Operation of Pumped Storage Hydropower (PSHP) in TEPCO



28th July 2015 Tokyo Electric Power Company (TEPCO)

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- General Figures of Pumped Storage Hydropower (PSHP) in TEPCO
- General Features of PSHPs (Operational Benefit of the PSHP)
- Advanced Technology: Adjustable Speed-type Pumped Storage Hydropower (AS-PSHP)

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 Hydropower (AS-PSHP)



PSHPs Operated by TEPCO

	Power Station	Output [MW]	Number of Unit	Commissioned	AS-PSHP
TEPCO	Yagisawa	240	3	1965	#2 unit
	Azumi	623	6	1969	-
	Midono	245	4	1969	-
	Shin-Takasegawa	1,280	4	1981	-
	Tambara	1,200	4	1982	-
	Imaichi	1,050	3	1988	-
	Shiobara	900	3	1994	#3 unit
	Kazunogawa	1,200	3 (to be 4)	1999	#4 unit
	Kannagawa	940	2 (to be 6)	2005	-
	Sub-Total	7,678	-	-	-
Electric Power Development Compar	Shiroyama	250	4	1965	-
	Numappara	675	3	1973	-
	Okukiyotsu	1,000	4	1978	-
	Shin-Toyone	500	2	1972	-
	Shimogo	1,000	4	1988	-
	Okukiyotsu - #2	600	2	1996	#2 unit
YL	Sub-Total	4,025	-	-	-
Total Installed Capacity · 15sites 11.703MW 51 units					

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Development Company (EPDC)

Load Curve and Power Source



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The Operational Advantages of PSHP

There are 5 major benefits from the viewpoint of power system operation.

Peak Load Power Source

Supplemental (Non-spinning) Reserve Capacity

Load Following & Frequency Control Functions

Synchronous Condenser Operation

(Voltage Control)

Power Source for Black Start

(1) Peak Load Power Source

PSHP's fixed cost is low

- It can be constructed at low unit cost per kW
- It comprises long-life structures (dams, conduits)

PSHP's variable cost is high

- About 30% of energy loss
 - Total performance strongly depends on the power source for pumping water



(2) Supplemental (non-spinning) Reserve Capacity

Rapid Response

Start up within 4 to 5 min. Reach to full power within 7 to 8 min. Fast output change rate





(3) Load Following and Frequency Control

Gradual Increase of Photo Voltaic in TEPCO's area



Year/Month

(4) Synchronous Condenser Operation

(Voltage Control)

- System operators can also use PSHPs as <u>synchronous</u> condenser operation.
- PSHPs can adjust network voltage by operating generator-motors <u>without load</u> and adjusting magnetic field currents to <u>provide or absorb reactive power</u>.
- (5) Power source for Black Start
 - PSHPs can be activated by the power from nearby run-of-river hydropower, even when entire power system is totally interrupted (Blackout).



Trend of Monthly Energy Supply from PSHPs We have been fully utilizing the pumped storage and got through some severe demand supply conditions.



Planning and Development Criteria for PSHP

TEPCO has used the following 4 criteria to ensure that the power plants are constructed in a most economical and efficient manner

- **High Storage Capacity**
- **Good Access to Power Supply Network**
- Suitability for Excavation of Large-scale Underground Caverns

High Head with Short Waterway

Planning and Development Criteria for PSHP Good Access to Power Supply Network

Power plants should be built;

- as close as possible in order to minimize power loss transmission cost
- in locations that provide good access to electric power from thermal and nuclear power plants for pumping up power source





New SPS against transient instability

- Requirements
- 1. Robustness
 - Handle all step-out phenomena, 1st wave step-out, Nth wave stepout, poor damping phenomenon.
 - Do not require complicated setting that varies by power system condition.
- 2. Low Cost
 - Do not require telecommunication channel considering cost.
- 3. High Reliability
- Do not trip unnecessarily with single malfunction in relay device.
- Equip powerful self-checking, self-testing functions.

15 sets of developed SPS have been installed in 12 PSHPs



SPS (Real Products)

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Regulatory Control on the Construction of PSHPs in Japan

1.Environmental Regulation

- (1) The Environment Impact Assessment Law
 - Assessment process of environmental impact will be required when hydropower stations (dams, waterways, generators, etc.) of more than 22.5MW capacity are planned.

(2) The River Law

Governmental permission will be required when exclusive use of running water or land, newly construction of structures, excavation of land, etc. are planned

(3) The National Parks Law, The Forest Law

Governmental permission will be required when construction works are conducted in the national parks or forest.

Regulatory Control on the Construction of PSHPs in Japan

2. Public Safety Regulation

(1) The Electric Utility Industry Law

- Construction plan of the electric facilities (generators, dams or others) should be submitted to the authorities.
- The electric facilities should conform to the technical standard or code set by the authorities in order to preserve of public safety.
- Utilities should formulate, submit and obey the self-governing rules for safe and stable Installation, maintenance, and operation of electric facilities.
- Pre-examination should be conducted

(2) The River Law

- Construction plan of the structures (dams, waterway or others) should be submitted to the authorities.
- Pre-examination should be conducted.

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Outline of Adjustable Speed (AS)- PSHP Structure of AS-PSHP System



Advantages of AS-PSHP

(1):Improvement of turbine efficiency in Generating mode

Comparison of turbine efficiency between Kazunogawa P/S #1, 2 (Conventional PSHP) and #4 (AS-PSHP)

Turbine efficiency can be improved especially lower output rate, due to appropriate control of rotational speed.



Advantage of AS-PSHP 2: Wider output power range in generating mode

Minimum output can be lowered and wider output range can be secured due to suppression of a vibration caused by water flow.



Advantages of AS-PSHP ③ :Wider Input Power Range in Pump Up Mode

AS-PSHP can change input power for pumping up water.



Field Test for Effectiveness of AS-PSHP



Thank you very much for your kind attention