HYDROPOWER DEVELOPMENT in the PHILIPPINES

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Abstract

The present policy on energy development is geared towards harnessing renewable and indigenous energy resource which can offer clean, abundant and efficient power supply for the country. A review of the current generation mix of the power system, especially the Luzon grid will establish a high dependency in imported fuel – oil and coal to power our generating plants. Thus, the policy of reducing dependence on imported fuel will depend largely on the success of tapping the alternative renewable and indigenous sources.

The sustainable development era of the '90's brought fresh interest on the performance and commercial viability of indigenous and/or renewable sources of energy such as wind, solar, geothermal, natural gas and water power or hydropower. Among these alternative renewable sources, water or hydropower is the most readily available, and will produce clean domestic source of electricity – no carbon dioxide, sulfur dioxide, nitrous oxide or any other air emissions. The potential is available in most parts of the country that are mountainous and have high rainfall. In terms of production, hydropower leads as the most developed and more proven in terms of commercial viability. It is also more reliable, efficient and less expensive than geothermal, biomass, wind and solar energy, as will be shown later.

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Hydropower Fundamentals

As can be seen and/or experienced, the roar of the waterfall suggests the power of water. The floodwaters rampaging through the river can uproot trees and destroy villages. However, the might of water is made even greater if it will flow through a steep slope of the river.

As the name hydropower suggests, water in lakes, rivers and other reservoirs is harnessed or put to work to produce kinetic energy. Hydroelectric dams are built to generate electric power by directing water through high pressure tunnels/penstocks to the turbines, which are wheels with curved blades as spokes. The falling water spins the blades of the turbines connected to generators. Hydtropower, therefore, is influenced by both the quantity of water flowing at a certain rate (discharge Q in cubic meter per second) and the difference in elevations at the head start and tail end of the flow (head h in meters). Please refer to Figure 1.

The basic formula for hydropower, therefore, is

$$P\ (kW) = 9.81\ n\ Q\ h$$

where n is the combined efficiency of the machine;

From the formula, the output depends upon the head of water, or height of stored water above the turbines. The higher the water, the more weight and pressure are exerted in the turbine blades. A second factor as mentioned is the volume of water throughout the year. The minimum flow in dry months fixes the amount of firm power which customers can rely upon regularly. Sometimes, extra power or run-of-river power, generated in wet season can be sold, usually at low rates.

The component civil structures of a typical hydropower project are (see Figure 2):

1. Depending on its height, the ***dam or weir*** is constructed for the purpose of impounding water (reservoir), create additional head and allow diversion of water;
2. The ***spillway*** is the structure that will pass the flood in excess of what can be stored in the reservoir. The spillway is usually designed to pass the maximum flood possible;
3. The ***intake*** structure allows entry of water from the reservoir or the river;
4. The *power conduit* which could either be a ***tunnel*** or ***an open channel*** or *canal* or *pipes* transports water from the reservoir to the turbine units inside the powerhouse;
5. The ***powerhouse*** or the ***power station*** houses the turbine, generator units and other associated equipment.
6. The ***tailrace*** is the structure which will conduct water after running the turbine back to the river;
7. The ***switchyard*** which will transform the kinetic energy generated to electric energy;
8. The ***associated transmission line*** which will conduct the electric energy to the nearest substation for distribution;

Aside from the above component structures, some electrical and mechanical equipment are required: turbines, governors, generators, control and switching apparatus and transformers.

There are two general types of hydropower development: the ***run-of-river*** and ***reservoir*** type. The reservoir type of development is a hydro with significant storage. Water are impounded behind the dam which are released later to generate energy during peaking periods. On the other hand, the run-of-river type has no storage and the dam/weir will primarily divert water. Thus, the turbines will be run by whatever inflow in the river that is available.

A variation to the reservoir type is the ***pumped storage*** where water from a lower reservoir is pumped to an upstream reservoir. An example of this type is the Kalayaan Pumped Storage Plant in Laguna sown in Figure 3. The water stored upstream is then used later on to generate during peaking periods. The principle in this scheme is that the energy used for pumping water is cheaper because it is an off-peak energy while the energy produced by the pumped storage plant during peak periods is of a higher value because it is needed during peak.

Hydropower vs. Thermal Generation

See Figure 4.

1. ***Investment, O & M Costs and Useful Life***

The hydropower project is capital-intensive, because of the many structures needed to be built. In addition, because of the required construction work, site investigation to be able to design the project is more extensive and expensive and implementation period is longer.

The hydropower is also site specific, and therefore, the cost of access and the associated transmission lines may be considerable.

Unlike the thermal power where fuel cost is significant, water which is the fuel for a hydro is free. It is also renewable as this is returned to the river after its use. The operating and maintenance cost for the hydro therefore is almost nil.

However, this resource (rivers and lakes) is a patrimony of the nation. The exploitation therefore, of this resource by a private individual must not be viewed as perpetual.

The economic life is also longer - 50 years compared to thermal which is between 15 to 30 years. Over the long term therefore, hydropower is the cheapest source considering the long useful life and the overall costs.

2. *Water Availability or Hydrology Risk*

As mentioned before, unlike the thermal power project where fuel cost is significant, water as fuel for hydropower is free. However, generation output depends on the volume of water available for the turbine. The amount varies, however, for any given time.

3. *Hydropower Performance in the System*

The hydropower project can be designed to serve any place in the load curve. It can either be a base load plant, a peaking station or an intermediate load station. It is versatile enough to be able to be operated to serve the needs of the system. Please refer to Figure 5.

There are two components of generation output associated with operation, namely, the firm energy or on-peak energy and the secondary or off-peak energy.

The firm energy is that output which can be guaranteed (defined at 90 to 95% reliability) to meet a certain system requirement for a specified period of time. This energy can be dispatched during that period and, therefore, has a high value than the second type. Associated with this energy is the dependable or guaranteed capacity which can actually displace an equivalent thermal plant capacity during operation of the system.

The secondary, off-peak or excess energy is that output which can be generated over and above the firm when the availability of water warrants. This type of energy cannot be dispatched and is valued less than the firm, specifically at the cost of the thermal fuel used by an equivalent plant when that energy was utilized by the system.

Hydropower Implementation – Stages of Development

See Figure 6.

There are four (4) major stages of implementation of a hydropower project. These are the: (1) Pre-feasibility or reconnaissance stage, (2) Feasibility and/or Definite Design stage, (3) Detailed Design stage, (4) Construction stage. Each stage takes the project a step forward in the development cycle, based on the findings from the actual and previous stages.

The planning stages cover the pre-feasibility and feasibility study phases. The main purpose for the Pre-feasibility stage is to perform river basin planning analysis which will allow the identification and ranking of the attractive hydropower sites for a particular river. Afterwards, having identified and ranked the best sites, a Feasibility Study needs to be conducted for each of the attractive sites. This is to establish the viability of the project considering the technical, economic and financial considerations. It is imperative, therefore, that at the feasibility level, a more improved data base should be secured, by the conduct of site investigation works (drilling, survey, etc.), so that the engineering design and estimates will be of better reliability.

The Definite Design study will confirm the findings in regard to the scheme of development proposed in the Feasibility. This is most important if there are new information/data available which will affect the design and cost, hence, the financing. The Detailed Engineering stage, on the other hand, is for the purpose of developing the engineering drawings for construction, development of tender documents for bidding out the construction of civil works and procurement of the equipment, including the tendering process itself.

The Construction stage covers the implementation of the project. This phase is difficult because of the many structures involved and the timing needed to have the structures completed in time for the installation of the equipment..

Status of Hydropower Development in the Philippines

The National Power Corporation formulated the 1997 Power Development Program (PDP) to establish the plans of the Philippine Government to meet the future loads by the coordinated addition of necessary generation and transmission facilities. The PDP confirms the need for the on-going projects, identifies critical new projects and provides direction for future courses of action.

For the period 1997 to 2010, the PDP indicates the need for new generating projects with capacity totaling to 11,126 MW. The PDP also projects that the demand for electricity is expected to grow at an average rate of 6.3 % for the next twelve years. To meet this growing demand and at the same time reduce dependence on imported fuel, the Government is considering indigenous and renewable alternative energy. One such alternative source is hydropower.

Prospects

Over 12,500 MW have been identified in the country as potential hydropower projects for development. Of these, only 19% have been developed. Figure 7 shows the summary of the resource potential for hydropower.

The summary of all existing and on-going hydropower projects are shown in Figure 8. For the future, the PDP has scheduled for commissioning a number of hydropower projects with a total capacity of 1,450 MW between years 2000 to 2005. In addition to these, a 50 MW window is made available every year for indigenous and small hydro projects. This is equivalent to 300 MW capacity slated for entry into the system by 2000 to 2005. A summary of the PDP capacity additions are shown as Figure 9.

BOT Tendering

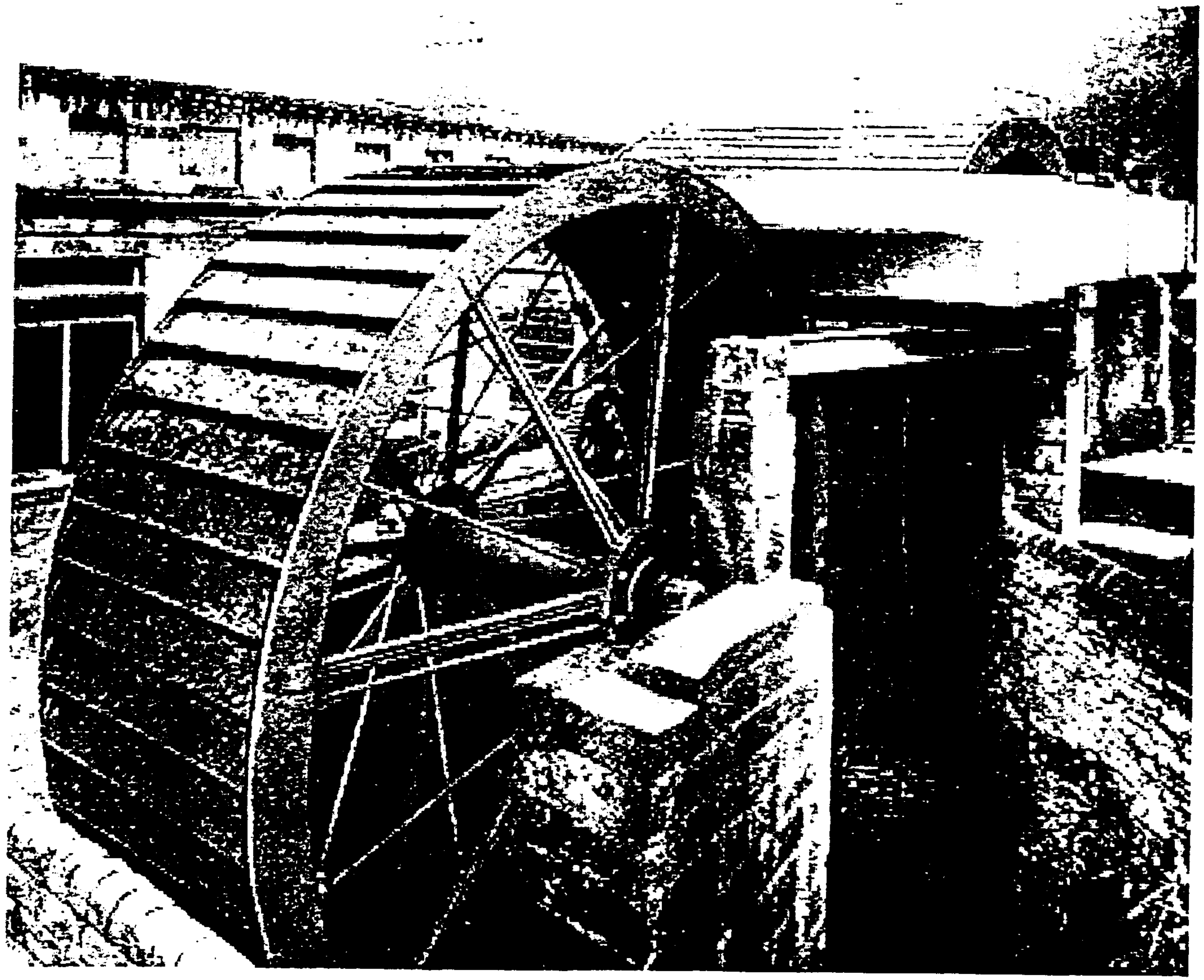
In line with the government's thrust to tap private capital in implementing infrastructure projects, NPC has been offering the hydropower projects to private developers through the Build-Operate-Transfer (BOT) Scheme.

NPC realized that the developers who choose to invest in hydropower project face many risks. However, it had identified the specific risks at every stage of the power projects life cycle and their cost implication. It is believed that a hydropower project implemented by a private group would be successful once these risks are effectively managed and properly allocated to the different players involved in a BOT arrangement.

NPC's experience in private hydropower was limited to the unsolicited mode or negotiation for rehabilitation projects such as Ambuklao, Binga and the new Casecnan multi-purpose project. Solicitation was only done three (3) years ago for the twelve (12) small hydros with capacities from five to 50 MW. However, there was a low turnout and the prices received were high. This can be attributed to the pricing policy adopted by NPC wherein the hydrology risk--an important component of hydro generation--was borne by the proponent of the projects tendered. Only one was successfully negotiated--the 70 MW Bakun Hydroelectric Project. It is now under construction.

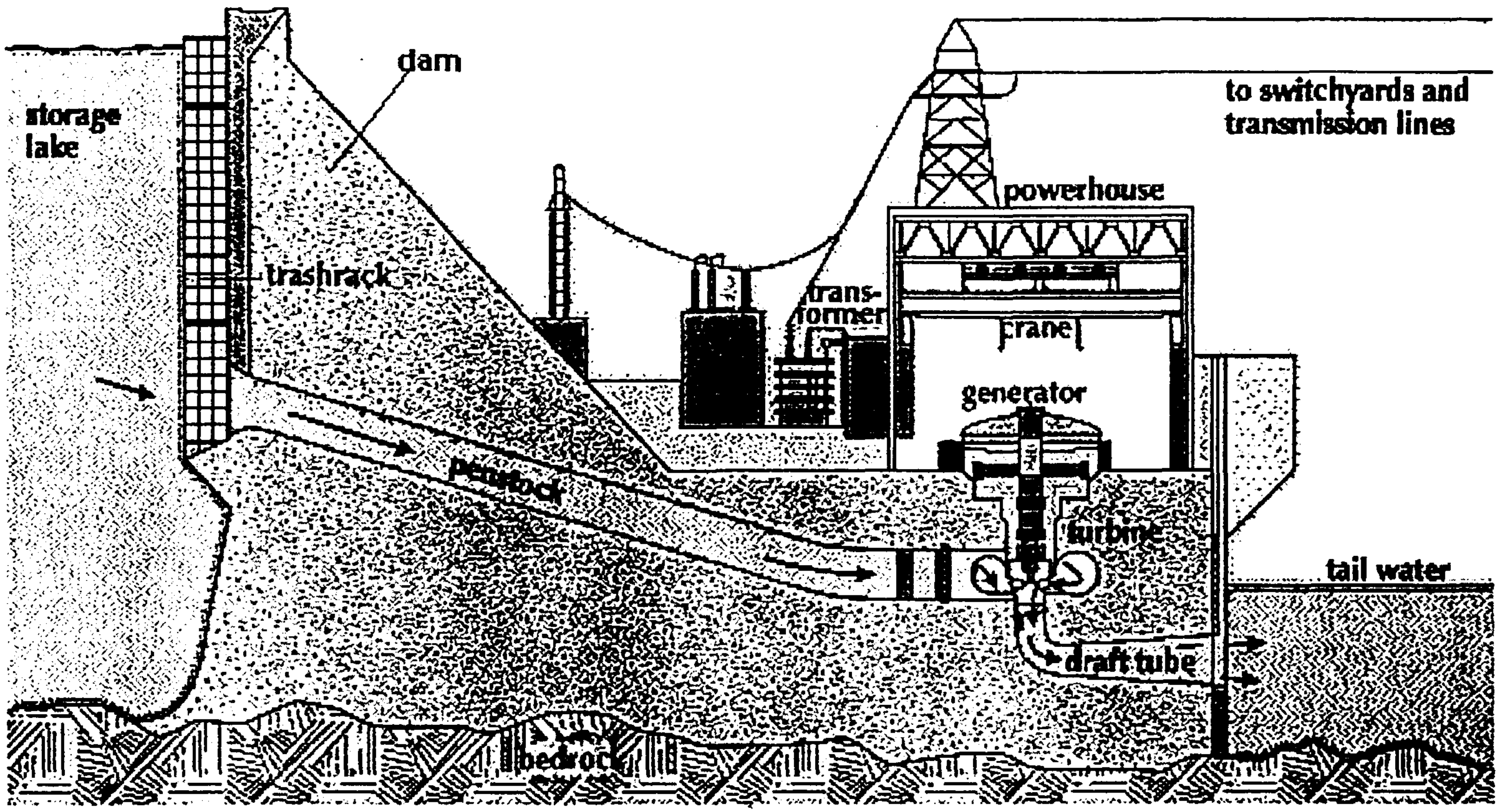
Recently, NPC adopted several policies which will reduce the risks of the proponent to manageable levels and reasonably enable them to recover their investments in the shortest possible time.

NPC's hydropower projects which are included in the country's Power Development Program (PDP) were offered for BOT implementation. Bids were received last February 1997 for about eight projects. NPC is now negotiating the Power Purchase Agreement with the lowest complying bidders for the projects and expects the award within the year. In fact, for the San Roque Multi-purpose Project, the PPA was already signed this month.



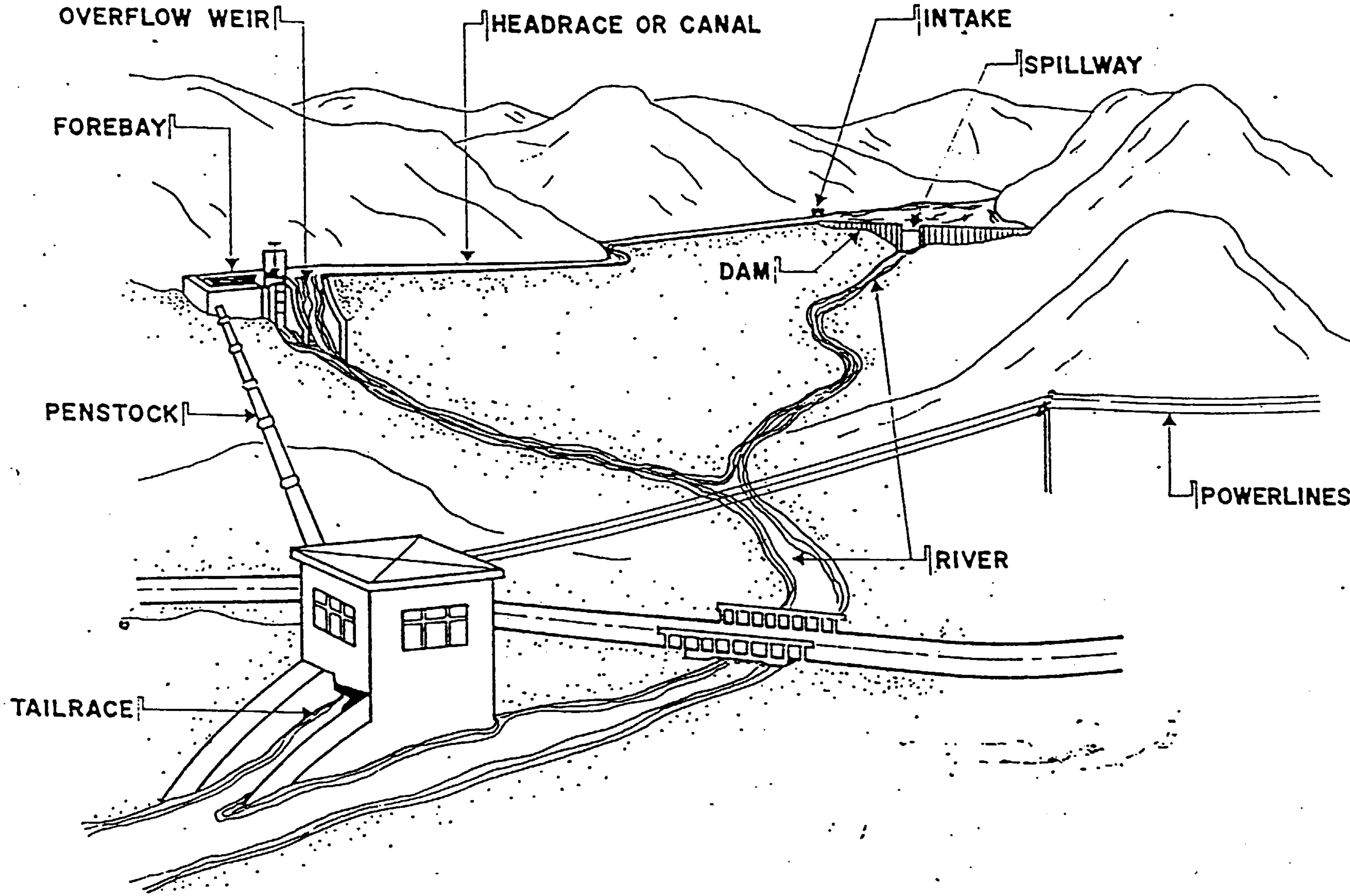
Undershot Water Wheels at Bakewell, Derbyshire

Figure 1



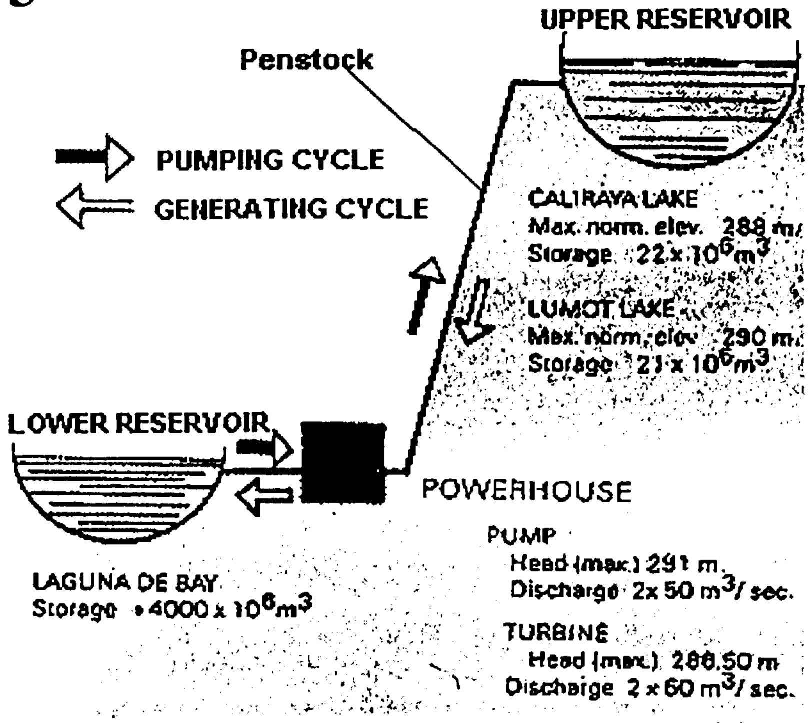
SAMPLE DESIGN OF HYDROPOWER PLANT

Figure 2

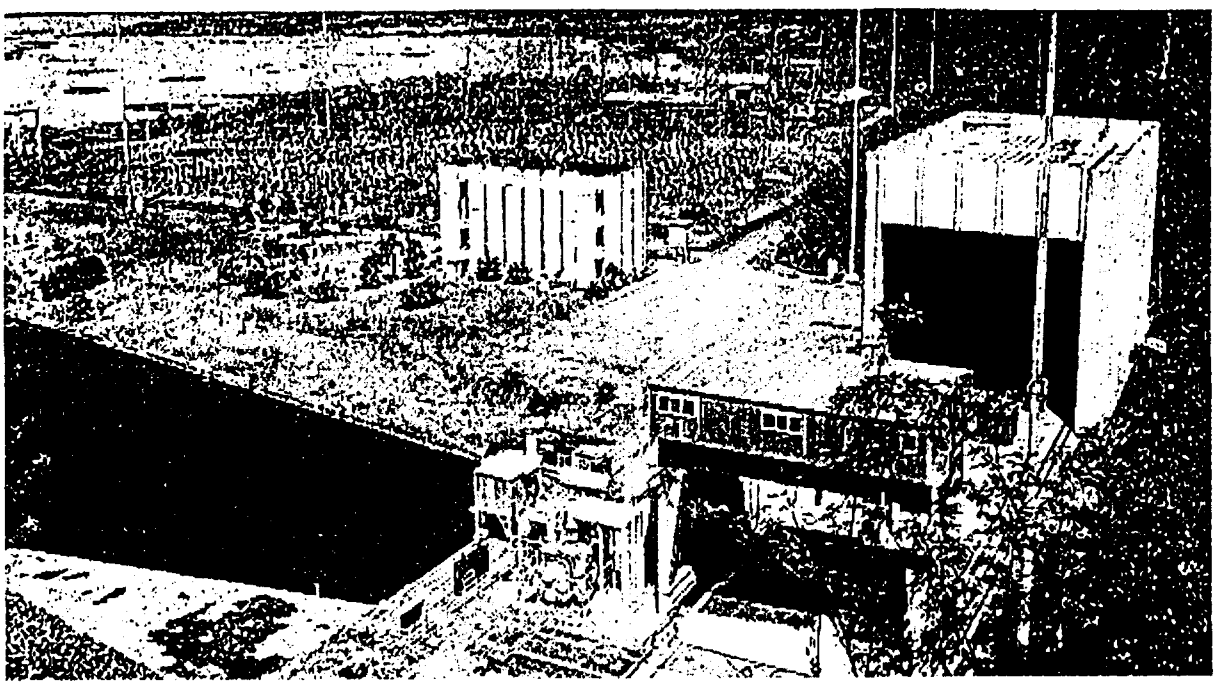


PERSPECTIVE VIEW OF CANAL TYPE SCHEME

Figure 3



SCHEMATIC DIAGRAM OF KPSPP



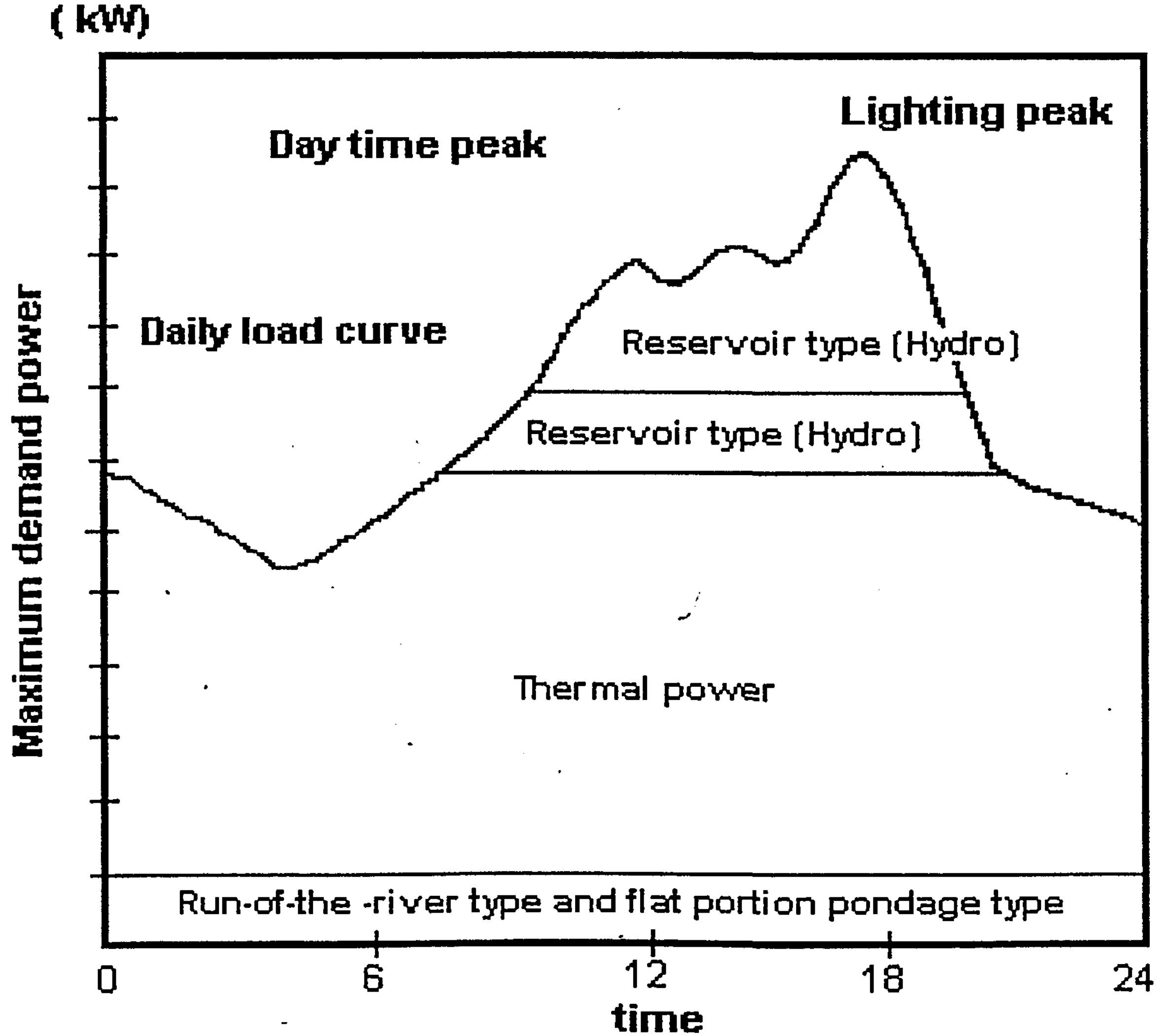
KALAYAAN PUMPED STORAGE POWER PLANT

Figure 4

HYDRO/THERMAL PLANTS CHARACTERISTICS

	HYDRO	THERMAL		
		COAL	GEOTHERMAL	OIL
RESOURCE	INDIGENOUS & RENEWABLE	IMPORTED	INDIGENOUS & NON-RENEWABLE	IMPORTED
LOCATION	STEEP RIVER/LAKE SITE SPECIFIC	NEAR THE SEA	VOLCANIC AREA SITE SPECIFIC	NEAR THE GRID
STRUCTURES				
CONSTRUCTION	5 TO 10 YEARS	3 TO 4 YEARS	2-3 YEARS	1 TO 3 YEARS
ENVIRONMENTAL CONSTRAINTS	INUNDATION AT THE RESERVOIR AREA	AIR POLLUTION	AIR POLLUTION	AIR POLLUTION
INVESTMENT COST	HUGE	MEDIUM	HUGE	MEDIUM
FUEL O & M	FREE	HIGH	MEDIUM	HIGH
ECONOMIC LIFE	50 YEARS	30 YEARS	20 YEARS	15-30 YEARS
OPERATING MODE	LOAD — BASED TO PEAK	LOAD — BASE	LOAD — BASE	LOAD — BASE TO PEAK

Figure 5



Example of daily load curve and power supply

Figure 6 HYDROPOWER DEVELOPMENT CYCLE

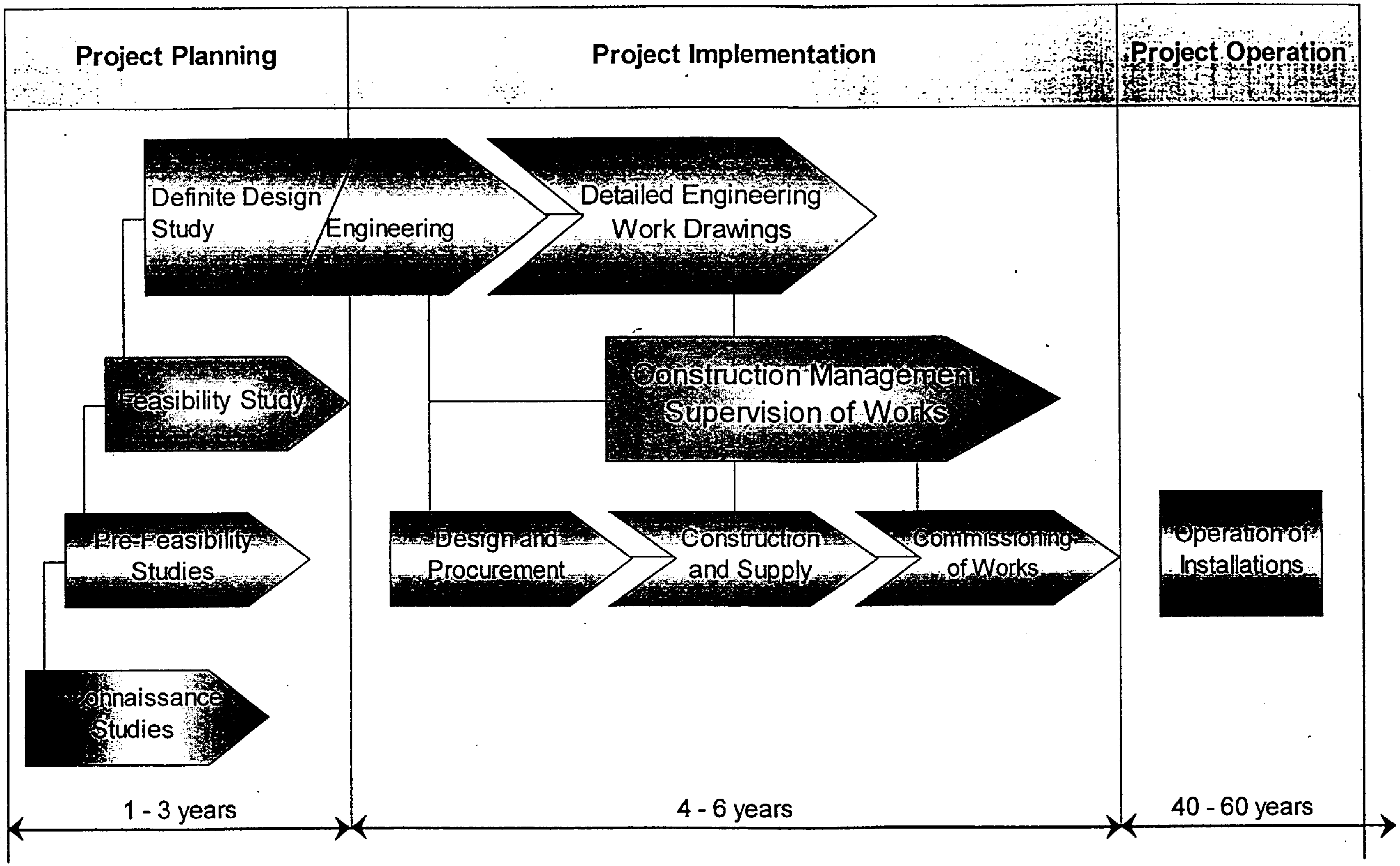


Figure 7

HYDRO RESOURCE POTENTIAL

LOCATION	STATUS	NO. OF SITES	CAPACITY		ENERGY	
			MW	%	GWH	%
LUZON	EXISTING	36	1,273	15	3,818	12
	PRE-FEASIBILITY	95	3,444	40	14,895	47
	FEASIBILITY	-	1,922	22	6,907	22
	DEFINITE DESIGN	-	1,950	23	6,185	19
	TOTAL	**131**	**8,589**	**100**	**31,805**	**100**
VISAYAS	EXISTING	11	13	3	51	3
	PRE-FEASIBILITY	21	95	22	403	27
	FEASIBILITY	-	226	53	833	55
	DEFINITE DESIGN	-	96	22	229	15
	TOTAL	**32**	**430**	**100**	**1,516**	**100**
MINDANAO	EXISTING	14	992	30	4,571	32
	PRE-FEASIBILITY	50	1,193	36	4,799	34
	FEASIBILITY	18	1,104	34	4,768	34
	DEFINITE DESIGN	-	-	-	-	-
	TOTAL	**82**	**3,289**	**100**	**14,138**	**100**
PHILIPPINES	EXISTING	61	2,278	19	8,440	18
	PRE-FEASIBILITY	166	4,732	38	20,097	42
	FEASIBILITY	18	3,252	26	12,508	26
	DEFINITE DESIGN	0	2,046	17	6,414	14
	TOTAL	**245**	**12,308**	**100**	**47,459**	**100**

Figure 8 HYDROPOWER PLANTS IN THE PHILIPPINES

C.Y.	Plant Name	Location	Scheme	Installed Capacity (MW)
LUZON GRID				
Existing NPC Power Plants				
1946-48	Botocan HE	Majayjay, Laguna		17.00
1947-50	Caliraya Unit 1-4	Lumban, Laguna		32.00
1956-57	Ambuklao Unit 3-4	Ambuklao, Bokod, Benguet	ROL	75.00
1957	Barit Mini-hydro	Sta. Justina, Buhi, Camarines Sur		1.80
1960	Binga Unit 1-4	Binga, Itogon, Benguet	ROL	100.00
1967-68	Angat HE	Norzagaray, Bulacan		200.00
1977	Pantabangan Unit 1-2	Pantabangan, Nueva Ecija		100.00
1978-86	Angat Aux.	Norzagaray, Bulacan		46.00
1981	Masiway	Pantabangan, Nueva Ecija		12.00
1982	Kalayaan 1/2 P.S.	Kalayaan, Laguna		300.00
1983-84	Magat Unit 1-4	San Ramon, Isabela		360.00
	Total			**1,243.80**
Existing Non-NPC Power Plants				
1993	HEDCOR	Benguet	PPA	12.10
1993	NMHC	Benguet	PPA	6.00
1993	NIA-Baligatan	Isabela	PPA	6.00
	Total			**24.10**
On-going NPC Power Plants				
1999	Casecnan	Nueva Vizcaya and Pantabanga, Nueva Ecija	BOT	140.00
2000	Bakun	Benguet and Ilocos Sur	BOT	70.00
2004	Kalayaan 3/4 P.S.	Kalayaan, Laguna		300.00
2005	San Roque	San Manuel, Pangasinan	BOT	345.00
2008	Ilaguen B	Ilagan, Isabela		88.00
2010	Agbulu	Kalinga-Apayao		360.00
2010	Addalam	Quirino		
	Total			**1,303.00**
VISAYAS GRID				
NPC Power Plants				
1957-67	Loboc Unit 1-3	Loboc, Bohol		1.[illegible]
1962	Amlan Unit 1-2	Amlan, Negros Oriental		0.80
	Total			**2.00**
Non-NPC Power Plant				
1990	Janopol	Janopol, Bohol	PPA	5.00
	Total			**5.00**
On-going NPC Power Plants				
2003	Timbaban	Madalag, Aklan, Panay		29.00
2003	Villa Siga	Villa Siga, Antique, Panay		32.00
	Total			**61.00**
MINDANAO GRID				
NPC Power Plants				
1957	Agusan M.H.			1.60
1953-77	Agus VI Unit 1-5	Fuentes, Iligan City		200.00
1979	Agus II Unit 1-3	Marawi City, Lanao del Sur		180.00
1982-83	Agus VII Unit 1-2	Fuentes, Iligan City		54.00
1985	Agus V Unit 1-2	Ditucalan, Iligan City		55.00
1985	Agus IV Unit 1-3	Baloi, Lanao del Norte		158.10
1985-86	Pulangui IV Unit 1-3	Maramag, Bukidnon		255.00
1992-94	Agus I Unit 1-2	Marawi City, Lanao del Sur		80.00
	Total			**983.70**
On-going NPC Power Plants				
2003	Tagoloan	Impasugong, Bukidnon		68.00
2004	Bulanog-Batang	Talakag, Bukidnon		132.00
2005	Pulangui V	Roxas, North Cotabato		218.00
2006	Agus III	Baloi, Lanao del Norte		224.00
	Total			**642.00**

Figure 9

REVISION 2
OCT97

1997 NPC POWER DEVELOPMENT PROGRAM 1/
INDICATIVE MW CAPACITY ADDITION
(1997 NPC LOW FORECAST)

YEAR	LUZON	INST. CAP	ANNUAL ADDITION	VISAYAS	INST. CAP	ANNUAL ADDITION	MINDANAO	INST. CAP	ANNUAL ADDITION	PHILIPP ANNUAL
1997			20			158			100	278
	BACMAN II-2 GEO	20		LEYTE-CEBU INTERCON.			ZAMBOANGA DIESEL	100		
				LEYTE GEO A	158					
1998			300			440			50	790
	LEYTE-LUZON INTERCON.			LEYTE GEO B	440		GEN SANTOS DIESEL	50		
	MASINLOC 1 COAL	300								
1999			1,440			0			30	1,470
	SUAL 1&2 COAL	1,000		LEYTE-BOHOL INTERCON.			MINDANAO GEO 2/	30		
	CASECNAN HYDRO	140								
	MASINLOC 2 COAL	300								
2000			70			0			135	205
	BAKUN A/C HYDRO	70					MINDANAO SC-GT	135		
2001			300			0			65	365
	SAN PASCUAL COGEN	300		UPRATING LEYTE-CEBU T/L			MINDANAO C. CYCLE	65		
2002			1,200			40			200	1,440
	ILIJAN (GREENFIELDS)	1,200		MAMBUCAL GEO 2/	40		MINDANAO COAL	200		
2003			0			161			68	229
				TIMBABAN HYDRO	29		LEYTE-MINDANAO INTERC.			
				VILLASIGA HYDRO	32		TAGOLOAN HYDRO	68		
				PANAY BASELOAD	100					
2004			300			375			182	857
	KALAYAAN 3/4 PS	300		CEBU BASELOAD A	200		BUL.-BATANG HYDRO	132		
				BOHOL BASELOAD	100		MINDANAO PEAKING A	50		
				SAMAR COAL	75					
2005			345			300			368	1,013
	SAN ROQUE HYDRO	345		CEBU BASELOAD B	100		PULANGUI V	218		
				CEBU PEAKING	50		MINDANAO MID-RANGE A	150		
				PANAY PEAKING	100					
				BOHOLPEAKING	50					
2006			150			200			224	574
	PEAKING PLANT A	150		VISAYAS BASELOAD A	200		AGUS III	224		
2007			300			100			300	700
	PEAKING PLANT B	300		VISAYAS PEAKING A	100		MINDANAO MID-RANGE B	300		
2008			188			250			200	638
	MID-RANGE PLANT A	100		VISAYAS PEAKING B	250		MINDANAO MID-RANGE C	150		
	ILAGUEN B HYDRO	88					MINDANAO PEAKING B	50		
2009			600			200			150	950
	MID-RANGE PLANT B	600		VISAYAS PEAKING C	200		MINDANAO BASELOAD A	150		
2010			960			300			300	1,560
	AGBULU HYDRO	360		VISAYAS BASELOAD B	200		MINDANAO BASELOAD B	300		
	MID-RANGE PLANT C	600		VISAYAS PEAKING D	100					
TOTAL			6,173			2,524			2,372	11,069

1/ For main NPC Grids only; Excludes Small Islands

2/ No contract yet; Subject to PPA negotiation between NPC and PNOC-EDC

Peaking Plant - 15% Plant Factor and Below
Mid-Range Plant - 16 - 69% Plant Factor
Baseload Plant - 70% Plant Factor and Above