated:

- Altınkaya PSPP–Altınkaya hydropower station 380 kV 11.1 km double circuit
- Altınkaya–Kayabasi–Baglum–Sincan 380 kV 394 km single circuit
- Cayirihan–Adapazari 380 kV 136 km single circuit

There are no overloaded circuits at normal operation or in case of a single circuit fault when Altınkaya PSPP pumps up the water during the off-peak period of time after the above-mentioned reinforcement. Furthermore, the results of the system stability analysis described later show that there are no significant problems in the system for the case of the single circuit fault at the interval of the transmission line with long length and heavy load conditions.

(b) Required circuits of the transmission lines for Gökçekaya PSPP operation

The required circuits of the 380 kV transmission lines for Gökçekaya PSPP operation were estimated in the base system. Gökçekaya PSPP was assumed to be connected to the Gökçekaya hydropower station by the double circuits of 380 kV transmission lines.

When the Gökçekaya PSPP is operated following Generation Pattern A, the 380 kV system would not have any overloaded circuits in the normal operation. However, the intervals of Gökçekaya–Eskisehir and the interval of Gökçekaya–Adapazari become overloaded when a single circuit fault occurs in some other circuits.

When the Gökçekaya PSPP is operated following Generation Pattern B, the 380 kV system would not have any overloaded circuits in the normal operation. However, the intervals of Gökçekaya–Eskisehir and the interval of Gökçekaya–Adapazari become overloaded when a single circuit fault occurs in some other circuits.

Thus, the following circuits are to be added so that the system becomes compatible with Generation Patterns A and B when the Gökçekaya PSPP is operated:

- Gökçekaya PSPP–Gökçekaya hydropower station 380 kV 1.8 km double circuit
- Gökçekaya PSPP (or Gökçekaya hydropower station) – Adapazari 380 kV 100 km single circuit

There are no overloaded circuits at normal operation or in case of a single circuit fault when Altınkaya PSPP pumps up the water during the off-peak period of time after the above-mentioned reinforcement. Furthermore, the results of the system stability analysis described later show that there are no significant problems in the system for the case of the single circuit fault at the interval of the transmission line with long length and heavy load conditions.

Here, the configuration of the transmission lines from Gökçekaya PSPP is assumed as shown in Figure 7. 22.

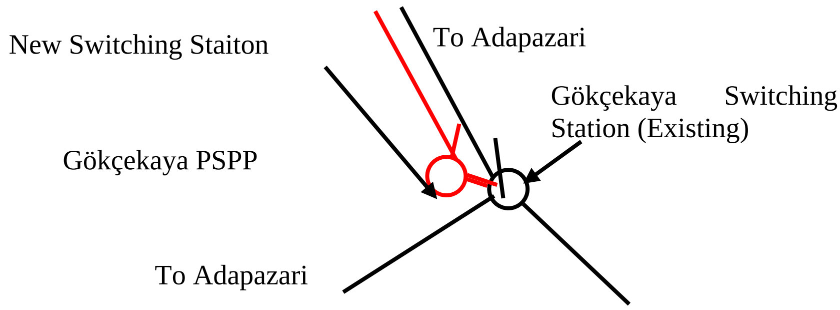


Figure 7. 22 Grid Connection from Gökçekaya PSPP

Figure 7. 23 shows the base system around Altınkaya and Gökçekaya HES. Figure 7. 24 shows the 380 kV system required for the case of the operation of Altınkaya PSPP. Figure 7. 25 shows the 380 kV system required for the case of the operation of Gökçekaya PSPP.

Figure 7. 26 and Figure 7. 27 show the swing curves illustrating the stability in the case of a single circuit fault at the interval of the transmission line with long length and heavy load conditions. The curves show the dynamic behavior of the internal phase angle of the generator located around the fault intervals that is swinging without diverging and indicate that the system can remain stable.

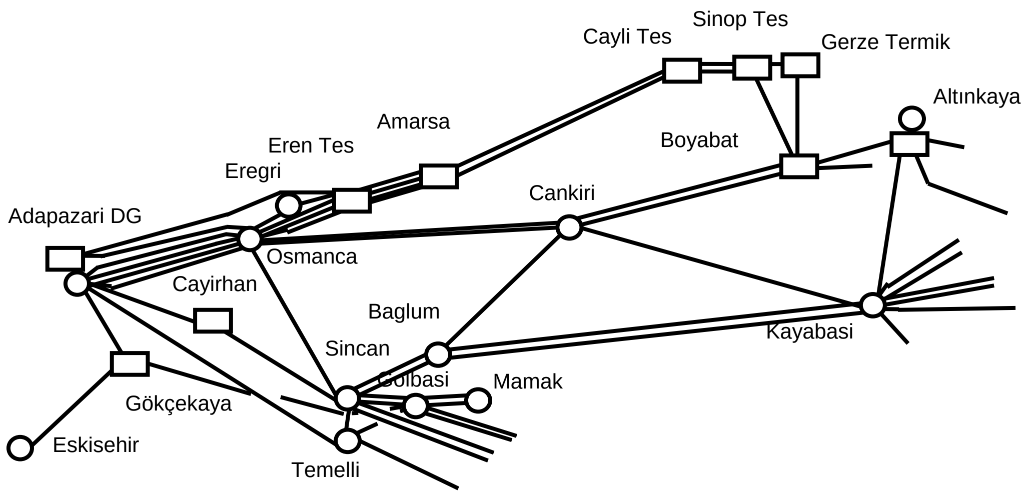


Figure 7. 23 380 kV System Compatible with Case of Increase in Power Generation in the Black Sea Coast Area and in the East Mountainous Area (Base System)

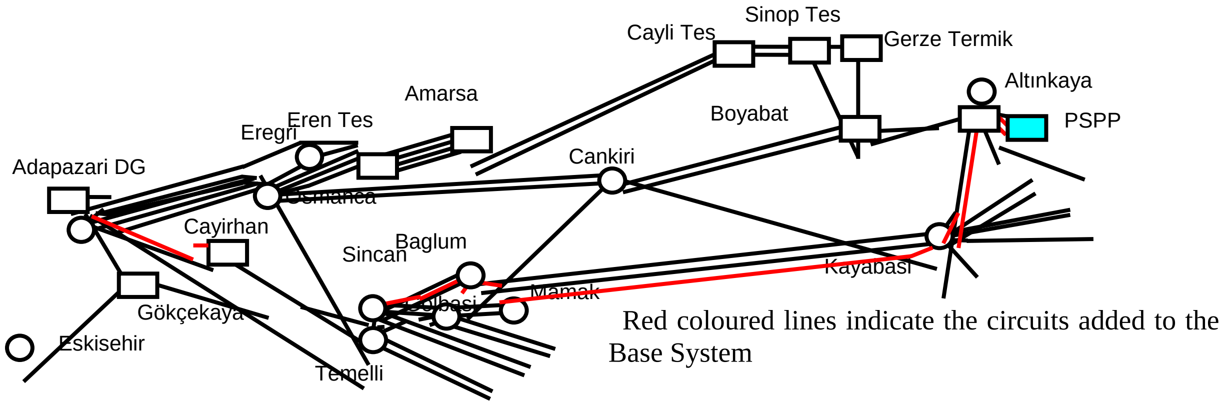


Figure 7. 24 Additional 380 kV Circuits Required for the Power Transmission from Altınkaya PSPP

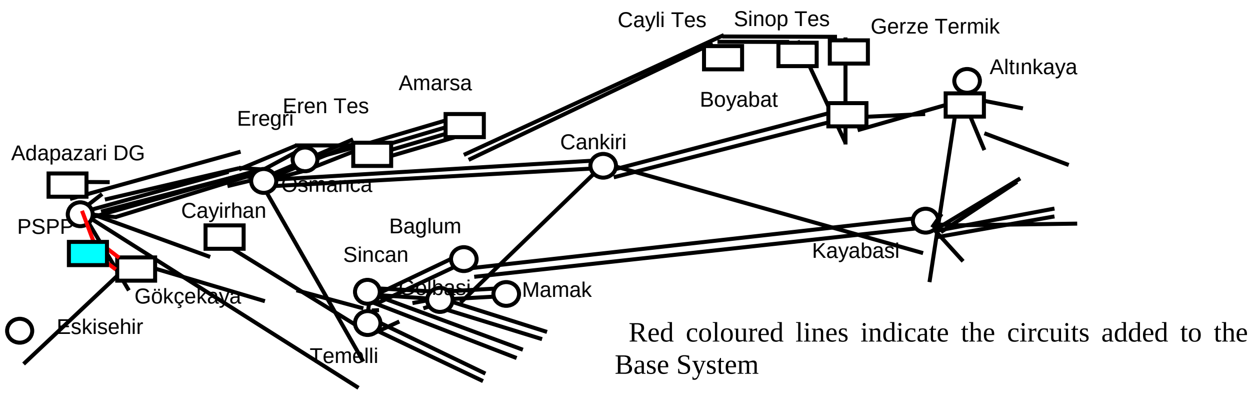
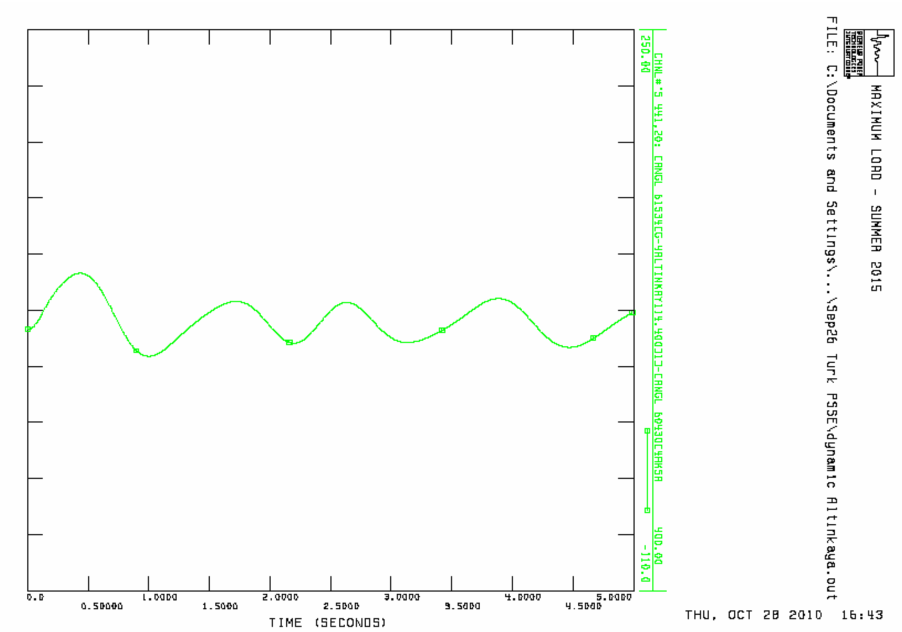
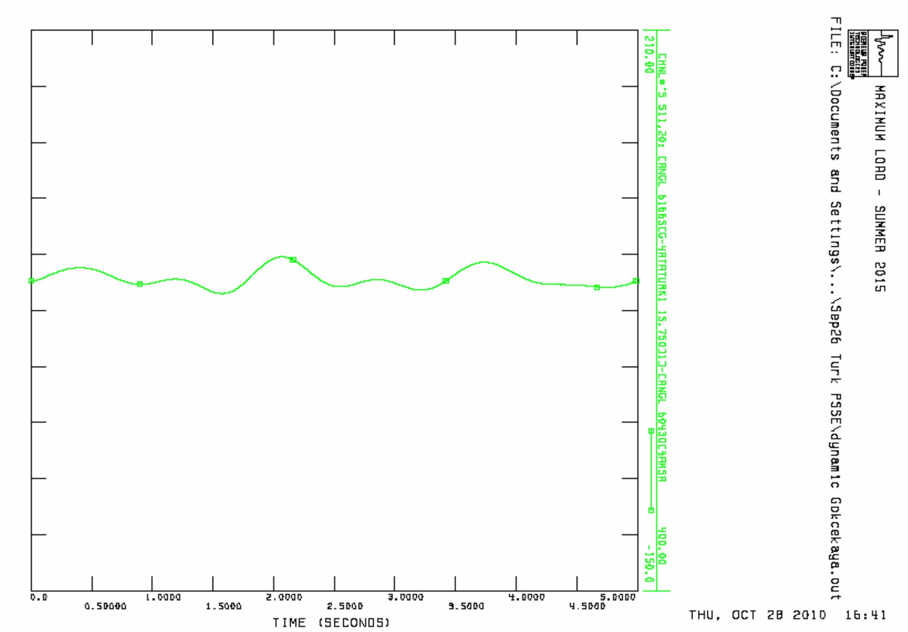


Figure 7. 25 Additional 380 kV Circuits Required for the Power Transmission from Gökçekaya PSPP



- ♦ The case of the line tripping of the Kayabasi–Baglum
- ♦ The difference of the generator internal phase angle between Altınkaya hydropower station and Aksa power station located in the south western area (tripping at 120 ms after the occurrence of three-phase short-circuit of a single circuit)

Figure 7. 26 The Stability Swing Curve (Generation Pattern A)



- ♦ The case of the line tripping of the Erbistan–Sinkan
- ♦ The difference of the generator internal phase angle between Ataturk hydropower station and Aksa power station located in the south western area (tripping at 120 ms after the occurrence of three-phase short-circuit of a single circuit)

Figure 7. 27 The Stability Swing Curve (Generation Pattern B)

(4) The volume of the additional circuits required for the operation of PSPP and the power transmission losses

The volumes of the additional circuits required for the operation of the Altınkaya PSPP and Gökçekaya PSPP are estimated as shown in Table 7. 23 from the results of the previous mentioned examination.

Table 7. 23 380 kV Additional Circuits Required for the Operation of PSPP

Case of Installation of Altınkaya PSPP	Case of Installation of Gökçekaya PSPP
Altınkaya PSPP – Kayabasi – Baglum - Sincan 380kV 394 km a single circuit added Cayirihan - Adapazari 380 kV 136 km a single circuit Total 530 km	Gökçekaya PSPP – Adapazari 380 kV 100 km a single circuit added Total 100 km

Because of long distance from Altınkaya PSPP to the power-consuming area, the length of the required additional circuits in the case of Altınkaya PSPP would be larger than in the case of Gökçekaya PSPP.

The power transmission losses in the cases of operation of Altınkaya PSPP and Gökçekaya PSPP are calculated as shown in Table 7. 24 categorized into the generation patterns. The transmission losses shown in the table are represented as whole system losses in the model used in the study.

Table 7. 24 Power Transmission Losses at the PSPP Operation

Case		Installation of Altınkaya PSPP		Installation of Gökçekaya PSPP	
Operation Pattern of PSPP	Generation Pattern	Power Transmission Losses	Loss Rate	Power Transmission Losses ( ): Difference from the case of Altınkaya PSPP	Loss Rate
Peak Demand, Power Generation of PSPP Load: 54,144 MW	Pattern A	1,482.6 MW	2.67%	1,378.5MW (▲ 104.1 MW)	2.48%
	Pattern B	1,465.3 MW	2.63%	1,381.9MW (▲ 83.4 MW)	2.49%
Off Peak Demand, Pumping up operation of PSPP Load: 32,486 MW	Pattern A	471.8 MW	1.43%	528.5MW (+ 56.7 MW)	1.60%
	Pattern B	514.8 MW	1.56%	556.8 MW (+ 42.0 MW)	1.69%

In the case of peak demand and power generation of PSPP, the power transmission loss in the case of the installation of Gökçekaya PSPP is less than in the case of the installation of Altınkaya PSPP by 80 ～100 MW. However, in the case of off-peak demand and power generation of PSPP, the power transmission loss in the case of the installation of Gökçekaya PSPP is greater than in the case of the installation of Altınkaya PSPP by 40～60 MW.

These differences of losses are considered to be caused by the fact that the power transmission loss of the generating operation of Altınkaya PSPP, which is located far from Ankara, becomes greater; however, the power transmission loss of the pumping-up operation of Altınkaya PSPP becomes smaller than in the case of the installation of Gökçekaya PSPP, because Altınkaya PSPP is located near the power sources for the pumping up.

It is difficult to make a precise estimation of the annual losses because the volume of them are largely dependent on the operational pattern of PSPP and the power sources for the pumping-up operation. Though it is impossible to compare precisely the annual losses of both cases, the difference of losses between the Altınkaya PSPP and the Gökçekaya PSPP is considered as not so large because of the short duration of power generation and the long duration of pumping-up operation despite that the peak loss of Altınkaya PSPP is larger than that of the Gökçekaya PSPP.

(5) A point to note about the installation of series capacitors

TEIAS system has series capacitors installed for some 380 kV transmission lines with long distance from the hydropower station located in the east region to keep up the system stability as previously mentioned. The series capacitors can contribute to enhance the system stability by compensating the series reactance of the transmission lines at the nominal system frequency of 50 Hz. However, the smaller system frequency makes the ratio of the compensation of the series capacitor larger and provides the system with the resonance of the frequency under 50 Hz. The generators rotating at synchronous speed suffer from the torque by the electric current produced by this lower frequency and the sub-synchronous oscillation might occur in the long shaft of the turbines of the thermal and the nuclear power plants. This phenomenon should be noticed when the thermal or the nuclear power stations are connected to the system where the series capacitors are installed.

On the other hand, the hydropower stations would not have problems with the sub-synchronous oscillation because of the short shaft of their turbines.

7.4.6 Rough Cost Estimate of Transmission Facilities

Tables shown below summarize the rough estimation of the construction cost of the required transmission lines for operation of Altınkaya PSPP and Gökçekaya PSPP.

The cost of the transmission lines required for Altınkaya PSPP is roughly estimated at 100 million USD and the cost of the transmission lines required for Gökçekaya PSPP is roughly estimated at 19 million USD

Table 7. 25 Case of Altınkaya PSPP

Altınkaya PSPP-Altınkaya HES	11.1km	2 circuits	4.4 million USD
Altınkaya-Kayabasi-Baglum-Sincan 380kV	394 km	1 circuit	70.9 million USD
Cayirihan-Adapazari	136 km	1 circuit	24.5 million USD
Total length of circuits	552 km		99.8 million USD

Table 7. 26 Case of Gökçekaya PSPP

Gökçekaya PSPP- Gökçekaya HES	1.8 km	2 circuits	0.7 million USD
Gökçekaya PSPP- Adapazari	100 km	1 circuit	18.0 million USD
Total length of circuits	104 km		18.7 million USD

7.5 Initial Environmental Examination（IEE）

The Study Team prepared Initial Environmental Examination (IEE) reports for Altınkaya PSPP and Gokcekaya PSPP based on the results of the primary site survey and the detailed site survey as well as data and information that the EIE collected after the site survey. Appendixes 7-5-1 and 7-5-2 are IEE reports for Altınkaya PSPP and Gökçekaya PSPP, respectively.

As described in Chapter 5, small-scale resettlement will be required for Gökçekaya PSPP. However, both projects do not have any crucial environmental and social issues on those developments in general as follows:

1) There are no national parks and other environmental protected areas around the project sites, and there is no information of endangered species at the project sites.
2) New construction of the lower dam is not required because the existing reservoir is utilized as a lower reservoir.
3) The scale of the upper reservoirs is relatively small in comparison to dams for large-scale conventional hydropower projects.
4) Most of the waterway and the powerhouse are underground structures.
5) There are existing roads which can be used for access roads to most of the construction sites. Only expansion of the existing roads is needed.
6) Once the upper reservoirs are impounded, it is not necessary to store additional water for plant operations.

7.6 Prioritization of PSPP Development

Priority of the two conceptual design sites (Altınkaya PSPP and Gökçekaya PSPP) was evaluated.

The evaluation points are as follows. First, rank was put on each PSPP by evaluation point; second, comprehensive rank was put on each PSPP.

- Social and natural environment impact
- Construction cost (power plant, transmission line)
- Distance from the demand center

Since contribution for the power system stability is considered as an evaluation point, the contribution by each PSPP project is described in another section.

Meanwhile, since the transmission lines of both PSPPs are planned to connect to the existing 380 kV switch yard of the hydropower plant, the construction cost of the connecting transmission line and the newly expanded transmission lines described in Section 7.4.6 are included.

The comprehensive rank of two priority PSPPs is shown in Table 7. 27.

Table 7. 27 Comprehensive Rank of Two Priority PSPP Projects

Evaluation Point		Altınkaya PSPP	Gökçekaya PSPP
Installed Capacity		1,800MW	1,400MW
Standard Development Schedule		13 years	12 years
Environment Impact	Social	**Number of Directly Affected Houses: 0 HH** Loss of Water mill: 2 units Loss of Agricultural Land: 16 ha	**Number of Directly Affected Houses: 2 HH** (Both of them are second houses) Loss of Storage for Animal Breeding: 2 houses Loss of Agricultural Land: 110 ha Several tens' Graves to be relocated Two new deep wells to be drilled
	Natural	**Some direct impacts to the environment, but limited.**	**Quite limited-direct impacts to the environment**
Construction Cost	Power Plant	1,201mil. USD, 667 USD/ kW	1,098 mil. USD, 785 USD/ kW
	Transmission Line	100 mil. USD (530km+11km)	19 mil. USD (100km+2 km)
	Total	1,301mil. USD, 723 USD/ kW	1,117 mil. USD, 798 USD/ kW
Distance from Ankara		About 300 km	About 170 km
Rank of Environment		①	②
Rank of Economy		①	②
Comprehensive Rank		①	②

7.7 Recommendation of Investigation Works for Next Step

7.7.1 Hydrological and Metrological Investigation

Although either of the conceptual design PSPP sites is planned to utilize the existing reservoir as a lower reservoir, it is recommended to install a gauging station near the upper dam site and measure hydrological data and meteorological data for the following main purposes:

- Altınkaya PSPP
  For design of the upper dam such as sedimentation volume, flood discharge, and dam height and construction planning
- Gökçekaya PSPP
  For design of the upper reservoir such as bypass channel around reservoir and countermeasure of sediment, and construction planning

7.7.2 Geological Investigation

(1) Altınkaya PSPP

Items to be clarified in the next step and recommendable geological investigation and laboratory tests for each item are summarized in Table 7. 28.

As for the upper dam, concrete gravity dam (or CFRD) is planned as the most convincing dam type and the dam height is 79m, and the crest length is 330m. In order to grasp the geological structure around the upper dam, ground surface reconnaissance should be executed. Besides, a grid of 100m is set throughout the dam site and seismic prospecting should be conducted on the grid. Bore-hole drillings should be conducted on the intersection points of 100m grids, and groundwater level on the both banks of the reservoir should be monitored for long term. Length of each bore-hole on the dam axis is set as 70m equivalent to the dam height, and is set 60m up and downstream of the dam center. Lugeon tests are executed for all bore-holes to determine the hydrogeological property of the dam foundation.

As for the sites of quarry, intake and outlet, geological conditions are basically investigated by bore-hole drillings and seismic prospecting.

Along the waterway, seismic prospecting is conducted throughout the waterway for geological interpretation. For the headrace surge tank, drilling and in-situ test of sonic logging through the bore-hole will be carried out, and also Lugeon tests below the ground water level are executed.

As for the underground powerhouse, in order to grasp the geological structure around the powerhouse, ground surface reconnaissance should be executed. In addition, drilling is conducted from ground surface to the underground powerhouse elevation in order to identify the surrounding rock condition of the powerhouse cavern. Then, in-situ tests such as sonic logging and Lugeon tests at the range of 100m from the bottom of bore-hole are executed.

Bore-holes drilling are also conducted at the both right and left abutment of the coffer dam. Sonic prospecting survey is carried out to clarify the subaqueous topography and sediment layer thickness around the dam bed.

Laboratory testes listed in Table 7. 30 should be executed for all structure sites. However, XRD (X-Ray Diffraction) analysis is executed only for drilled cores of weathered zone, which have a possibility of including expansive clay minerals.

Meanwhile, exploratory test adits for the upper dam, the quarry site, and the underground powerhouse and in-situ tests in the adits, i.e. rock shearing test, plate loading test, and measurement of initial ground stress of the UGPH will be carried out in the detailed design stage.

Table 7. 28 Proposal of Geological Investigation Works in the FS Stage for Altınkaya PSPP

Structure	Purpose	Investigation item	Notes
Upper dam / Reservoir	➢ Geological structure ➢ Geotechnical Property of dam foundation ➢ Permeability of dam foundation and hydrogeological feature of the reservoir ➢ Slaking properties of mudstone	1. Surface survey 2. Seismic prospecting 3. Drilling 4. Lugeon test 5. Long-term water level observation in bore-holes 6. laboratory tests	* Surface survey intends for whole area of the upper reservoir
Quarry site	➢ Quality of aggregate for concrete gravity dam, rock material for CFRD	1. Seismic prospecting 2. Drilling 3. Laboratory tests	
Intake	➢ Geological property of the intake and its surrounding area	1. Seismic prospecting 2. Drilling 3. Laboratory tests	
Waterway/ Surge tank	➢ Geotechnical feature of the waterway route (possibility of hidden weak zone such as fracture zones and hydrothermal altered zones)	1. Seismic prospecting 2. Drilling (including sonic logging in bore-hole) 3. Lugeon test 4. Laboratory tests	* Seismic prospecting intends for only a waterway route * Surface survey intends for surrounding area of the surge tank and the UGPH
Underground Powerhouse	➢ Geological structure ➢ Geotechnical Property of the UGPH and neighboring rocks	1. Surface survey 2. Drilling (including sonic logging in bore-hole) 3. Lugeon test 4. Laboratory tests	
Outlet/ Coffer dam	➢ Geological structure ➢ Subsurface loosened zone caused by rock creeping of the outlet site ➢ Weathering condition of the outlet site	1. Surface survey 2. Seismic prospecting 3. Drilling 4. Laboratory tests	* Surface survey intends for surrounding area of the outlet and along the service road in Altınkaya lake side
	➢ Geological condition of coffer dam foundation	1. Drilling 2. Laboratory tests 3. Sonic prospecting	

(2) Gökçekaya PSPP

Items to be clarified in the next step and recommendable geological investigation and laboratory tests for each item are summarized in Table 7. 29.

As for the upper dam and reservoir, full face artificial pond is planned as the most convincing reservoir type, and the earth fill type dam of 35m in height is planned. The most important issue of the upper reservoir is to elucidate the hydrogeological structure of the bedrock. The waterway goes through geology of Temg, PEg and PEge in order of depth, and the geology of most part of the waterway route belongs to PEg. Since PEge consists of limestone blocks, there might be some caves in them. Therefore, in order to grasp the geological structure around the upper reservoir, ground surface reconnaissance should be executed. Besides, two-dimensional resistivity prospecting and seismic prospecting should be executed on the same line. They are done on dam axis line, center of the pond line, and waterway route line. In addition, bore-hole drillings are conducted on dam axis and in the pond, and also, Lugeon tests and SPT (Standard Penetration Test) in the shallow depth are executed for all bore-holes. Moreover, bore-holes outside of the pond will be drilled to identify the ground water levels which are monitored for long term. XRD (X-Ray Diffraction) analysis is executed for tuffaceous rocks of Temg, which may contain expansive clay minerals, by using drilled cores.

As for the intake and outlet sites, geological conditions are basically investigated by bore-hole drillings and seismic prospecting.

Along the waterway, seismic prospecting is conducted throughout the waterway for geological interpretation. For the headrace surge tank, drilling and in-situ test of sonic logging through the bore-hole will be carried out, and also Lugeon tests below the ground water level are executed.

As for the underground powerhouse, in order to grasp the geological structure around the powerhouse, ground surface reconnaissance should be executed. In addition, drilling is conducted from ground surface to the underground powerhouse elevation in order to identify the surrounding rock condition of the powerhouse cavern. Then, in-situ tests such as sonic logging and Lugeon tests at the range of 100m from the bottom of bore-hole are executed.

Bore-holes drilling are also conducted at the both right and left abutment of the coffer dam. Sonic prospecting survey is carried out to clarify the subaqueous topography and sediment layer thickness around the dam bed.

As for the coffer dam, bore-holes drilling are conducted at the both right and left abutment of the coffer dam. Sonic prospecting is carried out to clarify the subaqueous topography and sediment layer thickness around the dam foundation.

Laboratory testes listed in Table 7. 30 should be executed for all structure sites.

Meanwhile, exploratory test adits for the upper dam, the quarry site, and the underground powerhouse and in-situ tests in the adits, i.e. rock shearing test, plate loading test, and measurement of initial ground stress of the UGPH will be carried out in the detailed design stage.

Table 7. 29 Proposal of Geological Investigation Works in the FS Stage for Gökçekaya PSPP

Structure	Purpose	Investigation item	Notes
Upper dam /reservoir	➢ Geological structure ➢ Geotechnical Property of the dam foundation ➢ Permeability of the dam foundation and hydrogeological feature of reservoir ➢ Hydrogeological feature of **Temg**, **PEg** and boundary between **Temg** and **PEg** ➢ Presence of expansive clay minerals	1. Surface survey 2. Seismic prospecting 3. Two-dimensional resistivity prospecting 4. Drilling (including sonic logging in bore-hole) 5. Standard Penetration test 6. Lugeon test 7. Long-term water level observation in bore-holes 8. Laboratory tests including XRD Analysis	* Surface survey intends for whole area of the upper reservoir * Both Seismic prospecting and Two-dimensional resistivity prospecting should be conducted on the same line *SPT should be taken at the weathered zone in borehole
Intake	➢ Geological properties of intake and its surrounding area	1. Drilling (including sonic logging in bore-hole) 2. Laboratory tests	
Waterway/ Surge tank	➢ Geological feature of the waterway route	1. Seismic prospecting 2. Drilling (including sonic logging in bore-hole) 3. Lugeon test 4. Laboratory tests	*Seismic prospecting is conducted for only the waterway route * Surface survey is conducted for surrounding area of the surge tank and the UGPH
Underground Powerhouse	➢ Geological structure	1. Surface survey 2. Drilling (including sonic logging in bore-hole) 3. Lugeon test 4. Laboratory tests	
Outlet/ Coffer dam	➢ Geological structure ➢ Subsurface loosened zone by rock creeping ➢ Weathering depth and geotechnical properties of outlet and surrounding area	1. Surface survey 2. Seismic prospecting 3. Drilling 4. Laboratory tests	* Surface survey is conducted for surrounding area of the outlet on the right bank of Gökçekaya reservoir
	➢ Geological condition of the coffer dam foundation	1. Drilling 2. Laboratory tests 3. Sonic prospecting	

Table 7. 30 List of Laboratory Tests of Drilled Core Rock

Laboratory Test	Output
a. Bulk specific gravity and absorption (saturated surface-dry basis) (e.g. ASTM C 127)	Specific gravity and absorption
b. Unconfined compressive strength of drilled core including Modulus and Poisson's Ratio (e.g. ISRM 1978 (a))	Compressive strength of rock
c. Confined compressive strength and tensile strength under strain control (for the Underground Powerhouse)	Stress strain curve, Mohr-Coulomb yield criterion
d. Ultrasonic velocity	Vp,Vs
e. Slaking test on Rock according to ISRM suggested method	Slaking grade
f. XRD (X-Ray Diffraction) analysis	Expansive clay materials

* Diameter of the specimen shall be more than 50mm.
* Total numbers of slaking test for Altınkaya PSPP is 1/3 of total number of the other test items
* Slaking test at Gökçekaya PSPP site is not required and XRD is executed only for **Temg** layer of the upper reservoir area.

7.7.3 Environmental Impact Assessment

Types and scale of projects which require full-scale Environmental Impact Assessment (EIA) are defined in Annex I of the bylaws of EIA as shown in Appendix 7-7. The criteria related to hydropower development are shown as follows:

- No. 15: Water storage facilities (dams and lakes with a reservoir volume of 10 million m^3 and over).
- No. 16: Run of river type hydropower plants with an installed capacity of 25 MW or more.
- No. 32: Construction of overhead electrical power lines with a voltage of 154 kV or more and a length of more than 15 km (transmission line, substation, switch areas).

According to the screening criteria of JICA and the World Bank, PSPP projects are categorized as "Category A," for which careful EIA procedures are required.

During full-scale EIA procedures, sufficient site investigation should be carried out to fully know the current environmental situation, and consultation with project-affected people (PAPs) and other related people should be done to reflect PAPs' opinion to the resettlement action plan (RAP) and environmental management plan (EMP).

In order to implement EIA procedures, environmental consultants or experts who are familiar with PSPP development will be hired. As for scope of work for EIA, it is required that EIA report should be complied with the General Format, which is prescribed in the Bylaws of EIA as well as guidelines of international donor agencies such as JICA.

7.7.4 Feasibility Study

(1) Scope of Work

For the first feasibility study on the PSPP projects, not only technical examination but also study on development program of PSPP such as necessity (scale, timing), operation, ownership and framework, etc. should be carried out as follows.

Items to be studied are as follows:

1. Background and Necessity of Pumped Storage Power Plants

1-1 Confirmation of the power development policy in Turkey
1-2 Review of actual demand and supply balance, power development plan
1-3 Confirmation of the progress of power sector reform
1-4 Evaluation on the necessity and validity of assistance for PSPP projects
1-5 Optimization of development schedule and transmission connection plan

2. Hydrological, Topographical and Geological Investigations and Comparative Study

2-1 Planning and execution of investigations
2-2 Review of basic plan based on the results of supplementary surveys
- To evaluate geological conditions
- To review design flood discharge and capacity of bypass channel
- To review design sediment volume and simulate sedimentation

2-3 Comparative study on alternatives (Including the results of TOR1-5 and 4-2)
- To review the optimal development scale
- To carry out comparative study of CGD and CFRD for the upper dam
- To carry out comparative study of location of UGPH and Waterway route
- To carry out comparative study of construction method of Outlet

3. Basic Design and Construction Planning

3-1 Basic design of civil structure and steel Structure
3-2 Review of design of electro-mechanical equipment
3-3 Evaluation on the possible application of new technologies
3-4 Review of construction planning

4. Environmental Impact Assessment

4-1 Review of environmental impact assessment report
4-2 Review of basic resettlements and land compensations plan

5. Effective Utilization of PSPP for the Optimal Power System Operation

5-1 Proposal on the optimal operation plan of PSPP
5-2 Proposal on the ancillary functions of PSPP for stability and quality improvement of power supply
5-3 Evaluation on the operation capability for power system of the developer in terms of facilities, technologies and human resources

6. Operation and Maintenance of PSPP

6-1 Examination on the optimal O&M structure of PSPP
6-2 Evaluation on the O&M capability for PSPP of the developer in terms of technologies and human resources

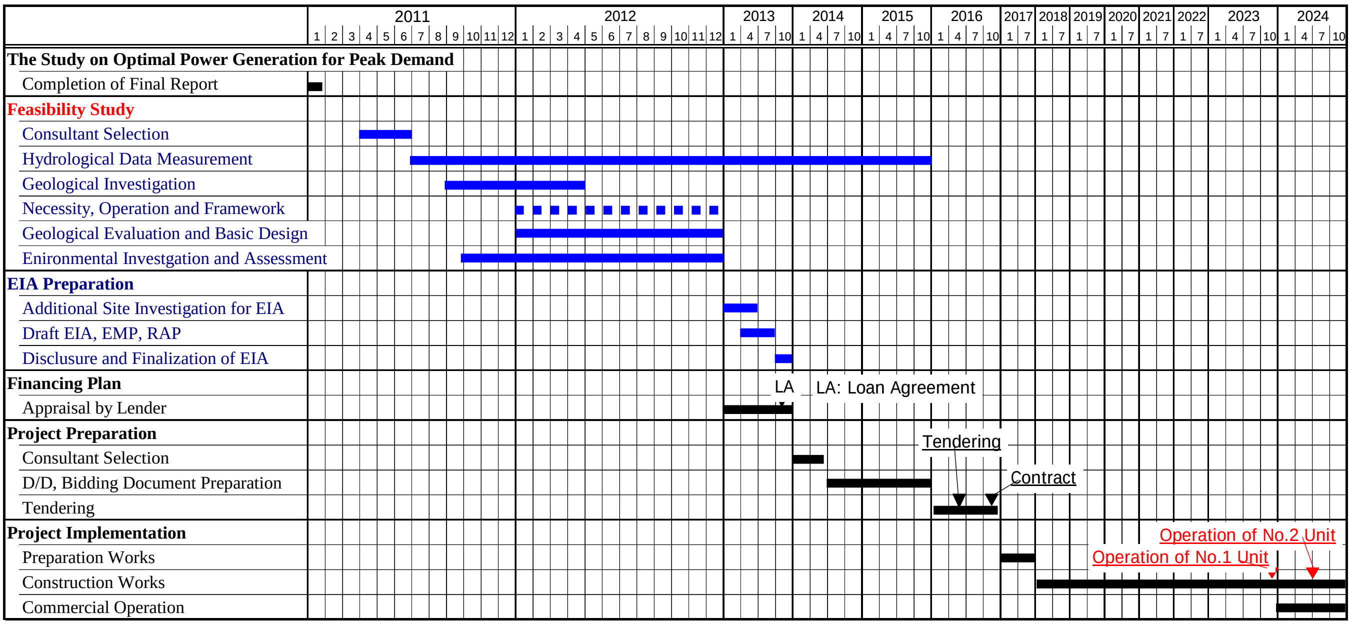
7. Project Implementation based on above-mentioned Study Results

7-1 Examination on the organizational structure, total cost, financial plan, schedule and procurement of equipment for project implementation
7-2 Economical and financial analysis (IRR, Cash flow)
7-3 Proposal on the assistance plan that contributes to the capacity building of the developer in the field of power system operation and operation & maintenance of PSPP
7-4 Proposal on TOR and Man Month for engineering services

(2) Implementation Schedule of Feasibility Study

Duration of the feasibility study will be two years as shown in Table 7. 31.

Table 7. 31 Draft Schedule of Feasibility Study and Development



Chapter 8 Recommendations from the Study Team

8.1 Proposal on Long-Term Development Plan

(1) Avoid risk from users' point of view

In Turkey liberalization of the electricity market is proceeding and there are many players in the power sector. Each player has its own interest and carries out its own business activity. Therefore, risk items vary from player to player and one way of hedging risks for some could be risk for the others.

In this chapter, risks in power supply will be studied from users' viewpoints.

There are two major risks for users:

- Decline of electricity quality
- Sharp rise of electricity prices

When the above-mentioned risks are taken into account, small-scale general power users would be left with the only option to avoid the risks, that is, not to want to purchase power. Therefore, if there is no alternative to electricity, general users who wish to buy power would be forced to purchase power from distribution companies despite quality or price levels.

In the course of liberalization of the electricity market, power generation companies in the private sector make decisions fully based on the cost basis. This means that they make decisions on the development of certain power plants when they judge they can supply power at lower prices via those plants than with other power plants. For this reason, electricity prices generally tend to decline. However, because private generation companies seek to maximize profit under the current system in which revenue increases according to utilization amounts, they constantly strive to operate their plants at 100% of their capacity.

On the other hand, in order to ensure stable power system operation and supply quality power to users, they need to satisfy the following two points:

(a) Secure reserve supply capacity

In a case of emergencies such as sudden forced outage of power plants or demand surge, it is necessary to secure certain generation equipment to generate reserve supply capacity and keep it on standby in an operative state at all times. Expecting to purchase power from other countries can be an option, but it would depend on the supply/demand condition of those countries. Therefore, it is essential to secure at least 3% or higher of the total power demand as reserve supply capacity within the country in preparation for a single unit of the largest output being shut down.

Equipment designated as providing reserve supply capacity is forced to stand by at normal time; thus, it operates at very low annual utilization rate of 10% or lower. Therefore, under the current system, it is very unlikely that private generation companies develop such facilities themselves. Hence it is feared that in the near future reserve supply capacity will run short, leading to blackout in wide areas on sudden shutdown of power plants.

(b) Secure frequency adjustment capabilities

In order to maintain the frequency of the power system, it is necessary to change the output of power plants as well as to match the demand profile which changes at every minute and every second. Giving command on output adjustment of power plants is basically conducted by a system operator. However competent a system operator is, without a power plant which can flexibly change output in accordance with the intentions of the system operator, it is impossible to supply power with quality to users. In other words, from the viewpoint of supplying good-quality power to users, it is absolutely necessary to have generation equipment whose output can be changed fast and to which a system operator can give command freely at its will.

EUAS-owned generation equipment currently accounts for more than half of the entire plants, and at power plants which are capable of frequency adjustment, frequency adjustment is carried out based on the system operator's command. In the near future, however, such power plants will be sold to private generation companies. Therefore, there are concerns that frequency adjustment function will be missing, which in turn will lower the power quality.

As mentioned above, from the viewpoint of securing power quality, it would be problematic to leave everything to the free will of private generation companies. It is important for the public sector that represents users to stay involved. Specific measures are described as follows:

- Design a system which makes private generation companies feel attracted to make frequency adjustment and standby operation.
  Build a system under which reasonable amount will be paid for all ancillary services
- The public sector owns power plants which contribute to the improvement of power quality (or owns right to freely operate them).
- Oblige all private generation companies to provide ancillary service based on their generation output.
  Also, by mandating private generation companies that are unable to provide the service to purchase it from other private generation companies, the ancillary service market will be formed.

(2) Consistency with national basic policy from frequency adjustment function

Numerical targets of the government on the electricity energy field are indicated in the "Electricity Energy Market and Supply Security Strategy Paper." Here is an overview on the issues toward meeting these targets by focusing on the frequency adjustment function.

(a) Nuclear power

In the strategy paper, a target has been set to raise the share of nuclear power to 5% of the total power output by 2020. Even though no further plan has been clarified, it is thought that development will be continuously made.

Under basic operation conditions, output adjustment will not be sought at nuclear power plants and even during off-peak periods full-load operation will be made. Therefore, as the ratio of nuclear power generation goes up, there will be a greater need for plants with frequency adjustment function during off-peak periods.

(b) Wind power

The strategy paper states a policy to place emphasis on domestic renewable energy from the energy security point of view and sets a target of 30% of the total power output of the country by 2023. Based on this policy, it has been decided that 20,000 MW of wind turbines will be developed by 2023, which makes it likely to see the acceleration of wind power development.

Throughout the year, 20-30% utilization can be expected with wind power facilities, which can surely contribute to the reduction of fossil fuel consumption and CO_2 emissions. However, the output timing of individual units is very unstable and output variation width and changing speed variations are great. As the number of units increases, individual variations tend to be summed up by the average. However, because output variations and changing speed become larger, the need to install equipment to adjust frequency to absorb those changes will become greater.

(c) Natural gas

The strategy paper sets a goal of bringing down the share of natural gas from the current level of around 50% to 30% or below from the energy security point of view.

The combined-cycle thermal power plant using natural gas has a very high thermal efficiency (around 55%). In addition, it is relatively easy to make the output adjustment; thus, it is possible to provide frequency adjustment function during off-peak period when the demand is low. However, since the government policy is to reduce the share of natural gas, it is expected that the frequency adjustment function provided by natural gas-fired thermal plants will gradually decline.

(3) Development plan of transmission network

TEIAS naturally has formulated the transmission network development plan. In the past, TEIAS obtained information on a future power plant development plan from EUAS and made efficient planning of transmission networks. However, with the power market increasingly getting liberalized, it is getting more difficult to obtain information on the power plant development plan. Therefore, it is becoming increasingly difficult to make an efficient planning of the transmission network development.

Power demand of Turkey is expected to grow at high levels of 6-7% a year from now on. With this demand forecast, in 2020 it will roughly double the current level, and triple in 2030. There is a need to develop transmission networks along with power plants in an accelerating manner in response to such demand growth. If a transmission network plan is formulated based on information on a relatively short-span planning of power plant development (about 5 years), only focusing on the transmission methods of those power plants in a near-sighted manner, it may lead to weakening transmission lines and higher cost.

Since power demand is expected to roughly triple the current level in 2030, it is likely that the current highest voltage of 380 kV transmission lines will reach the limit and higher-voltage lines will become necessary. In order to build transmission networks which have achieved stability and efficiency in a well-balanced manner in the future, the introduction of higher-voltage lines should be taken into account in formulating a future vision, and based on that vision transmission networks must be laid systematically.

Furthermore, in order to promote the selection of sites close to where power is needed, which can contribute to lower cost, or choose sites with smaller supply capacities from supply/demand balancing perspective, it is desirable to give incentives to power plant sites and introduce a system to induce the installation of power plants in areas that transmission companies find desirable.

8.2 Recommendation for Construction of PSPP

8.2.1 Introduction of Advanced Technologies

Since the following two advanced technologies of civil works have a high possibility to make the reduction of construction cost of Altınkaya PSPP, whose water head is very high and unit capacity is large, it is recommended to study the introduction of these advanced technologies for Altınkaya PSPP. In addition, since there is a high possibility to improve the PSPP function significantly by introducing an advanced technology of the electromechanical equipment, it is recommended to study the introduction of an advanced technology to both Altınkaya and Gökçekaya PSPPs.

- ◆ Civil structures
  - ・ Full-face tunnel boring machine (TBM)
  - ・ High-tensile-strength steel (HT100)
- ◆ Electromechanical equipment
  - ・ Splitter runner

(1) Full-face tunnel boring machine (TBM) for excavation of inclined penstock shaft

The merits of adopting this technology are as follows:

In the conceptual design of Altınkaya PSPP, the conventional method of Alimac Climber is considered as an excavation method for pilot tunnel of inclined penstock shaft. In this case, two interlevel working tunnels are required because the tunnel length excavated by Alimac Climber is limited to 300 m; on the contrary, the length of the inclined penstock shaft in Altınkaya PSPP is about 900 m.

The benefits of adopting a full-face TBM are as follows:

- ✓ Construction period of inclined shaft tunnel excavation is shortened.
- ✓ Safety of tunnel excavation is improved significantly.
- ✓ Penstock interlevel working tunnel can be omitted.
- ✓ Risk of choke of pilot tunnel can be hedged.

(2) High-tensile-strength steel (HT100)

In the conceptual design of Altınkaya PSPP, high-tensile-strength steel of HT80 is used for the penstock and the maximum thickness of steel pipe is estimated as 80 mm. HT100 can make the ratio of inner pressure burdened by surrounding rock of embedded penstock increase and reduce the total weight of penstock by more than 20% in comparison to HT80. Moreover, in line with the reduction of weight, the construction period of penstock also can be shortened by about 20%.

(3) Splitter runner

A splitter runner is newly developed for Francis-type reversible pump-turbine to enhance added value such as improvement of pump-turbine efficiency, expansion of output adjustable range, and applicability to the site with high head change ratio.

Figure 8. 1 shows a conceptual diagram and a photo of splitter runner which was installed in the Kannagawa PSPP.

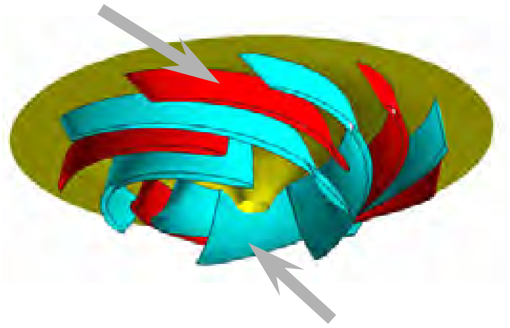


Figure 8. 1 Splitter Runner

It has a structure that full blades and splitter blades are arranged alternatively. In the Kannagawa PSPP equipped with the splitter runner, reversible pump-turbine efficiency was improved by 1.5% and operable range was expanded by 1.2 times in comparison to that of a conventional type.

The advantages by adopting this technology are as follows:

- ✓ To improve reversible pump-turbine efficiency due to rectification of flow pattern by increase in the number of blades and reduction of disk friction loss by downsizing of the runner diameter. The economical benefit of efficiency improvement is to reduce the pumping power cost with low power losses through pumping and generating cycle.
- ✓ To expand output adjustable range due to reduction of pressure fluctuation and improvement of cavitation performance. The economical benefit of output's adjustable range expansion is to allow thermal power plants to operate at high efficiency level, since additional operational reserve for automatic frequency control (AFC) is secured by minimizing the output level of PSPP improved with splitter runner. The improvement of minimum output level for generating operation reduces the pumping power. In addition, reduction of pressure fluctuation and pump-turbine oscillation lead to the extension of equipment life and reduction of maintenance cost.
- ✓ To enhance the reliability of runner in line with the improvement of runner rigidity by increase in the number of blades.

8.2.2 Environmental and Social Considerations

Environmental and social considerations for PSPP are not so different from those of ordinary large-scale hydropower projects, but special attentions to be paid for PSPPs are as follows:

1) Related to reservoir location
   - ➢ Since it has two reservoirs whose elevations are quite different, the water quality and temperature might also be different. Therefore, influence to water quality should be considered.
   - ➢ Ecosystem or biological systems of the reservoirs might be different. Therefore, influence to aquatic plants and animals should be carefully considered.

2) Related to plant operation
   - Water of two reservoirs is mixed during plant operation. Therefore, influence on water quality, especially temperature, turbidity, and other quality items, should be considered.
   - Daily draw-up and draw-down depths of reservoirs are large. Therefore, influence on users' activities and safety in the reservoirs should be considered.

3) Related to the scale of development
   - PSPP project consists of two dams, many tunnels, underground structures, and related access roads; hence, a wide range of land might be altered. Therefore, negative impact on local residents such as involuntary resettlement and changes of livelihood should be carefully considered. Negative impacts on important flora and fauna could also be the same.

The following are quite important in order to reduce the negative impacts as much as possible:

1) Not to select project sites which have heavy environmental load in the stage of potential study
2) To carry out sufficient site survey in order to understand the current environmental and social situation
3) To propose effective mitigation measures against negative impacts through appropriate assessment method in consideration of features of PSPP
4) To conduct sufficient monitoring

The Study Team prepared "Guidelines for Environmental and Social Considerations for PSPP Development" together with the counterpart of EIE. It is expected that the guidelines will be utilized for PSPP development in the future.

8.3 Suggestion for Possession of PSPP

The liberalization of the electric power market is being progressed in Turkey, and public sector organizations are not allowed to construct new power plants except for emergency cases under the current regulation. Therefore, "Who will construct a PSPP and how will its development fund be recovered?" will be the critical issue when developing PSPP in the future.

Since the liberalization of the electric power market in 2001, small-sized power plants such as gas-fired thermal and run-of-river type hydro have been mainly constructed because those types of power plants have little risks due to their prospective short development term and stable revenue. As a result, many of the large scale power plant projects are retarded, and it is anticipated that the power shortage might occur in the near future. Meanwhile, it is considered that Turkey's electric power market will be operated in accordance with the rules of EU network in the future since they are interconnected since September 2010.

Considering these situations, ownership and operation schemes of PSPP are studied in this section, for future PSPP development.

8.3.1 Ownership and Operation Schemes of PSPP in Other Countries

(1) EU Area

Turkey's electric power network was interconnected and synchronized with EU network through Greece and Bulgaria, in September 2010. After 1 year of various tests in synchronized operation, Turkey is planned to join EU power market. After the power market integration, the generated power in Turkey will be traded in European network, and the power of PSPP will also be included naturally.

In addition, EU committee is implementing "20-20-20 Strategy", which is to reduce greenhouse effect gas by 20%, increase the ratio of renewable energy in generated power energy to be more than 20%, and improve energy efficiency by 20%, all by 2020. Due to the effect of increasing renewable energy sources, issues of reserving power plants for demand supply control and network stabilizing facility are emerged. In this background, current situation of PSPP in European network is overviewed, taking RWE of Germany and Terna of Italy as example.

(a) Germany - RWE network

There are various ownership schemes of PSPP in Germany, e.g., i) owned by sole power generator, ii) jointly owned by multiple power generators, iii) jointly owned by power generator and other company, and so on. The right of owners consists of three layers, that is, asset ownership, operation right of the power plant, and the right of option trade of the generated power and pumping load.

In the case of i), for example, operation of a PSPP is planned in order to maximize total profit of the generation company, considering the market situation and the generation plans of other owned power plants. In this case, since every power generators have to generation reserve for backup to secure their "N-1" due to restriction in Germany, they need to keep some of their owned power plants to be standby, or purchase reserve power from the market. When some power generators have each portions of operation right of a PSPP, in the case of ii), each power generator plans for its portion of the power plant in the view of its own optimization, then, each operation plan is presented to the jointly owned operator of the PSPP, and those plans are coordinated and determined. In the case of iii), when a company has the right of PSPP operation but does not have proficiency of generators' operation, its portion of operation right can be sold.

Operation pattern of PSPP greatly changed by introducing power market in 1998. Before the liberalized power market, PSPP was usually pumped up at off peak hours and generated at peak hours, while in the situation under the market, in order to sell PSPP's reserves for both generating and pumping, regardless of peak or off peak hours, it is always planned to keep reserve and is not set at its full output. In this situation, frequent generation and pumping operations are planned, and startup times are increased by 78% from before market as a result. Due to the requirement of N-1 reserve for power generator as stated above, and other requirement to secure "black start reserve," hydro power plants are mainly utilized for its requirement because of their characteristics of quick startup and output change rate, therefore availability of PSPP has been decreased due to keeping reserves. For other power plants such as thermal power as well, they need to operate at its minimum output to reserve backup power in some cases, and this causes to make efficiency lower.

In the course of implementing ancillary services, TSO can prepare generation capability from the secondary market for the reserve of secondary frequency control. TSO purchases option of secondary reserve on future designated time from a power generator so that it will be able to purchase the reserve at listed price, choosing from the secondary market that 9 power generators make bids for every 15 minutes. When it comes to the designated time, TSO has the option whether it would activate its option and purchase reserve as determined or not, judging from current situation of market and demand supply condition.

Due to massive introduction of renewable energies, such as wind power, in recent years, there occurred cases of shortening reserves for demand supply control at off peak hours, and of negative price in the power market as a result. In 2009, wind power outputs were suppressed for the first time due to the shortage of primary reserve, and on December 26, 2009, the price in the power market recorded - 200Euro/MWh due to the low demand on holiday and the high wind power output.

It is planned to introduce 30GW of photovoltaic power by 2020, and to abolish nuclear power plants, which may cause more shortages of primary reserve, even in peak hours, and shortages of reactive power sources. Therefore, German government recognizes the necessity of PSPP development, as a measure of securing power supply quality.

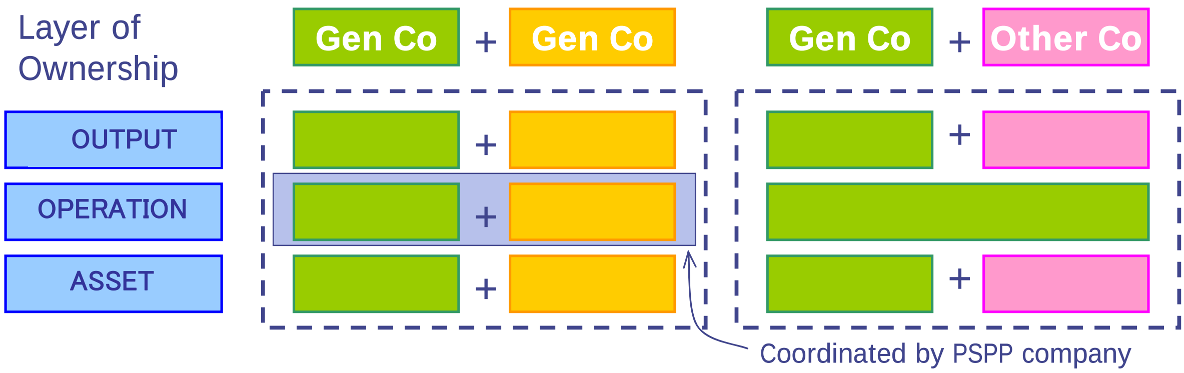
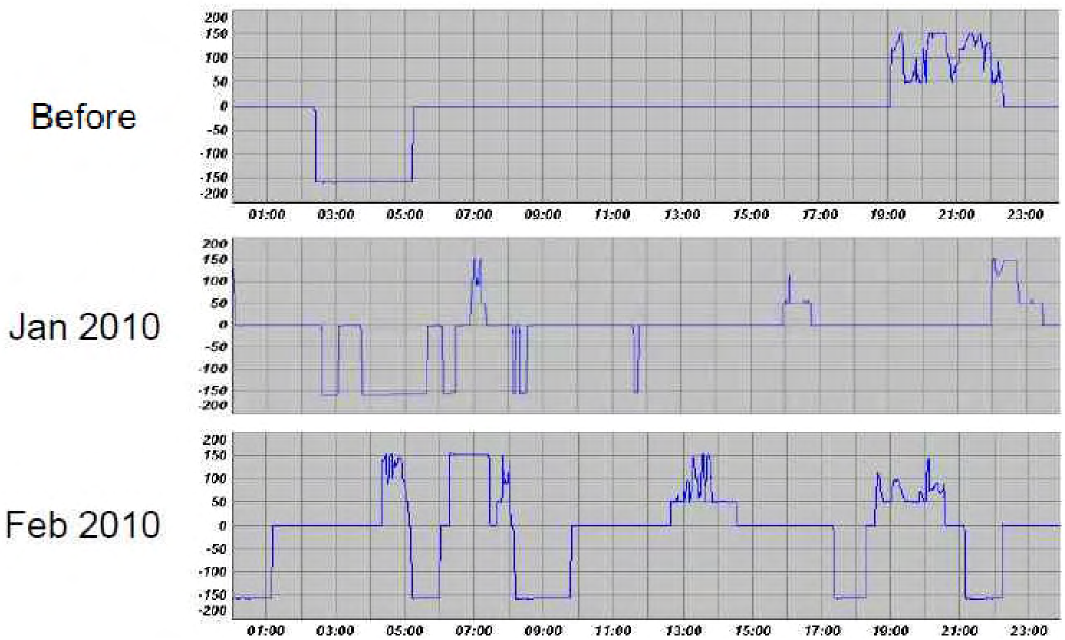


Figure 8. 2 Scheme of Ownership and Operation of Power Plant in Germany



Source: RWE

Figure 8. 3 PSPP Operations before and after Introducing Power Market

Source: EEX Web Page

Figure 8. 4 Record of EEX Power Trade on December 25 and 26, 2009

(b) Italy – Terna network

While Enel was the integrated power company in Italy, after disintegration of power generation and transmission, Enel became a generation company, and Terna became the TSO. Currently, most of PSPP in Italy were owned by Enel and more than 90% of Italy's PSPP are owned by Enel and Edipower.

Power market was introduced in 2005, with which one is the Energy Market for generated power, operated by GME (Gestore dei Mercati Energetici S.p.A.), and the other is the Ancillary Service & Balancing Market for secondary reserve, operated by Terna. For each power generator, 1.5% of its generation capacity is required to keep as the primary reserve.

In accordance with the economic growth, generated energy of PSPP has been greatly increased from 4,000GWh in early 90's to 10,000GWh in early 2000's. At around the year 2002, supply shortage became the problem, and after the Italian Peninsula Blackout in 2003, 20GW of CCGT were developed so as to recover the supply shortage. Those CCGT started to operate from 2005. Since CCGT is more efficient than conventional thermal power plant, its generated power was sold to the market at low price, hence those CCGT were made to operate even in off peak hours. For this effect, generated energy of PSPP started to decrease since market introduction in 2005, while total capacity of PSPP has not been much changed. In 2009, generated energy of PSPP was 6,000GWh, because the demand decreased by 6% due to the influence of economic crisis in the world.

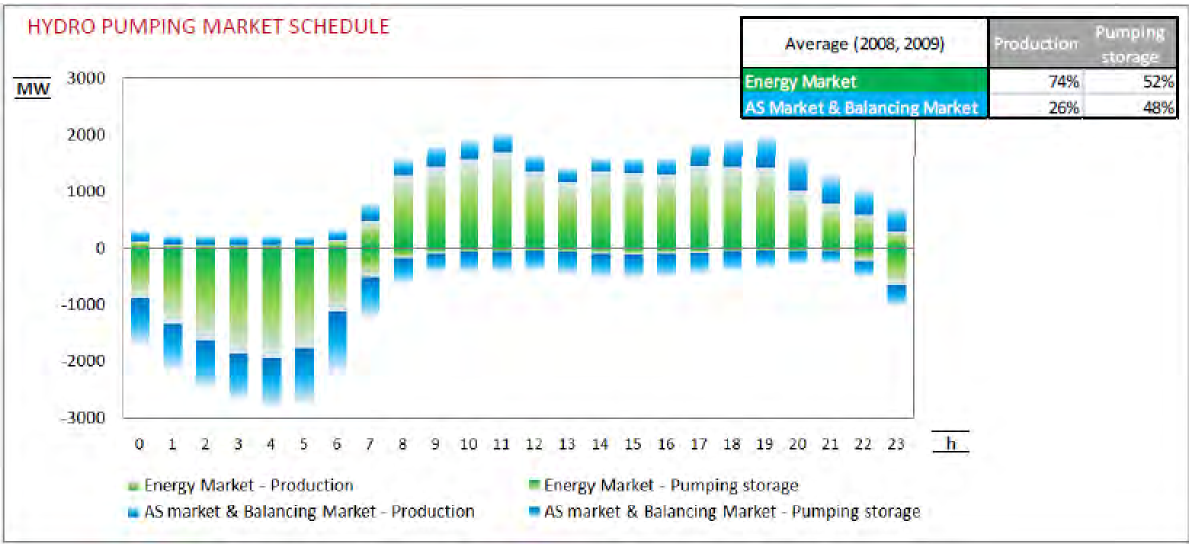
In 2010, average price of power in the Energy Market is around 70Euro/MWh, with around 90Euro/MWh at peak hours and around 40Euro/MWh at off peak hours. In the Ancillary Service & Balancing Market, the price is approximately twice of that of the Energy Market, 120-140Euro/MWh.

The basic operation scheme of PSPP is to purchase energy from the Energy Market for pumping up, and to sell generated energy in the Ancillary Service & Balancing Market. According to the records in 2008 and 2009, generation was traded in the Energy Market for 74% and in the Ancillary Service & Balancing Market for 26%, while pumping was traded in the Energy Market for 52% and in the Ancillary Service & Balancing Market for 48%.

On the Ancillary Service & Balancing Market, the prices of output raise and down are applied for bid at every hour. Terna makes the price list of reserve power for the following day based upon the bid result, operates based upon the list, and makes payment based upon the operation result. The output of PSPP is traded at the Ancillary Service & Balancing Market throughout a day for both directions of generation and pumping, which shows its contribution to stabilize the network frequency through the market, as well as the role of peak supply.

In accordance with the target of 2020 in EU Committee, Italy Government started to develop massive renewable energy, 12GW of wind power, 8GW of photovoltaic, and 8GW of bio-mass generation plants. Most of the wind power and photovoltaic plants are planned to construct in the southern region of Sicilia and Sardegna due to the climate and environmental situation, but since demand is low in this area, improvement of transmission network will be necessary in order to transmit power from the south to the central and northern regions of Italy.

So far, the shortage of the primary reserve in off peak hours due to increasing wind power is not very serious, and the output of wind power is not suppressed. However, it is recognized that the facilities of maintaining frequency and voltage in the transmission network will be further required as increasing renewable energy and long distance transmission line. In order that, Italian Government considers to allow Terna to develop and install the facility for stabilizing power network, and Terna started the study of the feasibility of PSPP, energy storage equipment such as battery, and SVC for this purpose.



Source: Terna

Figure 8. 5 PSPP Power Trade in Each Market in Terna Network

(2) Kalyaan PSPP in the Philippines

The Republic of the Philippines has only one PSPP. This PSPP is named Kalayaan PSPP, whose installed capacity is approximately 740 MW and located in Laguna area, 60 km southeast of metropolitan Manila.

As Stage I, 168 MW × 2 of PSPP was developed by National Power Corporation (NPC) in March 1983. Thereafter, No. 1 and 2 units had to require rehabilitation because of aging, and at the same time the PSPP expansion, which included the construction of No. 3 and 4 units (174 MW/unit) as Stage II, was required to meet the skyrocketing demand of Manila. For the rehabilitation and expansion plan, NPC contracted an Argentinean company, IMPSA, for build-rehabilitate-operate-transfer (BROT) in 1998. Subsequently, IMPSA and an American company, EME, established the CBK Power Company Ltd. (CBKPCL), which is a special purpose company for operation and maintenance (O&M), and NPC granted the company an O&M concession for PSPP in February 2001; that contract is to expire in 2026. From April 2005, a joint venture of J-power and Sumitomo Corporation took over CBKPL. Consequently NPC owns Kalayaan PSPP and CBKPL normally receives a constant O&M fee from NPC based on the concession contract at present.

The electricity produced by Kalayaan PSPP is sold in the wholesale electricity spot market (WESM). In terms of daily operation schedule, Power Sector Assets & Liabilities Management Corporation (PSALM), which is responsible for WESM dispatches' daily schedule in the previous day taking into account the power supply-demand balance, and operation managers direct their staffs to operate their units based on the dispatch.

The BROT contract prescribes allocations of maintenance outage hours (MOHs) and forced outage hours (FOHs) initially. The MOHs and FOHs are applied to schedule maintenance and forced outage, respectively. Annual MOHs and FOHs are calculated by subtraction of schedule maintenance hours and forced outage hours from the initial MOHs and FOHs. When the annual MOHs or FOHs are less than zero (0), it is recognized that availability ratio cannot go over 1.0. In such a case, the O&M company is to be imposed penalties through reduction of O&M fee and so on.

(3) Japan

The flow of power supply in Japan is illustrated in Figure 8. 6.

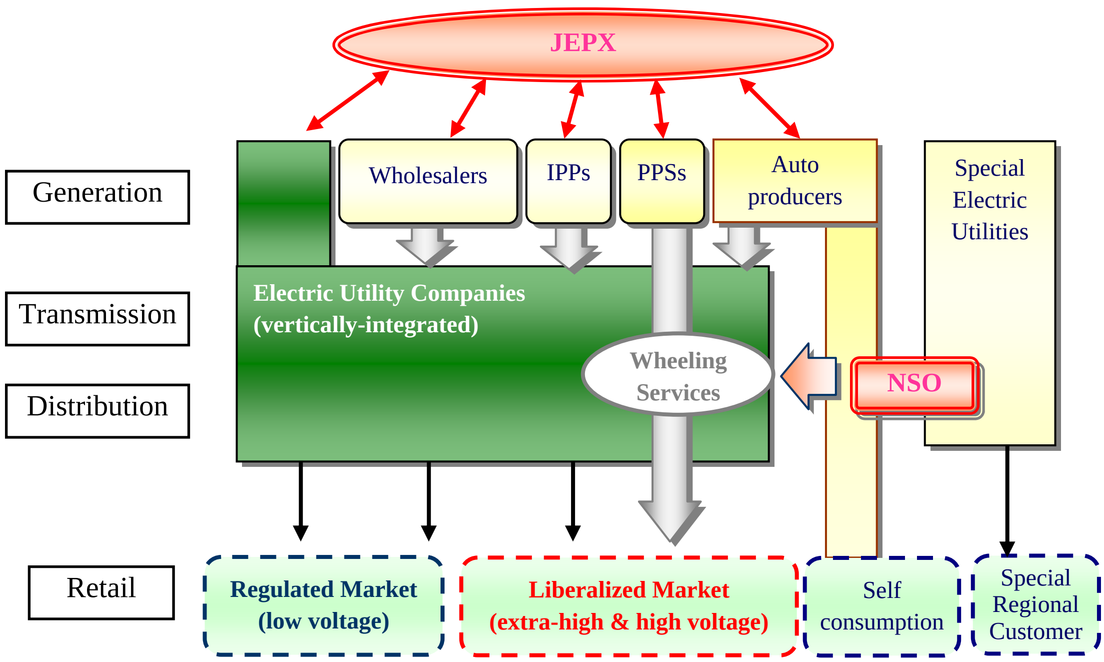


Figure 8. 6 The flow of power supply in Japan

In Japan, electric power companies are regionally divided, with one company possessing all of generation, transmission, and distribution facilities, and supplying power to users within a region by utilizing such facilities.

As for players in the generation sector, there are electric power companies themselves, wholesalers, IPPs, PPSs, auto producers, etc., who have their own generation facilities and supply power to their respective power users. When shortage occurs, mutually required amount of power can be purchased through Japan Electric Power Exchange, or JEPX. Among players in the generation, PPSs uses their own generation plants to supply power directly to users on the free market via transmission and distribution lines owned by electric power companies. On the other hand, wholesalers and IPPs basically sign relative contract with electric power companies and supply power to the electric power companies.

Among players in the generation sector, only power companies and wholesalers possess PSPPs. With regard to plants owned by power companies, no special contracts are signed. Power plants conduct day-to-day operations in accordance with command from their companies' central load dispatch centers.

On the other hand, electric power companies and wholesalers have signed contracts on power plants owned by wholesalers. Basic conditions of the contract are as follows:

- Costs necessary to operate power plants are borne entirely by power companies.
- Power plants are owned by wholesalers and operated and maintained by wholesalers' personnel.
- Authorities regarding the operation of the power plants entirely belong to the power companies. (Power plants are operated in accordance with the central load dispatch centers of power companies.)
- Power for pumping is supplied by power companies.

At the start of constructing power plants, when electric power companies judge that the PSPPs the wholesalers want to develop are economical, they sign long-term contracts with the wholesalers to give permission for the development. In addition, regarding the cost necessary to operate the power plants, the wholesalers make proposals to the electric power companies every year and they decide on the content and the amount after checking the proposals.

8.3.2 Potential Profitability of PSPP

Economic profitability was calculated in a case where a private company introduces PSPP under the current market rule.

(1) Calculation terms

(a) Generation cost

Regarding expenditure, fixed cost includes construction-related cost of PSPP (interest and depreciation) and operation and maintenance cost while variable cost includes electricity cost to pump for off-peak period.

- Construction unit price: 700 USD/kW
- Construction cost: 840 million USD (1,200 MW × 700 USD/kW)
- Annual fixed cost: 78.6 USD/kW/year (including operation and maintenance cost)
- Unit price of power for pumping: 0.052 USD/kWh (coal-fired thermal)
- Generation unit price: 0.142 USD/kWh (capacity factor = 10%)

(b) Revenue unit price (wholesale power selling price)

Because revenue can be gained by selling power during the peak period, if selling unit price remains constant, revenue will be in proportion to the electricity sold (plant capacity factor).

- Peak time zone (weekdays 4 hours × 100 days): 0.20 USD/kWh
- Daytime (weekdays 6 hours × 150 days): 0.15 USD/kWh
- Revenue from ancillary service including frequency adjustment and standby operation is not expected.

(2) Revenue and expenditure

The relationship between revenue and expenditure with the increase in capacity factor of PSPP is shown in Figure 8. 7.

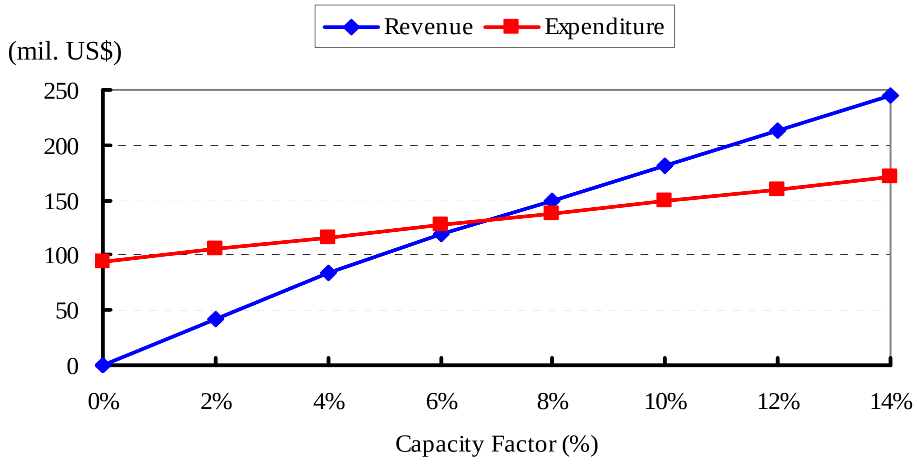


Figure 8. 7 Relationship between Revenue and Expenditure with Increase of Capacity Factor

According to this figure, when the capacity factor tops 7%, revenue exceeds expenditure and return on investment can be secured while necessary profit can be made. In contrast, when the capacity factor goes below 7%, revenue falls short of expenditure while return on investment cannot be expected. In a range of low capacity factors, in particular, very little revenue is made, following a path of extreme worsening of revenue/expenditure status.

In summary, under the current market rule, the profitability of PSPP is largely influenced by capacity factors.

8.3.3 Potential Risk

It was examined that what kind of risk could occur under the current market rule when a private company introduced PSPP.

(1) Risk of decline in plant capacity factor

The operation of PSPP is largely affected by supply/demand condition. When the supply reserve capacity rate goes below 3% and there is tight supply/demand condition, 10% or higher capacity factor can be expected. However, as the supply reserve capacity rate goes beyond 10% and supply capacity is sufficient, the need to operate the peak supply power including PSPP will be smaller, and more frequently it becomes necessary for the plants to stand by on ready-to-operate status in preparation for contingencies such as supply shortage due to plant accidents or sudden surge of power demand. Under such circumstances, revenues received based on the operational amount will become extremely low, making the revenue status extremely bad.

Furthermore, after interconnecting with the European power system (UCTE), power obtained from neighboring countries will be one of the competitors for peak supply capacity, thus making it possible to see even lower capacity factors of the PSPP.

(2) Risk of sharp increase in unit price of power for pumping

Purchasing power for pumping from the market is regarded as a part of demand. Therefore, the purchasing unit price must be comparable to those of distributing companies. An actual transaction price for nighttime power was 5 kr/kWh (0.033 USD/kWh), about half of the daytime price by relative contract. However, there are cases where transactions are made at 14 kr/kWh (0.093 USD/kWh) which is not so much different from the daytime price band of around 16 kr/kWh. This suggests that in the pricing mechanism of the current market transaction rule, when considering the possibility that the unit price for pumping power surges and about 30% of loss takes place in pumping, a selling unit price and purchasing cost (pumping power) may become negative net worth.

(3) Risk of being constrained by EU directives

As Turkey aims to be interconnected with the European power system (UCTE), it is assumed that the country will join ranks of UCTE in the near future and start operating its power system together with that of UCTE. In that case, it is very likely that the rules of the power system operation and market implementation will be identical with those of UCTE power systems. Then, if a different rule is used to implement the power system, it will be possible that an EU directive be issued to make a mandatory order for improvement. Especially, the implementation rule of UCTE is very strict about factors which hinder fair competition. Therefore, there is a possibility that UCTE will show reluctance to an idea of implementing a special rule for special power plants such as PSPPs and will issue an order to force improvements.

8.3.4 Proposal of Business Model

In examining this case, the following perspectives must be fully considered:

- Those who would enjoy benefits from the introduction of PSPP shall bear the counter cost.
  The greatest benefit deriving from the introduction of PSPP is to be able to raise the quality of power (by maintaining frequencies and voltage, enhancing stability at times of plant accidents, etc.). In this sense, recipients of this benefit are the general power users. Therefore, it is desirable to build a mechanism by which the cost is collected widely and thinly and then passed on to the owners of PSPP.
- To join the EU power system in the near future.
  It is desirable that necessary system be built first and then factors that could hinder fair competition be eliminated as much as possible.
- To seek to minimize the above-mentioned risks.
  Since the greatest risk investors face is the potential reduction of revenue, it is very important to take measures to hedge a risk for them.

(1) TEIAS guarantees a fixed amount of annual payment.
Owners: Private sector investors
Construction fund: Private sector funding
Revenue source: Annual fee from TEIAS

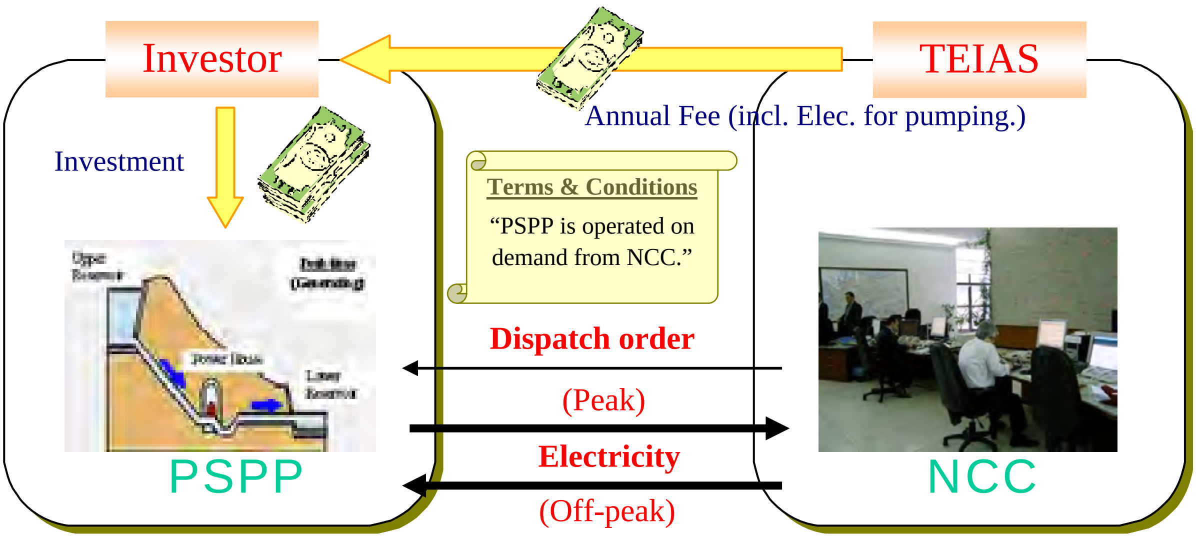


Figure 8. 8 Plan for TEIAS to guarantee annual fixed payment

By TEIAS paying the fixed amount of cost annually to the owner of PSPP, the owners can secure profitability. In exchange for receiving the annual fixed payment from TEIAS, the owner operates power generation and pumping in accordance with NCC command made by TEIAS. Furthermore, with regard to necessary annual maintenance, permission on the cost and timing must be obtained from TEIAS in advance. In addition, TEIAS provides power for pumping.

Regarding day-to-day operation of power plants, TEIAS makes one-day-ahead demand forecast for the next day, makes public bidding about power plants via PMUM, and decides which plants are to be operated based on the bid prices in the order of the cheapest upward. It is considered reasonable that at this time the expected output of power generation and pumping should be subtracted from the demand forecast and the rest is offered publicly via PMUM.

(2) Supply power and carry out ancillary service on completely free market.
Owner: Private sector investors
Construction fund: Private sector funding
Revenue source: Counter price for power supply + Power system ancillary service counter price

Owners of PSPP provide power and ancillary service on the completely free market and receive counter price as their revenue source. It is exactly the same with the EU system; thus, there is very little possibility that EU will issue directives to mandate improvements.

In order to make this plan feasible, it is necessary to appropriately evaluate functions of PSPP and build a system under which appropriate counter prices are paid in accordance with the functions. Specifically there could be the following two plans:

(a) Set reasonable unit prices for various ancillary services which PSPP can provide.

Set unit prices for the following services and TEIAS pays the counter prices in accordance with the amount of service.

- Per-second frequency adjustment (daytime, rapid demand growth in the morning, nighttime)
- Per-minute frequency adjustment (daytime, rapid demand growth in the morning, nighttime)
- Backup operation (in case of emergencies such as supply drop due to plant accidents or sharp demand surge, systems are maintained ready for operation at all times, and in a case of actual emergency, the plant gets connected to the power system in parallel to supply power)
- Voltage adjustment (reactive power generation)

(b) Oblige all power plants to offer ancillary service.

Mandate the provision of ancillary service in accordance with the generation output to all power plants which provide power (including renewable energy). By taking this measure, in a case of trying to operate power plants without a function to provide ancillary service, it becomes necessary to operators to have other power plant to substitute its function. This naturally creates an ancillary service market among power generation companies.

(3) Direct construction and ownership by TEIAS.
Owner: TEIAS
Fund: Public investment (or private sector funding)
Revenue source: Wheeling charge

PSPP is considered to be a facility to stabilize frequencies and voltages of the power system and improve the quality of power to be provided. Based on this thinking, TEIAS constructs, owns, and operates PSPP freely on its own judgment just like substations and transmission lines. To recover the invested capital cost, it is factored into the calculation of unit price of wheeling charge and is collected widely from general power users.

(4) Guarantee by TEIAS to pay fixed plant fee rate (take or pay contract)
Owners: Private investors
Construction fund: Private funding
Revenue source: Power supply counter price ＋ (In a case of low operation TEIAS guarantees the purchase.)

This is a plan in between Plan (1) and Plan (2). When a counter price for ancillary service remains at the current level and its functions are not appropriately evaluated, it is indispensable to operate at a certain capacity factor; in order to gain necessary income only with the power supply counter price coupled with ancillary service counter price as described in Plan (2), it is essential to operate at a certain capacity factor (5% or higher). However, as was described earlier, the capacity factor of PSPP is largely influenced by external factors such as supply/demand condition; thus, it is difficult to forecast revenue. Therefore, it is extremely difficult for private investors to make decisions on the construction of PSPP.

As a measure to complement this, an owner of PSPP and TEIAS can determine in advance the minimum amount to purchase power generated by the PSPP, and TEIAS guarantees the payment equivalent of the minimum power purchased to the owner despite the volume of the real generated power.

Basically, the owner of PSPP supplies power and provides ancillary service on the completely free market and receives revenue from counter prices for them, while TEIAS owns the right to give directives to the owner such as on the operation and standby as necessary. As a result, when the owner generates power below the agreed minimum purchase, TEIAS pays the difference with the amount equivalent to the agreed output. On the other hand, when the owner generates power more than the minimum purchase output and earns an amount greater than the predetermined level, neither party makes the payment adjustment.

(5) Implement long-term mutual transactions between distribution companies and generation companies

Owner: Private investors

Construction fund: Private funding

Revenue source: Annual fee from distribution companies

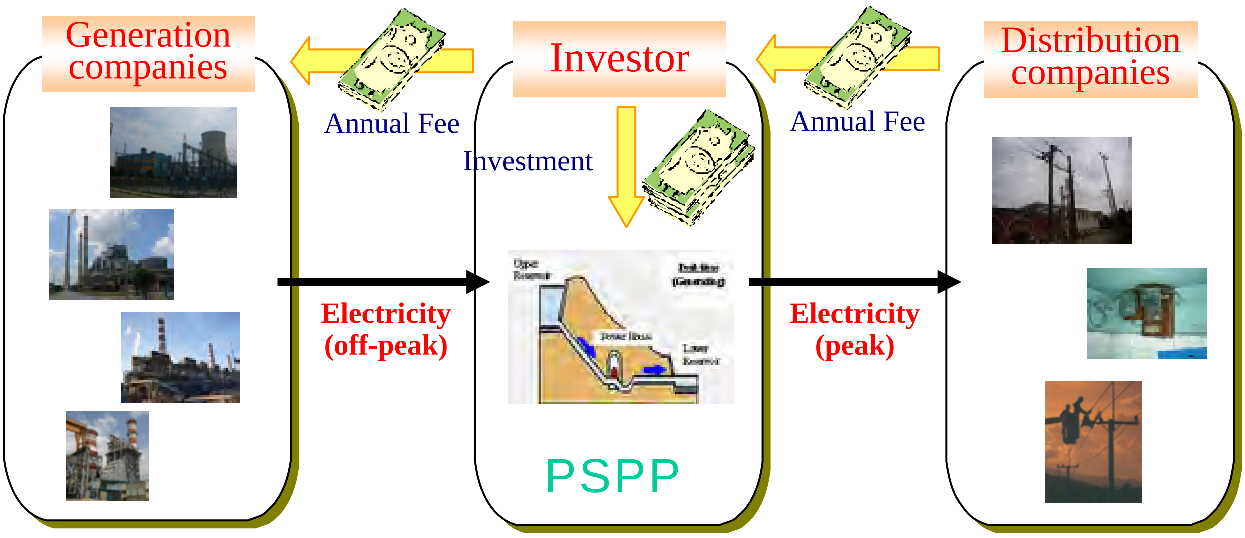


Figure 8. 9 Plan to sign relative contract with distribution companies, etc.

PSPP owners intend to keep stable income by signing long-term power supply/receipt contracts with multiple distribution companies during peak period to secure constant capacity factor.

Furthermore, with regard to power for pumping, it will be possible to avoid a risk of sharp rise in power for pumping by concluding relative contracts with multiple generation companies.

(6) Summary

Mentioned five measures are compared from the viewpoints of power quality, conformity to national policy and EU regulation, and risk hedge as shown below.

Table 8. 1 Comparison between proposed business models

	1	2	3	4	5
	TEIAS guarantees a fixed payment	Carry out ancillary service	Direct construction by TEIAS (EUAS)	Take or Pay contract (by TEIAS)	Long-term transactions between REDA
Owners	Private sector investors	Private sector investors	TEIAS (or EUAS)	Private sector investors	Private sector investors
Construction fund	Private sector funding	Private sector funding	Public investment	Private sector funding	Private sector funding
Revenue source	Annual fee from TEIAS	Counter price for power supply + ancillary service	Wheeling Charge	Counter price for power supply + guarantees	Annual fee from distribution companies
Risk Avoidance	**Excellent**	Bad	–	Good	Moderate
Consistency with Gov. policy	Moderate	**Excellent**	Bad	Good	Good
Consistency with EU rule	Bad	**Excellent**	Bad	Moderate	Moderate
Securing quality	**Excellent**	Good	**Excellent**	Moderate	Moderate
Priority order (Initial stage)	1	NG	1	2	NG
Priority order (in future)	NG	1	NG	3	2

The 1st measure is best in terms of risk hedge for investors since stable revenue is secured every year, and 2nd one is worst because all revenue depends on a market. From the view point of conformity to national policy, 2nd one which conforms to regulation 4628 is appropriate and 3rd one that public is in charge of development is worst. In terms of conformity to EU regulation, 2nd one is best, and 1st and 3rd are worst. In terms of supplying high quality power, 1st and 3rd measures are appropriate.

Under the current circumstances where appropriate counter prices are not paid as ancillary service, it is little possibility that PSPPs are installed into the power system even if 2nd measure is adopted because the risks on revenue are too high for private sectors to participate. When considering installing PSPPs as a measure to secure quality power, it is recommended that 1st and 3rd measures are adopted at first and shifted to 2nd measure after an appropriate system to pay counter prices as ancillary service is established.

(7) Requirements for Private Sectors to invest in PSPP

Since PSPP is able contribute to improve quality power and alternative measures are limited, conditions shown below are needed in order for private sectors to participate in PSPP project.

(a) Financial strength

A large-scale trouble could be fatal for owner companies because a large amount of repair cost would be needed and it could also result in no revenue. Under these circumstances, enough financial strength (or trust to raise funds) to recover operation after quick repair is needed.

(b) Know-how for Construction and Operation

Since special know-how is required to construct and operate PSPPs, experiences of working on construction and operation are imperative. Especially when operating PSPP, ability to operate efficiently in a large-scale market is necessary, besides just operating according to commands. Thus, it is desirable to establish an organization to provide technical assignments by organizing a joint venture or employing consultants with rich experience.

(c) Collaboration with Local Area

PSPP has several elements such as upper and lower reservoirs and driving channels, the development affects a wide area. Thus, there are many related organizations to develop PSPP. For example, approval form DSI is needed to use existing reservoirs owned by DSI. It is desirable to organize a joint venture with Turkish companies which are knowledgeable about regulations and are likely to be acceptable from local societies.

8.3.5 Option for Financing Capital Investment

There are various options to finance power development projects as shown in Table 8. 2. The selection of the best option depends on the characteristics of implementation entities and/or the scale of the project.

Table 8. 2 Major Financing Options

1) Internal financing	a. Retained earning	Cost of Equity	
	b. Depreciation etc.	Weighted Average Cost of Capital	
2) External financing	a. Equity finance	Cost of Equity	Direct: capital increase (share issue)
	b. Debt finance	Cost of Debt	Direct: corporate bond, commercial paper
			Indirect: Borrowing
	c. Asset finance		

(Source: "Accounting for Electricity Business", Energy Forum, Japan)

Power development projects generally require large investment. The expected revenue, part of which would be to meet the repayment of loans will be generated only after the project completion. Therefore, the required amount generally exceeds the sum of retained earning of a firm. This is the reason why power development projects require external financing. As shown in Table 8. 2, the optimal external financing depends on the characteristics of implementation entities. In Turkey, because any power development by state-owned-enterprises is prohibited in principle under the so-called 4628 law (the Electricity Market Law), the optimal external financing options exclude sources such as the government's annual budget and official development assistance, but include private financial sources like independent power producers.

BOX 8.1 Japanese Government's cooperation

Japanese Government has provided assistance to Turkey over 30 years since 1970, which amounts to more than 420 billion Japanese Yen through Yen loans and grant aid. Its Yen loan toward power sector has been provided mainly to hydropower plant projects in '70s. The last loan was implemented to Altınkaya hydropower plant project in 1984, amounting to 15.4 billion Japanese Yen.

The following part analyzes the optimal financing option by business model which has been proposed in 8.3.4.

(1) Analysis on financing option

The proposed 5 business models are shown below.

1. TEIAS guarantees a fixed amount of annual payment
2. Supply power and carry out ancillary service on completely free market.
3. Direct construction and ownership by TEIAS
4. Guarantee by TEIAS to pay fixed plant fee rate (Take or Pay contract)
5. Implement long-term mutual transactions between distribution companies and generation companies

Among the above 5 models, for the model number 3, because TEIAS is the state-owned-enterprise, Yen loan with long-term and low interest could be applicable as financing option in spite of the fact that Turkey's economy is well over the ODA criterion. The model, however, would not likely to be realized because the current law and regulation prohibit state-owned-companies to construct new power plants. For the models number 1 and 4, because the power purchase guarantee by the government has been terminated except power from wind-power generation, these two models will be less likely to be adopted. For those reasons, the following part assumes the models number 2 and 5, where only private companies would be involved. Table 8. 3 shows again the main features of the prioritized pumped storage power plant.

Table 8. 3 Main Features of Prioritized Pumped Storage Power Plant

Item	Description
Project name	IPP-based PSPP project in Turkey (Altınkaya PSPP)
Installed capacity	1,800 MW (450MW x 4 unit)
Total project cost	101 billion Japanese Yen (1.2 billion USD)
Unit cost	667 USD/ kW (without interest during construction period)
Project period	13 Years (6 years for construction)
Total efficiency	70%
Implementation entity	Domestic/ foreign private companies or their joint ventures.
Expected revenue sources	Main expected source is revenue from ancillary service by the system operator, TEIAS. Another source is revenue from the sales of power to 23 regional distribution companies and large-scale customers through bilateral contract.
Expected power purchaser	Regional distribution power companies, large-scale customers, and/or power exchange market (PMUM).

Currency exchange rate: 83.98 JPN/USD (as of 17. Dec. 2010. SOURCE: Yahoo Finance)

As for the project implementation entity, it is not determined whether existing private companies would launch the prioritized PSPP project or an independent company would be newly established for this project to conduct the project. Regarding financing scheme, corporate loan would be applicable to the former case, while project finance would be applicable to the latter case. Further, for the former case, other types of financing options summarized in Table 8. 1 such as corporate bond and capital increase would be also available.

The number of foreign companies which enters the Turkey's power generation market has decreased after the termination of the government's power purchase guarantee, while that of local companies has increased. If the scale of a power generation project is small, such a project might be financed fully by local commercial banks. Because the prioritized PSPP project whose installed capacity will be 1.8 GW would be, however, one of the country's largest power plant projects, the other types of financing options would be also required. As the countermeasure to mitigate so-called country risk, the integration of a syndicate loan involving public institutions such as international financial institutions and some country's export credit agencies would be effective. As an example of such international financial institutions, this study reviewed the case of International Finance Corporation (IFC) of World Bank Group as shown next.

IFC's investment menu is largely classified into equity finance and loan finance, selected in accordance with the condition/ circumstance of the targeted projects. In terms of the financing amount, a syndicate led by IFC would provide investment for the part of the project cost, while the rest would be provided by sponsors/ shareholders. As for loan finance, there are largely two categories, namely corporate finance and project finance. The former scheme provides financial service to corporations, while the latter scheme provides the service to Special Purpose Vehicle (SPV), which is established exclusively for the targeted project. Corporate finance provides its service based on the targeted corporation's financial status, while project finance provides its service expecting the project's future cash flows. Corporate finance would be applicable in case that a joint venture formed by a foreign company and a local company implements a power generation project. While project finance is called as non-recourse loan, sponsors would incur the debt in case of corporate finance.

For reference, Table 8. 4 summarizes the recent IFC's record of major investment in power generation projects in Turkey. Pricing data like interest are not disclosed.

Table 8. 4 Major Investment Projects in Power Generation Projects in Turkey by IFC

a. Enerjisa Enerji Uretim A.S. (Year 2008)

Company name:	Enerjisa Enerji Uretim A.S. (a joint venture formed by H.O. Sabanci Holding A.S. from Turkey and Österreichische Elektrizitätswirtschafts-Aktiengesellschaft (Verbund) from Austria.)
Project description:	The construction of a portfolio of a thermal plant and hydropower plants.
Total project cost:	2.0 billion USD (1.4 billion EUR). Among the cost, IFC is expected to assist 825 million USD.
Financing scheme:	The country's first combination of corporate loan (toward Enerjisa) and project finance (toward each project). The share of the latter is around 80% of the total.

b. Rotor Elektrik Uretim A.S（Year 2008）

Company name:	Rotor Elektrik Uretim A.S (a subsidiary company of Zorlu Enerji (one of the largest private power companies in Turkey)).
Project description:	The development of a 135 MW wind farm.
Total project cost:	UE 180 million. Among the cost, IFC is expected to assist up to 45 million EUR.
Financing scheme:	Project finance

c. Ak Enerji (Year 2010)

Company name:	Ak Enerji (owned mainly by CEZ (the power utility in Czech Republic) and Akkok Group of Turkey.
Project description:	Hydropower plants development.
Total project cost:	338 million USD. The proposed IFC investment is up to 75 million USD, consisting mainly of loan and partially of equity.
Financing scheme:	Corporate loan

As seen above, each project selects its optimal financing scheme flexibly.

CONCLUSION

The prioritized PSPP project can be financed by corporate loan in case that existing major private electricity firms are engaged in the project. The prioritized PSPP project could be an independent project taking into account the fact that the project would be the country's first symbolic PSPP project. In this case, project finance which raises fund externally would be appropriate considering the scale of the project. From the risk mitigation points of view, a syndicate involving public institutions such as JBIC and IFC would be favorable. Moreover, this prioritized PSPP project can take advantage of Japan's technical superiority in speed-adjustable PSPP technology. Indeed, the Turkey's counterpart also expects continuing assistance from Japan at the subsequent feasibility study stage. For these reasons, it would be preferable for the prioritized PSPP project to adopt project finance scheme integrating JBIC as a central component of a syndicate loan.

Figure 8. 10 shows the typical framework of the prioritized project financed through project finance scheme.

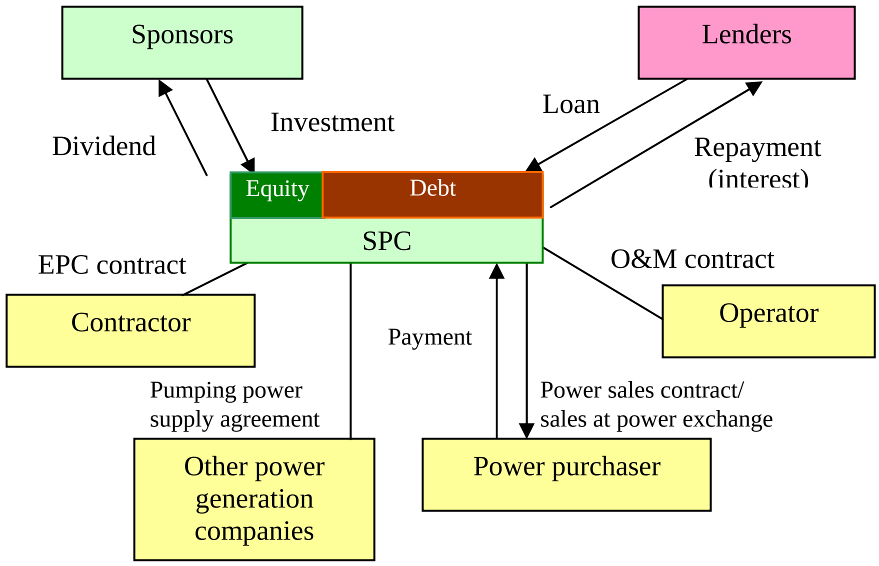


Figure 8. 10 Framework of Proposed PSPP Project

(2) Points to be concerned on financing scheme

The above parts have discussed how to finance the prioritized PSPP project. Because the government's power purchase guarantee has been terminated in Turkey, the business outlook of the PSPP project would not be prosperous in the Turkey's fully liberalized electricity market. Since project finance assumes that the targeted project is commercially viable, its project entity might face finance shortfall of the project if the commercial viability is not secured. Therefore, the project's implementation entity needs to demonstrate that the project would be bankable based on the financial analysis of the project. The project's feasibility study, which comes as next step, needs to nail down the most suitable business model in order to estimate revenue from the project. The feasibility study would tackle on the risk to recover the capital investment.

For example, in the case of the proposed business model number 2, "Supply power and carry out ancillary service on completely free market," it would be essential for the above purpose to set the ratio between the sale through the power exchange (PMUM) and the sale to distribution companies by bilateral contracts. It would be also essential to estimate the average unit revenue from ancillary service. Likewise, in the case of the model number 5, "Implement long-term mutual transactions between distribution companies and generation companies," it is essential to investigate the power purchasers' solvency through their balance sheets and past credit histories. In fact, it has been raised as the purpose of privatization of state-owned distribution companies to improve the bill collection rate which differs among the companies. Finally, it would be also useful in reducing the risk to clarify the uncertain risks like the impact by law and regulation through small-scale pilot projects.

Besides the risk of the capital recovery risk, one needs to anticipate that the project's lenders and sponsors might request for the explanation to mitigate other types of risk like completion risk. The subsequent feasibility study of the prioritized PSPP project would need to address these issues.

8.3.6 Cost Allocation Method for a Private Company to Use a State-Owned Reservoir as a Lower Reservoir of PSPP

Here, the Study Team introduces the cost allocation method of multipurpose dams in Japan.

(1) History of dam allocation regime in Japan

- Japan's multipurpose dam cost allocation regime was established with the incorporation of the Electric Power Development Act in 1952.
- The cost allocation regime employed at this time was based on the "alternative costs reasonable expenditures method."
- Overall revision of the acts due to the establishment of revised dam allocation regime of "separable cost, alternative cost, and reasonable expenditure method" was done in 1967.

(2) Concept of "separable cast, alternative cost, and reasonable expenditure method"

"Separable cost, alternative cost, and reasonable expenditure method" separates the total cost of a multipurpose dam to separable cost and remaining common use facility cost, which is distributed to each party jointly in response to its benefit. The burden charge of each party is calculated as the separable cost and the distributed remaining common cost.

- ✓ Separable cost: incremental cost jointly of a party in the multipurpose dam project. It is calculated by difference of the total cost between with and without of a party.
- ✓ Remaining common use facility cost: Total cost minus total separable cost.

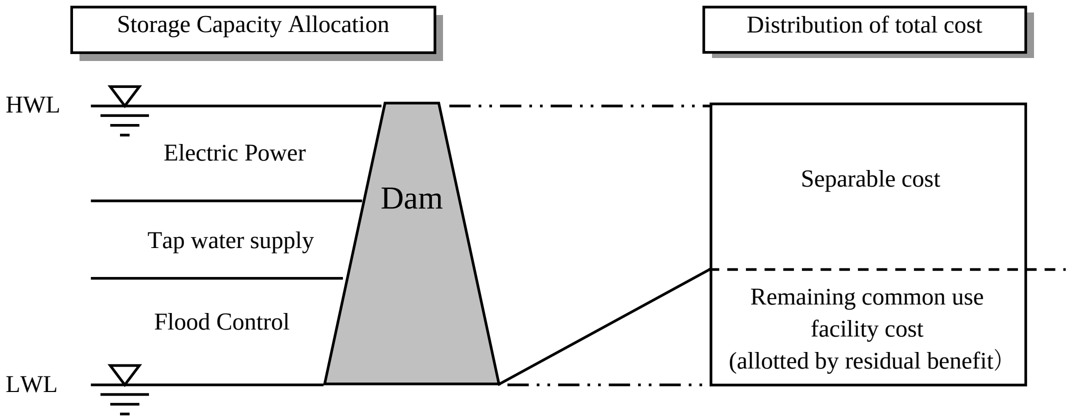


Figure 8. 11 Distribution of Total Cost of Dam

(3) Distribution method of remaining common use facility cost

"Residual benefit," the benefit of each party, is calculated to be the smaller one of either "alternative construction cost" or "reasonable investment cost" minus the "exclusive use facility cost" and "separable cost." The remaining common use facility cost is distributed according to the ratio of the residual benefit.

① Alternative construction cost : The cost that each party needs solely in order to obtain the same benefit as one which is obtained by participation in the joint project

② Reasonable investment cost : Investment cost which each party deems to be able to recover in this project

③ Exclusive use facility cost : Cost of facility such as conduits and electric power facility, which is used for a specific party, although it is installed integrally with the common use facility

④ Separable cost : Incremental cost by participation of a party, that is, a balance of total project cost between with and without participation of a party

⑤ Residual benefit ＝Min（①, ②）－③－④

(4) Calculation of alternative construction cost and separable cost

Storage capacity (SC) distribution

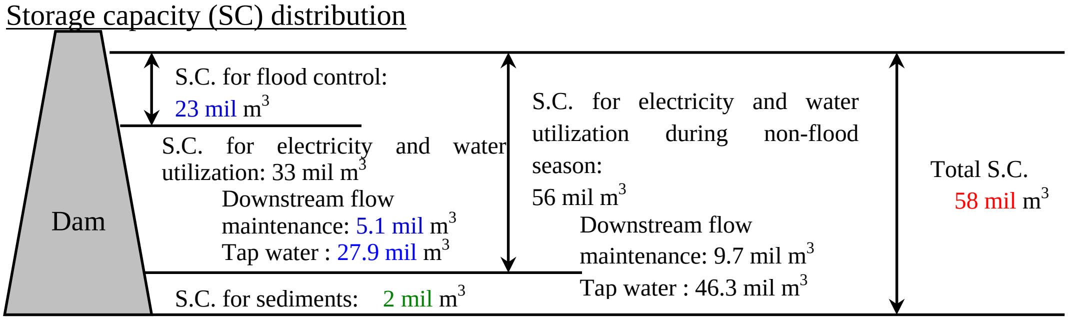


Figure 8. 12 Storage Capacity Distribution

Relation curve between storage capacity and construction cost

①Storage cap. for water utilization：23＋5,1＋2,0 (million m^3)

②Storage cap, excluding water utilization：58－23－5,1 (million m^3)

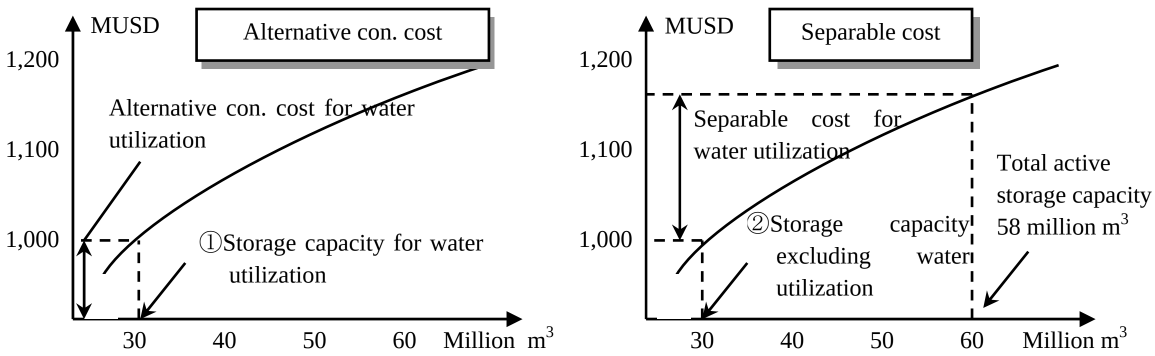


Figure 8. 13 Relation Curve between Storage Capacity and Construction Cost

(5) Calculation of reasonable investment cost

◆ Formula of reasonable investment cost (power generation, flood control, irrigation)

$$\text{Reasonable Investment Cost} = \frac{\text{Annual Benefit} - \text{Annual Cost}}{\text{Capital Recovery Rate} \times (1+ \text{Interest During Cons.})}$$

Table 8. 5 Calculation method of reasonable investment cost

Item	Calculation method (in the case of power generation)
Annual benefit	＝ Effective output × kW unit price ＋ effective generation energy × kWh unit price
Annual cost	Sum of labor cost, repair expenditure, water concession fee, business tax, other tax, maintenance allotment, and other expenditure
Capital recovery rate	$= \frac{i(1+i)^n}{(1+i)^n-1}\left(1-\frac{\beta}{(1+i)^n}+\gamma\frac{[(1+i)^n-1](i-\alpha)+in\alpha}{i^2(1+i)^n}\right)$ i : Discount rate, n : Service Life, α : Depreciation Rate, β : Remaining Value Rate, γ : Fixed Asset Tax

◆ Capital recovery rate and its assumption

Table 8. 6 Capital recovery rate and its assumption

Party	Recovery rate	Interest rate	Lifetime	Fixed asset tax rate
Electricity	0.0932	8.0%	45 years (residual rate 10%)	1.4%
Flood control	0.0464	4.5%	80 years	―
Irrigation	0.0604	5.5%	45 years	―

(6) Example of calculation of dam allocation

Table 8. 7 Example of allocation calculation

Item		Water utilization	Tap water	Power generation	Total	Note
a	Alternative construction cost	99,200	110,200	—	209,400	No calculation for power generation *1
b	Reasonable investment cost	183,213	—	2,341	185,554	No calculation for tap water *2
c	Smaller one (a or b)	99,200	110,200	2,341	211,741	
d	Exclusive use facility cost	—	—	1,588	1,588	Conduits, hydromechanical equipment, etc.
e	c - d	99,200	110,200	753	210,153	Limited investable cost
f	Separable cost	15,900	15,800	20	31,720	Remaining common use facility cost : 83,280 *3
g	Residual benefit (e - f)	83,300	94,400	733	178,433	Benefit of each party
h	Ratio of the above (%)	46.7	52.9	0.4	100.0	
i	Allotted remaining common use facility cost	38,892	44,055	333	83,280	Remaining common use facility cost × h (%)
j	Burden charge (f ＋ i)	54,792	59,855	353	115,000	

*1 In the case of power generation, "Alternative Construction Cost" is generally larger than "Reasonable Investment Cost"

*2 In the case of tap water, "Alternative Construction Cost" is assumed to be equal to" Reasonable Investment Cost"

*3 Remaining common facility cost = Total dam project cost － Sum of Separable costs

8.4 Proposal on Changes in Demand Profile

(1) Demand with sharpening peaks

As was mentioned in Section 4.3.2 , there is a huge gap in demand profile between urban and rural areas of Turkey. Specifically, there is a major gap as to when peak occurs. In urban areas, peak occurs at around 15:00 during daytime in summer, while in rural areas it appears at around 20:00 in winter. In other words, it is assumed that demand in urban areas is high in commercial sector, which is active during the daytime, while rural demand is pushed up more by household demand. In particular, commercial demand is closely related to air conditioners, judging from the peak period.

In the future, as urbanization is expected to progress in rural areas as well, air conditioner demand, both in commercial and in household sectors, is expected to grow, gradually expanding a gap between day and night and bringing about sharpening peaks of demand. It is more economical to deal with the peak supply capacity by utilizing peak-specific power plants rather than by using thermal power plants which are in operation at high output all day long. In other words, while it is expected that there will be a greater need for peak supply capacity, careful examination must be made on the trend of peak demand, especially the expansion of air conditioner use in developing peak supply capacity.

As the use of air conditioners becomes more widespread, correlation between power demand and ambient temperature becomes increasingly significant in summer. An example of TEPCO on relationship between ambient temperature and maximum power demand is shown below. When ambient temperature was 30 degrees Celsius power demand was around 50 GW, while at 35 degrees Celsius outside power demand was around 60 GW. In other words, as ambient temperature goes up by 1°C, power demand increases by 4%.

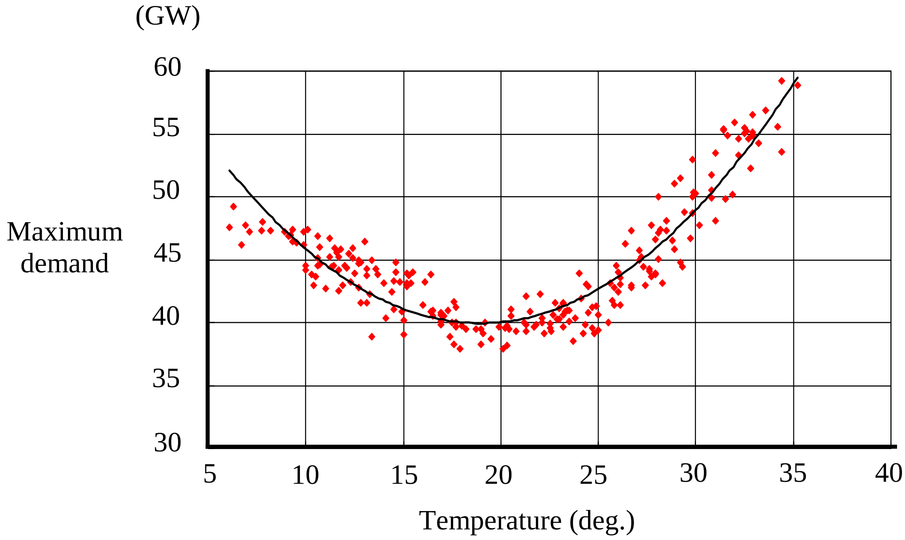


Figure 8. 14 Relationship between Ambient Temperature and Maximum Power Demand (Example of TEPCO: FY 1998)

On a daily basis, in summer time, demand sharply rises from morning to around noon. Figure 8. 15 shows an example of TEPCO's demand variations on the day when maximum demand took place.

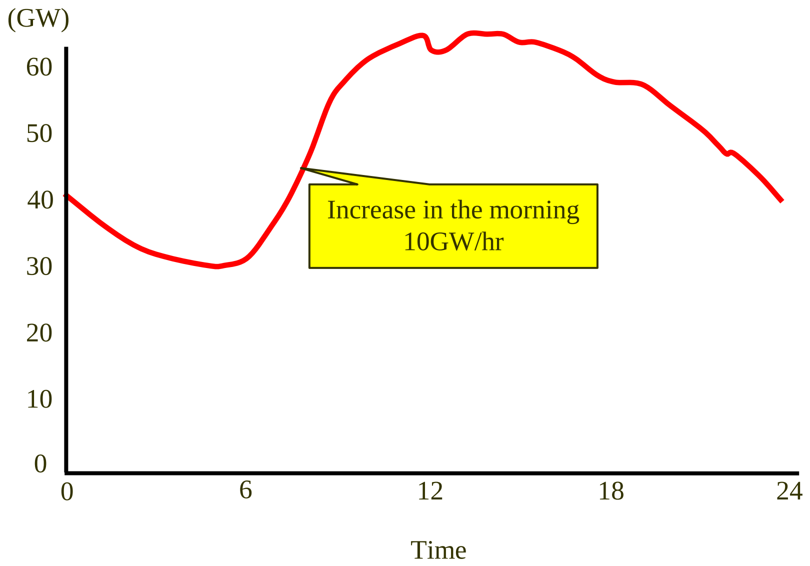


Figure 8. 15 Fluctuation in Demand (Example of TEPCO: Jul.24.2001)

The graph shows that power demand sharply rises from morning to noon as the ambient temperature goes up, with a changing speed of 10 GW per hour. In order to respond to such a rapid change and maintain power quality in a stable manner, it is indispensable to operate conventional hydropower and PSPPs that can quickly change power output in response to changes in the power demand.

(2) Promotion of demand-side management (DSM)

As was discussed in the previous section, as commercial power demand will grow further in the future, peak is expected to take a sharper form. With the peak becoming sharper, there will be a need to build power plants which can meet the growing demand, which will in turn lower the utilization rates of overall power plants and may push up the supply cost of the overall power system. In order to control the sharper peak profile, DSM must be actively promoted. There are four measures to do so:

- Peak shift: Shift peak demand to off-peak period
- Peak shave: Control peak demand
- Bottom-up: Create off-peak demand
- Energy saving: Control overall power consumption

Roughly, the following two specific measures are found to be effective:

(a) Change electricity tariff system

Create a significant gap between peak and off-peak electricity rates to control peak demand and induce peak power use to off-peak power use.

(b) Develop and introduce equipment which is capable of energy storage

- General power storage equipment
  - Lead-acid battery: lead electrode and sulfuric acid used as electrolyte. Has a long history.
  - NAS battery: Sodium (Na) for cathode, sulfur (S) for anode, and beta alumina ceramics for electrolyte layer to serve as a partition. MW class power storage is possible.

- ♦ Redox flow battery: storage battery using vanadium ion solution for cathode/anode electrolyte. Making high-capacity type is possible, but because of low energy storage density, wide space is necessary.
- ♦ Lithium rechargeable battery, nickel-hydrogen battery: Even though of small scale, by incorporating them into electric vehicles, the overall storage capacity may dramatically rise.

- ■ Equipment to store power by changing the energy form
  - ♦ Pumped storage power plant (PSPP): High-capacity storage (1000 MW or higher). Storage efficiency of around 70%.
  - ♦ Compressed air storage (CAES): Relatively high capacity (300 MW) storage is possible. Storage efficiency of around 50%.
  - ♦ Heat storage air conditioning system: Make ice via off-peak power and use the ice for space cooling during daytime (in summer).

Among the above-mentioned measures, of the demand-side measures, changing electricity tariff system is effective and energy storage equipment utilizing electricity rate gap (electric vehicles, heat storage air-conditioning systems, in particular) is expected to be effective in the future. On the other hand, on the supply side, only the PSPPs are expected to produce high capacity at the current technological level.

8.5 Proposal on Hybrid (Wind Power and PSPP) Power Project

(1) Outline of Yalova Hybrid Project

(a) Project Location

Project Site is located in Çinarcık District, Yalova Province as shown in Figure 8. 16. PSPP Site is located about 25km south-west from Yalova City. It takes about one hour by car from Yalova City to the site. The nearest town is Çinarcık, a coastal town facing Sea of Marmara. The site is located about 10km south-west from Çinarcık, and it takes 30 minutes by car. Wind Farm site is located 4-5km North-West of the PSPP site.

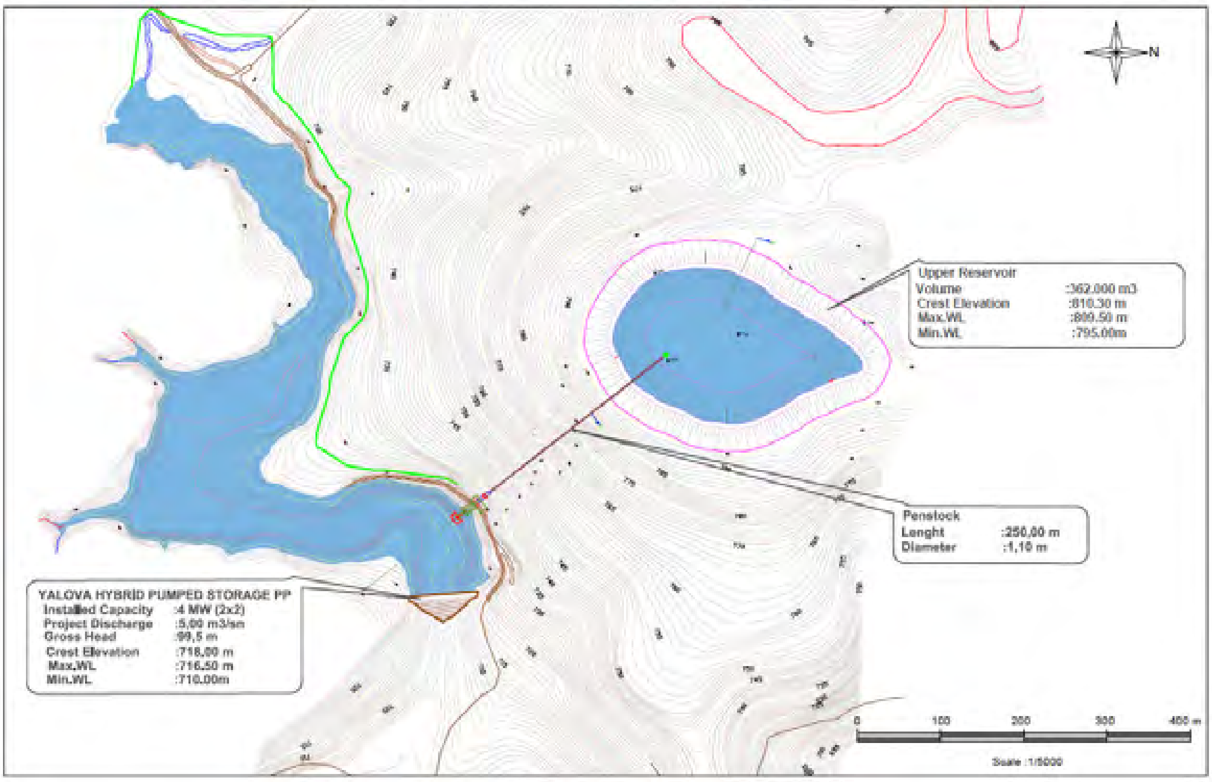
Figure 8. 16 Location of YALOVA Hybrid Power Project

(b) Description of Plan

Features of Yalova Hybrid Power Project and layout of PSPP are shown in Table 8. 8 and Figure 8. 17 respectively.

Table 8. 8 Features of YALOVA Hybrid Power Project

	Wind Farm		
1	Installed Capacity of the Wind Farm (MW)	:	**10**
	Pumped Storage Power Plant		
2	Generation, Pump Capacity (MW)	:	**4 (2x2), 4 (2x2)**
3	Generation, Pump Discharge (m^3/s)	:	**5, 3.5**
4	Generation, Pump Net Head (m)	:	**92.15, 106.85**
5	Generation, Pump Peak Duration (hours)	:	**20, 30**
6	Type of the Upper Reservoir	:	**Excavation & Erath Fill Dam**
7	Active Volume of the Upper Reservoir (m^3)	:	**362,000**
8	Upper Reservoir Max.WL (m)	:	**809..5**
9	Upper Reservoir Min.WL (m)	:	**795.0**
10	Type of the Lower Reservoir	:	**Concrete Gravity Dam**
11	Active Volume of the Lower Reservoir (m^3)	:	**375,000**
12	Lower Reservoir Max.WL (m)	:	**716.5**
13	Lower Reservoir Min.WL (m):	:	**710.0**
14	Number x Length (m) x Diameter (m) of Penstock	:	**1 x 250 x 1.10**
15	Type of the Power House	:	**Semi-underground**



Source : EIE

Figure 8. 17 Layout of YALOVA PSPP

(2) Site Observation of PSPP Site

The Study Team carried out site observation of Yalova PSPP Project Site. They checked topographical, geological and environmental conditions of the upper reservoir site, the lower dam and reservoir site. Description of site observation (Location map of Hybrid Power Project), track of site observation and photographs of site observation are shown in Appendix 8-5-1, 8-5-2, 8-5-3 respectively.

Meanwhile, the Study Team could not visit the wind farm project site because the site was not accessible without four-wheel driving cars.

(a) Access to PSPP Site

The access road is a paved provincial road, and its condition is good. It is possible to directly access to the lower dam site by car. There is no access road to the upper reservoir site.

(b) Topography and Geological Conditions

Yalova PSPP site is located near the end of peninsula, which is stayed away about 30 km south from Istanbul faced sea of Marmara.

The peninsula was formed by the North Anatolian faults, which is the most active in Turkey, and diverged to north and south and hidden in the Sea of Marmara. The northern one formed Izmit bay and the southern one formed Gemlik bay and Iznik lake.

The site is located in the middle of the peninsula, which width is approximately 20km. The upper reservoir site is located on the small hill on the left bank of the lower reservoir.

The top of the hill is relatively flat, and the upper pond seems to be constructible, however, since the storage volume of pond will be secured by excavation, the excavation volume will become relatively large.

The massif of the peninsula is formed by Pre-Cambrian rocks which belong to the Caledonian and Hercynian orogeny. According to the explanation of Iatanbul quadrangle, the rocks of the area consist of undifferentiated gneiss, schist, metagranite, migmatite, and amphibolites etc.

Since the geology of the project site is Precambrian Gneiss, it seems that the bedrock of both the upper pond and the lower dam/reservoir is stable, and the permeability is low.

At the upper pond site, top soil with 2~3meters thick covers weathered rocks. Since the top soil will be unsuitable for materials of embankment for the upper pond, they should be excavated and disposed outside of the pond area.

As for the foundation of the lower dam, since fresh outcrops were observed around the riverbed, the depth of weathered rocks on the both banks of the river seems relatively shallow. Therefore, there are no particular concerns for the construction of the lower dam.

(c) Environmental and Social Conditions

- Natural Environment

  There is no National Parks around the project site at this moment. However, the surrounding area is designated as Hunting Prohibited Area in 2010-2011 and Key Biodiversity Area (KBA). Authorities and agencies of environmental conservation keep their eyes on the area as an important area for birds.

  The vegetation of the project site is mainly beech forest. It is relatively dense forest but secondary forest. The beech trees are grown still between ten to twenty centimeters around.

- Social Environment

  There are no social activities at the project area.

  There is a house near the end of the lower reservoir. But residents already left the house and no one are living in the house.

  Only affected facilities are a part of the existing road and transmission line. Those facilities should be relocated or set backed.

  The access road is named as “Yaşil Mavi Yol”, which means “Green Blue Road”.

(3) Evaluation and Recommendation

(a) Evaluation Results

According to the site observation, it seems that construction of the project site can be done, since there are no crucial concerns on geological conditions and environmental conditions. However, there are the following technical issues:

Power Project Plan

- Since peak duration hours for either generation or pump is as long as 20 hours or 30 hours, optimal storage capacity should be studies taking into consideration operation and economical efficiency of PSPP.
- Both capacities of generation output and pump input are set as 4 MW. However, since turbines and pumps are planned to install separately, the optimal capacity of pump input should be studied taking into consideration operation and total efficiency of 70% of PSPP.

Upper Reservoir

- Since the upper reservoir is planned to be artificial pond with excavation and earth fill dam on the top of hill, there is a risk of water leakage due to short pass of seepage around the upper pond. Therefore, the plot plan of the upper reservoir should be studied including leverage of terrain of valley near the original alternative.
- Top soil with 2~3meters thick covers weathered rocks and is unsuitable for the material of embankment, therefore, disposal yards should be secured.

Lower Reservoir

- In order to lower the dam height as much as possible, sediment inflow should be sluiced to the downstream, thus sediments discharge facility of the lower dam should be studied carefully.
- The dam site should be selected so that the required storage capacity is secured effectively and the length of the existing road and the distribution line to be resettled or set backed is reduced as much as possible.

Penstock and Powerhouse

- The steel pipe will be applied for the conduits of the project. Optimal diameter and number of the steel pipe should be studied based on the calculation of correlation among diameter, head loss and total weight (construction cost). Besides, adoptability of siphon type should be considered from the viewpoint of economy.
- Since a certain suction head is required for pumping up water, the elevation of pump center will be lower than the elevation of the riverbed. Therefore, the power house should be designed taking into consideration measures against buoyancy, water leakage into the powerhouse and drainage.

As for environmental and social aspects, the negative impacts by the projects seem to be limited. However, coordination with environmental authorities should be sufficiently conducted.

(b) Recommendation

At earliest, feasibility study should be carried out including studies on the above mentioned technical issues.

Chapter 9 Technology Transfer

9.1 Potential Study on Pumped Storage

9.1.1 Research and Design

In the first workshop, the JICA team presented the Japanese instance of potential study on PSPP, design of facilities of PSPP (Civil structure and Electro-mechanical equipment), and environmental and social considerations.

The Study Team together with the counterparts of EIE carried out the project findings of PSPP, evaluation and prioritization of potential sites of PSPP, and site survey of PSPP candidate sites and evaluated the results of the site survey. Thus, the Study Team provided the counterpart with OJT for potential study on PSPP projects.

In concrete terms, the Study Team conducted technology transfer as follows:

- In setting criteria for finding potential sites of PSPP, the Study Team explained criteria and their grounds, and deepened counterparts' understanding.
- The Study Team explained the results of the primary evaluation of PSPP potential sites, special attention points for evaluation. After that, through discussion with counterparts, their technology of research and planning was improved.
- The Study Team had civil engineers, geologists, and environment specialists in EIE participating in the site survey, and it conducted OJT in the respective field of site survey.
- The Study Team explained the results of site survey and prioritization of candidate sites surveyed, and then deepened counterparts' understanding of the evaluation and prioritization method. Furthermore, the Study Team explain further research items and investigation methods, and then improved counterparts' research and planning technology.

During the second workshop, the Study Team explained the methodology of layout design, construction cost estimate, and geographical and geological survey, and the evaluation results of development priority of PSPP candidates. The Study Team provided the counterparts with OJT through the detailed site survey of the priority PSPPs.

During the third workshop, the Study Team explained the results of detailed site survey, conceptual design (civil structure and electrical and mechanical equipment), and cost estimate, and also introduced advanced technologies of pumped storage power plant.

9.1.2 Environmental and Social Considerations

As for environmental and social considerations for hydropower projects, environmental engineers of EIE have been carrying out field survey at EIA level. Therefore, they are sufficiently familiar with EIA procedures and related laws and regulations.

Private companies seldom take environmental and social aspects into consideration during the planning stage of hydropower development. Though environmental engineers of EIE are aware of the necessity of environmental consideration even during planning stage, environmental and social aspects are not reflected to the site selection of hydropower projects.

Taking into account the situation mentioned above, the Study Team explained the flowchart of environmental and social considerations for PSPP development as shown in Figure 9. 1 during the first and second study in Turkey, and explained the subjects to be considered especially for PSPP development as follows:

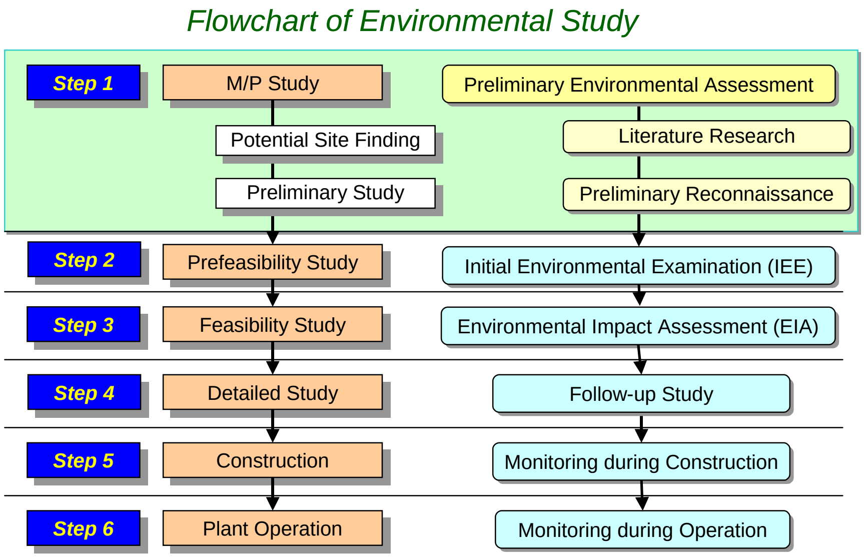


Figure 9. 1 Flowchart of Environmental and Social Considerations for PSPP Projects

Environmental and social considerations for PSPP are not so different from those of large-scale conventional hydropower projects, but special attention has to be paid to PSPPs taking into account characteristics of PSPPs such as matters related to location of dams and reservoirs, plant operation, and scale of development. During the first workshop, the Study Team explained the necessary considerations to EIE counterparts and the rest of the audience.

During the second workshop, the Study Team explained the methodology of environmental and social survey for PSPP potential sites and survey results.

The Study Team also explained the results of the initial environmental examination of two priority PSPP sites as well as impacts assessment method and good practice of environmental mitigation measures which are applied to the previous PSPP projects in Japan.

Furthermore, the Study Team explained how to determine water outflow volume from dams of hydropower plants for maintaining river functions in Japan as required by EIE because there is no standard for maintenance water outflow in Turkey.

The Study Team together with the counterpart of EIE set criteria for finding potential sites, prepared a check sheet for preliminary site survey, carried out site survey, evaluated the results of the site survey, and prepared IEE reports and draft of guidelines for environmental and social consideration for PSPP project. Through the above study, the Study Team provided the counterparts with OJT for preliminary study on environmental and social considerations for PSPP projects.

9.2 Power Development Planning Formulation Technique

9.2.1 The First Training

PDPAT training was implemented for young engineers for EIE and TEIAS for 2 days on June 28 and 29, 2010. Prior to the training session, a demand and supply operation simulation tool, PDPAT II, and a reliability evaluation tool in an interconnected system, RETICS, were provided to EIE and TEIAS.

Details of the first training are as shown in Table 9. 1.

Table 9. 1 Training Program

	Hands-on training using computer	Lectures
A.M. on June 28	Explanation on PDPAT use method and on data Study of optimal peak supply capacity rate	Method for calculating generating cost
P.M. on June 28	Explanation on RETICS use method and on data Relationship between LOLE and supply reserve capacity rate	Concept of supply reliability
A.M. on June 29	Study on optimal PSPP ratio	Method for calculating supply capacity of PSPP, Method for determining optimal pondage volume
P.M. on June 29	Study when interconnected with other systems	Method for calculating merits when interconnected with other systems






9.2.2 The Second Training

In the first training, the program to make data for PDPAT II was requested from the counterparts. The second training was implemented based on the above request. Additional PDPAT training was implemented for young engineers for EIE and TEIAS on September 2, 2010. The program provides information on a method to make data of PDPAT II and evaluation of calculated data.



9.3 Organizing Workshops

9.3.1 The First Workshop

The first workshop was implemented for 3 days on May 13, 14, and 17, 2010.

Institutions related to this project were invited to the workshop, and the situation in Japan and the method employed by Tokyo Electric Power were introduced on the following contents, with questions and answers:

- Day 1 (May 13): Electricity sector, actual status of electricity trading, method for formulating power development planning
- Day 2 (May 14): Method for selecting pumping sites, pumped storage power generation facilities (civil engineering, electromechanical), and environmental measures
- Day 3 (May 17): System operation method, tariff system related to DSM

The workshop venue was an auditorium accommodating approx. 200 people. The workshop was successful for all 3 days, with more than 70 participants on each day.

Generation, transmission, and distribution are completely separated in Turkey, which is different from the system in Japan. Because of such situations, there were many questions on the PPS entry system in Japan, the tariff-setting method, the frequency adjustment method, concept of the fuel cost for PSPP, etc. Note that since there were many detailed questions on the system operation, a question-and-answer session was conducted only with the parties involved in a separate room on May 18.

		
Presentation on PDP team	Q&A session	Presentation on PSPP team
		
Social interaction at tea break	Q&A session	Closing remark

		
Group photo of the hosts	Q&A session regarding the system operation	Q&A session regarding the system operation

9.3.2 The Second Workshop

The second workshop was implemented on August 26, 2010.

Institutions related to this project were invited to the workshop, and the contents of the Interim Report were introduced, with questions and answers. The workshop was successful with more than 51 participants.

- Long-term supply/demand plan
- Evaluation of PSPP in terms of power system operation
- Selection and evaluation of potential sites of PSPP
- Geological investigation for PSPP
- Methodology of cost estimation
- Environmental and social considerations

Their discussion focused on the following issues:

- In accordance with the national liberalization policy, public sector organizations do not plan to construct a new power plant. Who will construct a PSPP and collect money for investment?
- Since September 18, 2010, Turkey will be officially interconnected with the European power systems. How will the power system in Turkey be operated after the interconnection?
- As there is much potential for hydropower plants in Turkey, is a new PSPP really needed?

In addition, introduction of demand supply control rules and frequency/voltage control rules of a Japanese power company and related Q&A session were held in TEIAS on August 23, in response to the request from the EIE/TEIAS delegation at the session in Japan.

		
Workshop at EIE	Workshop at EIE	Session at TEIAS

9.3.3 The Third Workshop

The third workshop for PDP and PSPP were held on November 26 and December 1, 2010, respectively. Institutions related to this project were invited to the workshops, and the contents of the Draft Final Report were introduced.

<Workshop for PDP>

- Long-term Power Development Planning (2011-2030)
- Feasibility of Extension Plan of Existing Reservoir Type Hydropower Plant
- PSPP Operation Scheme in Europe
- Ownership and Contract Condition of PSPP

<Workshop for PSPP>

- Outline of Priority PSPPs, Altınkaya PSPP and Gökçekaya PSPP
- Topographic and geologic feature of the Priority PSPP sites
- Results of Initial Environmental Examination
- Conceptual Design (Civil structures of Priority PSPPs)
- Conceptual Design of Priority PSPPs (Electrical & Mechanical Equipment)
- Proposal and Recommendation of Further Step

There were especially many questions on the contents of PSPP operation in Europe.

		
Workshop for PDP	Workshop for PSPP	Present form EIE