ISLAMIC REPUBLIC OF PAKISTAN
Water and Power Development Authority (WAPDA)

PREPARATORY SURVEY FOR MANGLA HYDRO POWER STATION REHABILITATION AND ENHANCEMENT PROJECT IN PAKISTAN

Final Report

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JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

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ABBREVIATIONS

AC	Alternating Current
ADB	Asia Development Bank
AEDB	Alternative Energy Development Board
AJK	Azad Jammu Kashmir
AVR	Automatic Voltage Regulator
BCL	Bamangwato Concessions Ltd.
BOD	Biochemical Oxygen Demand
BOP	Balance of Plant
BPS	Basic Pay Scales
BS	British Standard
C&M	Coordination & Monitoring
CDO	Central Design Office
CDWP	Central Development Working Party
CCC	Central Contract Cell
CDM	Clean Development Mechanism
CE	Chief Engineer
CER	Certified Emission Reductions
CIF	Cost, Freight and Insurance
CS	Consultancy Services
CM	Carrier Management
CPPA	Central Power Purchase Agency
CRBC	Chashma Right Bank Canal
CRR	Chief Resident Representative
CWE	China International Water and Electric Corporation
DC	Direct Current
DG	Director General
DISCO	Distribution Company
DSO	Dam Safety Organization
ECNEC	Executive Committee of National Council
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EOI	Expression of Interest
EPA	Environmental Protection Agency
EPD	Environmental Protection Department
FC	Foreign Currency
FESCO	Faisalabad Electrical Supply Company
FIRR	Financial Internal Rate of Return
FNPV	Financial Net Present Value
FS	Feasibility Study
FY	Fiscal Year starting on 1st July ending on 30th June in Pakistan
GBHP	Ghazi Barotha Hydropower Project
GCB	Gas Circuit Breaker
GENCO	Generation Company
GEPCO	Gujranwala Electrical Power Company
GHG	Greenhouse Gas
GM	General Manager
GOP	Government of Pakistan
HESCO	Hyderabad Electrical Supply Company
HR & A	Human Resources and Administration
IEE	Initial Environmental Examination
I&P Dept.	Irrigation and Power Development
I&P	Insurance & Pensions
IESCO	Islamabad Electrical Supply Company
IPB	Isolated Phase Bus
IPC	Interim Payment Certificate
IPP	Independent Power Producer
IRSA	Indus River System Authority
JBIC	Japan Bank for International Cooperation
JICA	Japan International Cooperation Agency
JPY	Japanese Yen
KESC	Karachi Electric Supply Company
KFW	Kreditanstalt für Wiederaufbau
L/A	Loan Agreement
LA & R	Land Acquisition and Resettlement
LC	Local Currency
LCC	Life Cycle Cost
L/C	Letter of Credit
LEA	Law Enforcing Agencies
LESCO	Lahore Electrical Supply Company
M&S	Monitoring and Surveillance
MOI	Ministry of Interior
MoWP	Ministry of Water and Power
MS	Medical Services
MEPCO	Multan Electrical Power Company
MTDF	Medium Term Development
NAP	Northern Area Project
NCS	Pakistan National Conservation Strategy
NEPRA	National Electric Power Regulatory Authority
NEQS	National Environmental Quality Standard
NJHEPC	Neelam Jehlum Hydro Power Project Company
NOC	Non Objection Certificate
NPCC	National Power Control Center
NPSEP	National Power System Expansion Plan
NPV	Net Present Value
NTDC	National Transmission and Dispatch Company
O&M	Operation and Maintenance
ODA	Official Development Assistance

O.E	Operation Engineer
OJT	On-the-job Training
P&D	Planning and Design
Pak-EPA	Pakistan Environmental Protection Agency
PAEC	Pakistan Atomic Energy Commission
PC	Personnel Computer
PC-1	Planning Commission Form 1
PC-2	Planning Commission Form 2
PCB	Poly Chlorinated Biphenyl
PEC	Pakistan Engineering Council
PEPC	Pakistan Environmental Protection Council
PEPA	Pakistan Environmental Protection Act
PEPCO	Pakistan Electric Power Company
PESCO	Peshawar Electrical Supply Company
PF	Power Factor
PLC	Programmable Logic Controller
PM	Project Manager
PMU	Project Management Unit
PMOs	Principle Medical Offices
PPIB	Private Power Infrastructure Board
PRS	Pakistan Rupees
PSO	Principal Staff Officer
QBS	Quality Based Selection
QCBS	Quality and Cost Based Selection
QESCO	Quetta Electrical Supply Company
RAP	Resettlement Action Plan
R.E.	Resident Engineer
RTD	Resistance Temperature Detectors
SCADA	Supervisory Control and Data Acquisition
SCF	Standard Conversion Factor
SSG	Speed Signal Generator
SOPs	Standard Operation Procedures
STEP	Special Terms for Economic Partnership
T&D	Transmission and Distribution lines
TESCO	Tribal area Electric Supply Company
TDP	Tarbela Dam Project
TDS	Total Dissolved Solid
TOR	Terms of Reference
TS	Technical Services
USD	United States Dollars
UPS	Uninterruptible Power Supply
VAT	Value Added Tax
WASC	WAPDA Administrated Staff College
WAPDA	Water and Power Development Authority
WEA	WAPDA Engineering Academy
WRPO	Water Resources Planning Organization
WSB	WAPDA Sports Board
WUA	Water User Association
WUC	Water Use Chares
XLPE	Cross-Linked Polyethylene Insulation

UNITS

Length

mm	Millimeter
cm	Centimeter
m	Meter
km	Kilometer
in	Inch (=25.4 mm)
ft	Feet (=305 mm)

Extent

cm^2	Square-centimeter
m^2	Square-meter
km^2	Square-kilometer
ha	Hectares
AF	Acre Feet (=1,233.5 m^3)

Volume

cm^3	Cubic-centimeter
m^3	Cubic-meter
Nm^3	Normal cubic-meters at 0°C and at 1 barometric pressure
gal	Gallon (=3.78 L)

Weight

g	Grams
kg	Kilograms
mg	Milligram
ton	Metric ton

Pressure

cft	Cubic feet sec (=0.0283 m^3/s)
psi	Pounds Per Square Inch (=0.0703 kg/cm^2)

Time

sec.	Seconds
min.	Minutes
hr.	Hours

Temperature

°C	Degree Celsius

Currency

USD	United State Dollars
JPY	Japanese Yen
PRs	Pakistan Rupees

Electric

V	Volts (Joule/coulomb)
kV	Kilo volts
A	Amperes (Coulomb/second)
kA	Kilo amperes
W	Watts (active power) (J/s: Joule/second)
kW	Kilo watts
MW	Mega watts
Wh	Watt-hours
kWh	Kilo watt-hours
MWh	Mega watt-hours
GWh	Giga watt-hours
VA	Volt-amperes (apparent power)
kVA	Kilo volt-amperes
MVA	Mega volt-amperes
BHP	British Horse Power (=745.7 W)

Speed of Turbine/Generator

min^{-1}

Frequency

Hz	hertz

FINAL REPORT
for
The Preparatory Survey for Mangla Hydro Power Station Rehabilitation and Enhancement Project in Pakistan

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CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 Background of the Survey

1.1.1 Present Situation of Power Supply and Demand

In the Islamic Republic of Pakistan (hereinafter referred to as “the country”), the power demand has increased at about 10.3% per annum in the past ten years along with the economic growth rate of the country. However, the power supply did not catch up with the power demand which continue to increase year after year. About 6,105 MW power supply-demand gap was recorded in the summer of 2011. Under these circumstances, the people of the country have to brace the planned power outage for about eight hours daily on the average. The planned power outage has caused difficulties in people’s lives and derailed the development of agriculture which depends on irrigation. The industries have also suffered great economic losses due to power outage causing unemployment in the country and high production cost of finished products. Therefore, the closing of the supply-demand gap in power sector is urgently required.

1.1.2 Political Measures on Energy Sector and Development Plan

The Vision 2030 and the Medium Term Development Framework (MTDF) 2005-2010, are the forefront policies of the country which formulated energy policies, namely, i. developing power sources through the use of local resources such as hydropower, coal, and natural gas, ii. promoting power generation through public private partnership, iii. promoting privatization of all power sectors, and iv. reducing power system losses. In addition, the government has announced its energy policy on power supply. It is envisioned that power supply will increase to 20,000 MW by 2020, where the 6,000 MW is expected to come from hydropower generation.

1.1.3 Aid Program by Government of Japan

According to the assistance program of the Government of Japan (GOJ) in February 2005, GOJ has set high-ranked targets in the aid program to the country for the "construction of a sustainable society and its progression". In addition, the GOJ has also cited three directionalities for the assistance strategy, which are: i. developing a strong market economy, ii. ensuring human security and human development, and iii. providing a well-balanced development of the community and the economy. The Mangla Hydro Power Station

Rehabilitation and Enhancement Project (hereinafter referred to as "the Project") [1] is positioned as part of expanding and upgrading the economic infrastructure in support to the activation of the market economy and reduction of poverty in pursuant to the directionalities mentioned above.

1.1.4 Objective of the Project

The Project is consistent with the above-mentioned strategies aimed to upgrade the energy sector and development plan of the country. The Survey Team will collect basic information related to the Project and analyze it for the formulation of a project under Japanese ODA Loan. The objective of the Project is to contribute in the improvement of the present power supply situation in the country through the rehabilitation and enhancement of aged power generating equipment like the water turbines, generators, and ancillary equipment in the Mangla Hydro Power Station.

1.2 Objective of the Survey

1.2.1 Objective of the Survey

The Survey aimed at enhancing the maturity of the Project appropriate for Japanese ODA Loan financing and searching for the possibility of applying the Special Terms for Economic Partnership (STEP) condition to the Project.

The Survey was carried out as a supplemental survey to the feasibility study (hereinafter referred to as "the F/S") conducted by Water and Power Development Authority of the country (hereinafter referred to as "WAPDA") in June to December 2011.


Source: Prepared by the Survey Team

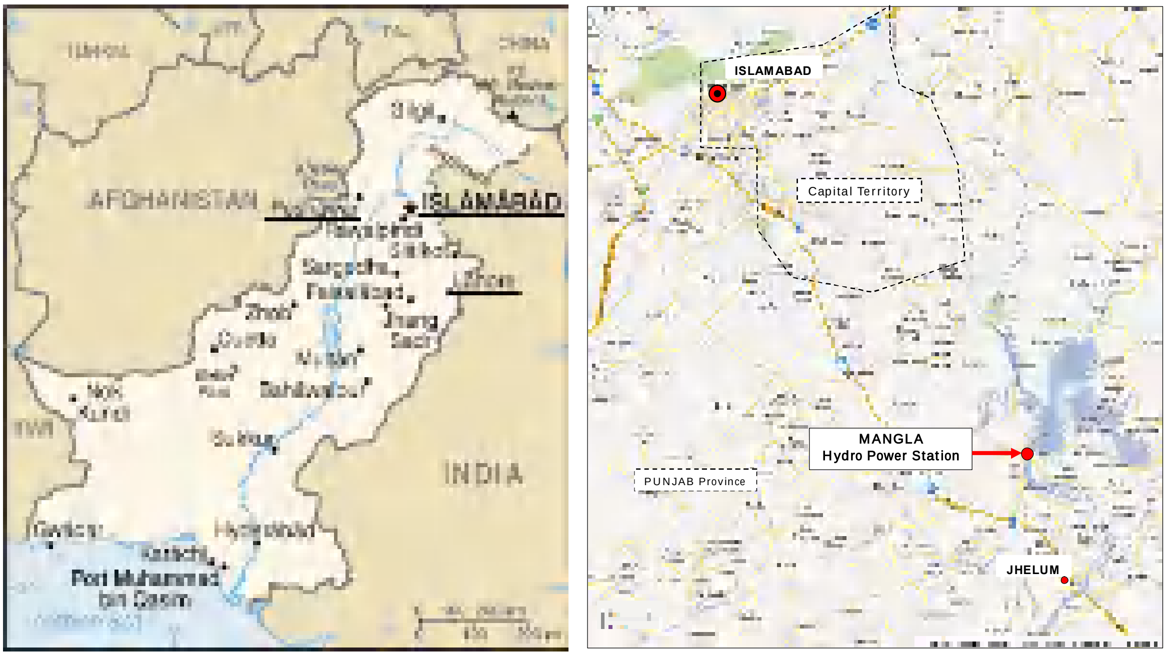
Photo 1-1 Mangla Hydro Power Station and Guest House

[1] The Project is recognized by the Water and Power Development Authority (WAPDA) and the Government of Pakistan as the "Up-gradation and Refurbishment of Generating Units of Mangla Power Station".

1.2.2 Objective Area of the Survey

The Mangla Hydro Power Station is located in Azad Jammu Kashmir, Pakistan. The power station and related dam are situated in a place called Mangla on the Jhelum River, lying in Azad Jammu and Kashmir (District Mirpur), located about 30 km upstream of Jhelum City (120 km from Capital Islamabad).

The related reservoir of the dam lies in Azad Jammu and Kashmir (AJK) and the Punjab Province (Districts Jhelum and Rawalpindi). The boundary between AJK and Punjab passes through the center of the Jhelum River. The power station and dam stand in AJK side, which lies on the left bank side of Jhelum River, and the Punjab side is located on the right bank of the river. A fairly good network of paved roads exists in and around the project area.



Source: Central Intelligence Agency

Source: Google

Figure 1-1 Location Map

1.2.3 Scope of Work of the Preparatory Survey

(1) Field Site Survey

1) To identify the current status and issues of the power sector in the country;
2) To confirm the current situation of Mangla Hydro Power Station and identify the issues concerned;
3) To confirm the necessity of the Project; and
4) To review and confirm the structure of the Project.

(2) Estimation of the Project Costs

1) To review and estimate the total project cost including financial plan with funding arrangements;
2) To review and assess the future operation and maintenance (O&M) costs; and
3) To propose the estimation of annual fund requirements under the Japanese ODA Loan scheme.

(3) Composition of the Project Components

1) To compose several project components;
2) To propose an implementation schedule;
3) To suggest a time-bound action plan; and
4) To suggest the procurement packages and technical specifications to meet the STEP conditions.

(4) Elaboration of Project Implementation and O&M Plan

1) To propose the institutional framework for the project implementation, including procurement and disbursement.
2) To propose the institutional framework for O&M.

(5) Review of Environmental and Social Consideration

1) To review and confirm the environmental and social considerations based on "JICA Guidelines for Environmental and Social Considerations".
2) To conduct a climate change mitigation analysis to identify/collect quantitative data needed to compute greenhouse gas (GHG) emissions and to estimate the reduction in emission of GHG of the Project.

(6) Confirmation of the Project Effect

1) To propose the operation and effect indicators such as baseline data and target value method of data acquisition.
2) To calculate the financial internal rate of return (FIRR) and the economic internal rate of return (EIRR).

(7) Draft of the Project Implementation Program and Project Status Report (PSR)

1.3 Basic Concept

1.3.1 Project Planning Based on the F/S Report Prepared by WAPDA

The Survey was stated as a supplemental to the F/S carried by WAPDA in June to December 2011. The work procedure of the Survey for project planning is as follows.

(1) Step 1

The Survey Team studied the outline of the Project based on the F/S report prepared by WAPDA and the relevant existing documents owned by WAPDA.

(2) Step 2

The Survey Team collected the operation records, accident/malfunction records, and maintenance records for the Mangla Hydro Power Station from WAPDA, and carried out site investigation to assess the degree of deterioration of the power generating equipment through visual check and by simple inspection, without stopping the operation of the generating equipment.

(3) Step 3

The Survey Team listed all of the items of power generating equipment which were evaluated for rehabilitation and enhancement. Based on the results of Step 1 and Step 2 mentioned above, the listed items of power generating equipment were reviewed, keeping in view the following points:

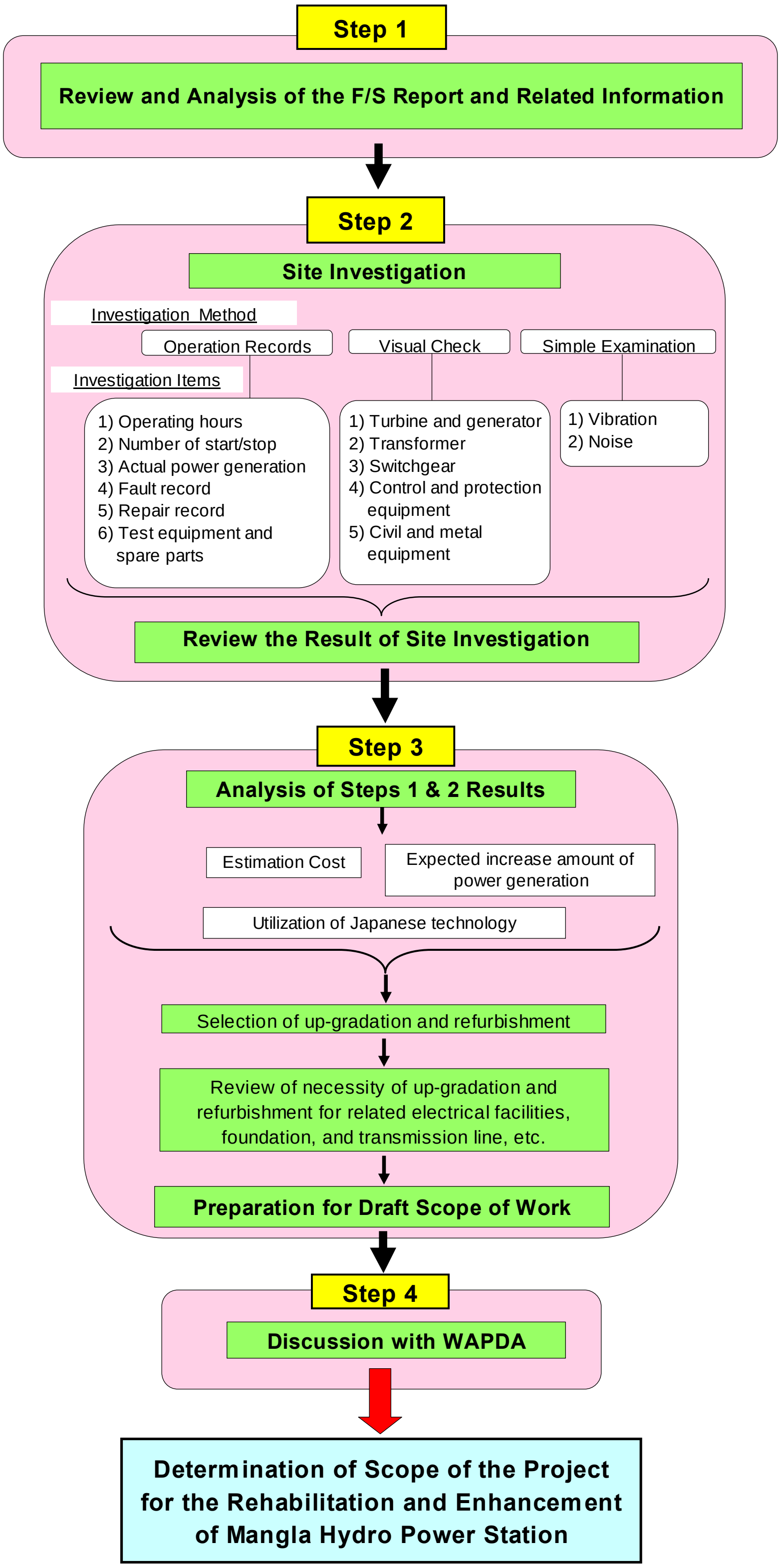
1) Expected increase in energy through the rehabilitation and enhancement project;
2) Estimated project cost; and
3) Possibility of utilization of Japanese technology.

The Survey Team reviewed the necessity of the rehabilitation or enhancement of other facilities such as concrete foundations of the equipment, substation and switching station inside power station, and transmission lines along with the existing power generating facilities and equipment, which are expected to increase the supply of energy.

The Survey Team made a draft scope of work of the project based on the result of the reviews.

(4) Step 4

The Survey Team discussed the draft scope of work of the project with WAPDA and later finalized it.



Source: Prepared by the Survey Team

Figure 1-2 Work Procedure of the Survey

1.3.2 Project Planning aiming for STEP Project Utilizing Japanese Technology

The Survey was implemented aiming to formulate the Project for STEP yen loans. The guideline published by the Ministry of Foreign Affairs of Japan stipulates the following conditions in applying for STEP yen loans:

(1) Procurement Condition

The borrowing country should procure the equipment manufactured in Japan which cost more than 30% of the total contract amount of the project.

(2) Contractor's Condition

The main contractor of the project should be a Japanese firm incorporated and registered under the laws of Japan. In case of a consortium, it should consists of a Japanese firm and a foreign firm, where the Japanese firm shall be the consortium leader.

Adding to the above, the condition cited below is applied to the Project and other project components such as hydropower generation, dam, tunnel, port and harbor, and sewer.

As for the portion of the project which is expected to utilize the Japanese superior technology during construction, the service cost shall be included in the calculation of Japanese procurement portion as well as the equipment cost.

1.3.3 Latest Status of the F/S

The F/S for the Project on the refurbishment and up-gradation of the Mangla Power Station was conducted by the MWH and NESPAK (Consultants JV) as per advice of WAPDA. The F/S was completed in December 2011. According to the information of WAPDA, starting of June 2012, the present status of the Project is as follows:

1) PC-I for up-gradation and refurbishment of generating units of Mangla Power Station has been preparing by WAPDA.
2) WAPDA has requested the Consultants JV to prepare the detailed design and tender documents for up-gradation and refurbishment for all 10 units. The works of detailed design (tender stage) of turbine, generator, excitation system, governor, and instrumentation are to be completed on 31 August 2012. The works of detailed design of power station cranes and lifting devices, intake, tunnels, bifurcations, draft tube gates, turbine inlet valves, and cooling water system are to be completed by the end of December 2012.

CHAPTER 2

BASIC DATA AND INFORMATION

CHAPTER 2 BASIC DATA AND INFORMATION

2.1 Power Sector's Issues

2.1.1 Annual Power Supply and Demand Gap

As of March 2012, the total installed capacity of Pakistan through all resources was around 21,527 MW. However, rapid demand growth and insufficient generation development created a gap between supply and demand resulting to significant load shedding.

Table 2-1 below shows the level of power shortage in recent years from zero power shortage in 2003 to almost 23% in 2010.

Table 2-1 Power Shortage Level between National Sale and National Demand

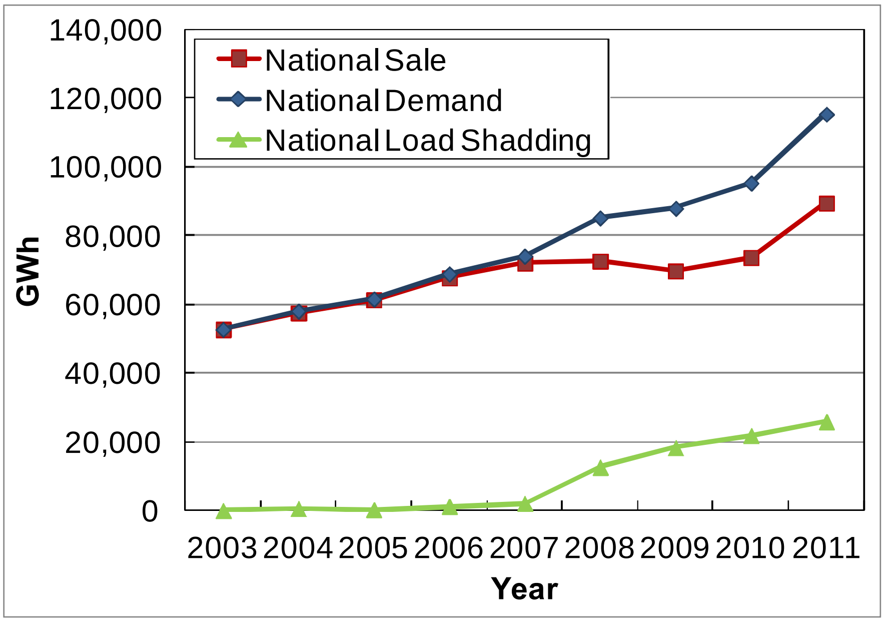
Year	National Sale[1] [GWh]	National Demand [GWh]	National Power Shortage [GWh]	Power Shortage Rate [%]
2003	52,661	52.661	-	0.0
2004	57,467	57,986	520	0.9
2005	61,247	61,512	265	0.4
2006	67,608	68,815	1,208	1.8
2007	71,947	73,982	2,040	2.8
2008	72,518	85,096	12,578	14.8
2009	69,668	87,890	18,222	20.7
2010	73,595	95,238	21,821	22.9
2011	89,402	115,247	25,845	22.4

Source: Power System Statistic 35th Edition and National Power Control Center

The annual power demand and supply gap which started in 2004 created a slight increase up to 2.8% in 2007. The gap then abruptly increased to 14.8% in 2008 and further increased to 22.9% in 2010.

The trend graph for the national sale and national demand are shown in Figure 2-1.

[1] Peak generation power is a maximum generating power on hourly average in the year.



Source: Prepared by the Survey Team based on the data in Table 2-1

Figure 2-1 Trend Graph for National Sale and National Demand

2.1.2 Peak Generation and Peak Demand Gap

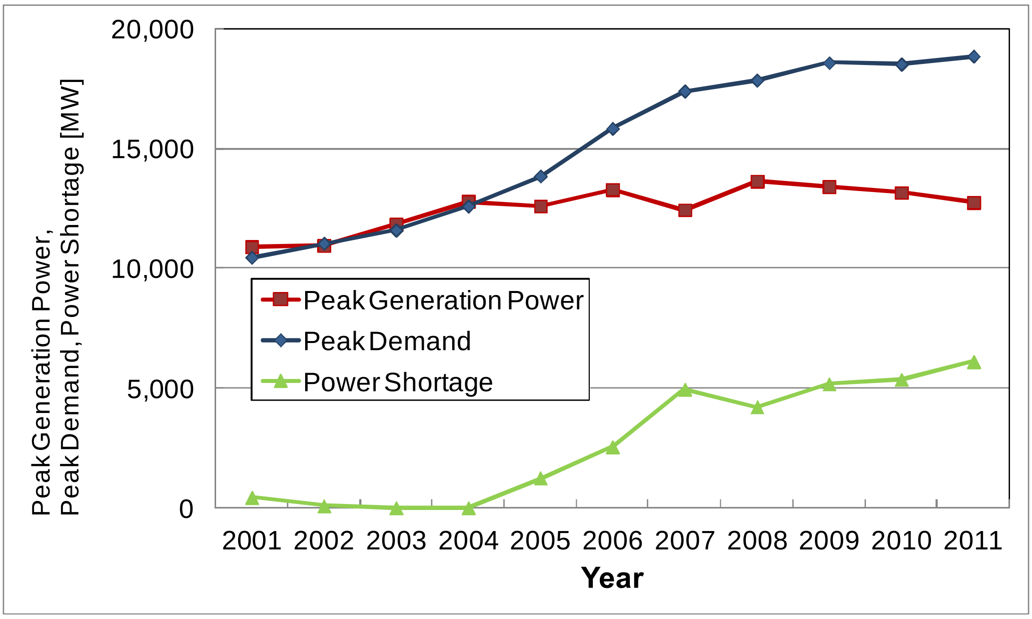
The peak demand increased rapidly at 62.6% in eight years from 2003 to 2011. On the contrary, peak generation power increased only at 7.8%, which caused a huge gap between generation and demand as shown in Table 2-2 and Figure 2-2.

During the survey conducted in May 2012, the scheduled outage of power was for 12 hours in urban areas and 18 hours in rural areas.

Table 2-2 Power Shortage Levels between Peak Generation Power and Peak Demand

Year	Peak Generation Power [MW]	Peak Demand [MW]	Power Shortage [MW]	Power Shortage Rate [%]
2001	10,894	10,459	435	4.2
2002	10,958	11,044	86	0.8
2003	11,834	11,598	-236	-2.0
2004	12,792	12,595	-197	-1.6
2005	12,600	13,847	1,247	9.0
2006	13,292	15,838	2,546	16.1
2007	12,442	17,398	4,956	28.5
2008	13,637	17,852	4,215	23.6
2009	13,413	18,583	5,170	27.8
2010	13,163	18,521	5,358	28.9
2011	12,755	18,860	6,105	32.4

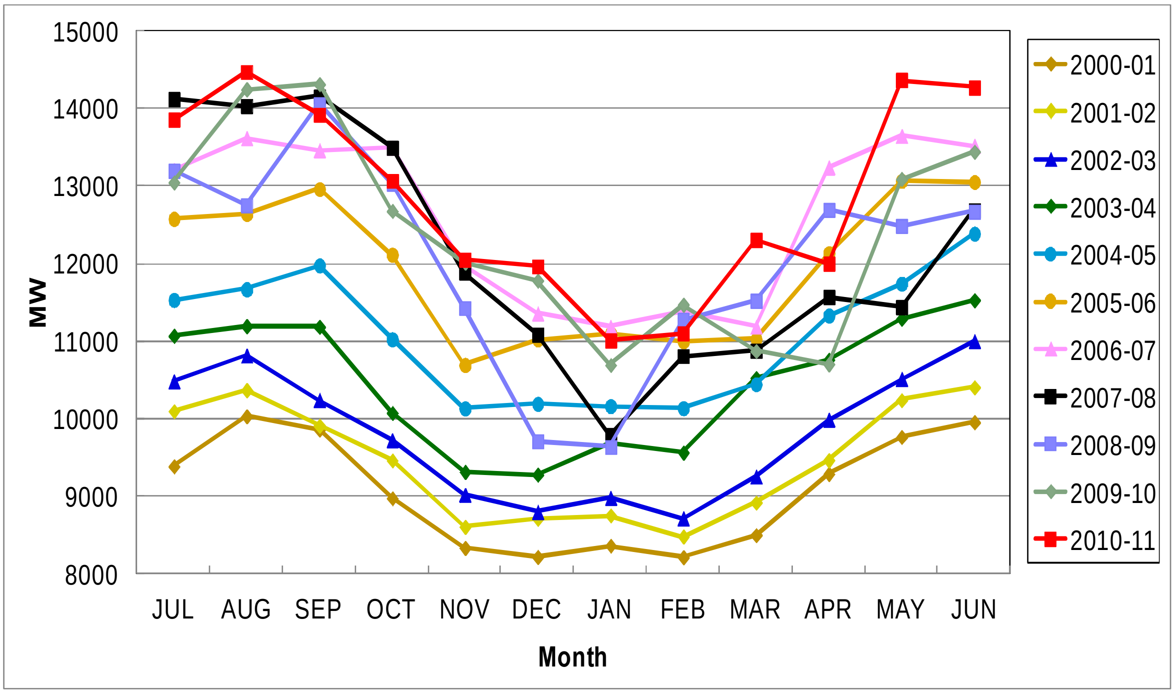
Source: Presentation Documents for Participants in the 10th SMC of National Institute of Management, Karachi



Source: Prepared by the Survey Team based on the data in Table 2-2

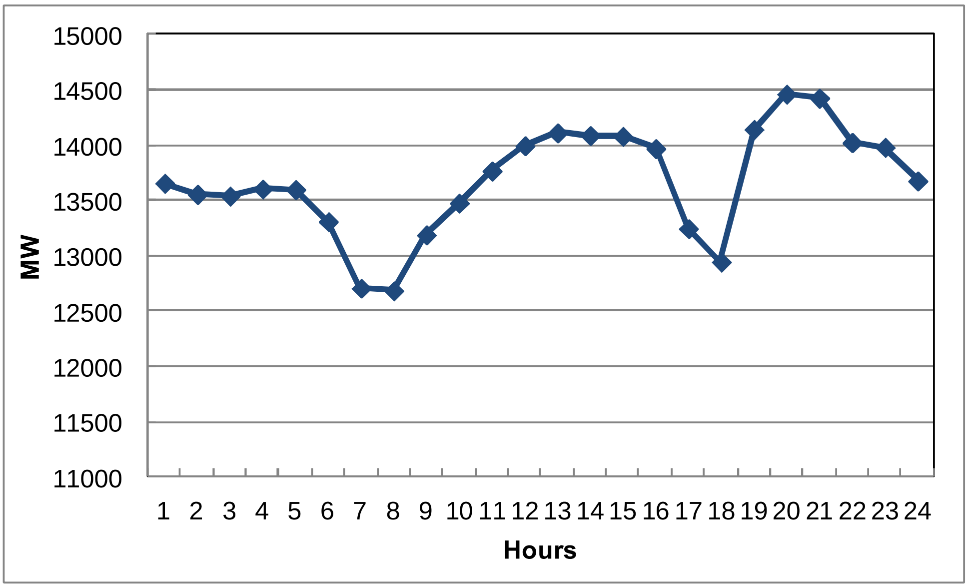
Figure 2-2 Trend in the Peak Generation Power and Peak Demand

The monthly peak demand for the ten-year period from 2000 to 2010 and the load curve peak demand on August 30, 2011, which recorded the highest peak demand in 2011, are shown in Figure 2-3 and Figure 2-4 respectively.



Source: NTDC Yearly System Operation Data, 2012

Figure 2-3 Monthly Peak Demand for the Past 10 Years



Source: NTDC Yearly System Operation Data, 2012

Figure 2-4 Load Curve of Peak Demand on August 30, 2011

2.2 National Power System Expansion Plan

2.2.1 Objective of National Power System Expansion Plan (NPSEP)

In order to address this gap, the National Transmission and Dispatch Company (NTDC) of Pakistan developed a National Power System Expansion Plan (NPSEP).

The objective is to provide a plan for the development of hydro-electric, thermal, nuclear, and renewable energy resources to meet the expected load up to the year 2030. Given the chronic and ever increasing power shortage, the need for an expansion plan was recognized as an urgent matter. This plan was prepared during the period from December 1, 2010 to May 31, 2011.

2.2.2 Scope of National Power System Expansion Plan (NPSEP)

The scope of the NPSEP is to determine new generation facilities and transmission reinforcements required to meet future load growth using the latest available data. Based on the review of the load forecast (prepared by NTDC and reviewed by SNC-Lavalin), the least cost generation expansion plan was prepared, taking into consideration the government policies, environmental considerations, and fuel constraints. An indicative transmission plan to evacuate power was developed using the generation expansion plan in 2030 and the network reinforcement requirements for the distribution company (DISCO) in 2020. These generation and transmission plans were the key inputs in developing the financial plan and the annual revenue requirements to build and operate the system. The investments required by each

DISCO to effectively reduce losses and optimize their systems were also calculated but did not form part of the overall investment requirements in the NPSEP.

2.3 Generation Planning

2.3.1 Strategic Consideration of National Power System Expansion Plan (NPSEP)

In order to develop an effective generation plan to meet the power demand of the country, NPSEP was prepared for both strategic considerations and constraints faced by Pakistan.

Table 2-3 Policy Statements

Title of Policy	Statement of Policy
Policy for Power Generation Projects Year 2002	- To provide sufficient capacity for power generation at the least cost, and to avoid capacity shortfalls. - To encourage and ensure exploitation of indigenous resources, which include **renewable energy** resources. - To attune to safeguarding the environment.
The Natural Gas Allocation and Management Policy 2005	- Power plants would get gas supply after meeting the requirements of domestic, commercial, fertilizer, and industrial sectors.
The Policy for Development of Renewable Energy for Power Generation 2006	- Increase the deployment of renewable energy (defined as wind, solar and small hydro –less than 50 MW) technologies so that renewable energy provides a minimum of 9,700 MW by 2030.

Source: National Power System Expansion Plan 2011–2030 Main Report

Table 2-4 Constraint and Solutions

	Description
Constraint	- Pakistan faces several constraints as it strives to meet its current and expected power demand. Perhaps the most significant constraint is the scarcity of capital, which has affected not only the power sector but also the development of other infrastructure critical to power sector development.
Short-term Solution	- In the short-term, the main focus has been in the reduction of load shedding and its focus has often taken the attention away from an optimum long-term growth strategy. It is accepted that it will probably take several years for the target reliability level of 1% loss of load probability to be achieved. - The short-term focus is the rehabilitation of existing plants, on demand side management, and implementation of fast-track projects to reduce load shedding.
Long-term Solution	- It is assumed that the country's policy will continue to focus on the

	development of indigenous resources, particularly Tharparkar coal and hydro projects, as well as increasing the use of renewable resources and keeping power tariffs at affordable level. - Also barring major gas discoveries, the country's policy of allocating gas will remain unchanged and future gas based power generation will be based on imported gas or LNG.

Source: National Power System Expansion Plan 2011–2030 Main Report

2.3.2 Existing Installed Capacity of Power Generation Plants

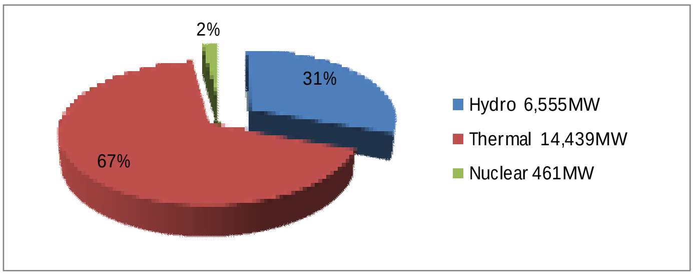
The total installed capacity of existing hydro and thermal generation units in the country including the Karachi Electric Supply Company (KESC) system and independent power producers (IPPs) was about 21,527 MW, as of March 2012. However, due to seasonal variation of water inflow for hydro plants and the capacity de-rating for thermal units, the dependable capacity for the systems was estimated at 15,259 MW during winter. The installed capacity of hydro plants was about 31%, thermal capacity was 67% and nuclear capacity was less than 2%. The total installed capacity from IPPs was about 38% of the total installed capacity. The breakdown is shown in Table 2-5 and Figure 2-3.

Table 2-5 Summary of Existing Power Plants

Type of Plant	Owner	Installed Capacity[2] (MW) A	Capacity in Winter (MW) B	Ratio B / A
Hydro Plant	WAPDA	6,516	2,308	35.4%
	IPPs	111	111	100%
	Sub-Total Hydro	*6,627*	*2,419*	*(36.5%)*
Thermal Plant	-	-	De-rated Capacity (MW) B	-
	PEPCO	4,829	3,580	74.1%
	IPPs for PEPCO	7,475	6,909	92.4%
	Rental for PEPCO	113	113	100%
	KESCO	1,655	1,463	88,4%
	IPPs for KESCO	367	353	96.2%
	Sub-Total Thermal	*14,439*	*12,418*	*(86.0%)*
Nuclear Plant	for PEPCO	325	300	92.3%
	for KESC	136	122	89.7%
	Sub-Total Nuclear	*461*	*422*	*(91.5%)*
	Total	**21,527**	**15,259**	**70.9%**

Source: National Power System Expansion Plan 2011-2030

[2] The installed capacity in Table 2-13 is the total MW of operational generating plants in the country, as of March 2012.



Source: National Power System Expansion Plan 2011-2030

Figure 2-5 Installed Capacity of Power Plants

2.3.3 Existing Hydropower Plants

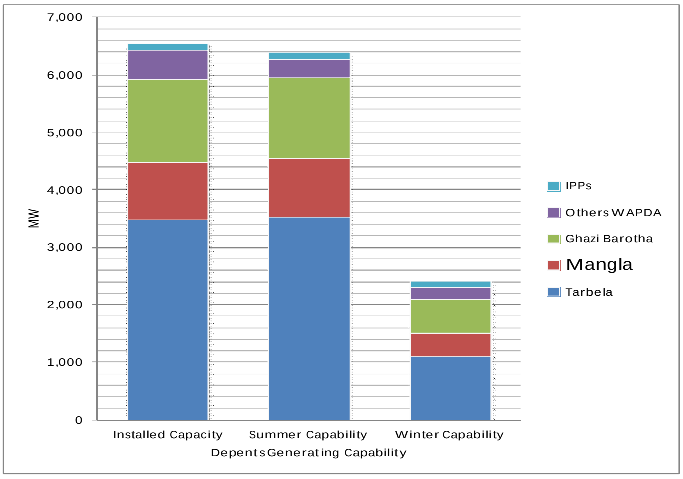
Existing hydropower plants (HPP), as of March 2012, are listed in Table 2-6. The installed capacity including IPP's hydropower stations was 6627 MW, as of March 2012 . However, due to the seasonal variation of inflow, the capability of generation during summer and winter seasons were 6,445 MW or 97% of installed capacity, and 2419 MW or 37% of installed capacity, respectively.

Table 2-6 Summary of Existing Hydropower Plants

Owner	No.	Name of Power Station	Installed Capacity (MW)	Capability (MW)		
				Summer	Winter	Win/Sum
WAPDA	1	Tarbela	3,478	3,521	1,101	31.3%
	2	Ghazi Barotha	1,450	1,405	580	41.3%
	3	Mangla	1,000	1,014	409	40.3%
	4	Warsak	234	171	145	84.8%
	5	Chashma Low Head	184	91	48	52.7%
	6	Khan Khwar *1	72	68	5	7.4%
	7	Small Hydros	89	64	20	31.3 %
		Sub-Total WAPDA	6,516	6,334	2,308	*36.4%*
IPPs	8	Jagran	30	30	30	100%
	9	Malakand-III	81	81	81	*100%*
		Sub-Total IPP	111	*111*	*111*	*100%*
Total			6,627	**6,445**	**2,419**	**37.5%**

Source: National Power System Expansion Plan 2011-2030/ *1 Khan Khwar HPP, which started operation in November 2010, was added by the Survey Team based on the information given by WAPDA.

At present, Mangla HPP is the third largest hydropower station in Pakistan, which contributes 15.1% of the hydropower installed capacity, and produces 15.7% and 16.9% of generating capability during summer and winter respectively, as illustrated in Figure 2-4.



Source: National Power System Expansion Plan 2011-2030

*1 Khan Khwar HPP, which started operation in November 2010, was added by the Survey Team based on the information given by WAPDA

Figure 2-6 Role of Mangla HPP in Existing Hydro Plants

Source: Presentation Documents on the Role of Hydropower in Addressing the Energy Crisis, WAPDA

Photo 2-1 Tarbela Dam Powerhouse

Source: Presentation Documents on the Role of Hydropower in Addressing the Energy Crisis, WAPDA

Photo 2-2 Ghazi Barotha Dam Powerhouse and Spillway

2.3.4 Future Planning of Hydropower Plants to be commissioned by 2020

"Vision Statement for Accelerated Development of Pakistan's Power Sector for Sustained Economic Growth" at the Energy Summit held at Islamabad in May 2010. The "Vision" includes a "20,000 MW addition by 2020 programme" which targets installation of 20,000 MW of capacity in addition to the presently installed capacity. The "20,000 MW addition by 2020 programme" comprises 6,000 MW of hydro, 6,000 MW of coal (mainly by domestic production), 5,000 MW of gas, 1,000 MW of naphtha and other indigenous fuels and the remaining 2,000 MW from alternative energy resources, specifically solar and wind.

The future planning of hydropower plants to be commissioned by 2020 is shown in Table 2-7.

It is expected to be commissioned 18 hydropower plants (6,654 MW in total) by 2020.

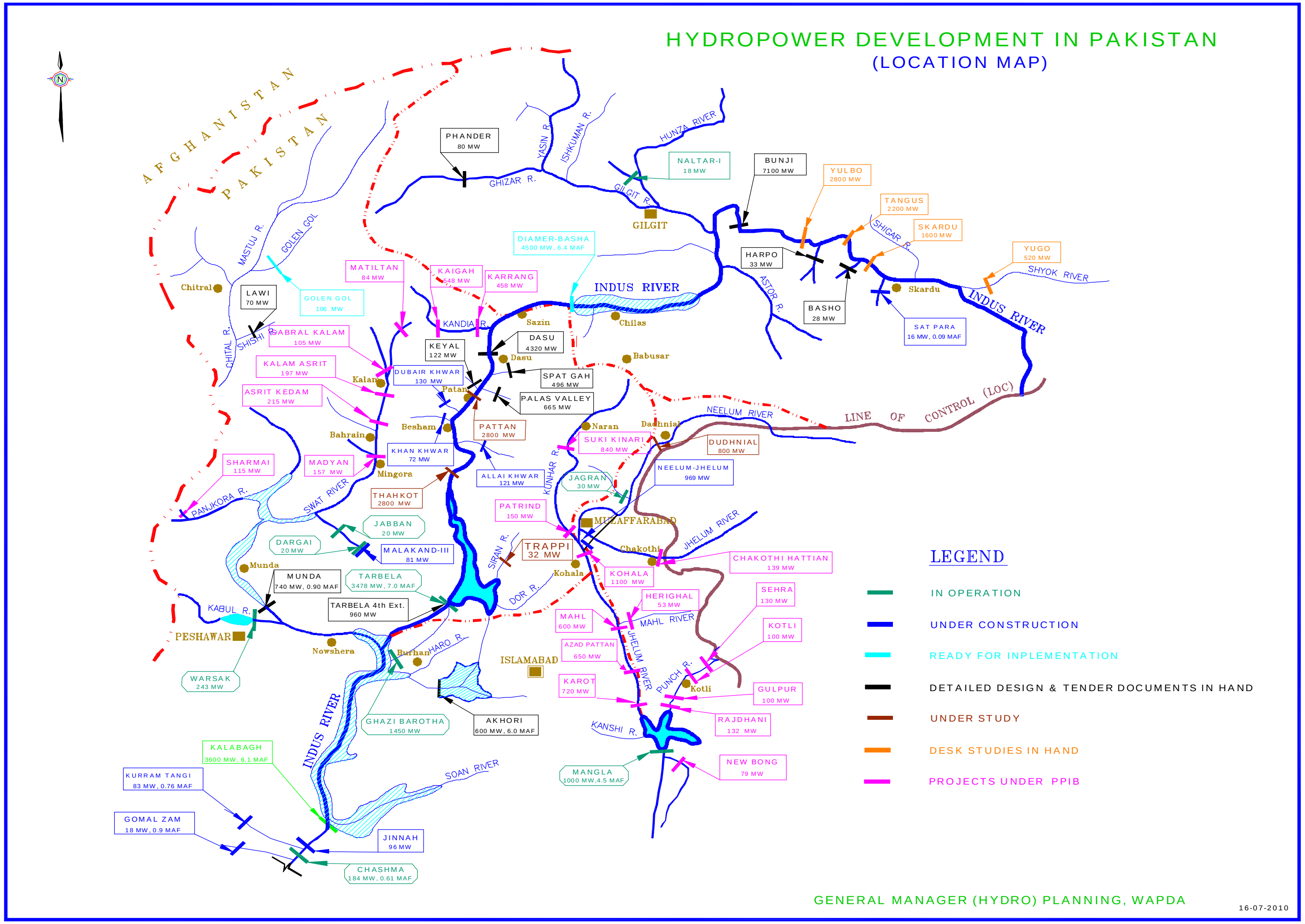
Table 2-7 Future Planning of Hydropower Plants by 2020

Owner	Components	Installed Capacity (MW)	Expected Commissioning Year
WAPDA	Mangla Dam Raising	*644 (GWh)*	-
	Allai Khwar	121	Oct. 2012
	Duber Khwar	130	Mar. 2013
	Jinnah Barrage	96	Dec. 2012
	Satpara Dama	17.4	Feb. 2013
	Gomal Zam	17.4	Jan. 2013
	Neelum Jhelum	969	Oct. 2015
	Kurram Tangi	83	Dec. 2015
	Golen Gol Chitral	106	Feb. 2015
	Kurram Tangi – Fata	84	2015
	Tarbela 4th Extension	1,410	2017
	Kohala AJK	1,100	2020
	Dasu	2,160	2020
	Keyal Khwar	122	2018
	Phandar	80	2018
	Basho	40	2017
	Harpo	34.5	2017
	Sub-Total	*1,432*	-
IPP	New Bong Escape	84	2013-14
Total		**6,654**	-

Source: Hydel Development Department of WAPDA

The Mangla Hydro Power Station is also listed in the Committed Hydro Plant remarked with installed capacity not increased, annual generating power of 644 GWh being increased due to the increased water storage capacity by the dam raising.

The preparatory survey's aim was not only for rehabilitation but also for the enhancement of the installed capacity. Figure 2-7 presents the hydropower development in Pakistan.



Source: Presentation Documents on the Role of Hydropower in Addressing the Energy Crisis, WAPDA

Figure 2-7 Hydropower Development in Pakistan

2.4 Power Sector Environment

2.4.1 Current Structure of Power Sector

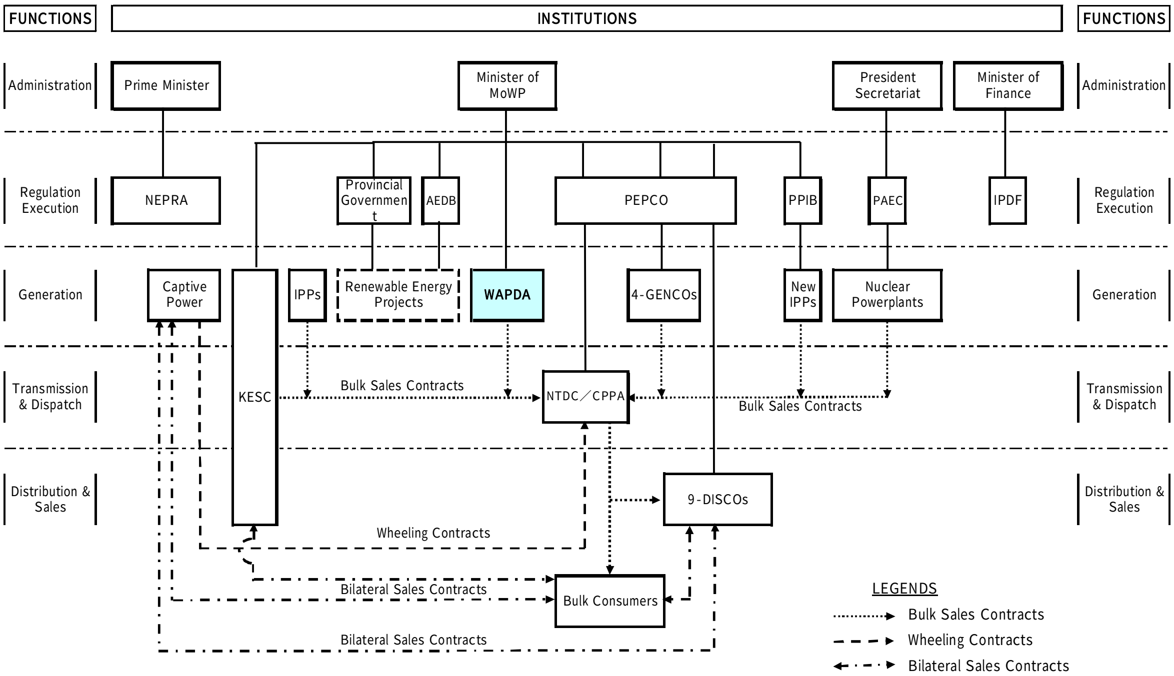
Formerly, the power sector in Pakistan was primarily managed by WAPDA, which was established in 1958. WAPDA, which has been split into two companies in 1998, provided services throughout the country except for Karachi and its adjoining areas. These areas were served by the Karachi Electric Supply Company (KESC), which was established in 1913. In addition, the Pakistan Atomic Energy Commission (PAEC) established in 1956, has been responsible for all aspects of nuclear power generation working under the President Secretariat.

In 1998, the Government of Pakistan (GOP) established the National Electricity Regulatory Authority (NEPRA) to regulate all aspects of the power sector, including tariff-determination. Later, the GOP divided WAPDA into a new WAPDA and the Pakistan Electric Power Company (PEPCO). The new WAPDA is responsible for developing and operating water resources, including hydro-power. While PEPCO is responsible for the operation and maintenance of public-sector thermal plants and transmission and distribution network. PEPCO takes care of and provided technical support to its 14 corporate entities, including four thermal power generation companies (GENCOs), nine distribution companies (DISCOs) and the National Transmission and Power Dispatch Company (NTDC), which controls power transmission from all generating stations including independent power producers (IPPs).

PEPCO also acts as the Central Power Purchase Agency (CPPA), the country's sole electricity procurement agency.

In addition, the GOP established the Private Power and Infrastructure Board (PPIB) in 1994 to provide a one-stop service to power-sector investors interested in developing power generation projects and related infrastructure. The GOP also established the Alternative Energy Development Board (AEDB) in 2003 as an autonomous body to promote and facilitate the exploitation of renewable energy resources in Pakistan to achieve government targets for renewable energy development.

The schematic diagram of the power sector in the country is shown in Figure 2-8.



Source: Modified by the Survey Team based on WAPDA's information

Figure 2-8 Schematic Diagram of Power Sector in Pakistan

2.4.2 Status of WAPDA in the Government

WAPDA was established through a parliamentary enactment in February 1958 for an integrated and rapid development and maintenance of water and power resources of the country. Since October 2007, WAPDA has been divided into two distinct entities, i.e., WAPDA and PEPCO. WAPDA was made responsible for water and hydropower development, whereas PEPCO was vested with the responsibility of thermal power generation, transmission, distribution, and billing.

WAPDA is now fully responsible for the development, operation, and maintenance of hydropower and water sector projects.

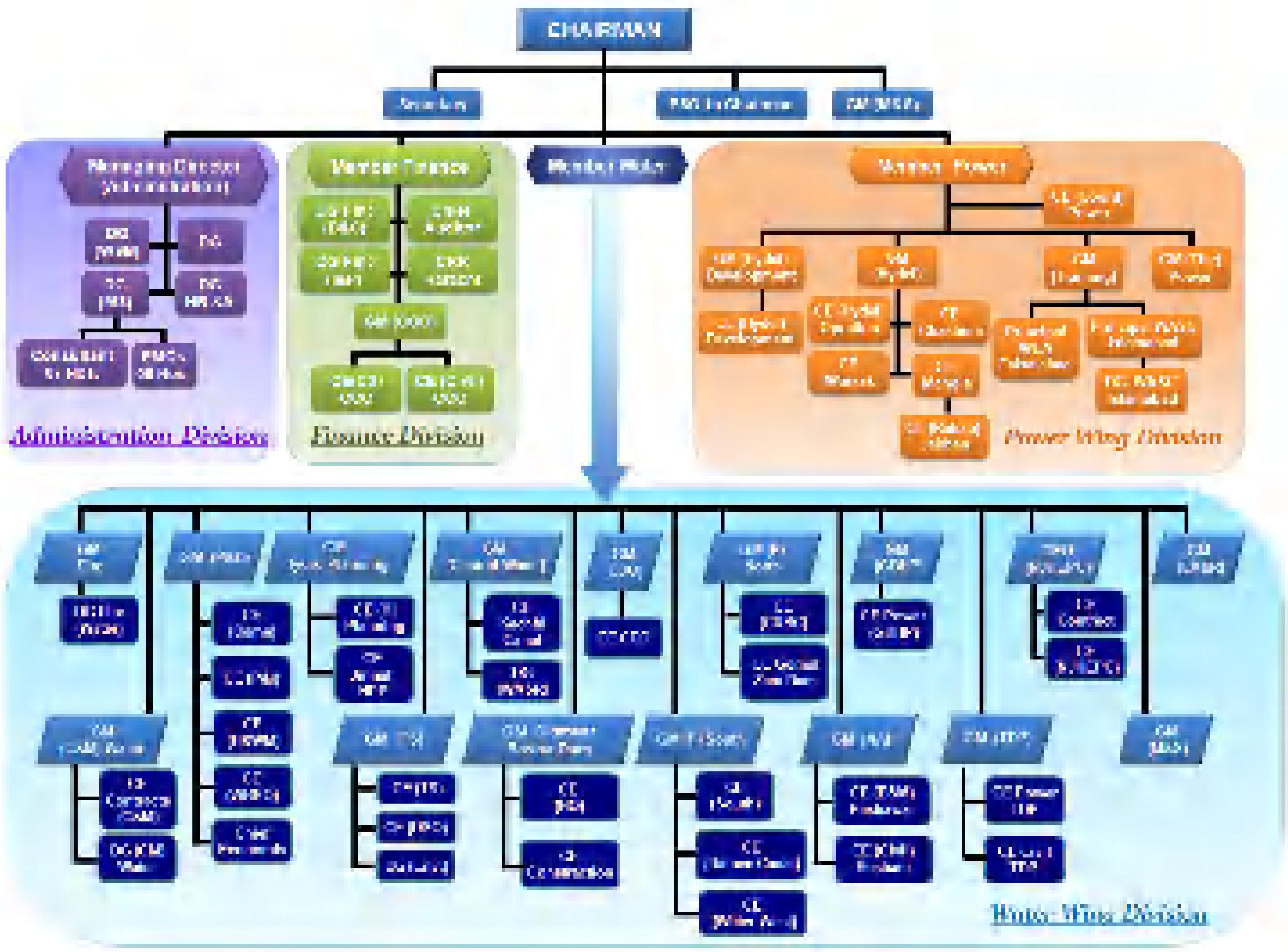
2.4.3 Organization of WAPDA

WAPDA was established with the following main charter of duties:

1) Integrated and rapid development and maintenance of water and power resources of the country;
2) Control of soil salinity and water logging to rehabilitate the affected land in order to strengthen the predominantly agricultural economy of the country;
3) Development of irrigation, water supply, and drainage projects;
4) Flood control;
5) Inland navigation.

6) Development of new hydropower projects in the public sector;
7) Operation and maintenance of hydropower stations; and
8) Refurbishment/rehabilitation of old hydro units.

The organizational structure of WAPDA is shown in Figure 2-9 below.



Source: Prepared by the Survey Team

Figure 2-9 Organizational Structure of WAPDA

WAPDA consists of four divisions, i.e., Administration, Finance, Water Wing, and Power Wing. The main roles of each division are described below:

<u>Administration Division</u>

The Administration Division is run by the managing director under direct control of the chairman. The managing director of the Administration Division is responsible for the following activities:

1) The director general of the WAPDA Sports Boards looks after the affairs of different

sports boards of WAPDA for better sports activities among WAPDA employees and with other organizations.

2) The director general of Services looks after all service matters of the WAPDA employees including service structure of different employees and the implementation rules. It also keeps records and takes care of all properties belonging to WAPDA.

3) Overall medical services provided to the employees of WAPDA are under the director general of Medical Services.

4) The director general of Human Resources and Administration looks after the human resources activities, dealing establishment matters (BPS[3]-1-20), handling of deputation cases, and coordination between WAPDA and the Ministry of Water and Power.

Finance Division

The member finance is responsible for the functioning of the departments of Finance, Internal Audit, and Budget and Accounts headed by the chief auditor of the Internal Audit and the director general finance of B&C. He also exercises administrative control over the general manager of the Central Contracts Cell, director general of Taxes and director public relations.

The managing director of Administration is vested with the responsibility of overall administration and services.

The secretary of WAPDA, in addition to its role in looking after the day-to-day affairs of the Secretariat, prepares minutes of the authority's meetings, maintains records of its decisions, issues directives, monitors and implements authority's decisions, and coordinates among the different wings.

Water Wing Division

The Water Wing Division headed by member water is responsible for the following activities:

1) Execution of surface and sub-surface water projects;

2) Reconnaissance survey, preparation of feasibility reports, detail designs, tender documents, bidding process, supervision and implementation of the water resource projects including multipurpose hydropower projects, interprovincial canals, and reservoirs for irrigation and water supplies;

3) Operation of reservoirs and maintenance of dams and their associated structures;

4) Control of water logging and soil salinity to rehabilitate the affected land (salinity control and reclamation projects);

5) Collection/maintenance of hydrological data for utilization in future projects as well as for

[3] Basic Pay Scale (BPS), all WAPDA's staffs are placed in BPS ranging from 1 to 22 depending on the educational background and work experience.

operation; and

6) Flood control and inland navigation.

Power Wing Division

The Power Wing Division headed by member power is responsible for the following activities:

1) Refurbishment/rehabilitation of old hydropower stations.
2) Preparation of feasibility reports, detailed designs, tender documents, bidding documents, award of contracts, supervision and implementation of hydropower stations including switch yards in collaboration with Water Wing.
3) Operation and maintenance of all hydropower stations.
4) Procurement of spare parts for all hydropower stations in operation.
5) Maintenance of operational data of all hydropower stations.
6) Provision of necessary budget/funds for new/existing hydropower stations.
7) Sale of hydel energy generated to NTDC/CPPA and related affairs.

Training of all existing and newly recruited officers of Power Wing, Water Wing and Finance Divisions. The manpower of each division of WAPDA, as of June 2012, is shown in Table 2-8.

Table 2-8 Manpower of WAPDA

No.	Position	Division				Total
		Administration	Finance	Water Wing	Power Wing	
1	Managerial Staff (BPS 18 to 21)	256	48	132	42	478
2	Sr. Engineers/Sr. Scientific Officer (BPS-18)	-	-	339	61	400
3	Technical Staff	-	-	1,037	1,793	2,830
4	Non-Technical Staff (BPS 1 to 17)	2,963	891	8.308	2,324	14,486
Total		3,219	939	9,816	4,220	18,194

Source: Prepared by the Survey Team

2.4.4 Roles of Key Positions in the Power Wing Division

The Project is aimed to implement the rehabilitation and enhancement of the Mangla Power Station, the Project will be managed by the Power Wing Division of WAPDA as described in Sub-clause 2.3.3. The chief engineer of Coordination, general manager of Hydel Development, chief engineer of Hydel Development, general manager of Hydel, and chief engineer of Hydel Operation are key positions and persons for the Project. The main roles of each position are described below:

(1) Chief Engineer of Coordination

The chief engineer of Coordination under member power looks after the following activities:

- Coordination with other divisions of WAPDA regarding matters on power sector, and
- Arrangement of meetings to be convened by member power.

(2) General Manager of Hydel Development

The general manager of Hydel Development looks after the following activities:

- Refurbishment/rehabilitation of the existing hydropower station;
- Preparation of feasibility report, detail design, tender documents, bidding documents, award of contracts, supervision and implementation of refurbishment/rehabilitation works of the existing hydropower stations;
- Monitoring the progress of new hydropower projects being developed by the Water Wing Division;
- Preparation of the progress report of hydropower project under rehabilitation; and
- Arrangement of budgetary requirement for the on-going/future rehabilitation projects.

(3) Chief Engineer of Hydel Development

The chief engineer of Hydel Development is a staff officer to the general manager of Hydel Development. He assists the general manager of Hydel Development in all official matters as listed above.

(4) General Manager of Hydel

The general manager of Hydel looks after the following activities:

- Operation and maintenance issues on all hydropower stations,
- Preparation of operational data of all hydropower stations,

- Procurement of spare parts of all hydropower stations,
- Provision or arrangement of necessary budget for all existing hydropower stations,
- Sales of hydel energy generated to NTDC/CPPA and its related affairs, and
- Training of all present and newly recruited officers of Power Wing, Water Wing and Finance Division of WAPDA.

(5) Chief Engineer of Hydel Operation

- A staff officer of the general manager of Hydel Operation.
- Assists the general manager of Hydel Operation in all operation and maintenance matters of existing hydropower stations.
- Preparation of operational data/reports to be submitted to the higher offices in the country.

2.4.5 Financial Condition of WAPDA (Nondisclosure)

2.4.6 Present Activities/Status of Projects Supported by Other Donors

The present activities and status of projects in the power sector of Pakistan supported by other donor countries are summarized below:

WORLD BANK

No.	Project Description	Power Generation	Project Cost	Present Activities/Status
1 (i)	Tarbela 4th Ext. Hyd. Project - Consultancy Services, Assignment – A, Project being developed by WAPDA.	1,410 MW	USD 6.315 million	Preparation of the final tender documents for Civil and EM Works completed last week of April 2012.
(ii)	Tarbela 4th Ext. Hyd. Project Construction Phase, Assignment – B.	-	USD 928.9 million	Negotiations with the Consultants for carrying out Assignment – B, i.e., contract management and construction supervision commenced in May 2012. Project completion is expected in April 2017.
2	Dasu Hydropower Project being developed by WAPDA.	4,320 MW	USD 100 million	The Feasibility Study of Dasu Hydropower Project was completed on February 28, 2009. World Bank offered financing for the detailed engineering design and tender documents and project construction if project would be developed in stages. The proposal was agreed by WAPDA and Government of Pakistan. The Consultants were mobilized and commenced their services on September 19, 2011 for the preparation of detailed engineering design and tender documents.
3	Suki – Kinari Hyd. Power Project being developed through PPIB.	840 MW		The project being developed through private sponsors by PPIB. Tariff approved by NEPRA, WUA signed between sponsors and Govt. of KPK. Negotiation on other project agreements in progress, and Consultants are preparing detailed engineering design.
4	Pakistan Natural Gas Efficiency Project Rehabilitation of Natural Gas Pipeline Network and its Adjoining Facilities (Reduction of Unaccounted for Natural Gas (UFG) in Sui Southern Gas Company (SSGC) Gas Distribution Network)	-	IDA Credit: USD 100 million IBRD Loan: USD 100 million	The project aims to enhance the supply of natural gas in Pakistan by reducing the physical and commercial losses of gas in the pipeline system. The project in designed to reduce SSGS's UFG to about 5%, i.e., building up UFG reductions year by year until eliminating 22 billion cubic feet of UFG annually. An agreement has recently been signed between World Bank and Government of Pakistan for supply of IDA credit of USD 100 million and IBRD Loan USD 100 million for reduction of unaccounted for natural gas, for implementation of the project through SSGC.
5	Pilot Projects for Alternative Energy Development Board (AEDB) Replacement of Conventional Gas Geysers with Solar Water Heaters.	-	The loan from the World Bank is not yet finalized	Government of Pakistan is considering option for introducing solar water heaters to replace conventional gas geysers as a gas conservation measure as well as increase the overall efficiency of energy consumption. This program is under process with AEDB in consultation with the World Bank, but yet not finalized.

Source: Prepared by the Survey Team

United States Agency for International Development (USAID)

No.	Project Description	Power Generation	Project Cost	Present Activities/Status
1	Repair and Maintenance of Tarbela Power Station	-	USD 16.5 million	USAID has provided a grant facility under Fixed Amount Reimbursement Agreement (FARA) of USD 16.5 million for the procurement of spare parts and equipments for the reliability enhancement of Tarbela Power Station. Following spare parts/equipmen has been purchased. Stator windings (Class F) for eight generators. Up-gradation of Scada System. Replacement of I.V and R.V seals. Replacement of worn out drainage pumps. Replacement of worn out un-watering pumps. Replacement of electro-mechanical Governors with PID control digital governors. Training/capacity building of officers. Out of USD 16.5 million, an amount of USD 10.879 million has been reimbursed to WAPDA and the remaining is to be reimbursed up to December 31, 2012.

Source: Prepared by the Survey Team

Asian Development Bank (ADB)

No.	Project Description	Project Cost	Present Activities/Status
1	Power Distribution Enhancement Project (Tranche-II): Loan No. 2727	USD 242 million	The project was approved by ECNEC on September12, 2010 and loan agreements were signed on January 28, 2011, sub projects are expected to be completed by June 30, 2018. The procurement under this tranche is in the advanced stage and cost of the project is estimated to be USD 302 million with a loan amount of USD 242 million which only covers STG component. Physical progress was not started, but majority of turn key projects are at the stage of contract signing. The contractors are expected to mobilize by the second quarter of. 2012.
2	Power Distribution Enhancement Investment Program Support Component: Loan No. 2439	USD 10 million	Loan for support component of USD 10 million was signed with PEPCO on September 29, 2008 with loan closing date on December 31, 2018 for project preparation, implementation and monitoring activities and for capacity building of DISCOs. RFP issued six shortlisted firms, however, five firms submitted their proposals on February 9, 2012, which were evaluated by NTDC and after getting ADB's concurrence on the financial proposal of these firms was opened on March15, 2012. The matter is now with ADB for approval.
3	Renewable Energy Development Sector investment program	USD 20 million	The Management Review Meeting held on 18 November, 2009 and the Board Approval was issued on 13 December, 2010. The project will focus on wind and other renewable energy power plants. It is expected that IPPs would add cumulative generating capacity of 150 MW – 250 MW.
4	Uch-II Thermal Power Project (private sector)	USD 150 million	The project is under implementation by a Private Power Production Company under PPIB. The expected commercial date of operation is December, 2012
5	Pak Zorlu Energy Power Project (private sector)	USD 36.8 million	The financial closing has been announced. Construction has been started. Expected commercial operation date is January, 2013
6	Pak Daharki Power Project (Dual Cycle Gas Fired Thermal Project) (private sector)	USD 46.75 million	The project has been commissioned in March 2011 through Foreign Foundation Private Producing Company under PPIB.
7	New Bong Escape Hydropower (private sector)	USD 37.3 million	This is the first Hydropower Project being constructed in Private Sector by Laraib Energy Limited. The Expected date of Commercial Operation is November, 2012.

Source: Prepared by the Survey Team

KFW AND KOREAN BANK

No.	Project Description	Project Cost	Present Activities/Status
1	220 KV Grid Station Ghazi Road Lahore and Allied Transmission Line Grid Station Transmission Line	EUR 11.290 million; W 17,903 million	Grid Station = Bidding/tendering in progress Transmission Line Material Procurement = 100% Total Disbursement Grid Station = EUR 0.067313 million Transmission Line Material = W 17,903 million

Source: Prepared by the Survey Team

2.5 Mangla Hydro Power Station

2.5.1 General

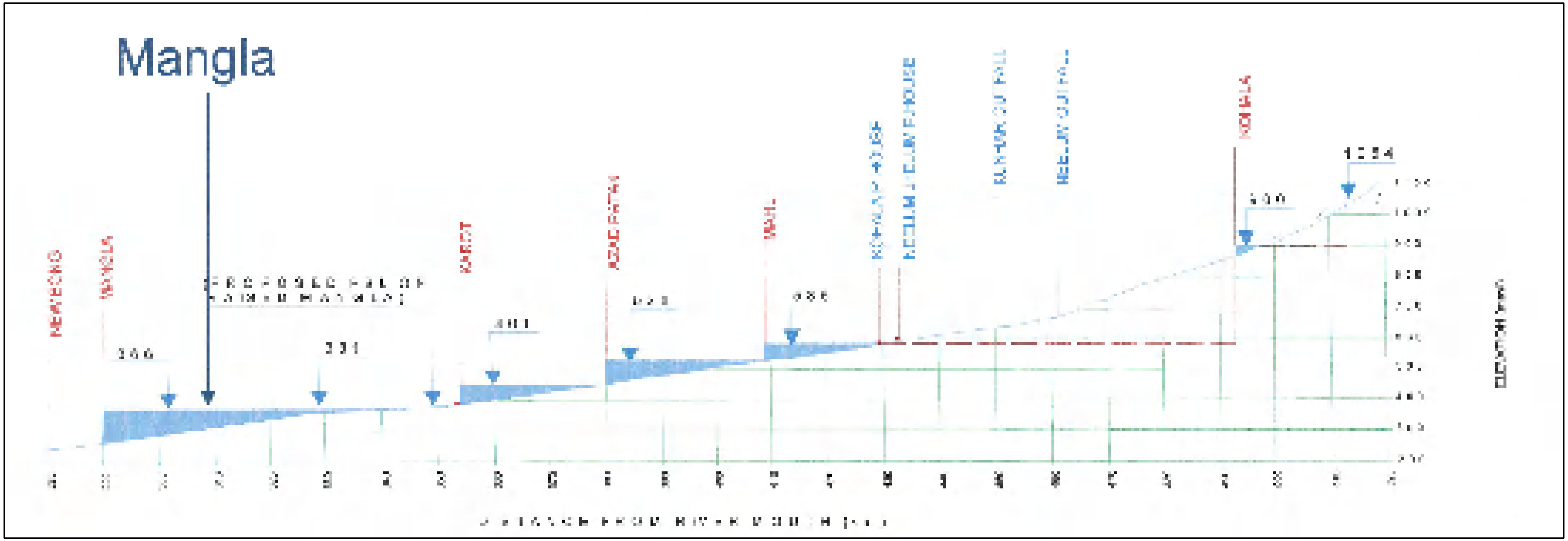
The Mangla Dam Project completed in 1967 is located on the Jhelum River about 120 km from the Capital Islamabad as illustrated in Figures 2-11 and 2-12. The project attained its maximum capacity of 1000 MW with the final extension of Units 9 and 10 (2 x 100 MW) in 1993-94. During high reservoir level period, Mangla is able to generate 1150 MW against the rated capacity of 1000 MW due to permissible overloading of 15%. The power station has been one of the major contributors to the national grid during the year (see Photo 2-1). The maximum load of 1150 MW and maximum daily generation of 27.600 MKWh were recorded on various dates. The power station contributed 6108 million units during the year, which was 1,335 million units more than last year's generation of 4,772.4 million units. The total generation since the commissioning was 194.4 billion units (KWh) as of June 30, 2011.

Source: Mangla Power Station Presentation File
"Briefing for JICA on February 28, 2012.pptx"

Figure 2-11 Overall Arrangement of Mangla Power Station

Source: Mangla Power Station Presentation File
"Briefing for JICA on February 28, 2012.pptx"

Photo 2-3 Overview of Mangla Power Station

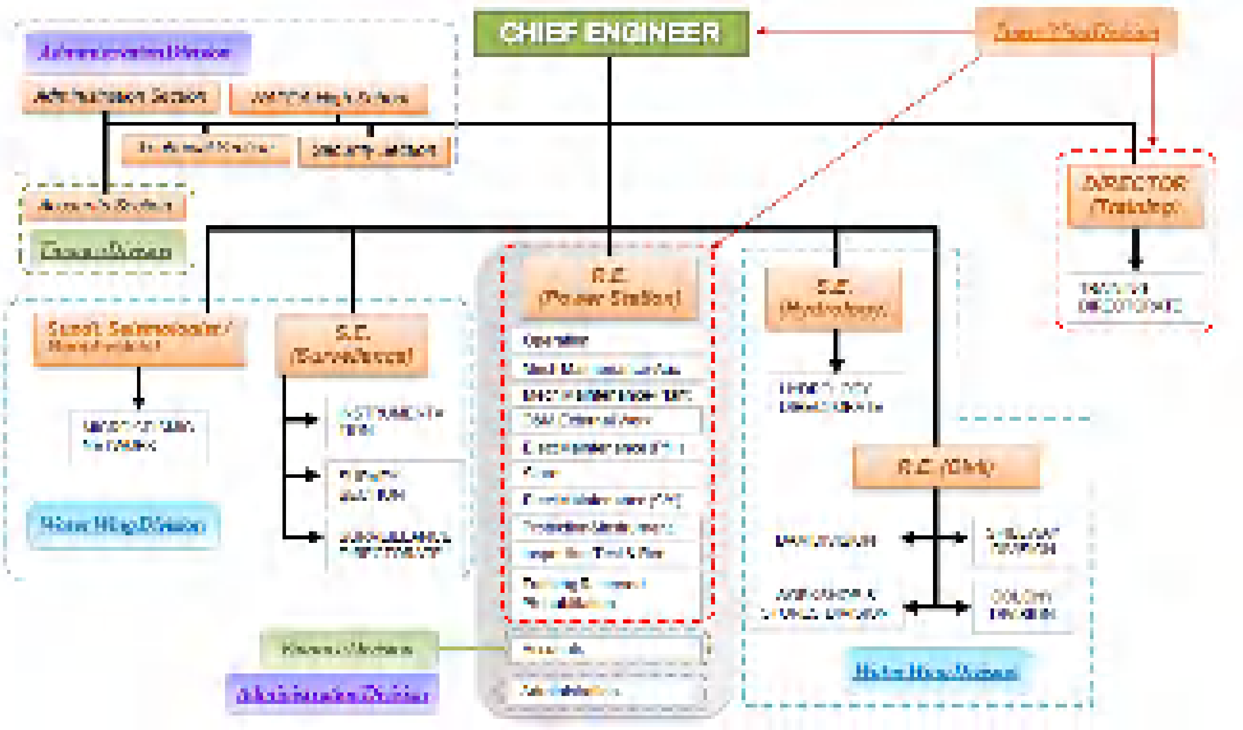


Source : Provided by WAPDA

Figure 2-12 Profile of Jhelum River

2.5.2 Organization of Mangla Power Station

Mangla Power Station is headed by the chief engineer. The present organization of Mangla Power Station is shown in Figure 2-13.



Source: Prepared by the Survey Team

Figure 2-13 Organizational Structure of Mangla Power Station

In the above organizational structure, the chief engineer and resident engineer of the Power Station are positions with great responsibility in the operation and maintenance of the Mangla Power Station.

The main roles of chief engineer and resident engineer (power station) are described below:

Chief Engineer

The chief engineer has overall responsibility for Mangla Dam, Mangla Power Station, small hydropower stations like Rasul Power Station, Shadiwal, Nandipur, Chichokimalian, and Renala. All the civil structures of dam, colonies, and offices are being looked after by the resident engineer (civil) while the Mangla Power Station is being controlled by the resident engineer (power station). One training directorate is also being run by director training under the chief engineer. The training directorate gives training to newly hired junior engineers and other technical staff to be assigned to different hydropower stations like Tarbela, Mangla, Ghazi Barotha, Chashma, and Warsak.

Resident Engineer (Power Station)

The resident engineer (power station) has overall responsibility for the Mangla Power Station. He is responsible for the operation, maintenance, and protection of the power station. All sectional heads who are senior engineers directly report to the resident engineer. The resident engineer also performs liaison function between the Indus River System Authority (IRSA) and National Power Control Centre (NPCC) for the water releases and generation of the Mangla Power Station in light of allowed releases of IRSA and power requirements of NPCC.

The main activities of each section which are directly managed by the resident engineer (power station) are described below:

Operation Section

The Operation Section of Mangla Power Station is headed by a senior engineer who reports to the resident engineer (power station). The operation engineer (OE) is in charge of the operation and releasing of water as per requirement of IRSA, from Mangla Lake, through the power station for generation of electricity. The O.E. also supervises all technical/non-technical staff working in all shifts for round the clock operation of the power station. The O.E. generates trouble reports (TRs) in case of malfunction/faulty defect on any machine/equipment and refers to the concerned section for rectification of faults.

Mechanical Maintenance Auxiliary Section

The Mechanical Maintenance Auxiliary Section is headed by a senior engineer who is in charge of the mechanical maintenance of all the auxiliary equipment of the Mangla Power Station such as air compressors and O/H cranes dewatering pumps. This section is also responsible for the cleanliness of the power station.

Mechanical Maintenance Plant Section

This section looks after the mechanical maintenance of machines parts such as turbines, intake gates, draft tube gates, and governors. This section is also headed by a senior engineer (mechanical) who directly reports to resident engineer (power station).

Operation and Maintenance External Work Section

This section headed by a senior engineer is responsible for the electrical as well as mechanical maintenance of external works such as spillway gates, Jary irrigation outlet, power intake gates, Bong escape gates, and their associated structures.

Electrical Maintenance (Power House) Section

This section is also headed by a senior engineer (electrical) who directly reports to the resident engineer (power station). This section is responsible for the maintenance of all electrical equipment within the power house such as generators, exciters, compressor motors, gov. motors, power transformers, excitation, transformers, and D.C. batteries of the power station.

Store Section

This section headed by a senior engineer is responsible for the safety storage and handling of store items such as spare parts, transformer oil, turbine oil, and other consumable items. This section also keeps a record of all items received, issued, surveyed off, on a daily basis, as per requirement of different sectional heads.

Electrical Maintenance (Switch Yard) Section

This section headed by a senior engineer (electrical) is responsible for the electrical maintenance of 132/220 KV switchyard which includes circuit breakers, interconnecting transformers, isolators, bus bars, cable tunnel, 220 V D.C. batteries, and air compressors.

Protection and Instrumentation Section

This section headed by a senior engineer is responsible for the testing, calibration, and maintenance of all protection relays and instruments installed in the power house as well as the switchyard.

Inspection, Test and Record Section

This section headed by a senior engineer is responsible for the preparation of trouble reports, rectification and records. This section is also responsible for keeping a record of testing of all equipment by different sections. Also, it prepares monthly and annual reports for the information of the higher offices. In addition, this section is also responsible for the procurement of all spare parts as per requirement of different sections.

Rehabilitation Section

The Rehabilitation of Mangla Power Station is being looked after and co-ordinated by a senior engineer working directly under resident engineer (power station). He is also responsible for providing data specifications of the equipment required by the consultants/contractors. He reports progress of the rehabilitation to the resident engineer (power station) abd higher offices.

Accounts Section

This section headed by a budget and accounts officer reports directly to the resident engineer (power station) and deals with the preparation of annual budget of the power station, salaries, and annual increments to the employees. This section also keep an eye on the expenditure of the different sections as per their budget provisions. They also prepare next year budget as per demand of the different sections of Power Station.

Administration Section

This section headed by an assistant director (administration) directly reports to the resident engineer (power station). This section deals with all administrative matters relating to the employees of the power station like leave, service record, promotion/demotion, punishment/rewards, recruitment and transfer of the employees with the approval of the competent authority.

The manpower for each section of the Mangla Power Station, as of June 2012, is shown in Table 2-18.

Table 2-17 Manpower of Mangla Power Station

No.	Position	Division				Total
		Administration	Finance	Water Wing	Power Wing	
1	Managerial Staff (BPS 18-21)	-	-	4	2	6
2	Operation Staff (BPS-18)	8	-	14	10	32
3	Technical Staff	-	-	289	344	633
4	Non-technical Staff (BPS 1-17)	-	34	341	90	465
Total		8	34	648	446	1,136

Source: Prepared by the Survey Team

2.5.3 Mangla Dam Raising Project

The Mangla reservoir had an initial capacity of 5.88 minor allele frequencies (MAF), which was reduced to 4.674 MAF in 2005 and will further reduce with the passage of time due to sediment deposition. Keeping in view the capacity loss due to sedimentation and provision for raising it to the original construction design, the raising of Mangla Dam was considered to cope with the ever increasing shortage of irrigation water and mitigate the effects of capacity loss of country's two major storage reservoirs in Mangla and Tarbela. The raising of Mangla Dam by 30 ft has almost been completed to regain the reservoir capacity loss due to sediment deposition and to make provision for future sedimentation.

The contract for the Construction of Main Works (Contract MDR-10) of the Mangla Dam Raising Project was awarded to a joint venture of one Chinese and five Pakistani contractors (CWEJV) on June 14, 2004 for an amount of PRs 13.793 billion. The joint venture is composed of the China International Water and Electric Corporation (CWE) as the lead company, and local contractors including DESCON Engineering, Sardar M. Ashraf D. Baluch, Interconstruct and Sachal Engineering Works. The construction schedule was completed in 39 months in September 2007. Construction of major components for main works i.e., main dam and power intake embankment, Sukian Dyke, Jari Dam and rim works, main and emergency spillways and Mirpur Bypass Road were substantially completed on December 26, 2009 except for some minor varied works.

Table 2-18 Salient Features of Raising of Mangla Dam

Item	Original Design	After Raising	Comparison
Reservoir			
Max. Water Level	366.5 m(1,202 ft)	378.7 m(1,242 ft)	+12.2 m
Min. Water Level	317.1 m(1,040 ft)	317. 1m(1,040 ft)	+0.0 m
Reservoir Capacity	5,553 Mm^3(4.5 MAF)	9,132 Mm^3(7.4 MAF)	+3,579 Mm^3
Dam Body			
Crest Height	138.5 m(454 ft)	147.6 m(484 ft)	+9.1 m
Crest Length	3,350 m(10,300 ft)	3,400 m(11,150 ft)	+50 m
Intake level	376.2 m(1,234ft)	386.0 m(1,266 ft)	+9.8 m
Additional Capacity	-	3,550 Mm^3(2.88 MAF)	-
Annual Generation	-	644 GWh	-

Source：WAPDA Hydrological Section of Mangla Dam

The scope of resettlement works for the Mangla Dam Raising Project is listed below:

- Land acquisition: 16,384 acres
- Number of population: 50,000
- Number of houses and other buildings: 13,404

The actual progress of the resettlement works, as of end of July 2012, is shown in Table 2-20. All construction works for houses, public utility buildings, water treatment system and roads etc., in the new town has been already completed.

Table 2-19 Overall Progress of Resettlement Works

Name of New Town	Overall Progress	Remaining Number of Plots to be Handed Over
MIRPUR NEW CITY	86.3%	169
ISLAMGARH	96.0%	132
CHAKSAWARI	85.6%	362
DUDIAL	100.0%	-
SIAKH	100.0%	-

Source: Mangla Raising Project Office

It is expected to complete all remaining resettlement works including handover of housing to the residents as stated on the above table by the end of September 2012. Photos 2-4 and 2-5 show the aerial view of the Mangla Hydro Power Station and the embankment after dam raising.

Source: Prepared by the Survey Team

Photo 2-4 Mangla Hydro Power Station

Source: Prepared by the Survey Team

Photo 2-5 Embankment after Dam Raising

2.5.4 Hydel Training Center Mangla

The Hydel Training Center Mangla plays a pivotal role in capacity building of the officers and officials of Hydel organizations in WAPDA. It is the sole institution functioning at present to impart training to all the technical/non-technical employees of Water and Power Wings in WAPDA.

The detailed number of officers and officials trained in 1997 up to January 2012 at Hydel Training Centre Mangla is summarized in Table 2-20.

Table 2-20 Detailed Number of Trained Staffs from 1997 to 2012

No.	Categories	Name of Course	Number of Staffs Trained
1	Sr. Engineer due for Promotion as Superintending Engineer	Refresh Course	19
2	Jr. Engineer due for Promotion as Sr. Engineer	Sector Specific Course	29
3	Fresh Jr. Engineer of Hydel Generation	Induction Course	373
4	Turbine Operators and Sr. Attendants	Advance Operator Course	300
5	Fresh Attendants and Assistant Station Attendants	Basic Operator Course	728
6	Jr. Technicians, Fitters, Electricians, Assistant Station Attendants, Hammer Men, Blacksmith, Test Inspector, Welder, etc.	Basic Craftsman Course	785
7	Jr. Clerks, Sr. Clerks, Office Assistant	Ministerial Staff Course	201
8	Jr. Clerk eligible for Steno Grade-II	Ministerial Staff Course	26
9	Steno-Grade II to Steno Grade-I	Ministerial Staff Course	46
10	Jr. and Sr. Store Keepers Store Supervisor	Store Staff Course	24
11	Tracers, Draftsmen, Assistant Draftsman	Drawing Staff Course	23
12	Telephone Lineman, Operators, and Supervisors	Telephone Staff Course	34
13	Computer Office Application Course for Officers and Officials Stationed at Mangla	-	186
14	Internship of Student from Different Engineering Universities	-	246
Total			**3,020**

Source: Briefing to the Delegation at WAPDA Hydel Training Centre Mangla (1977-2011)

The annual schedule of training for the year 2012 at Hydel Training Centre Mangla is shown in Figure 2-14. It is expected that 200 staffs will be trained in year 2012.

Sr	Detail of Course	BPS	Code	capacity	Duration in weeks	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	**Refresher Course (Pre-promotion)** **Category: Senior Engineer (Hydel Generation)**	18	RC	10	04				16	12							
2	**Sector Specific Course (Pre-promotion)** Category: Junior Engineer (Hydel Generation)	17	SSC	10	06			5	14								
3	**Junior Engineer Induction Course** Categories:- Fresh Junior Engineer	17	JIC	10	8	9		3									
4	**Upper Technical Subordinate Staff Course** **Category: Foreman / Operator**	16	UTS	15	04						11	14					
5	**Advance Operator Course** Categories:- Turbine Operators & Sr. Attendants	11 & 12	AOC	15	8	2	25										
6	**Basic Craftsmen Course (E&M)** Categories:- Fitters/ASA's, Hammer men, Blacksmith, Electricians, Test Inspector, Lab Asstt: Winders Linemen, Asstt: Foreman, & related categories	5-15	BCC	15	14			5			9						
7	**Basic Operator Course** Categories:- Fresh Turbine Operators, Attendants & Sr. ASA's or related cat.	5-15	BOC	15	12									03		24	
8	**Ministerial Training Course** Categories:- Jr. Clerks, Sr. Clerks, Assistants & Jr. Suptd.	5-15	MTC-1	15	3												3 22
9	**Ministerial Training Course** Categories:- Jr. Clerks eligible for promotion as Stenographer-II	7	MTC-2	15	3				2 21								
10	**Ministerial Training Course** Categories:- Stenographer-II	12	MTC-3	15	3										1 20		
11	**Store Staff Training Course** Categories:- Jr. & Sr. Storekeepers & Store Supervisor	7-15	SST	15	3							2 21					
12	**Drawing Staff Training Course** Categories:- Tracer, Draftsmen,	7-15	DST	15	3											12	1
13	**Telephone Staff Training Course** Categories:- Telephone linemen, Operators, Supervisors	5-15	TST	15	3												10 29
14	**Internship Training Course** for Student Engineers	---	ITC	15	4					28	23	2 28	6	1 3 29			
15	**Computer Office Application Course** Categories:- Officers & Officials of Mangla only	5-17	COA	5	12	Continued Activity after every 3 months											

Source: Briefing to the Delegation in WAPDA Hydel Training Centre Mangla (1977-2011)

Figure 2-14 Annual Schedule of Training for the Year 2012

CHAPTER 3

REVIEW ON FEASIBILITY STUDY REPORT

CHAPTER 3 REVIEW ON FEASIBILITY STUDY REPORT

3.1 Outline of F/S

3.1.1 Objective of the F/S

The WAPDA has conducted the F/S for the up-gradation and refurbishment of generation units of the Mangla Power Station in 2011. The F/S was prepared by the joint venture of MWH (USA) and NESPAK (Pakistan) to help WAPDA in identifying the improvements of the Mangla generation units.

The objectives of the F/S were to determine the most viable alternative, in terms of the technical as well as the economical aspect for the up-gradation and/or refurbishment of the existing units of the Mangla Hydro Power Station. The adverse effect by the aging electrical / mechanical equipment and the effective utilization of the improved power potential after completion of the Mangla Dam Raising Project should be kept in mind.

The F/S was carried out in the period from June to December 2011.

3.1.2 Contents of the F/S Report

The F/S report consists of the following eight volumes.

Volume 1	Executive Summary
Volume 2	General
Volume 3	Condition Assessment Generation and Unit Electrical
Volume 4	Condition Assessment Turbine and Unit Electrical
Volume 5	Condition Assessment Balance of Plant
Volume 6	Development and Evaluation of Up-gradation and Rehabilitation Alternative
Volume 7	Environmental Studies
Volume 8	Appendices

3.1.3 Summary of the F/S Report

The F/S was carried out after the investigation and evaluation of a number of electrical and mechanical equipment, civil structure, hydrological data, outflow consideration/limitations at upstream and downstream, financial and economical considerations. This provided different refurbishment alternatives.

In the F/S report based on the assessment of the plant equipment, four alternatives namely Alternatives 0, 1A, 1B, and 2, were presented.

The summary of each alternative as described above is shown in Table 3-1.

Table 3-1 Expected Increase in Energy Output by Up-gradation/Refurbishment

Alternative	Unit Rating	Description	Remarks
0	No Up-gradation from the existing 1,150 MW in total (only rehabilitation) Units 1-10: 115 MW	<u>Turbine</u> - Replacement of turbine runner <u>Generator</u> - Replacement of stator winding - Replacement of stator core (Units 1-6) - New static digital excitation system	–
1A	Up-gradation to 1,310 MW in total Units 1-6: 135 MW Units 9-10: 135 MW Units 7-8: 115 MW (no change)	<u>Turbine</u> - Replacement of turbine runner (same as Alternative 0) <u>Generator with higher capacity</u> - Replacement of core and winding for generator (Units 1-6, 9-10) - New static digital excitation system <u>Others</u> - New power transformer and IPB	–
1B	Up-gradation to 1,380 MW in total Units 1-6: 135 MW Units 7-8: 150 MW Units 9-10:135 MW	<u>Turbine</u> - Replacement of turbine runner (same as Alternative 0) <u>Generator with higher capacity</u> - Units 1-6, 9-10: same as Alternative 1A - Units 7-8: complete replacement of generators with 150 MW <u>Others</u> - New power transformer and IPB	–
2	Up-gradation to 1,500 MW in total Units 1-10: 150 MW	<u>Turbine</u> - Replacement of turbine runner (same as Alternative 0) <u>Generator with higher capacity</u> - Units 1-10: complete replacement of generators with 150 MW <u>Others</u> - Modification of intake structure - New power transformer and IPB	Demolition works of existing concrete foundation of generators required for all units except for Units 7 & 8.

Source: Feasibility Study for Up-gradation and Refurbishment of Generating Units of Mangla Power Station, December 2011

Each generating unit from Unit 1 to Unit 10 were ranked utilizing the ranking methodology. It assessed both the condition and the consequence.

The assessment concluded the urgent rehabilitation of generating equipment units 5, 6, 2, 1, 3 and 4 in order (Table 3-2).

Table 3-2 Recommended Unit Rehabilitation Order

Rank	Unit	Consolidated Score	Remarks
1	Unit 5	1.0000	Urgent
2	Unit 6	0.974	
3	Unit 2	0,755	
4	Unit 1	0.728	
5	Unit 3	0.581	
6	Unit 4	0.581	
7	Unit 7	0.111	
8	Unit 8	0.032	
9	Unit 9	0.000	
10	Unit 10	0.000	Less Urgent

Source: Feasibility Study for Up-gradation and Refurbishment of Generating Units of Mangla Power Station, December 2011

The construction costs were estimated for each alternative. The net present value (NPV), economic internal rate of return (EIRR), financial internal rate of return (FIRR) and benefit -cost ratio (BCR) were calculated with the utilization of inflation and escalation rates specified for the different inputs. Details are discussed in Sub-clause 7.3.

Table 3-3 Economic Analysis of Up-gradation Alternatives (2013 to 2047)

Alternative	Construction Cost		NPV		EIRR	FIRR	BCR
	million USD	billion PRs	million USD	billion PRs			
Alternative 0 1150 MW	350.8	29.82	181.0	15.38	20.9%	Not done	2.54
Alternative 1A 1310 MW	369.4	31.4	234.9	19.97	24.0%	22.6%	2.89
Alternative 1B 1380 MW	446.2	37.93	222.4	18.91	22.6%	Not done	2.52
Alternative 2 1500 MW	684.3	58.17	158.7	13.49	17.8%	Not done	1.69

Source: Feasibility Study for Up-gradation and Refurbishment of Generating Units of Mangla Power Station, December 2011

The F/S report concluded that Alternative 1A to be the most economically alternative, though the detailed information such as assumptions (discount rate) and methodology (calculation of economic benefit) were not described. It was also difficult to judge the accuracy of the figures shown in the report.

The F/S report also conducted the financial and economic analyses in case of including the benefit from CDM CER credits. The F/S also concluded that the additional benefit is marginal and there is not much difference in the result of calculation.

Table 3-4 Economic Analysis with CDM Allotment (2013 to 2047)

Alternative	NPV with CDM		EIRR w/ CDM	BCR w/ CDM
	million USD	billion PRs		
Alternative 0 1150 MW	N/A	N/A	N/A	N/A
Alternative 1A 1310 MW	246.5	20.95	24.5%	2.98
Alternative 1B 1380 MW	234.3	19.92	23.0%	2.60
Alternative 2 1500 MW	171.1	14.54	18.2%	1.74

Source: Feasibility Study for Up-gradation and Refurbishment of Generating Units of Mangla Power Station, December 2011

3.1.4 Conclusion and Recommendation of the F/S

The F/S report concluded that Alternative 1A (1310 MW total) is recommended since it satisfies all objectives from the scope of works. Alternative 1A also has the highest NPV, BCR, EIRR, and FIRR.

The F/S also recommended considering implementation of Alternative 1B, which is a modified version of Alternative 1A.

Investing in Static Var compensators, or by other means to satisfy the necessary reactive power requirements for the power system were also suggested.

3.2 Recommendation in the F/S and View of the Survey Team

3.2.1 Hydraulic Consideration and Limitations

The hydraulic limitations in the F/S report are the reservoir water level, tailrace water level ,and water passage for consideration of turbine ratings.

When the dam height was increased by 30 feet, the reservoir water level increased by 40 feet, which is from 1202 feet to 1242 feet.

The water passages include the intake screen (trashracs), intake gate, concrete lined tunnel, steel lined tunnel, inlet valve, and tailrace channel (Bong Cannel). The water passage limitation is the base data for deciding the maximum output capacity of the turbine together with the head loss. Maximum water passage limitation is 49,000 cfs, (4,900 cfs/unit) which is the tailrace channel water passage limitation.

As the result of review, the Survey Team has judged that the above recommendation in the F/S report is acceptable.

3.2.2 Condition Assessment of Turbine and Unit Mechanical

The F/S report recommendations for the turbine and mechanical units are preferable as shown in Tables 3-9 to 3-12. The results of the review on the F/S report are as follows:

(1) Units 1 to 4

Most of the recommendations made in the F/S report are acceptable except for some comments as mentioned in Table -9.

(2) Units 5 and 6

Most of the recommendations made in the F/S report are acceptable except for some comments as mentioned in Table 3-10.

(3) Units 7 and 8

Most of the recommendations made in the F/S report are acceptable except for some comments as mentioned in Table 3-11.

(4) Units 9 and 10

Most of the recommendations made in the F/S report are acceptable except for some comments as mentioned in Table 3-12.

3.2.3 Condition Assessment of Generator and Unit Equipment

The essence of the current condition quoted from the F/S report is summarized in Table 3-13 to Table 3-16.

The F/S report mentioned the details of the current condition of the equipment, and methods of rehabilitation. Most of the requirements on the F/S report are understandable. The rehabilitation and up-grading idea is appreciated as mentioned on the attached tables.

There were a few site measurement data and analyses by the measuring data. Therefore, the Survey Team has added some analysis by data measured during the site visit. The result of analysis is mentioned in Chapters 4 and 5.

The comments of the Survey Team are described below:

According to the F/S report, almost all main parts of the generator and turbine would be rehabilitated; especially for Units 1 to 4, 5, and 6, with some of the main parts to be replaced with new ones. For example, for generator stator, the F/S report recommended replacing the core and winding only on the existing frame. This method is the most economical, but only the original manufacturer can do it more efficiently because only the original manufacturer knows the detail design of the existing equipment. It will be difficult for the other manufacturers to match with the new rating and efficiency of the up-graded/rehabilitated equipment.

In addition to the above, the upper guide bearing's design is required to be changed, therefore, all parts of the generator are recommended to be replaced for Units 5 and 6.

(1) Units 1 through 4

Most of the requirements pointed out in the F/S report are understandable and the rehabilitation idea is appreciated with some comments, as mentioned in Table 3-13.

For up-gradation, the F/S report described different alternatives, and one of them requires foundation modification.

(2) Units 5 and 6

Most of the requirements pointed out in the F/S report are understandable and the rehabilitation idea is appreciated with some comments, as mentioned in Table 3-14.

For up-gradation, the F/S report described different alternatives, and one of them requires foundation modification.

(3) Units 7 and 8

Most of the requirements pointed out in the F/S report are understandable and the rehabilitation idea is appreciated with some comments, as mentioned in Table 3-15.

For up-gradation, the F/S report described different alternatives, and one of them needs foundation modification.

(4) Units 9 and 10

Most of the requirements pointed out in the F/S report are understandable and the rehabilitation idea is appreciated with some comments, as mentioned in Table 3-16.

For up-gradation, the F/S report described different alternatives, and one of them needs foundation modification.

The summary of up-gradation alternatives in the F/S report is shown in Table 3-18.

3.2.4 Condition Assessment of Balance of Plant (BOP)

(1) General

The essence of the current condition quoted from the F/S report is summarized in Table 3-17.

The control and protection system are involved in the BOP of the F/S. The scope of the control and protection system is classified into three categories: i. generation units, ii. switchyard, and

iii. station service.

The F/S evaluated almost all control and protection system that are outdated, and it recommended replacing a new system.

(2) Switchyard

Almost all devices are outdated. The F/S recommended replacing them with modern state-of-the-art substation automation system (SAS). Bus bar protection relays are scheduled to be replaced by digital relays. Battery systems for switchyard are all new within the last 10 years. It is assessed that the battery systems are not required to be replaced immediately.

The Survey Team has confirmed that the renovation works of the switchyard facilities are on going by another project. The evaluation of the switchyard is required more elaborately study and the interface arrangement with another project at the detailed design stage. The control and protection system for feeder lines of upgrading generators are included as the scope of project but transmission-lines' are not included.

(3) Station Service

The F/S report described the issues on the station service system as shown below:

The plant operation and maintenance personnel have reported that they faced a number of problems during the restoration process after a blackout scenario when they have to perform multiple manual operations to restore the normal configuration. There are many interlocking devices between the various breakers making the system very complex.

The F/S report recommended replacing the system entirely with a new system. The said report presented several alternative designs for replacement. The final recommendation was chosen to be Option 5 in Table 3-5.

The Survey Team has recommended replacing the station service circuits, namely 11kV and 415V circuits, as recommended in the F/S report.

Especially, the alternatives of the Options 4 and 5 in the F/S, those alternatives will be required the longer stoppage compared to another alternative options.

The Survey Team suggests considering the simplification of interlock, and total coordinated power supply redundancy among the high-voltage, medium-voltage and low-voltage.

The oil circuit breakers in 11kV circuits which are recommend replacing as described in the F/S report. The oil circuit breakers have a risk of fire and troublesome maintenance, therefore it is not used in the present industrial field.

In the power station, the station service circuit, especially 415V circuits are complicated and modified frequently, therefore in many cases; the circuit diagrams are not reflected actual circuit correctly.

Table 3-5 Alternative Plans for Station Service Refurbishment in the F/S

Alternatives	Outline	Feature
Option-1 (Figure 3-1)	Refurbish but retain existing configuration	The 132 kV system failed to bring power station down.
Option-2 (Figure 3-2)	Refurbish and shift one SOTH to 220 kV side of the switchyard while retaining the existing configuration	The above trouble will be mitigated by using the 220 kV system supply.
Option-3 (Figure 3-3)	Refurbish and revise unit auxiliary supply configuration	Power supply redundancy will be further increased from Option-2. Switches changeover operation and interlock becomes more complicated.
Option-4 (Figure 3-4)	Refurbish and utilize unit block configuration	Automatic unit supply change over circuit is required at unit start/stop time. Switches changeover operation and interlock becomes more complicated. When the 220 kV and 132 kV fail, the same with Option-2.
Option-5 (Figure 3-5)	Refurbish and apply generator circuit breaker configuration	Two generator circuit breakers are attached to Units 2 and 7. Switches changeover operation and interlock becomes more complicated.

Source: Prepared by the Survey Team

(4) Assumption of reason for recommendation of Option 5 for the Station service circuit in the F/S report

In the F/S report, there is no description why Option 5 is recommended preferentially.

The Survey Team assumes the reason of recommendation of Option 5 in the F/S report as below:

a) Option-5 makes redundant power supply system from the two different generation units, which are connected different high voltage bus as 220kV and 132kV. It is more reliable compare to the actual system.

b) Station service power supply will not be affected substation system troubles since the power is directed from the generation bus.

The Survey Team would like to point out the following matters against the Option 5.

i) Spacing for circuit breaker installation is required the more deep study at site, and it possibility will be judged.

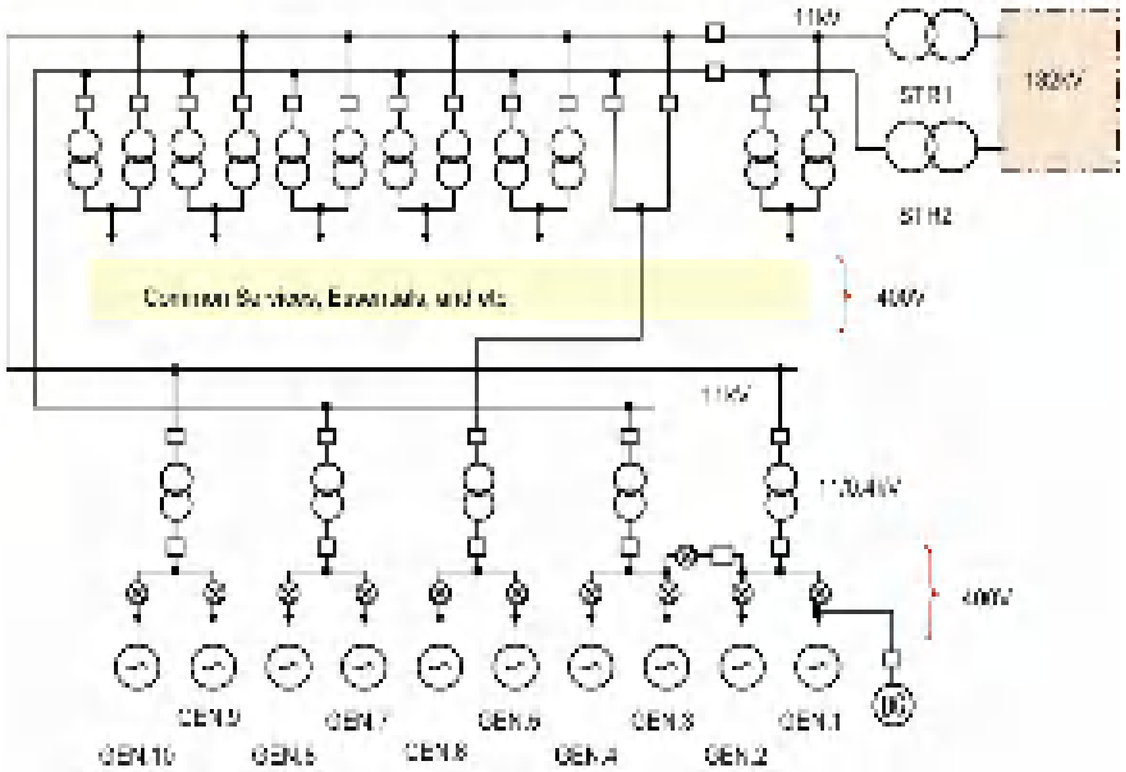
ii) The installation work is required IPB piping modification with bending; it brings the reducing the ventilation efficiency.

iii) Different protection schema and operation manner will be required such two units against remaining eight units. Unified schema is easier for operation and maintenance.

iv) The Redundancy of power supply can be realized by the study team’s plan also.

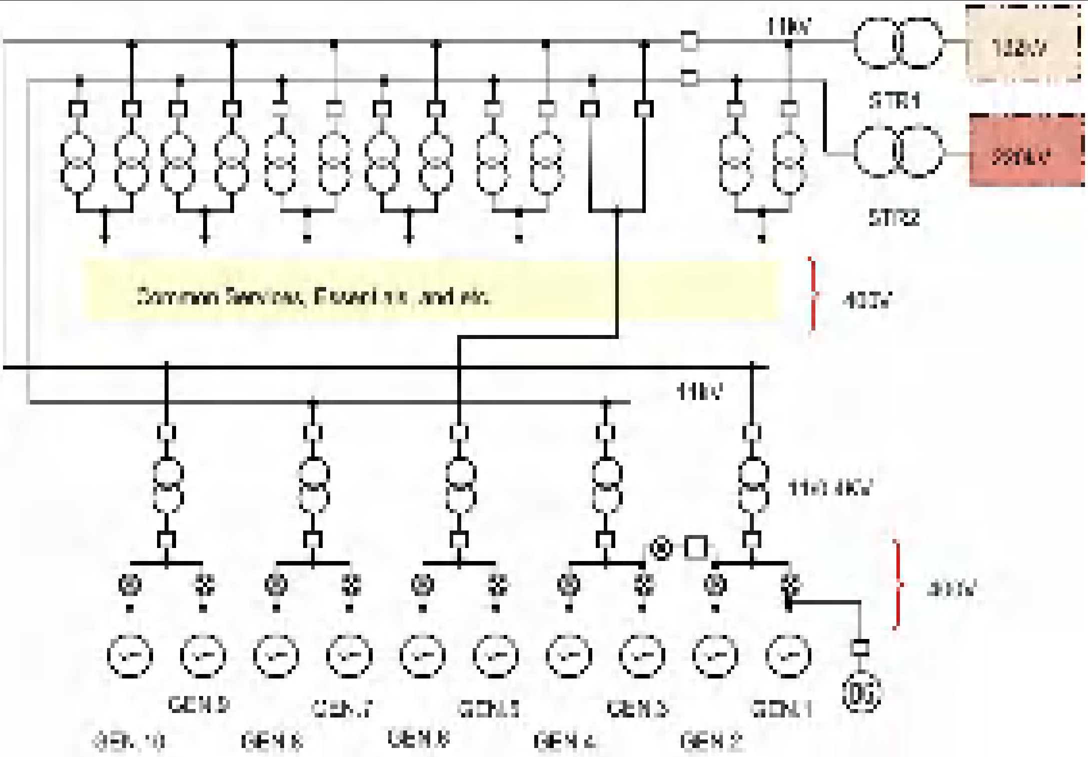
v) BUS system modification scheduling with units stop in the Option-5, which is difficult to make realizing. Unit shutdown of all units will be required more longer with comparing another alternatives.

vi) The Survey Team plan can be proceeded to follow the unit upgrading schedule, because the configuration will not be changed dynamically at one time.



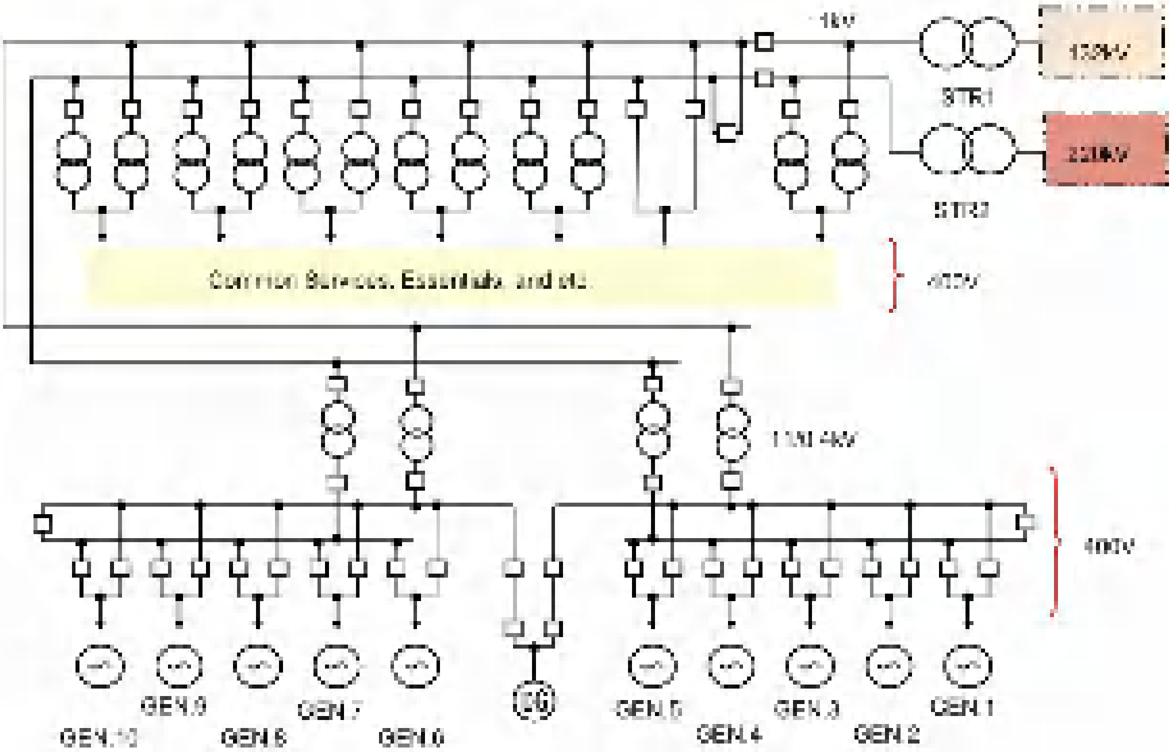
Source: Prepared by the Survey Team

Figure 3-1 Station Service Configuration, Option-1



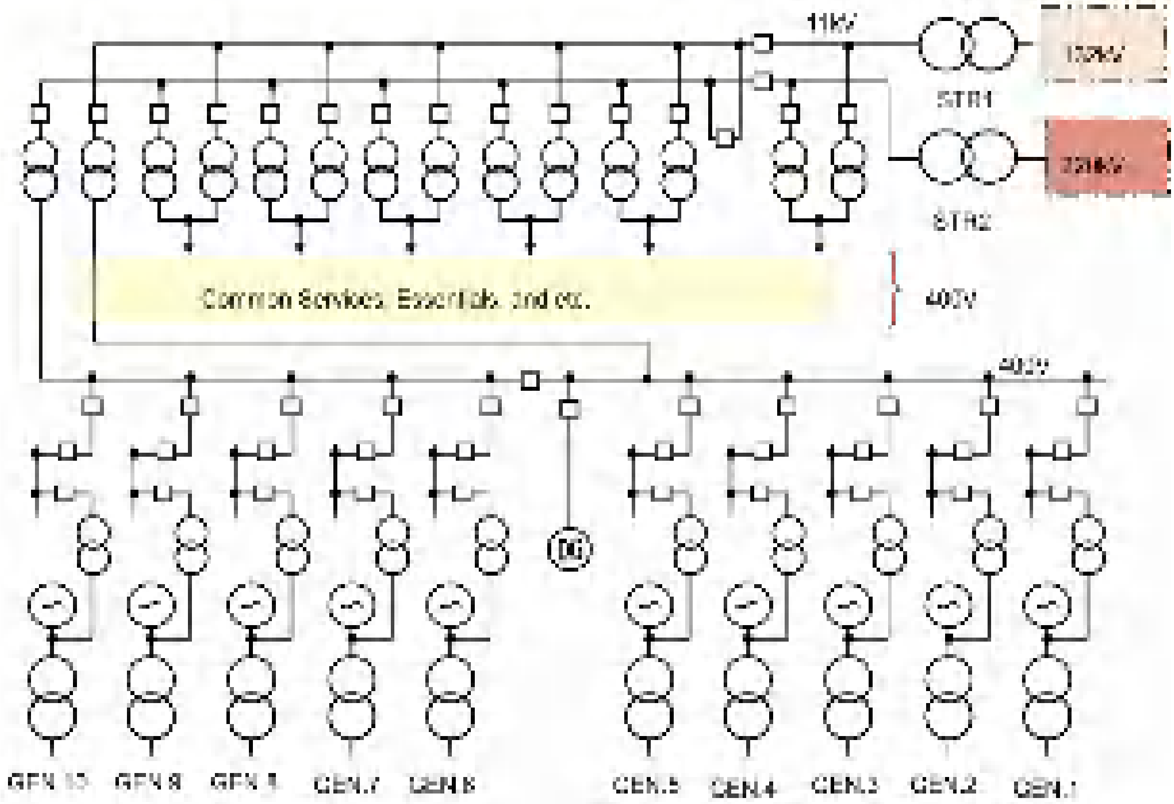
Source: Prepared by the Survey Team

Figure 3-2 Station Service Configuration, Option-2



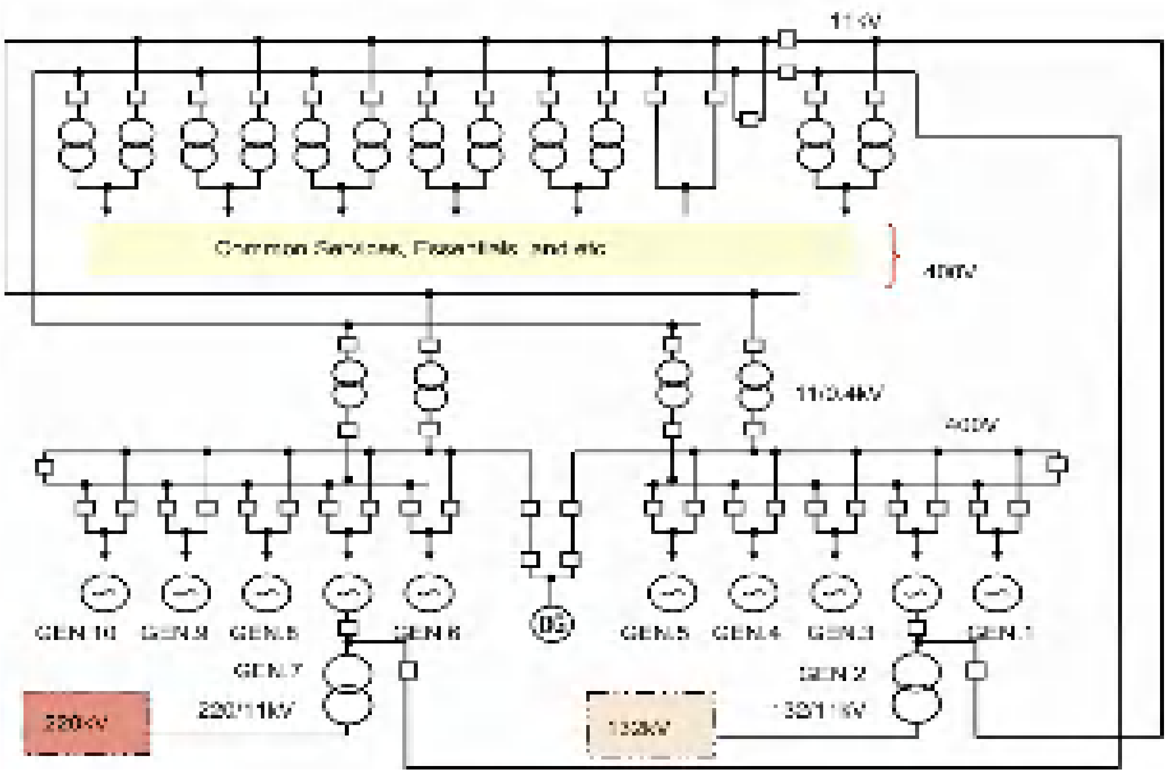
Source: Prepared by the Survey Team

Figure 3-3 Station Service Configuration, Option-3



Source : Prepared by the Survey Team

Figure 3-4 Station Service Configuration, Option-4



Source : Prepared by the Survey Team

Figure 3-5 Station Service Configuration, Option-5

3.2.5 Condition Assessment of Civil Works

(1) Water Balance of Mangla Dam

The F/S report mentioned in the study under civil works includes the hydrological methodology and analysis procedure (RESOP-1 software by NESPAK), the dam sedimentation analysis (HEC-6 software by the United State Army Corps of Engineers) and the countermeasures against concrete degradation of generator and turbine foundations. The hydrological analysis forecast on inflow discharge until year 2097/98 for 88 years were based on the data from year 1922/23 to 2009/10 of the Mangla dam basin using by the RESOP-1 program. The result of the analysis is shown in Table 3-6 below.

Table 3-6 Water Balance in Mangla Dam Basin

Inflow and Outflow	MAF	mm^3
Average Annual Inflow	22.75	28,062
Average Annual Outflow for Irrigation	20.91	25,792
Average Annual Outflow in Kharif (April to September)	10.24	12,631
Average Annual Outflow in Rabi (October to March)	10.67	13,161
Average Annual Spill	2.00	2,467

Source: Feasibility Study for Up-gradation and Refurbishment of Generating Units of Mangla Power Station, December 2011

The penstock discharge from one intake gate was estimated at 9,000 ft^3/s (254.9 m^3/s). In the case of generating power using 10 generators with five penstocks, the planned discharge was calculated at 45,000 ft^3/s (1,274 m^3/s). After generating power at the Mangla Power House, the water flows to the New Bong Power Station (independent power project: IPP). The water intake of the New Bong Power Station, which is located downstream of the Mangla Power Station and under construction, is separated from the tailrace cannel of the Mangla Power Station. The capacity of the tailrace cannel flow is 49,000 cfs. Therefore, the water intake of the New Bong Power Station shall be designed to be less than capacity of the said cannel flow. Besides, the maximum water discharge of the Mangla Power Station before dam raising was designed as 45,000 cfs.

In consideration of the above, the Survey Team has judged that the quantity of the water discharge of the Mangla Power Station is not effect on the generating capability of the New Bong Power Station.

(2) Concrete Repair at Power House

Based on the results of the evaluation of the F/S report and the description of the site investigation under this study, concrete repair works at generators and turbines in the power houses are under consideration. Some cracks in the concrete surrounding the turbines have been observed, specifically at Units 5 and 6 which have big cracks with approximately 5 mm width. According to the F/S report, the use of epoxy injection and replacement of concrete with approximately 5.4 m^3 were recommended as solution. However,, this study shall recommend the use of epoxy injection and carbon fiber sheet. The reason for the occurrence of the serious cracks is not mentioned in the F/S report. In addition, the surrounding concrete of Unit 8 turbine has some leakage which should be repaired. The surrounding concrete of each intake structures (5 intakes in total) also have some minor cracks, which shall also be injected with epoxy, as recommended by the F/S report. However, more cracks from the concrete surrounding the turbines and generators of Units 1, 2, 4, 7, 9, and 10 were observed but not structurally serious. Concrete strength was examined using Schmidt Hammer and found no deterioration on the concretes. The locations recommended for repair/reinforcement under the study are shown in Table 3-7.

Table 3-7 Location for Concrete Repair and Strength of Existing Concrete

<table>
<tr><th></th><th>No.1</th><th>No.2</th><th>No.3</th><th>No.4</th><th>No.5</th><th>No.6</th><th>No.7</th><th>No.8</th><th>No.9</th><th>No.10</th></tr>
<tr><td>Turbine</td><td></td><td></td><td></td><td></td><td>○</td><td>○</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Leakage</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>○</td><td></td><td></td></tr>
<tr><td>Intake</td><td colspan="2">○</td><td colspan="2">○</td><td colspan="2">○</td><td colspan="2">○</td><td colspan="2">○</td></tr>
<tr><td>Concrete Strength (MPa)</td><td>48.2</td><td>50.3</td><td>44.0</td><td>48.5</td><td>51.6</td><td>52.4</td><td>50.2</td><td>51.6</td><td>48.3</td><td>50.2</td></tr>
</table>

Note: Locations for repair are described as ○ Standard strength for concrete is F=30 MPa
Source：Prepared by the Study Team

(3) Evaluation of Sedimentation

The sedimentation volume in the future may be estimated as follows and the comparison between the F/S report and actual survey data was conducted and summarized in Table 3-8**.**

1) Using sedimentation volume based on the previous surveyed data (1967-2010) and applying the same ratio to year 2011-2093.
2) Using sedimentation volume based on the sedimentation analysis for the F/S

Accordingly, the sedimentation will be reduced in the next 83 years by approximately 8%. It was explained that the mountainous slopes and river courses will gradually stabilize in the future. The sedimentation analysis in the F/S report may be correct and it would be the proper approach to calculate the volume of future sedimentation.

Table 3-8 Evaluation of the F/S Report on Sedimentation

<table>
<tr><th colspan="2">Year</th><th>1967-2010</th><th>2011-2050</th><th>2051-2093</th><th>Total</th></tr>
<tr><td colspan="2">Duration</td><td>44 years</td><td>40 years</td><td>43 years</td><td>127 years</td></tr>
<tr><td colspan="2">Catchment Area</td><td colspan="3">33,343 km^2</td><td>-</td></tr>
<tr><td rowspan="4">Sedimentation Volume</td><td rowspan="2">Actual Survey</td><td>1,589 mm^3</td><td>1,445 mm^3</td><td>1,554 mm^3</td><td rowspan="2">4,588 mm^3</td></tr>
<tr><td>(0.5%)</td><td>(0.5%)</td><td>(0.5%)</td></tr>
<tr><td rowspan="2">WAPDA F/S Report</td><td>1,589 mm^3</td><td>1,461 mm^3</td><td>1,178 mm^3</td><td rowspan="2">4,228 mm^3</td></tr>
<tr><td>(0.5%)</td><td>(0.4%)</td><td>(0.3%)</td></tr>
</table>

Note: Figure inside the parenthesis describes the reducing rate of reservoir storage capacity
Source：Prepared by the Survey Team

Table 3-9 Review of the F/S Report Units 1 to 4 for Turbine Equipment

Parts Name	Recommendations in the F/S Report	Comments of the Survey Team	Note
Inlet Valves	Overhaul is recommended for all units with partial repairing together with the replacement of bypass valves and pipings for all units.	By-plane type inlet valves are recommended for reducing head loss and minimizing water leakage. Bypass valves and its piping are also replaced.	-
Spiral Casing	The wire draw, wire gall, lower guide vanes, and facing plates should be replaced. Overhaul of the inside casing including stay vane is recommended with repainting and wearing elements replacement.	Same as left. Measuring instruments including turbine water flow detector shall be replaced.	-
Turbine Runner	The current runner shall be replaced with a new runner.	New runners including runner corns shall be replaced.	-
Runner Wearing Rings	The new runners will be provided with new wearing rings and spares.	Same as left.	-
Guide Vane	All guide vanes for replacement units are recommended.	Same as left.	-
Guide Vane Operating Mechanism	Overhaul of the mechanism is recommended with parts replacement such as linkage bushings, gate operating ring, and bushings.	Same as left.	-
Head Cover	The wire draw, wire gall, upper guide vane and facing plate is replaced. Inspection of all head cover is recommended.	The head cover shall be replaced including adopting new design for turbine shaft and shaft seal.	-
Turbine Shaft	Inspection and one spare shaft for four units are recommended.	Same as left but does not require spare shaft supply.	-
Shaft Seal	Overhaul is recommended with wearing elements replacement.	The shaft seal shall be replaced by new one for improving the shaft seal performance.	-
Discharge Ring and Draft Tube	Inspection of rings and liners are recommended with blast and recoat.	Same as left	-
Pressure Balancing	No necessary work is expected.	Same as left.	-
Turbine Guide Bearing	No recommendation is provided.	All guide bearings shall be replaced by new one.	The thrust and guide bearings are to be included in the generator section.
Governor	New governors should be provided because spare parts are no longer available.	The new governor shall be of latest design, digital type with additional speed detector of SSG type.	-
Governor Pressure Oil system	Aside from maintenance, occasional component replacement is recommended.	The governor pressure oil supply system shall be replaced.	-

Source：Prepared by the Survey Team

Table 3-10 Review of the F/S Report Units 5 and 6 for Turbine Equipment

Parts Name	Recommendations in the F/S Report	Comments of the Survey Team	Note
Inlet Valves	Overhaul is recommended for all units with partial repairing. Replacement of bypass valve and piping for all units shall also be applied.	By-plane type inlet valves are recommended for reducing head loss and minimizing water leakage. By-pass valve and its piping are also replaced.	-
Spiral Casing	The wire draw, wire gall, lower guide vane, and facing plates should be replaced. Overhaul of the casing inside including the stay vane is recommended with repainting and wearing elements replacement.	Same as left.	-
Turbine Runner	The current runner shall be replaced with a new runner.	Same as left.	-
Runner Wearing Rings	The new runners will be provided with new wearing rings and spares.	Same as left.	-
Guide Vane	All guide vanes for all replacement units are recommended.	Same as left.	-
Guide Vane Operating Mechanism	Overhaul of the mechanism is recommended with parts replacement such as linkage bushings, gate operating ring, and bushings.	The guide vane operating mechanism shall be replaced.	-
Head Cover	The wire draw, wire gall, upper guide vane, and facing plate are replaced. Inspection of all head cover is recommended.	The head cover shall be replaced, including adopting a new design for the turbine shaft and shaft seal.	-
Turbine shaft	Inspection and one spare shaft for two units are recommended.	The turbine shaft shall be replaced by new design runner, although a spare shaft is not required.	-
Shaft Seal	Overhaul is recommended with wearing elements replacement including shaft sleeve replacement.	Shaft seal shall be replaced with a new design.	-
Discharge Ring and Draft Tube	Inspection of rings and liners are recommended with blast and re-coat.	Same as left	-
Pressure Balancing	No necessary work is expected.	Same as left.	-
Turbine Guide Bearing	No recommendation is provided.	All guide bearings shall be replaced by new one.	The thrust and guide bearings are to be included in the generator section.
Governor	New governors should be provided because spare parts are no longer available.	The governor shall be replaced with the latest digital type design with an additional SSG type speed detector.	-
Governor Pressure Oil System	Aside from maintenance, occasional component replacement is recommended.	The governor pressure oil supply system shall be replaced.	-

Source：Prepared by the Survey Team

Table 3-11 Review of the F/S Report Units 7 and 8 for Turbine Equipment

Parts Name	Recommendations in the F/S Report	Comments of the Survey Team	Note
Inlet Valves	Overhaul is recommended for both units with partial repairing. Replacement of by-pass valve and piping for both units shall also be applied.	Same as left.	-
Spiral Casing	The wire draw, wire gall, lower guide vane, and facing plates should be replaced. Overhaul of the casing inside including the stay vane is recommended with repainting.	Same as left.	-
Turbine Runner	The current runner shall be replaced with a new runner.	Same as left.	-
Runner Wearing Rings	The new runners will be provided with new wearing rings and spares.	Same as left.	-
Guide Vane	All guide vanes for all replacement units are recommended.	Same as left.	-
Guide Vane Operating Mechanism	Overhaul of the mechanism is recommended with parts replacement such as linkage bushings, gate operating ring, and bushings.	Same as left.	-
Head Cover	The wire draw, wire gall, upper guide vane, and facing plate are replaced. Inspection of all head cover is recommended.	Same as left.	-
Turbine Shaft	Inspection and one spare shaft for two units are recommended.	Same as left but not recommended on spare shaft.	-
Shaft Seal	The shaft seal is not functioning. New design was requested, including the shaft sleeve replacement.	Same as left.	-
Discharge Ring and Draft Tube	Inspection of rings and liners are recommended with blast and recoat. Unit 8 leakage must be found and corrected. The source of this water leakage shall be found and repaired.	Same as left	-
Pressure Balancing	No necessary work is expected.	Same as left.	-
Turbine Guide Bearing	No recommendation.	Same as left.	The thrust and guide bearings are to be included in the generator section.
Governor	Although the condition of the governor is acceptable, new governors should be provided because spare parts are no longer available.	Same as left.	-
Governor Pressure Oil System	Aside from maintenance, occasional component replacement is recommended.	Same as left.	-

Source：Prepared by the Survey Team

Table 3-12 Review of the F/S Report Units 9 and 10 for Turbine Equipment

Parts Name	Recommendations in the F/S Report	Comments of the Survey Team	Note
Inlet Valves	Overhaul is recommended for all units with partial repairing. Replacement of by-pass valve and piping for all units shall also be applied.	Same as left.	-
Spiral Casing	The wire draw, wire gall, lower guide vane, and facing plates should be replaced. Overhaul of the casing inside including the stay vane is recommended with repainting and wearing elements replacement.	Same as left.	-
Turbine Runner	The current runner shall be replaced with a new runner.	Same as left	-
Runner Wearing Rings	The new runners will be provided with new wearing rings and spares.	Same as left.	-
Guide Vane	All guide vanes for all replacement units are recommended.	Same as left.	-
Guide Vane Operating Mechanism	Overhaul of the mechanism is recommended with parts replacement such as linkage bushings, gate operating ring, and bushings.	Same as left.	-
Head Cover	The wire draw, wire gall, upper guide vane, and facing plate are replaced. Inspection of all head cover is recommended.	Same as left.	-
Turbine Shaft	Inspection and one spare shaft for two units are recommended.	Same as left but spare shaft supply is not recommended	-
Shaft Seal	Overhaul is recommended with wearing elements replacement.	Same as left.	-
Discharge Ring and Draft Tube	Inspection of rings and liners are recommended with blast and recoat.	Same as left	-
Pressure Balancing	No necessary work is expected.	Same as left.	-
Turbine Guide Bearing	No recommendation is provided.	Same as left.	The thrust and guide bearings are to be included in the generator section.
Governor	New governors should be provided because spare parts are no longer available.	Same as left.	-
Governor Pressure Oil System	Aside from maintenance, occasional component replacement is recommended.	Same as left.	-

Source：Prepared by the Survey Team

Table 3-13 Review of the F/S Report Units 1 to 4 for Generator and Associated Equipment

Parts Name	Recommendations in the F/S Report	Comments of the Survey Team	Note
Stator	Replacement of core and windings is recommended. One new frame is required to be purchased.	In addition to the F/S report, air cooler should also be replaced. The F/S report also recommended in items for cooling system.	-
Rotor	Re-insulate poles with new top and bottom insulation collars. Provide new pole keys. Replace pole lead and damper connections. Rim shall be restacked and re-shrunk with new shrink keys.	All poles should be replaced due to their deterioration with new ones and with new keys. Also, brake ring should be replaced. Same idea as the F/S report for other items.	-
Thrust and Guide Bearing	Good condition.	Thrust bearing, thrust runner, and guide bearing are still in good condition but they were not replaced since commissioning. Therefore, replacement is recommended. Also, LBB may be replaced if the vertical weight of turbine/generator is increased.	-
Brake and Jack	Rehabilitate existing brakes and jacks. Supply and install new brake ring.	Same idea as the F/S report. Brake ring of the rotor should be replaced.	-
Cooling System	Install 12 new air intake RTDs and 12 new air exhaust RTDs. Replace all 12 coolers. Install water treatment and filtering system.	Same idea as the F/S report.	-
Brush Assembly and Collector Ring	Rehabilitate collector rings. Dismantle and dispose DC exciter, brushes, brush holder and commutator. Install new brush holder. Install new static excitation system.	Same idea as the F/S report. In case DC exciter will remain in existing position to keep generator in flywheel effect, the collector ring and brush holder should be replaced.	-
Main Leads	Most of the parts can be reused. Replace flexible connections as required.	Same idea as the F/S report.	-
Excitation System	Replace with static, digital system.	Same idea as the F/S report.	-
Circuit Breaker	No medium voltage circuit breaker		-
Main Bus (IPB)	Rated 13.2 kV, 6287 A and possible to reuse.	Same idea as the F/S report.	-
Fire Protection	It is maintained in a ready to operate condition.	Same idea as the F/S report.	-
Protective Relaying	Replace with modern digital protective relays	Same idea as the F/S report.	-
Unit Controls, Instrumentation and Mechanical Protections	Replace with modern digital control system. Replace all instruments. Provide additional instrumentation. Upgrade mechanical protection system.	Same idea as the F/S report.	-
Step-Up Transformer	Rehabilitation is necessary, such as oil processing, refurbishing of oil coolers, replacing tap changers, and so on.	Same idea as the F/S report.	-

Source：Prepared by the Survey Team

Table 3-14 Review of the F/S Report Units 5 and 6 for Generator and Associated Equipment

Parts Name	Recommendations in the F/S Report	Comments of the Survey Team	Note
Stator	Replacement of core and windings is recommended. One new frame is requested to be purchased.	Replacement of all the parts are required with the reason mentioned in Sub-clause 3.2.3 and due to the following; - Major short circuit happened. The design of upper guide bearing should be changed. - Unit 5 is operating with only limited output. - Both coils for Units 5 and 6 were damaged and were replaced with non-original manufacturer's coil.	-
Rotor	Re-insulate poles with new top and bottom insulation collars. Provide new pole keys. Replace pole lead and damper connections. Replace pole tangential supports with new clamping hardware. Rim shall be re-shrunk with new shrink keys.		-
Thrust and Guide Bearing	The cause of the oil vapors and splashes from the upper and lower guide bearings should be found and corrected.		-
Brake and Jack	Rehabilitate existing brakes and jacks. Replace air and oil lines. Supply and install new brake ring.		-
Cooling system	Install 12 new air intake RTDs and 12 new air exhaust RTDs. Replace all 12 coolers. Install water treatment and filtering system.		-
Brush Assembly and Collector Ring	Rehabilitate collector rings. Dismantle and dispose DC exciter, brushes, brush holder, and commutator. Install new brush holder. Install new static excitation system.		-
Main Leads	Most of the parts can be reused. Replace flexible connections as required.		-
Excitation System	Replace with static, digital system.		-
Circuit Breaker	No medium voltage circuit breaker		-
Main Bus (IPB)	Rated 13.2 kV, 6287 A and possible to reuse.	Same idea as the F/S report.	-
Fire Protection	It is maintained in a ready to operate condition.	Same idea as the F/S report.	-
Protective Relaying	Replace with modern digital protective relays	Same idea as the F/S report.	-
Unit Controls, Instrumentation and Mechanical Protections	Replace with modern digital control system. Replace all instruments. Provide additional instrumentation. Upgrade mechanical protection system.	Same idea as the F/S report.	-
Step-Up Transformer	Rehabilitation is necessary such as oil processing, refurbishing of oil coolers, replacing tap changers, and so on.	Same idea as the F/S report.	-

Source：Prepared by the Survey Team

Table 3-15 Review of the F/S Report Units 7 and 8 for Generator and Associated Equipment

Parts Name	Recommendations in the F/S Report	Comments of the Survey Team	Note
Stator	As the typical life expectancy will come soon, windings should be replaced with minimal priority. Its core should be replaced with the same reason given above.	In addition to the above, one frame should be replaced to mitigate risks.	-
Rotor	Field poles and windings can be reused after re-insulation. Most other parts are possible to use.	Same idea as the F/S report.	-
Thrust and Guide Bearing	Good condition		-
Brake and Jack	Gaskets, return springs, limit switches and brake pads should be replaced and other parts can be reused after some rehabilitation.		--
Cooling System	Air coolers, all TRDs, piping inside of air housing should be replaced.		-
Brush Assembly and Collector Ring	Most of the parts can be reused with some rehabilitation. Old finger type brush holders should be replaced.		-
Main Leads	Only flexible connectors shall be inspected and replaced, if necessary.		-
Excitation System	Voltage regulator should be replaced with digital type.		--
Circuit Breaker	No medium voltage circuit breaker	-	-
Main Bus (IPB)	Rated 12.5 kV, 6000 A and possible to reuse.	Same idea as the F/S report.	-
Fire Protection	It is maintained in a ready to operate condition.		-
Protective Relaying	Outdated, replace with modern digital protective relays.		-
Unit Controls, Instrumentation and Mechanical Protections	Outdated, upgrade and replace with modern digital control system.		-
Step-up Transformer	Rehabilitation is necessary such as oil processing, refurbishing of oil coolers, replacing tap changers and so on.	Same idea as the F/S report.	-

Source：Prepared by the Survey Team

Table 3-16 Review of the F/S Report Units 9 and 10 for Generator and Associated Equipment

Parts Name	Recommendations in the F/S Report	Comments of the Survey Team	Note
Stator	To assure reliability for the next 40 years, the winding shall be replaced in 10 to 15 years.	Same idea as the F/S report.	-
Rotor	Most of the parts are possible for reuse.		-
Thrust and Guide Bearing	Good condition		-
Brake and Jack	Only brake pads should be replaced.		-
Cooling System	For every cooler, one RTD for measuring the inlet air temperature and one RTD to measure the exhaust air temperature should be installed. Air coolers and piping material inside of the air housing should be replaced.		-
Brush Assembly and Collector Ring	All of the parts can be reused.		-
Main Leads	Suitable to reuse.		-
Excitation System	The forced outage rate, plus the lack of spare parts mean that the voltage regulator portion of the system requires updating.	According to the Mangla engineer; AVRs of units 9 and 10 are more sensitive. Any variation in the system trips the units. In order to avoid frequent tripping of units and to keep the system stable, whenever the load demand decreases there is an option to shut down any unit, units 9 and 10 were preferred to be shut down first. Due to problematic AVRs, these units start to peak and shut down afterwards. These factors contributed to more numbers of start/stop. Therefore, these systems are recommended for replacement.	-
Circuit Breaker	No medium voltage circuit breaker		-
Main Bus (IPB)	Rated 15 kV, 10,000 A and possible to reuse.	Same idea as the F/S report.	-
Fire Protection	It is maintained in a ready to operate condition.		-
Protective Relaying	Outdated, replace with modern digital protective relays.		-
Unit Controls, Instrumentation and	Outdated, upgrade and replace with modern digital control system.		-

Mechanical Protections			
Step-Up Transformer	Rehabilitation is necessary such as oil processing, refurbishing of oil coolers, and so on.	Same idea as the F/S report.	-

Source：Prepared by the Survey Team

Table 3-17 Review of the F/S Report for Balance of Plant (BOP)

Plant Name	Recommendations in the F/S Report	Comments of the Survey Team	Note
Intake Structure and Power Tunnels	Trash rack at Intake No.2 should be repaired and all of the intake trash racks should be inspected for damage. Steel tunnel coating is required for Tunnel 5. All concrete surface spells and cracks with seeping water will need to be repaired.	Same idea as the F/S report	-
Bifurcation and Penstocks	The penstock liners and the bifurcations are expected to be suitable for another life cycle with little or no corrective action. It is recommended that Tunnel 5 should have the scoured portion of its coating system restored.	Same idea as the F/S report.	-
Irrigation Valves	The irrigation valves and operating systems appeared to be in good condition. In order to continue for another 40 years of operation, the valve operating mechanisms should be disassembled, inspected, tested, and repaired as needed.	Overhaul and water leakage stop repair are recommended for another 40 years of operation.	-
Draft Tube Gates and Associated Structures and Equipment	An additional mechanism for positioning the gate guides in the pier is recommended. But this additional mechanism requires an extension of the gate guide, which causes interference to irrigation valve operation. Detailed study is requested as a part of the project upgrade.	Same idea as the F/S report.	-
Spillway Gates	It was not required for any rehabilitation of spillway gates because the said gates were rehabilitated during the dam raising project.	Same idea as the F/S report.	-
Powerhouse Cranes	The powerhouse cranes appeared to be in good condition and should require only periodic maintenance and testing to provide an additional 40 years of operation.	Same idea as the F/S report	-
Cooling Water Systems	The cooling water systems are currently functional, but piping and valve replacement will be necessary to continue a reliable operation for an additional 40 years.	Same idea as the F/S report.	-
Station Drainage and Unit Dewatering Systems	The drainage and dewatering systems seem to be in satisfactory condition. It is recommended that all drainage and dewatering pumps must be replaced to continue for additional	Same idea as the F/S report	-

	40 years of operation.		
Fire Protection Systems (non-generator)	The fire protection system performance should be improved by adding fire detection devices (smoke or heat detectors) to the control room, 11 kV switchgear rooms, cable tunnels and the transformers bay.	Same idea as the F/S report	-
Generator Fire Protection Systems	No issues were noted with the generator fire protection systems.	Same idea as the F/S report	-
Oil Purification Systems	This system is in good condition. No additional work should be required.	Same idea as the F/S report	-
Compressed Air Systems	No additional work is expected to be required for the powerhouse compressed air system.	Same idea as the F/S report	-
Heating Ventilation and Air Conditioning	No additional work is expected to be required for this system.	Same idea as the F/S report	-
Service Water System	No additional work is expected to be required for this system.	Same idea as the F/S report	-
Sewage Systems	No additional work is expected to be required for this system.	Same idea as the F/S report	-
Switchyard	Switchyard will remain operational for another life cycle.	Same idea as the F/S report	-
Switchyard Protection, Metering and Control Systems	Switchgears replacement plan was managed by the other project. Most of the control and protection equipment are outdated. It is recommended to replace the modern system as substation automatic system (SAS). Protection relays are also recommended to replace the numerical (digital) relay system.	Refurbish plan of switchyard shall be followed to the NPCC plan. The refurbish work by this project will be limited to the necessary refurbishing work with generation upgrading. Switchyard Supervisory Control and Data Acquisition System (SCDA) is implemented based on the NPCC plan. Most switchyard refurbish works can be planed independently without generation upgrading work, therefore it is preferable to plan as the other project.	-
Switchyard DC Systems (batteries, chargers, DC distribution systems)	Battery was replaced recently, so no requirement of change. One battery charger is recommended to replace.	Ditto as above.	-
Station Service/Auxiliary Electrical Systems – AC (switchgear, transformers, panelboards, motor control centers)	The FS recommended the new station service circuit with two generators circuits breakers which is selected from five alternative ideas in the FS.	The MV, LV circuit related generation upgrading will be renewed. MV system configuration will be redesigned to be more reliable. It is not the same with the FS recommendation.	-
Station DC Systems (batteries, chargers, DC distribution systems)	Battery was replaced recently, so no requirement of change. There are 50 V, and 230 V DC voltage systems. It is recommended to consider the unified voltage.	The redesign of DC supply system will be required by changing the excitation systems and new SCADA system.	-
Standby Generators	The standby generators are recent generators and there sizes are suited for load with ample overcapacity. The standby	Same idea as the F/S report.	-

	generators themselves are suitable for use during the life cycle of the plant.		
Powerhouse Grounding System	No additional work is expected to be required for this system.	Same idea as the F/S report.	-
Station Low Voltage Systems – Lighting, Receptacles	It is recommended that the entire low voltage system be replaced with a new one as part of the unit and station auxiliary supply system upgrade.	LV circuit related generation upgrading that will be renewed. The building service facilities will not be touched.	-
Station Fire Detection	There is no fire detection system. It is recommended that a modern, digital fire detection system be implemented throughout the powerhouse.	The building service facilities will not be touched by this project.	-
Instrumentation and Control Systems	The FS recommended the replacement of the whole units control systems.	Systems related upgrading of generation units will be renewed using programmable logic controller (PLC) and SCADA	-
Communication with Load Dispatch System	The load dispatch system (LDS) upgrading project is under implementation.	The plan will be managed by the NTDC/NPCC. The automatic load frequency control (ALFC) or other active and reactive power control matters from the NPCC will be consistent with the new PLC and SCADA design.	-
Elevators and Other Systems,	Based on the age of elevators, the elevators should undergo an inspection by a qualified elevator service representative. The result of the inspection should be incorporated in the scope of work for elevator service.	Same idea as the F/S report.	-

Source：Prepared by the Survey Team

Table 3-18 Review of the F/S Report - Summary of Up-gradation Alternative

Alternative	-	1 – 4	5 and 6	9 and 10	7 and 8	Comments of the Survey Team
Up-gradation Alternative 1	Output after Up-gradation	168.75 MVA (135 MW)			143.75 MVA (115 MW) (overload value)	-
	Modification	The generator rotor would be reused and the generator stator would be replaced.			No margin to upgrade without changing the dimensions, therefore output is the same as existing.	-
Up-gradation Alternative 2 (Option 1)	Output after Up-gradation	187.5 MVA (150 MW)			187.5 MVA (150 MW)	Foundation for all units except units 7 and 8 should be changed. (Demolition is necessary)
	Modification	Diameter of the generator will be increased.			Stator core length will be increased while maintaining the diameter.	
Up-gradation Alternative 2 (Option 2)	Output after Up-gradation	187.5 MVA (150 MW)			187.5 MVA (150 MW)	Foundation modification is necessary but not significant demolition.
	Modification	Stator core length will be increased.			Stator core length will be increased while maintaining the diameter.	

Note: This table is the summary of Up-gradation Alternative Study described in the Sub-clause 1.3.8.3 of the F/S Report. This study comprised two up-gradation alternatives, i.e., 135 MW and to 150 MW.

Source：Prepared by the Survey Team

Table 3-19 Review of the F/S Report - Summary of Categories

Category 1	Do nothing	Minimal maintenance and running the units to failure.	-
Category 2	Up-gradation to existing overload rating 115 MW	Turbine replacement required. Generator would be provided with new core, rewound with new stator windings. Excitation system would be changed.	-
Category 3	Up-gradation to 135 MW with minimum modifications	Generator will require new stators and rebuild rotor components. Not necessary to add a significant cost to the turbine components compared to the 115 MW alternative.	Recommended up-gradation is 135 MW each for Units 1-4, 5 & 6, and 9 & 10. For Units 7 & 8 are to be rehabilitated to 115 MW each.
Category 4	Up-gradation to maximum possible output of 150 MW	New generator will be provided.	-

Note: This table is the summary of the four categories for each output of 115 MW, 135 MW, and 150 MW.

Source：Prepared by the Survey Team

Table 3-20 Summary of Up-Grade Idea in the F/S Report

Number of Alternative	Recommendations in the F/S Report	Comments of the Survey Team	Remarks
Alternative 0	Base case, 1150 MW station, existing 125 MVA, 0.8 power factor (just rehabilitation)	-	-
Alternative 1A	Up-gradation to 1310 MW, 2 x 125 MVA and 8 X 168 MVA generators, 0.8 power factor	-	Up-gradation to 144 MW per unit, 180 MVA with power factor 0.8
Alternative 1B	Up-gradation to 1380 MW, 2 x 187.5 MVA and 8 x 168 MVA generators, 0.8 power factor	-	
Alternative 2	Up-gradation to 1500 MW, 10 x 187.5 MVA generators, 0.8 power factors	Proposal on the F/S report can be achieved only by demolishing the foundation of generators for all units except for units 7 and 8. The Survey Team recommended the up-gradation without demolish work.	

Note: This table is the summarized alternatives described in Sub-clause 1.4.5 of the F/S report with the Survey Team's comments.

Source：Prepared by the Survey Team

3.3 Points to be stated in the F/S Report and to be considered in the Detailed Design

3.3.1 Points to be Stated in the F/S Report

The following items have not been studied in the F/S report.

(1) Estimation of winding life

The winding life should be analyzed using common methods. The result of analysis by the Survey Team is described in Sub-clause 5.2.1.

(2) Measuring data

There is no measuring data (such as insulation resistance) in the F/S report. The result of measuring of insulation resistance is described in Sub-clause 4.6.1.

(3) Maximum gross head and effective head after dam raising.

There is no description of maximum gross head and effective head after dam raising. The result of study by the Survey Team is described in Sub-clause 5.6.1.

3.3.2 Main Points to be Considered in the Detailed Design

The following items shall be considered at the Detailed Design Stage.

(1) Lower bearing bracket

The weights of rotating parts are increased when upgraded. The bearing bracket should be studied according to the upgraded weight.

(2) Rotating parts weight and water thrust

The weight of rotating parts and water thrust are increased when upgraded. Proper analysis is also needed.

(3) Operation limit study and setting change

There is no description of the operation limit study and setting change for limiting generator output after dam raising.

(4) Station service circuit

The simplification of interlock, and total coordinated power supply redundancy among the high-voltage, medium-voltage and low-voltage shall be considered.

CHAPTER 4

FINDINGS IN THE PLANT SURVEY

CHAPTER 4 FINDINGS OF THE PLANT SURVEY

4.1 Basic Features of the Plant

4.1.1 Dam Water Level

The basic features of the water level of Mangla Dam for generation are shown in the following Table 4-1:

Table 4-1 Basic Features of the Plant

Contents	Before Dam Raising	After Dam Raising
Max. Reservoir Water Level	EL 1,102 ft = 336.1 m	EL 1,142 ft = 348.3m

Source: Prepared by the Survey Team

4.1.2 Turbine

The main ratings of turbine are as follows:

i. Units 1 through 4

Manufacturer	Mitsubishi Heavy Industry, Japan
Type	Francis
Rated Output	138,000 BHP at 295 ft head (103 MW at 89.9 m head)
Maximum Output	198,000 BHP at 380 ft head (147.7 MW at 115.8 m head)
Rated Discharge	4,550 cfs (129 m^3/s)
Rated Speed	166.7 rpm
Rough zone	0-80 MW, with a less rough spot around 30 MW
Commissioning Year	1967 for Units 1 and 2, 1968 for Unit 3, 1969 for Unit 4

ii. Units 5 and 6

Manufacturer	CKD Blansko, Czechoslovakia
Type	Francis
Rated Output	138,000 BHP at 295 ft head (103 MW at 89.9 m head)
Maximum Output	198,000 BHP at 380 ft head (147.7 MW at 115.8 m head)
Rated Discharge	4,515 cfs (128 m^3/s)
Rated Speed	166.7 rpm
Rough zone	0-80 MW, with a less rough spot around 30 MW
Commissioning Year	1973 for Unit 5, 1974 for Unit 6

iii. Units 7 and 8

Manufacturer	ACEC, Belgium
Type	Francis
Rated Output	103 MW
Maximum Output	148 MW
Rated Discharge	4,306 cfs (122 m^3/s)
Rated Speed	166.7 rpm
Rough zone	0-80 MW, with a less rough spot around 50 MW
Commissioning Year	1981

iv. Units 9 and 10

Manufacturer	CKD Blansko, Czechoslovakia
Type	Francis
Rated Output	103 MW at 90 m/295 ft head
Maximum Output	148 MW at 115 m/380 ft head
Rated Discharge	4,515 cfs (12.9 m^3/s)
Rated Speed	166.7 rpm
Rough zone	0-80 MW, with a less rough spot around 50 MW
Commissioning Year	1993 for Unit 9, 1994 for Unit 10

4.1.3 Generator

The main ratings of generator and electrical equipment are as follows:

(1) Generator

i. Units 1 through 4

Manufacturer	Hitachi, Japan
Rated Output	125,000 kVA
Rated Power Factor	0.8
Rated Voltage	13,200 V
Rated Frequency	50 Hz
Rated Speed	166.7 min^{-1}
Insulation Class	B
Overload	115%
Year of Manufacture	1965 for Units 1, 2, and 3, 1967 for Unit 4

ii. Units 5 and 6

Manufacturer	SKODA, Czechoslovakia
Rated Output	125,000 kVA

Rated Power Factor	0.8
Rated Voltage	13,200 V
Rated Frequency	50 Hz
Rated Speed	166.7 min^{-1}
Insulation Class	F
Overload	115%
Year of Manufacture	1971

iii. Units 7 and 8

Manufacturer	Hitachi, Japan
Rated Output	125,000 kVA
Rated Power Factor	0.8
Rated Voltage	13,200 V
Rated Frequency	50 Hz
Rated Speed	166.7 min^{-1}
Insulation Class	B
Overload	115%
Year of Manufacture	1979

iv. Units 9 and 10

Manufacturer	SKODA, Czechoslovakia
Rated Output	125,000 kVA
Rated Power Factor	0.8
Rated Voltage	13,200 V
Rated Frequency	50 Hz
Rated Speed	166.7 min^{-1}
Insulation Class	F
Overload	115%
Year of Manufacture	1991

(2) Isolated Phase Bus

i. Units 1 through 4

Manufacturer	BBC, Germany
Current Capacity	6,287 A

ii. Units 5 and 6

Manufacturer	BBC, Germany
Current Capacity	6,287 A

iii. Units 7 and 8

Manufacturer	Simelectro, France
Current Capacity	6,000 A (This figure is smaller than the current of 115% overload operation)

iv. Units 9 and 10

Manufacturer	Energoved Praha, Czechoslovakia
Current Capacity	10,000 A

(3) Generator Transformer

i. Unit 1

Manufacturer	Savigiliano, Italy
Rated Capacity	138 MVA (This is smaller than the overload output of the generator)
Rated Voltage	12.5/132 kV

ii. Unit 2

Manufacturer	Skoda, Czechoslovakia
Rated Capacity	138 MVA (This is smaller than the overload output of the generator)
Rated Voltage	12.5/132 kV

iii. Unit 3

Manufacturer	Skoda, Czechoslovakia
Rated Capacity	144 MVA
Rated Voltage	12.5/220 kV

iv. Units 4 through 6

Manufacturer	Savigiliano, Italy
Rated Capacity	138 MVA (This is smaller than the overload output of the generator)
Rated Voltage	12.5/220 kV

v. Unit 7

Manufacturer	Italtrafo, Italy
Rated Capacity	144 MVA
Rated Voltage	12.5/220 kV

vi. Units 8 through 10

Manufacturer	Skoda, Czechoslovakia
Rated Capacity	144 MVA
Rated Voltage	12.5/220 kV

All units are properly operating with appropriate temperatures of generator winding and bearing during the Survey Team's site visit except Unit 5. Only Unit 5 is operating with the limit output of 70 MW to 80 MW due to past accident as described in Sub-clause 4.6.1.

4.2 Operating History of the Plant

All units are properly operating except Unit 5, and operating history is as follows:

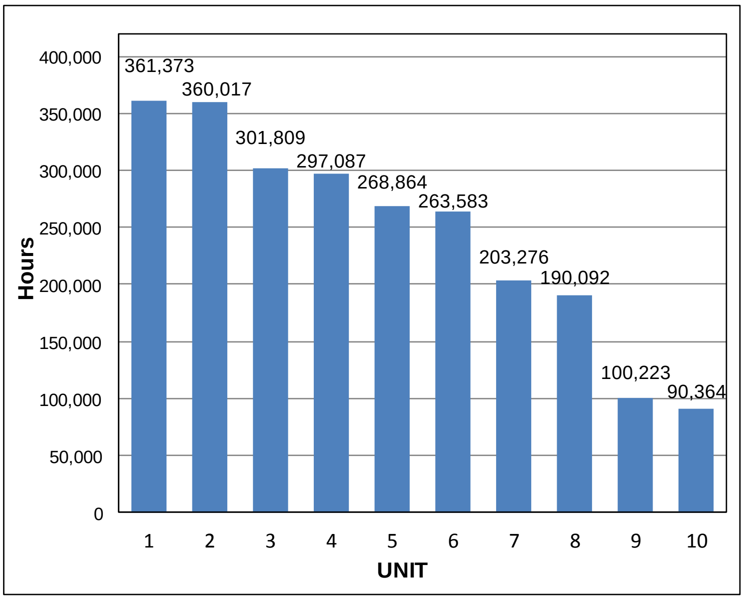
(1) Commissioning Dates and Accumulated Operating Hours

Commissioning dates and total operating hours since commissioning for each unit shown in the following Table 4-2 and Figure 4-1:

Table 4-2 Total Operating Hours (up to 31 Dec. 2011)

Unit Number	Total Operating Hours	Commissioning Date	Unit Number	Total Operating Hours	Commissioning Date
Unit 1	361,373 hrs	03/07/1967	Unit 6	263,583 hrs	11/03/1974
Unit 2	360,017 hrs	14/07/1967	Unit 7	203,276 hrs	19/06/1981
Unit 3	301,809 hrs	07/03/1968	Unit 8	190,092 hrs	22/08/1981
Unit 4	297,087 hrs	17/06/1969	Unit 9	100,223 hrs	24/09/1993
Unit 5	268,864 hrs	29/12/1973	Unit 10	90,364 hrs	06/07/1994

Source: WAPDA (Mangla Hydro Power Station)



Source: WAPDA (Mangla Hydro Power Station)

Figure 4-1 Total Operating Hours from Commissioning for Each Unit

(2) Number of Start/Stop

List of number of start/stop of each unit is collected and shown in the following Table 4-3:

Table 4-3 Number of Start/Stop

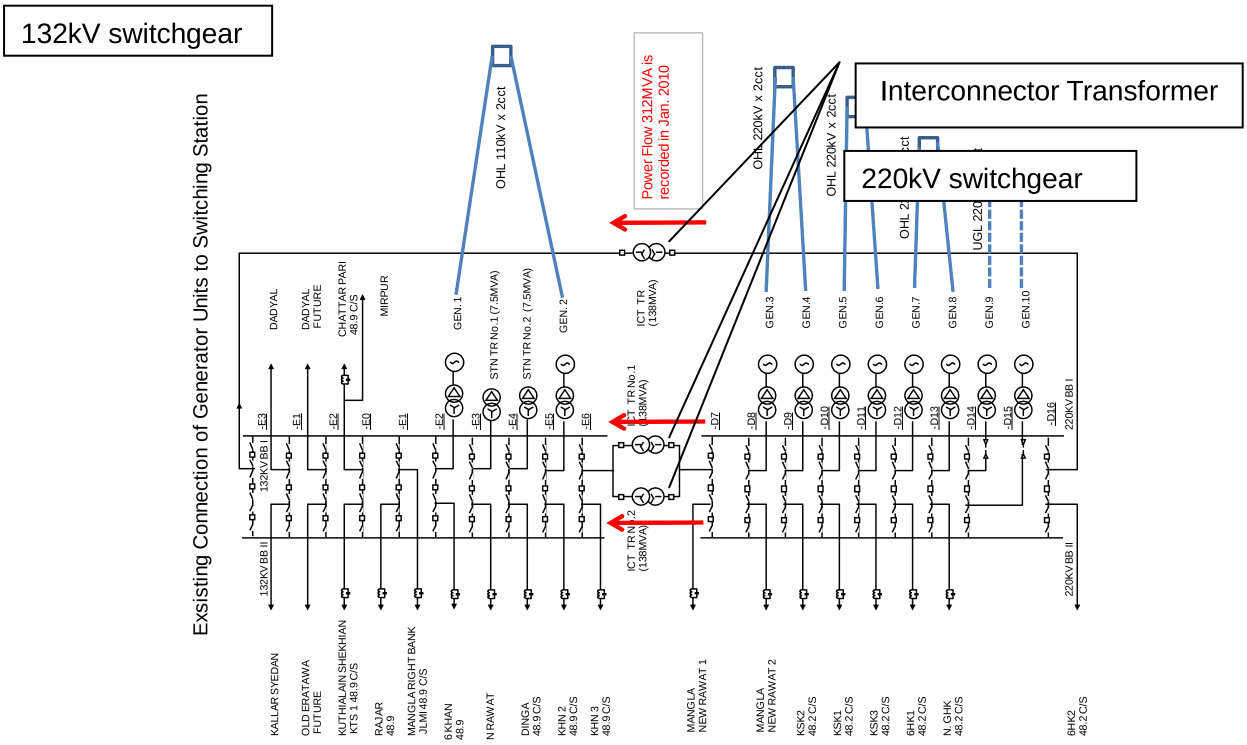
Year	U-1	U-2	U-3	U-4	U-5	U-6	U-7	U-8	U-9	U-10
1969	50	115	57	42	-	-	-	-	-	-
1970	37	44	86	102	-	-	-	-	-	-
1971	26	74	66	75	-	-	-	-	-	-
1972	22	62	76	50	-	-	-	-	-	-
1973	15	33	53	28	-	-	-	-	-	-
1974	30	86	191	25	61	77	-	-	-	-
1975	26	67	84	36	76	84	-	-	-	-
1976	38	50	103	33	52	60	-	-	-	-
1977	28	49	120	82	38	38	-	-	-	-
1978	32	60	81	115	34	42	-	-	-	-
1979	64	37	82	82	25	43	-	-	-	-
1980	35	65	82	73	21	24	-	-	-	-
1981	21	78	88	104	33	20	84	82	-	-
1982	24	23	110	96	97	35	203	198	-	-
1983	21	19	55	50	28	39	79	105	-	-
1984	14	29	141	135	88	51	225	214	-	-
1985	35	84	197	184	79	40	250	253	-	-
1986	27	22	60	71	40	39	105	68	-	-
1987	22	23	36	99	50	48	67	69	-	-
1988	13	23	88	74	58	63	23	26	-	-
1989	14	22	36	13	61	59	61	66	-	-
1990	25	26	54	23	76	31	35	38	-	-
1991	14	18	43	36	10	15	35	36	-	-
1992	11	19	71	85	20	21	83	100	-	-
1993	26	39	123	150	31	25	54	85	45	-
1994	48	54	142	106	20	21	54	65	50	22
1995	16	23	73	89	18	22	79	35	46	53
1996	14	24	33	52	19	20	50	45	52	54
1997	23	33	222	149	17	23	113	163	261	240
1998	19	22	109	124	22	24	133	151	172	184
1999	19	49	165	167	22	34	241	276	256	262
2000	54	56	296	266	32	37	270	318	321	412
2001	74	44	278	333	53	59	297	268	357	356
2002	66	20	335	334	25	27	324	349	422	399
2003	43	29	197	204	96	96	50	66	112	138
2004	58	37	206	179	196	102	96	160	225	261
2005	43	41	179	145	55	47	41	90	127	126
2006	31	20	204	173	34	74	35	94	137	153
2007	13	15	101	98	101	129	24	83	148	118
2008	27	15	125	131	142	180	31	104	125	109
2009	14	16	88	87	88	90	34	77	96	77
2010	23	36	101	96	104	168	129	172	143	152
2011	10	15	182	181	18	135	196	198	206	144
Total Number	1,265	1,716	5,219	4,777	2,040	2,142	3,501	4,054	3,301	3,260

Source: WAPDA (Mangla Hydropower Station)

From the above table, there are some points which were clarified by WAPDA as described below.

A large difference between the total numbers of start/stop of Units 1 and 2 and those of Units 3 and 4 is found from the above table. This reason is to avoid overloading of 138 MVA, 132/220 kV interconnector transformers and to enhance system stability, as Units 1 and 2 are connected to 132 kV bay in the switchgear while Units 3 and 4 are connected to 220 kV bay. Therefore, the numbers of start/stop of Units 1 and 2 are less as compared to Units 3 and 4.

To easily understand the above explanation, the connection diagram of 132/220 kV interconnector transformers in the switchyard is shown in Figure 4-2 below.



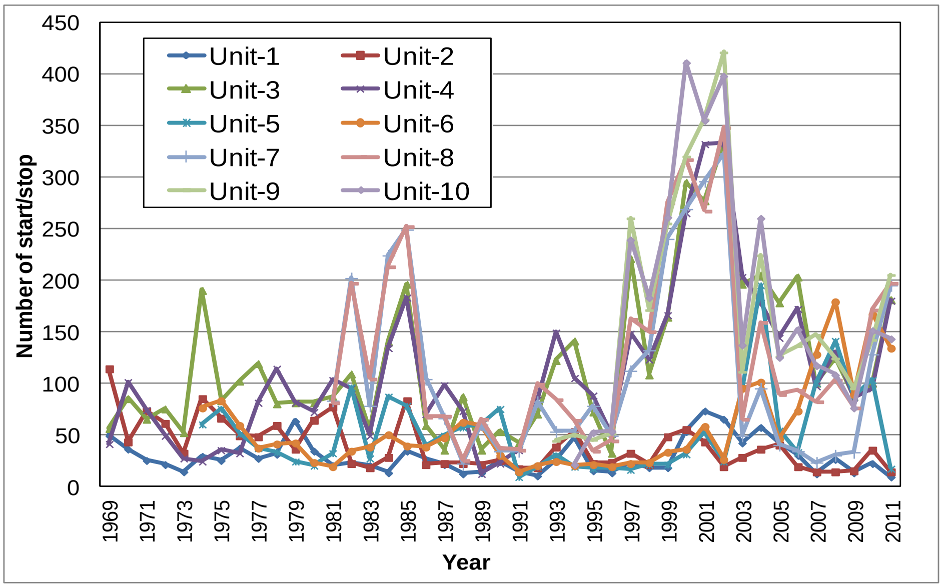
Source: Prepared by the Survey Team

Figure 4-2 Connection Diagram of 132/220 kV Interconnector Transformers

The power flow of the switchyard is always one-way, as indicated by the arrow above.

The total numbers of start/stop of Units 9 and 10 are relatively large although these units are new as compared to the other units. This is because the AVRs of Units 9 and 10 are more sensitive and any variation in this system trips the units. In order to avoid frequent tripping of units and to keep the system stable, whenever load demand decreases and there is option to shut down any unit, Units 9 and 10 are preferred to be shut down first. Due to problematic AVRs, these units were started for peaking and shut down afterwards. These factors contributed to higher number of start/stop.

From 1997 to 2002, a large number of start/stop was carried out since the start/stop of the generating units has been dictated by the National Power Control Center (NPCC) in Islamabad based on prevailing system requirements/conditions.

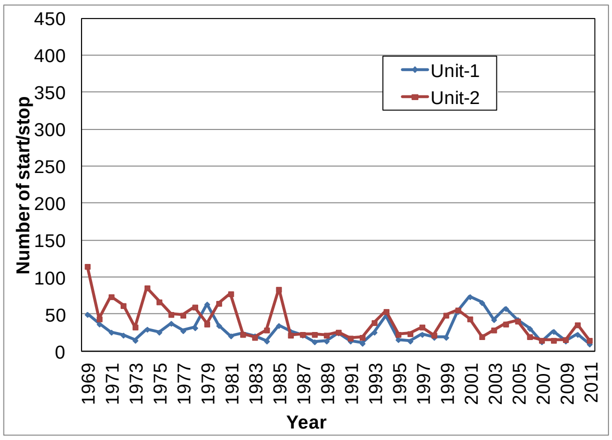


Source: WAPDA (Mangla Hydro Power Station)

Figure 4-3 Number of Start/Stop (All Units)

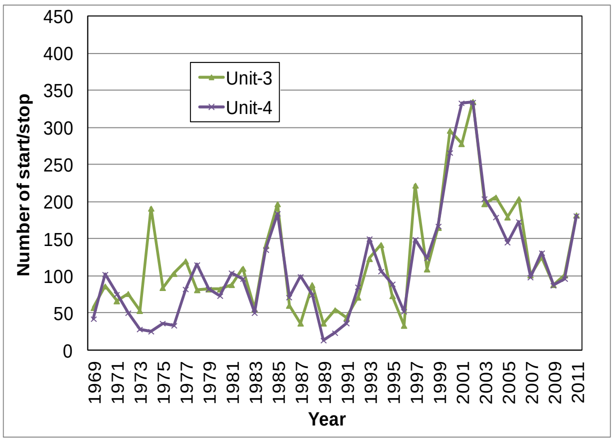
The above Figure 4-3 shows the number of start/stop of all units from their commissioning date up to 2011. As it is difficult to see the operation trend in this graph, it was divided into groups as shown in Figures 4-4 to 4-8 below.

These five graphs show the trend of the group operation. Operation of power station is decided according to the request of NPCC, and this trend means that the power station accordingly selects units by groups.



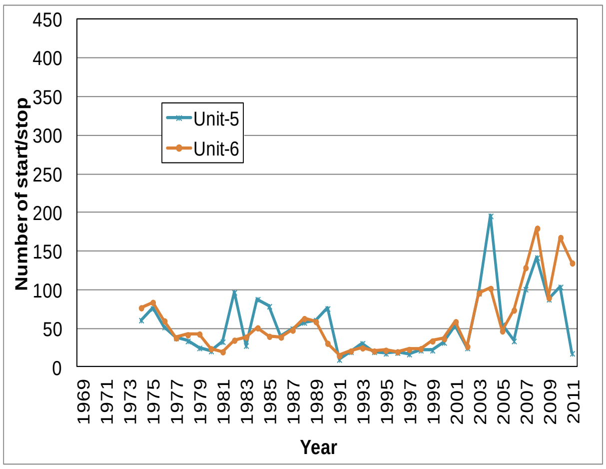
Source: WAPDA (Mangla Hydro Power Station)

Figure 4-4 Number of Start/Stop (Units 1 & 2)



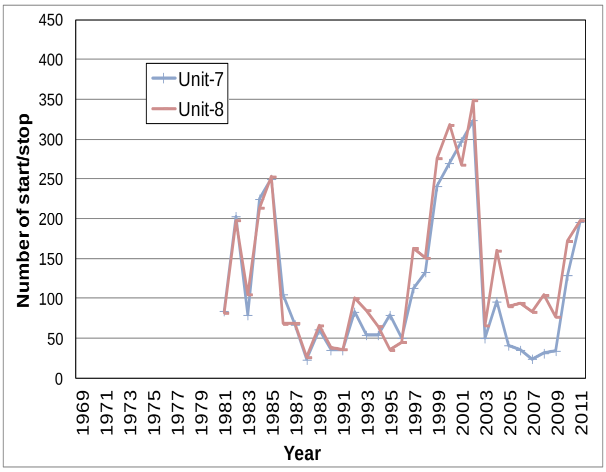
Source: WAPDA (Mangla Hydropower Station)

Figure 4-5 Number of Start/Stop (Units 3 & 4)



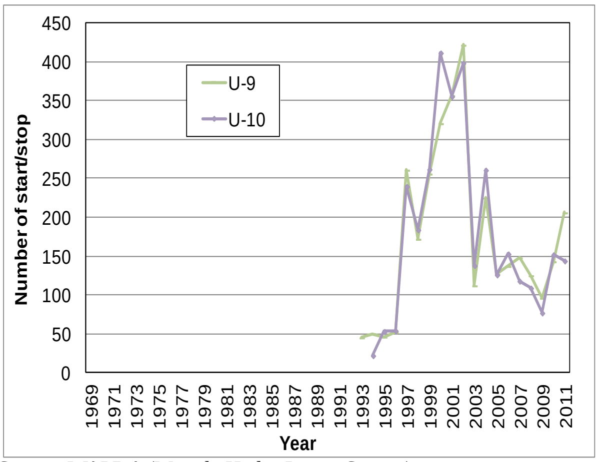
Source: WAPDA (Mangla Hydro Power Station)

Figure 4-6 Number of Start/Stop (Units 5 & 6)



Source: WAPDA (Mangla Hydro Power Station)

Figure 4-7 Number of Start/Stop (Units 7 & 8)



Source: WAPDA (Mangla Hydro Power Station)

Figure 4-8 Number of Start/Stop (Units 9 &10)

(3) Study of Operating Head after Raising the Reservoir Level

The dam level is raised up to 30 feet and reservoir water level is raised to 40 feet. The turbine output shall be studied in consideration of head loss at each water flow operation. The study result on this issue is described in Section 5.3.

(4) Operation Limit Study and Setting Change

After raising the reservoir water level without any rehabilitation and enhancement of the electrical equipment capacity such as generator, IPB and main transformer together with associated auxiliary equipment, the turbine output shall be limited below the maximum capacity of electrical equipment for preventing overloading. Naturally, the limiting output manual operation is possible, but it is preferable to limit the guide vane opening by turbine load limiting device at high reservoir water level. The load limiting operation shall be high reservoir season (rainy season) and the limiting value shall be set considering capability and characteristics of each turbine.

4.3 Maintenance Management

4.3.1 Staffs for the Maintenance Work

The maintenance work of all mechanical and electrical equipment of Mangla Power Station is carried out by Mechanical Maintenance Auxiliary Section, Mechanical Maintenance Plant Section, Operation and Maintenance External Work Section, Electrical Maintenance (Power House) Section, and Electrical Maintenance (Switch Yard) Section under the organization of Mangla Power Station as described in Sub-clause 2.5.2. The total number of maintenance staffs in Mangla Power Station who belong to the Power Wing Division of the said organization is approximately 200 out of 446 total staffs of Power Wing Division in Mangla Power Station.

4.3.2 Maintenance Conditions

All equipment are properly maintained by power station maintenance staffs and the prescribed check sheets/formats are duly filled by them on daily, monthly, and biennial bases.

This is the reason that all the equipment are in good condition and operating safely though more than 40 years have passed especially for Units 1 to 4.

4.3.3 Subcontract for Maintenance

The maintenance work is done by WAPDA without any maintenance contract with any original supplier or any maintenance company. Main equipment such as turbine/generator are maintained properly by the staffs who were trained by the original manufacturers.

4.3.4 Spare Parts Management

Most of the spare parts are stored in the warehouse properly. According to the information of the store engineer, sufficient spare parts are stocked except for Units 5 and 6. Storing conditions of stator windings are shown in Photo 4-1 while some types of stored carbon brushes are shown in Photo 4-2. Stator windings were stored with dust but they are in useful condition, and carbon brushes are available from the market in Pakistan.

Source: Prepared by the Survey Team

Photo 4-1 Storing Conditions of Stator Windings

Source: Prepared by the Survey Team

Photo 4-2 Some Types of Carbon Brushes

Furthermore, the most important apparatuses such as lifting beam for tandem operation by two overhead travelling cranes and lifting device to lift up the generator rotor are stored in the erection bay with good maintenance. Photo 4-3 and Photo 4-4 show the lifting beam and device.


Source: Prepared by the Survey Team

Photo 4-3 Lifting Beam


Source: Prepared by the Survey Team

Photo 4-4 Lifting Device

4.4 Hydraulic Mechanical

4.4.1 General

Total nominal discharge capacity : 49,000 cfs (1,386 m^3/s)

Each tunnel discharge capacity : 9,800 cfs (277 m^3/s)

4.4.2 Turbine Inlet Valves

(1) Units 1 through 4

Type	: Butterfly with solid disc
Manufacturer	: Mitsubishi Heavy Industry, Japan
Size	: 16 ft (4.88 m) diameter
Design Head	: 560 ft (170.8 m)

(2) Units 5 and 6

Type	: Butterfly with solid disc
Manufacturer	: Mitsubishi Heavy Industry, Japan
Size	: 16 ft (4.88 m) diameter
Design Head	: 560 ft (170.8 m)

(3) Units 7 and 8

Type	: Butterfly with bi-plane disc

Manufacturer	: ACEC, Belgium
Size	: 16 ft (4.88 m) diameter
Design Head	: 560 ft (170.8 m)

(4) Units 9 and 10

Type	: Butterfly with flow through disc
Manufacturer	: CKD Blansko, Czechoslovakia
Size	: 16 ft (4.88 m) diameter
Design Head	: 560 ft (170.8 m)

4.5 Turbine and Unit Mechanical Equipment

The vibration and noise level of turbine and unit mechanical equipment are measured on all operating units, which are shown in the data sheet in Table 4-4. The Survey Team confirmed that there is no abnormal vibration and noise level for the existing turbine and unit mechanical equipment.

(1) Noise Level Measurement

Measurement positions for checking the noise level are presented below:

1) About 1 m from the turbine pit entrance
2) Turbine pit inside
3) About 1 m from draft tube manhole

(2) Vibration Level Measurement

Measurement positions for checking the vibration level are presented below:

1) Turbine bearing
2) Surrounding turbine upper cover fixing bolt
3) Top of the guide vane
4) Surrounding centre of draft tube manhole
5) Top of generator upper bracket

Table 4-4 Data Sheet of Vibration and Noise

Measuring unit No.	GV Opening (%)	Output (MW)	Date	Noise level (Db)			Vibration level (1/100 mm/s)					
				(1)-1	(1)-2	(1)-3	(2)-1a	(2)-1b	(2)-2	(2)-3	(2)-4	(2)-5
1	102	50	2012/3/12	98/104	105/109	108/115	1.7	6.2	1.8	1.4	No data	0.9
2	94	50	2012/3/12	95/102	103/107	106/114	1.9	5.3	1.7	1.0	35.0	0.9
3	94	51	2012/3/12	100/105	105/109	106/115	6.7	2.7	2.0	1.3	14.3	0.8
4	93	51	2012/3/12	99/105	105/109	109/115	1.0	6.5	2.8	1.3	38.2	0.8
5	92	58	2012/3/12	96/104	102/109	103/107	1.6	2.5	1.7	1.3	19.5	0.8
6	Under stopping											
7	98	60	2012/3/12	87/99	91/99	91/101	1.0	0.8	0.4	0.4	3.5	0.4
8	98	60	2012/3/12	87/95	90/99	94/103	0.8	0.8	0.4	0.4	3.3	0.5
9	90	65	2012/3/12	91/99	98/104	102/108	1.4	1.6	0.8	0.9	38.0	0.5
10	91	65	2012/3/12	93/100	98/105	104/108	2.5	2.2	1.0	0.8	33.0	0.6

Source : Survey Team

(1)-1 About 1 m from the turbine pit
(1)-2 Turbine pit inside
(1)-3 About 1 m from draft tube manhole

(2)-1a At turbine bearing (1)
(2)-1b At turbine bearing (2)
(2)-2 Near turbine upper cover fixing bolt
(2)-3 Top of the guide vane
(2)-4 Near the centre of draft tube manhole
(2)-5 Top of generator upper bracket

4.6 Generator

4.6.1 Current Operating Conditions

(1) Insulation Resistance Measurement Test

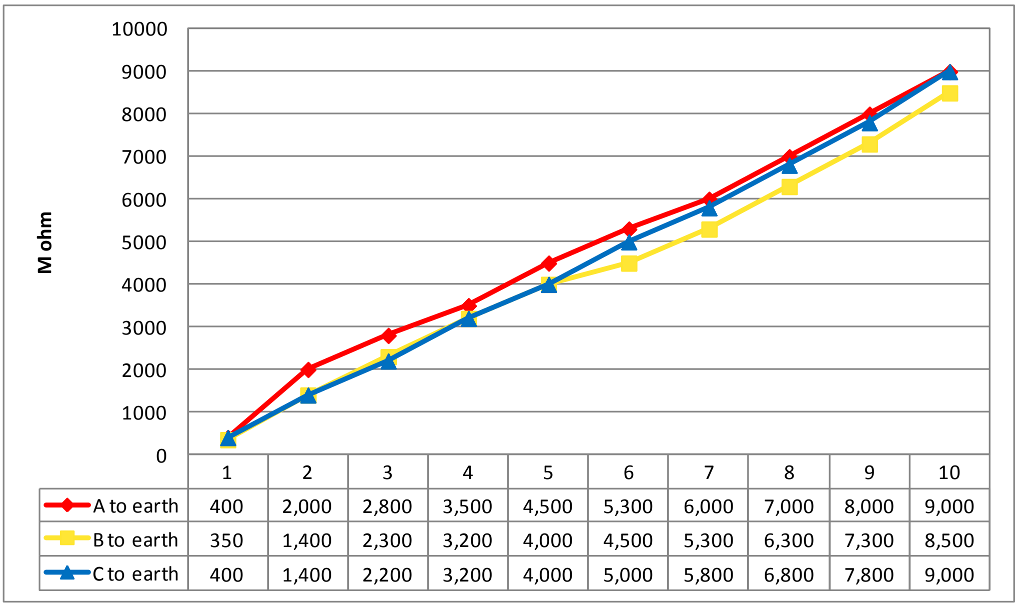
In addition to the data collection, the Survey Team measured insulation resistance of stator winding of Unit 6, which has been stopped for normal maintenance work since February 29, 2012. The measured data of Unit 6 are shown in Table 4-5 and Figure 4-9.

Table 4-5 Insulation Resistance

[unit: M-ohm]

PHASE	1 min	2 min	3 min	4 min	5 min	6 min	7 min	8 min	9 min	10 min
A to earth	400	2,000	2,800	3,500	4,500	5,300	6,000	7,000	8,000	9,000
B to earth	350	1,400	2,300	3,200	4,000	4,500	5,300	6,300	7,300	8,500
C to earth	400	1,400	2,200	3,200	4,000	5,000	5,800	6,800	7,800	9,000

Source: Data measured by the Survey Team



Source: Prepared by the Survey Team

Figure 4-9 Insulation Resistance of Unit 6

A, B and C means each phase, i.e.: A is red phase, B is yellow phase and C is blue phase, in accordance with WAPDA's standards.

From the above figure, polarization index (PI) value for each phase is as follows:

Phase A: 22.5
Phase B: 24.3
Phase C: 22.5

These figures appeared too high, and when the measuring data is read, the measuring range was changed after 1 minute reading. The 2 min. to 10 min. readings have the same range.

Therefore, tentative PI values are just calculated as (10 min. value)/(2 min. value) and these figures are:

Phase A: 4.5
Phase B: 6.1
Phase C: 6.4

These figures are still more than 2.5. Therefore, the coils are not in absorption condition. This is because WAPDA's maintenance is so good. ("More than 2.5" is quoted from the Technical Report No. 752 issued by The Institute of Electrical Engineers of Japan. This report suggested that PI should be more than 1.5 to 2.5)

The figures of other units' test data, which were measured by WAPDA, are shown in Table 4-6.

Table 4-6 Test Data of Insulation Resistance

UNIT 1	1 min	10 mins	Measuring Date	Temperature	Winding Resistance
A to earth	950	5,000			
B to earth	950	5,000	19 Jan. 2010	17 ℃	2.6 mΩ
C to earth	1,000	5000			

PI value is 5 ～ 5.3

UNIT 2	1 min	10 min	Measuring Date	Temperature	Winding Resistance
A to earth	850	3,000			
B to earth	950	3,000	08 Nov. 2009	28 ℃	2.8 mΩ
C to earth	850	2,800			

PI value is 3.2 ～ 3.5

UNIT3	1 min	10 min	Measuring Date	Temperature	Winding Resistance
A to earth	1,400	4,500			
B to earth	1,200	4,000	08 Feb. 2010	24℃	2.6 mΩ
C to earth	1,200	4,200			

PI value is 3.2 ～ 3.5

UNIT 5	1 min	10 min	Measuring Date	Temperature	Winding Resistance
A to earth	2,300	15,000			
B to earth	2,000	18,000	04 Jan. 2009	18.7℃	2.4 mΩ
C to earth	2,000	17,000			

PI value is 6.5 ～ 9.0

UNIT 6	1 min	10 min	Measuring Date	Temperature	Winding Resistance
A to earth	1,800	15,000			
B to earth	1,800	14,500	25 Jan. 2009	21℃	2.4 mΩ
C to earth	1,800	15,000			

PI value is 8.1 ～ 8.3

UNIT 8	1 min	10 min	Measuring Date	Temperature	Winding Resistance
A to earth	1,000	3,200			
B to earth	900	3,000	24 May 2009	30℃	3.2 mΩ
C to earth	1,000	3,200			

PI value is 3.2 ～ 3.3

UNIT 9	1 min	10 min	Measuring Date	Temperature	Winding Resistance
A to earth	2,000	7,500			
B to earth	2,000	6,000	24 Mar. 2009	27℃	3.8 mΩ
C to earth	1,800	6,500			

PI value is 3.0 ～ 3.8

UNIT 10	1 min	10 min	Measuring Date	Temperature	Winding Resistance
A to earth	2,000	7,500			
B to earth	1,900	7,500	16 Apr. 2009	28℃	3.8 mΩ
C to earth	1,800	6,500			

PI value is 3.6 ～ 3.9
Source: WAPDA (Mangla Hydro Power Station)

The above measurement data reveal that all the stator coils are operating in good condition.

(2) Power Factor under Operation

Power factor was calculated by dividing the generated power (MW) by the reactive power (MVar) from the operation record on a typical day having maximum power generated for each month during 2011.

Maximum power generation date for each month is shown in Table 4-7 below.

Table 4-7 Maximum Power Generation Date for Each Month

Season	Month	Load (MW)	Time/Date
Spring	February	776	7 p.m. on 18-02-2011
	March	712	7 p.m. on 01-03-2011
	April	889	8 p.m. on 30-04-2011
Summer	May	1,060	5 p.m. on 31-05-2011
	June	1,097	8 p.m. on 20-06-2011
	July	1,035	8 p.m. on 03-07-2011
Autumn	August	1,060	8 p.m. on 31-08-2011
	September	1,120	1 p.m. on 09-09-2011
	October	1,115	8 p.m. on 05-10-2011
Winter	November	1,115	6 p.m. on 30-11-2011
	December	1,111	7 p.m. on 01-12-2011
	January	754	7 p.m. on 22-01-2011

Source: WAPDA (Mangla Hydro Power Station)

Active power (MW) and reactive power (MVar) during each time/date above have been checked from the operation records and the power factor calculated from these figures is shown in the following Table 4-8:

Table 4-8 Operation Record with Power Factor (PF)

At 7 p.m. on 18 Feb. 2011

Unit No.	1	2	3	4	5	6	7	8	9	10
Power (MW)	87	87	84	84	Stand-by	88	86	86	87	87
Reactive Power (MVAR)	-10	-10	-10	-10		-10	-10	-10	-10	-10
Power Factor	-0.99	-0.99	-0.99	-0.99		-0.99	-0.99	-0.99	-0.99	-0.99

At 7 p.m. on 01 Mar. 2011

Unit No.	1	2	3	4	5	6	7	8	9	10
Power (MW)	80	80	77	77	Stand-by	79	79	80	80	80
Reactive Power (MVAR)	0	0	0	0		0	0	0	0	0
Power Factor	1.0	1.0	1.0	1.0		1.0	1.0	1.0	1.0	1.0

At 8 p.m. on 30 Apr. 2011

Unit No.	1	2	3	4	5	6	7	8	9	10
Power (MW)	91	91	90	90	70	93	90	90	92	92
Reactive Power (MVAR)	30	30	30	30	10	30	30	30	30	30
Power Factor	0.95	0.95	0.95	0.95	0.99	0.95	0.95	0.95	0.95	0.95

At 5 p.m. on 31 May 2011

Unit No.	1	2	3	4	5	6	7	8	9	10
Power (MW)	111	111	111	109	70	112	108	108	111	111
Reactive Power (MVAR)	40	40	40	40	10	40	40	40	40	40
Power Factor	0.94	0.94	0.94	0.94	0.99	0.94	0.94	0.94	0.94	0.94

At 8 p.m. on 20 Jun. 2011

Unit No.	1	2	3	4	5	6	7	8	9	10
Power (MW)	114	114	114	114	70	115	113	113	115	115
Reactive Power (MVAR)	40	40	40	40	10	40	40	40	40	40
Power Factor	0.94	0.94	0.94	0.94	0.99	0.94	0.94	0.94	0.94	0.94

At 8 p.m. on 03 Jul. 2011

Unit No.	1	2	3	4	5	6	7	8	9	10
Power (MW)	115	115	115	115	Stand-by	115	115	115	115	115
Reactive Power (MVAR)	20	20	20	20		20	20	20	20	20
Power Factor	0.99	0.99	0.99	0.99		0.99	0.99	0.99	0.99	0.99

At 8 p.m. on 31 Aug. 2011

Unit No.	1	2	3	4	5	6	7	8	9	10
Power (MW)	110	110	110	110	70	110	110	110	110	110
Reactive Power (MVAR)	30	30	30	30	10	30	30	30	30	30
Power Factor	0.96	0.96	0.96	0.96	0.99	0.96	0.96	0.96	0.96	0.96

At 1 p.m. on 09 Sep. 2011

Unit No.	1	2	3	4	5	6	7	8	9	10
Power (MW)	115	115	115	115	85	115	115	115	115	115
Reactive Power (MVAR)	40	40	40	40	0	40	40	40	40	40
Power Factor	0.94	0.94	0.94	0.94	1.0	0.94	0.94	0.94	0.94	0.94

At 8 p.m. on 05 Oct. 2011

Unit No.	1	2	3	4	5	6	7	8	9	10
Power (MW)	115	115	115	115	80	115	115	115	115	115
Reactive Power (MVAR)	30	30	30	30	0	30	30	30	30	30
Power Factor	0.97	0.97	0.97	0.97	1.0	0.97	0.97	0.97	0.97	0.97

At 6 p.m. on 30 Nov. 2011

Unit No.	1	2	3	4	5	6	7	8	9	10
Power (MW)	115	115	115	115	80	115	115	115	115	115
Reactive Power (MVAR)	31	29	29	29	0	30	30	30	29	30
Power Factor	0.97	0.97	0.97	0.97	1.0	0.97	0.97	0.97	0.97	0.97

At 7 p.m. on 01 Dec. 2011

Unit No.	1	2	3	4	5	6	7	8	9	10
Power (MW)	115	115	114	114	80	115	114	114	115	115
Reactive Power (MVAR)	30	30	30	30	0	30	30	30	30	30
Power Factor	0.97	0.97	0.97	0.97	1.0	0.97	0.97	0.97	0.97	0.97

At 7 p.m. on 22 Jan. 2011

<table>
<tr><th>Unit No.</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th></tr>
<tr><td>Power (MW)</td><td>94</td><td>94</td><td>93</td><td>93</td><td rowspan="3">Stand-by</td><td>96</td><td>94</td><td rowspan="3">Stand-by</td><td>95</td><td>95</td></tr>
<tr><td>Reactive Power (MVAR)</td><td>20</td><td>20</td><td>20</td><td>20</td><td>20</td><td>20</td><td>20</td><td>20</td></tr>
<tr><td>Power Factor</td><td>0.98</td><td>0.98</td><td>0.98</td><td>0.98</td><td>0.98</td><td>0.98</td><td>0.98</td><td>0.98</td></tr>
</table>

Source: WAPDA (Mangla Hydro Power Station)

The above data show that all units are operated with power factor of more than 0.9 although the rated power factor is 0.8.

Operating power factor of the power station is normally requested by NPCC according to the system requirement. Then, the power factor of Mangla is purely controlled by NPCC to meet the system requirement.

(3) Temperature of Stator Winding and Thrust Bearing

Temperature of stator winding and thrust bearing was confirmed from the operation records.

i. Temperature of Stator Winding

Temperature of stator winding is shown in Table 4-9 and described below. The generators seem to be operated safely.

Alarm temperature is 85ºC and temperatures of Units 7 and 8 on May 31, 2011 were above this value. But the plant engineer explained that these figures are the results of visual measurement of the meter, and they do not know the actual figures. However, nothing abnormal was observed on that day. To eliminate the malfunction like this, these temperature meters will be calibrated during rehabilitation work, and this calibration will be required in the Tender Specification.

Table 4-9 Temperature of Stator Winding

[ºC]

Date	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7	Unit 8	Unit 9	Unit10
18 Feb. 2011	50	50	49	52	-	50	51	53	50	46
01 Mar. 2011	48	48	48	50	-	49	54	57	47	43
30 Apr. 2011	62	61	62	65	57	62	63	63	66	61
31 May 2011	73	73	69	77	56	71	86	85	74	73
20 Jun. 2011	71	74	72	80	57	67	74	76	70	70
03 Jul. 2011	71	69	71	77	-	66	76	77	66	65
31 Aug. 2011	75	78	78	65	40	55	74	79	62	61
09 Sep. 2011	75	77	79	81	No data					
05 Oct. 2011	73	78	81	81	64	70	No data			

Source: WAPDA (Mangla Hydro Power Station)

ii. Temperature of Thrust Bearing

Temperature of thrust bearing is shown in Table 4-10, and generators seem to be operated safely. Alarm temperature is 65ºC. Some are over this figure. Same explanation as in the stator winding was made by the plant engineer.

Table 4-10 Temperature of Thrust Bearing

[ºC]

Date	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7	Unit 8	Unit 9	Unit10
18 Feb. 2011	53	-	59	55	-	27	46	46	49	61
01 Mar. 2011	54	-	-	-	-	28	46	39	50	62
30 Apr. 2011	58	-	62	59	-	45	46	40	59	69
31 May 2011	56	-	62	59	49	45	46	39	57	70
22 Jan. 2011	53	-	58	52	-	25	46	-	48	59

Source: WAPDA (Mangla Hydro Power Station)

(4) Stopping Units during the Survey Team's Visit

During the site visit of the Survey Team from February 27 to March 3, 2012, Unit 6 was stopped on February 29 for normal maintenance by WAPDA and Unit 9 was stopped on March 1, 2012 according to the request of National Transmission Dispatch Company (NTDC). This stoppage gave an opportunity for the Survey Team to inspect the units closely and to perform certain tests required.

(5) Past Incident Record

Major faults and/or incidents occurred only in Units 5 and 6, and the course of major faults of Unit 5 is shown in Table 4-11.

Table 4-11 Past Incident Record for Unit 5

Date of Tripping	Cause/Extent of Damage	Repair/Date
29-07-1990	Unit while running at 100 MW and 48 MVAR tripped on split phase protection due to failure of straight joint of one of the three parallel paths of Y-phase.	Repaired by WAPDA staff. Unit is synchronized with the system on 04-08-1990.
04-08-1990	Unit tripped on split phase and generator differential protection while increasing load from 30 MW to 80 MW and the following damages occurred: 67 coils damaged (44 front and 23 rear); Gouging of stator core at three different points; and Grounding of six poles of main rotor.	Repaired by WAPDA staff. Unit is synchronized with the system on 22-10-1990.
31-12-1990	Unit tripped on split phase protection while increasing load from 30 MW to 100 MW due to failure of joints of the two parallel paths of Y-phase.	Repaired by WAPDA staff. Unit is synchronized with the system on 06-01-1991.
18-01-1991	At the time of synchronization, unit tripped on over speed and the following apparent damages occurred: Stator Coils: 338 Nos.(169 front & 69 rear) Field Pole Winding: 13 Nos. (out of 36) Brake Ring Segments: 5 Nos. (out of 12) Brake Pad Lining: 10 Nos. (out of 10) Brake Assembly: 1 No. (out of 3) Rotor Fan Plate: 1 No. (out of 3) Rotor Fan Blades: 12 (out of 36) Space Heaters: 3 Nos. (out of 6) Micro Switch for Brakes: 3 Nos. Bottom Cover Plates of Stator Windings: 9 Nos.	Repair of core, rotor and rewinding of stator with F-class insulation (previously B-class) was carried out by M/S DEC China through a contract with WAPDA. Unit is synchronized with the system on 17-03-1992.
11-05-1996	Unit tripped while running at 125 MW, 15 MVAR on generator differential protection and generator stator earth leakage and the following damages occurred: Yellow phase line lead bus bar had sparked over; Red and yellow phase line lead bushing was damaged; and Top layer of insulation of red and blue phase line lead busbar was burnt.	Repaired by WAPDA staff. Unit is synchronized with the system on 18-05-1996.
11-11-2010	Unit tripped while running at 115 MW, 20 MVAR on split phase and generator differential protection and the following damages occurred: 31 front and 7 rear coils affected/damaged; Pressing fingers and stator core laminations between Slots No. 250 & 253 were found damaged/affected; and Insulation resistance of 3 rotor poles was zero and voltage drop across 6 rotor poles was less than permissible value.	Repaired by WAPDA staff. The representative of original manufacturer of equipment, M/S CKD NOVE ENERGO, visited Mangla from 05-02-2011 to 07-02-2011 and inspected the repair work carried out by WAPDA. He submitted the preliminary inspection report. Detailed permanent technical solution report is pending.

Source: WAPDA (Mangla Hydro Power Station)

The course of major fault of Unit 6 is shown in Table 4-12.

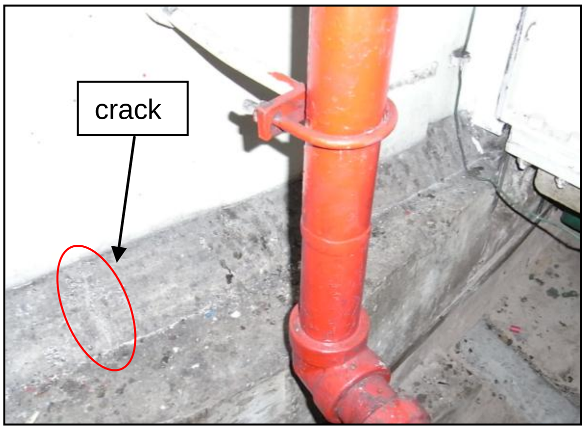
Table 4-12 Past Incident Record for Unit 6

Date of Tripping	Cause/Extent of Damage	Repair/Date
27-01-1985	Unit while running at 90 MW, -1 MVAR tripped on stator earth leakage protection due to insulation failure of red phase coil and the following damage occurred: One coil (front) of red phase is found punctured at the top edge.	Repaired by WAPDA staff. Unit is synchronized with the system on 04-04-1985.
22-05-1990	Unit while running at 82 MW, 36 MVAR tripped on split phase protection due to insulation failure of the three parallel paths of yellow phase.	Repaired by WAPDA staff. Unit is synchronized with the system on 04-06-1990
30-11-1990	Unit while running at 100 MW, 30 MVAR tripped on split phase protection due to opening of yellow phase joint and the following damages occurred: 3 stator coils of yellow phase; and Pole No. 18 of main rotor found earthed.	Repaired by WAPDA staff. Unit is synchronized with the system on 19-02-1991.
20-09-1992	Unit while running at 100 MW, 20 MVAR tripped on over speed due to failure of governor and the following damages occurred: Stator windings were found damaged at different places; Stator core was also found damaged at a number of places around the periphery; and Field coil of Pole No. 30 and damper windings of all the rotor poles were found damaged.	Repair of core, rotor and rewinding of stator with F-class insulation (previously B-class) was carried out by M/S DEC China through a contract with WAPDA. Unit is synchronized with the system on 29-03-1993.
01-04-1993	Unit while running at 85 MW and 2 MVAR tripped on stator earth leakage and over speed and the following damages occurred: All the three bus bars between stator and Joint No. 1 along with fiber supporting at two different places were found sparked over.	Repaired by WAPDA staff under the supervision of M/S DEC China. Unit is synchronized with the system on 07-04-1993.

Source: WAPDA (Mangla Hydro Power Station)

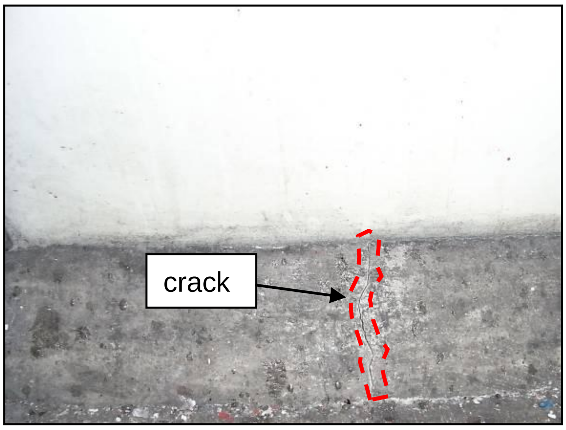
(6) Small Cracks on the Concrete below the Stator Frame

Some cracks were found on the concrete below the stator frame, when the Survey Team entered Unit 2 generator pit (inside of air housing), as shown in Photo 4-5. This shall be inspected in detail at the detailed design stage.



Source: Prepared by the Survey Team

Photo 4-5 Cracks on Concrete of Stator Frame (1/2)



Source: Prepared by the Survey Team

Photo 4-5 Cracks on Concrete of Stator Frame (2/2)

(7) Condition of Auxiliary Equipment

i. Cooling Water Supply System

Cooling water supply system is nominally connected by the same interconnected piping. It is tapped from the upstream side of the turbine inlet valves on all units (as shown in Photo 4-6 below) except for Units 5 and 6, which are supplied water from the downstream of the valves. Units 1 through 4 each have standby cooling pumps (as shown in Photo 4-7 below).

Source: Prepared by the Survey Team

Photo 4-6 Cooling Water Supply System

Source: Prepared by the Survey Team

Photo 4-7 Standby Cooling Pumps for Units 1 to 4

ii. Compressed Air System for Brake

The system is still in good condition as shown in Photo 4-8 below. This photo shows the compressors for Units 1 to 4.

Source: Prepared by the Survey Team

Photo 4-8 Compressed Air System for Units 1 to 4

iii. Oil Lifting Equipment

Equipment is still in good condition as shown in the photos below. Photo 4-9 shows the equipment for Unit 3 and Photo 4-10 shows that for Unit 7.

Source: Prepared by the Survey Team

Photo 4-9 Oil Lifting Equipment for Unit 3

Source: Prepared by the Survey Team

Photo 4-10 Oil Lifting Equipment for Unit 7

iv. Overhead Travelling Crane and Lifting Beam for Generator Rotor

According to the senior mechanical engineer in Mangla, the condition of both cranes is satisfactory as shown in Photos 4-11 and 4-12 below. Therefore, no replacement of parts is required. In addition to this, the lifting beam for tandem operation of both cranes and lifting device for rotor are safely stored in the erection bay.

Source: Prepared by the Survey Team

Photo 4-11 Over Head Traveling Crane

Source: Prepared by the Survey Team

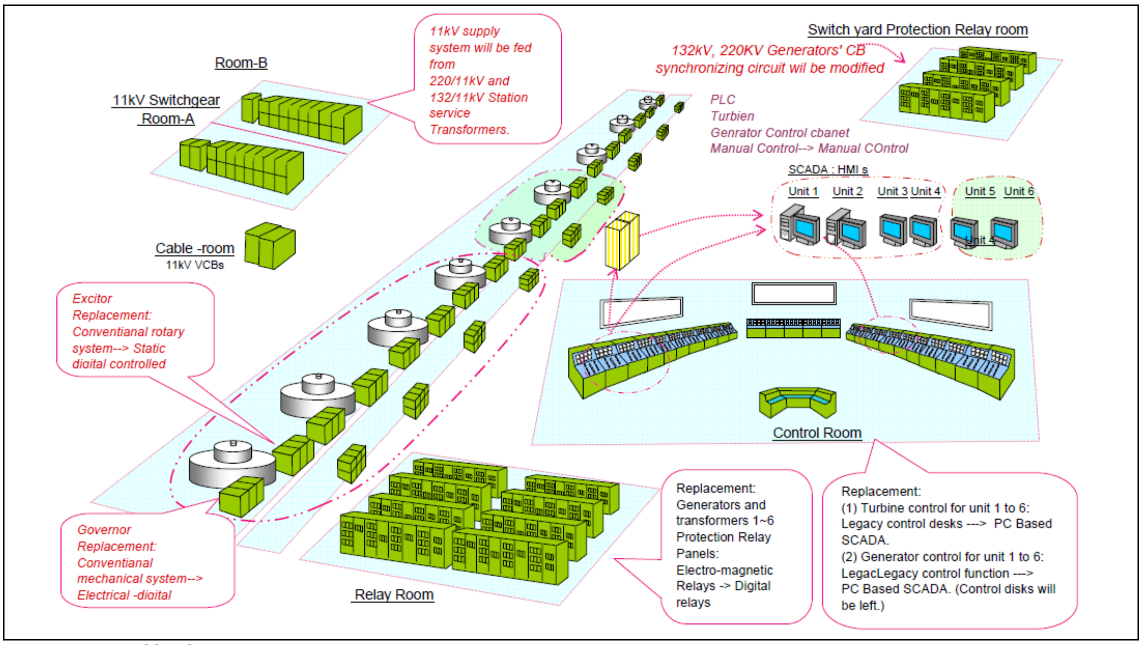
Photo 4-12 Lifting Beam for Generator Rotor

4.7 Control and Protection

4.7.1 Present Situation of Control and Protection System

The control and protection system have been modified whenever generation units and transmission lines were expanded. At present, 220 kV and 132 kV transmission lines and ten sets of turbine-generator, intake gates, and irrigation valves are supervised and controlled from the control room of the Mangla Power Station.

Figure 4-10 below shows the overview of control and protection facilities for Mangla Power Station.



Source: Prepared by the Survey Team

Figure 4-10 Conceptual Picture of Power Station Control System

The system is well managed and maintained by the staffs of the power station. Though the system performance is maintained as the original condition, the devices and wires in the control and protection circuit were deteriorated. The renewal of such wires and devices is a pressing issue for reliable operation.

Actually, implementation of SCADA system for transmission lines by NTDC/NPCC is ongoing. The requirement for more linked and flexible operation with the network will be increased by reason of the growing electrical demand. The correspondence on this matter will be required for the control and protection system. The present system faces difficulty to meet this requirement.

4.7.2 Subject of Survey for Control and Protection

The components of control and protection system for Mangla Power Station are vast and complicated. Understanding the whole system requires further site investigation. Therefore, the subjects of site investigation focus on the control and protection equipment related to the generator and turbine refurbishment and upgrading.

The key points of the site survey are as follows:

a. Which equipment requires renovation or replacement with the upgrade of generating capacities?

b. Which equipment has potential risks on the future operation due to the aging of material and devices?

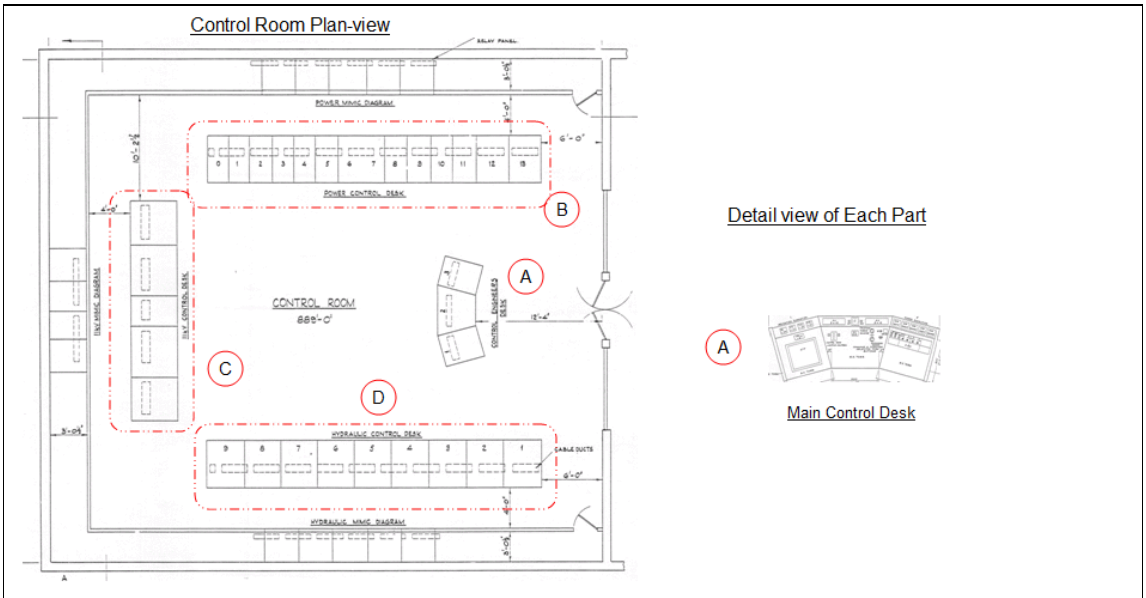
c. What are the present issues on the operation and maintenance of the facilities?

4.7.3 Control Room Arrangement

Almost all facilities in the power station, switchyard, and Mangla Dam can be monitored by the control desks in the control. The major status of equipment, fault status, and measured values are indicated on the control desks with conventional lamps and meters.

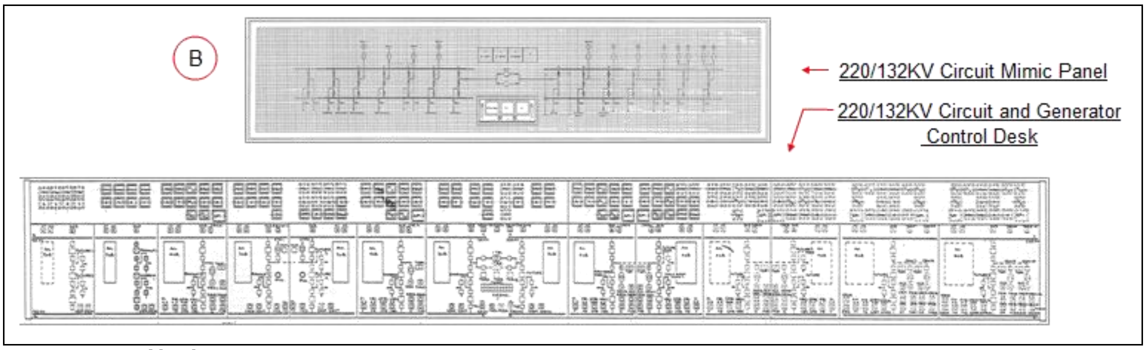
The arrangement of control desk is shown in Figures 4-11 through 4-14.

The SCADA system consoles for generation unit will be installed in the control room.



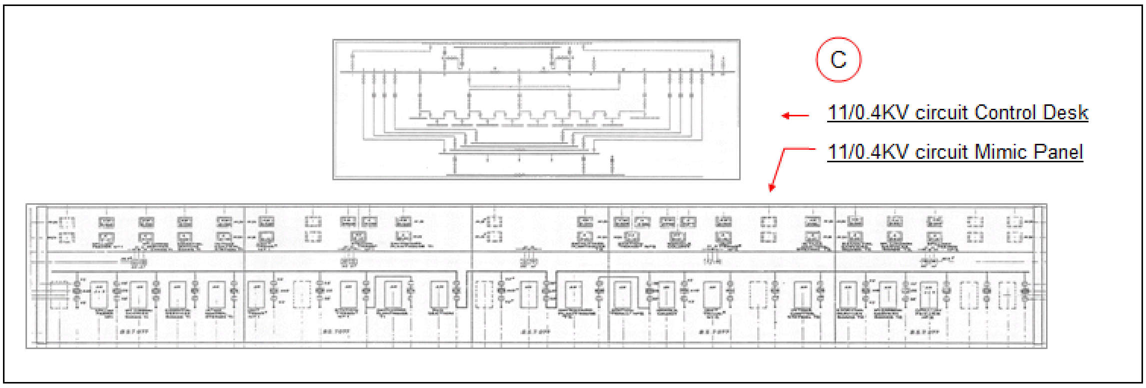
Source: Prepared by the Survey Team

Figure 4-11 Control Desk Arrangement in Control Room



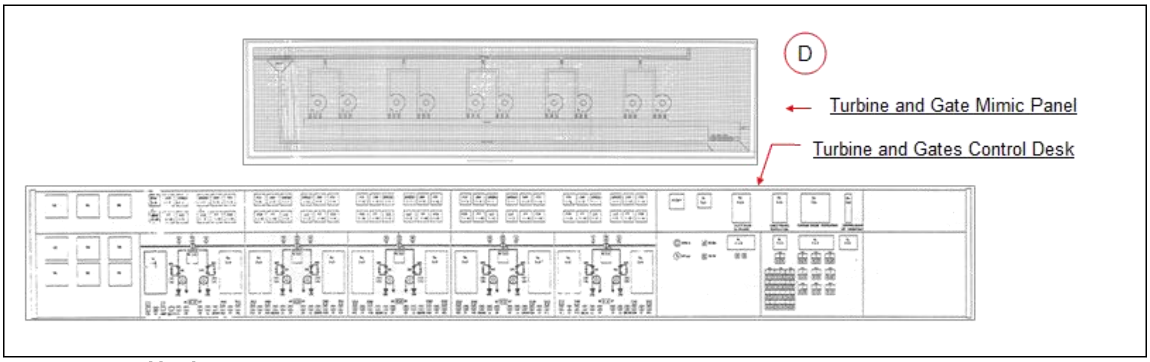
Source: Prepared by the Survey Team

Figure 4-12 Switchyard Control Desk Arrangement in Control Room



Source: Prepared by the Survey Team

Figure 4-13 Station Service Control Desk Arrangement in Control Room



Source: Prepared by the Survey Team

Figure 4-14 Turbine Control Desk Arrangement in Control Room

4.7.4 Control and Protection for Turbine-Generator

(1) Control

The present control is through manned manual semi-automatic start control. The generator and turbine status are continually monitored at the generator room through the governor/turbine.

Control cabinets and AVR/generator control the cabinets. The control room also monitors such status as needed through the control desks.

The unit is controlled, step by step, from the control room with manual operating or regulating switches on the control desk. The operation proceeds through the following steps by the operator manually:

Inlet valve open → Turbine start → Excitation → Synchronizing

Auxiliary equipment such as cooling water pumps and oil pressure pumps are controlled locally with local control panels. The system consists of conventional magnetic relays, switches, and indicators.

(2) Protection

There are three trip modes, i.e: 86-1, 86-2, and 86-3. The irrigation valve control is required at the trip situation. The protection relays are almost BBC's and Hitachi's old electro-mechanical types. These were not manufactured. The relays are well maintained; however, the potential of malfunction or non-operation due to aging cannot be measured. The generation unit protection panels are installed at places shown in Table 4-13 below.

Table 4-13 Installation Place of Protection Relay Panels

Protection Areas	Installation Place of Protection Relay
Generator and Turbine	Relay room in power station
Step-up Transformer	
HV Generator Feeder	Relay room in switchyard control house

Source: Prepared by the Survey Team

(3) Irrigation Valve Control

The irrigation valves require combinational governing operation with turbine. The new design must involve such operation manner.

4.7.5 Control and Protection for Generation Units

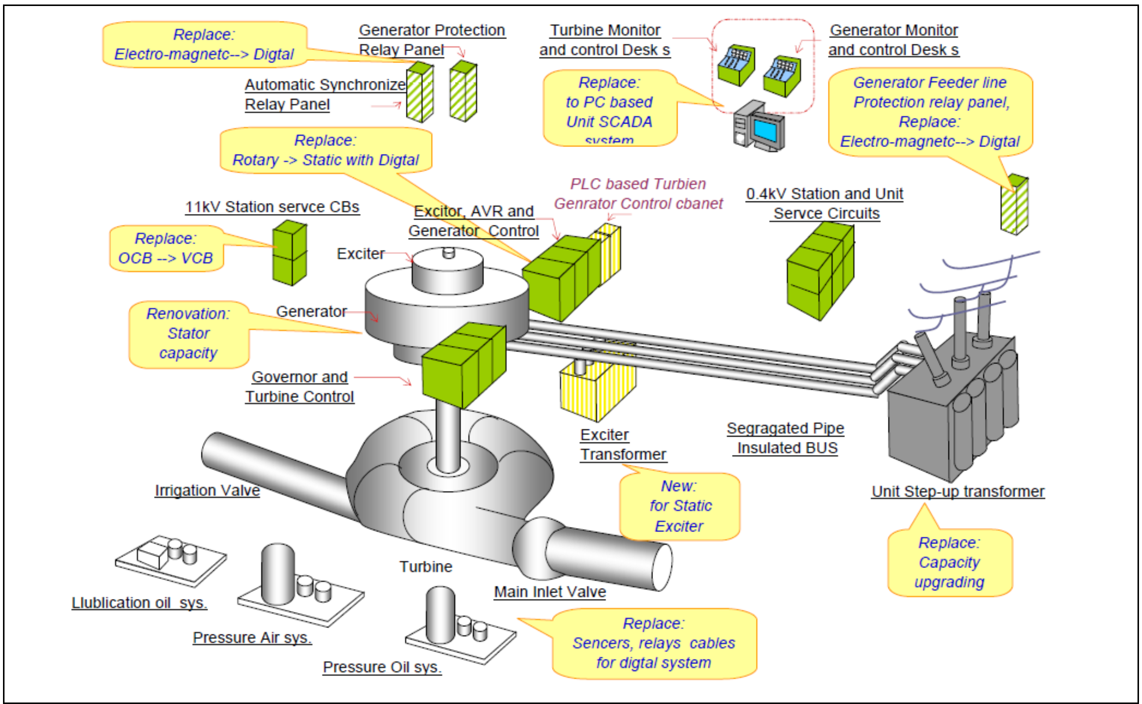
Main equipment and their peripheral equipment are summarized in the following Table 4-14. These are targets for control and protection of generation units.

Table 4-14 Target Equipment of Generation Units Control System

Main Equipment	Peripheral Equipment
Turbine	Turbine, Irrigation Valve, Governor/Turbine Control Panel and Peripheral Equipment of the Turbine.
Generator	Generator, Exciter, AVR/Generator Control Panel, IPB and Peripheral Equipment of the Generator.
Step-up Transformer	Step-up Transformer, Cooling System for the Transformer, Tap Changer and Peripheral Equipment of the Transformer.

Source: Prepared by the Survey Team

The image of control equipment and subjected control facilities are shown in Figure 4-15 below.



Source: Prepared by the Survey Team

Figure 4-15 Conceptual Picture of Generation Unit Control System

4.7.6 Control and Protection for Step-up Transformer

(1) Control

The generation unit does not furnish the generator circuit breaker. The generator feeder is directly connected to the step-up transformer. High voltage feeder of the step-up transformer is connected to one and half circuit breakers.

The step-up transformer furnishes off-load tap changer and transformer cooling system. The transformer status is monitored from the control room.

(2) Protection

The protection relay for transformer consists of conventional electro-magnetic protection relays and mechanical relays such as Buchholz relay. Both the generator heavy fault and transformer heavy fault bring the generator emergency stop into high voltage (220 kV or 132 kV) circuit breaker trips.

4.7.7 Control and Protection for Switchyard

(1) Circuit Configuration

The facilities of power transmission are installed in the switchyard. The system consists of eight transmission lines with one and half circuit breaker configuration (1.5 CB) on 220 kV and 13 transmission lines with one and half circuit breaker configuration (1.5 CB) on 132 kV. The 132 kV and 220 kV systems are linked by the three inter-connection transformers. The two generators are connected to the 132 kV system via two step-up transformers while eight generators are connected to the 220 kV system via eight step-up transformers.

The switchyard facilities are monitored and controlled from the control room in the powerhouse. The protection relays for switchyard facilities are installed in the relay room in the switchyard. The control and protection signals are linked by the long distance (about 2 km) cables between the powerhouse and the switchyard.

(2) Actual Refurbishment Work

The replacement work of old circuit breakers and protection relays is implemented along the NTDC/NPCC's plan. The SCADA of Mangla switchyards has been implemented by NTDC/NPCC. It intends to control the circuit breakers from the dispatch center and control room of Mangla via SCADA system.

(3) Control

The control and protection system mainly consists of conventional wired logic relay schematic sequence circuits. Indicator, auxiliary relays and wires are still used from the original installed condition. Present control system and supervised facilities are shown in Table 4-15 below.

Table 4-15 Switchyard Control System Work

Circuit	Present Condition
Control and Monitoring for Transmission Lines	Conventional monitoring systems are installed in the power station control room. SCADA control system is under implementation.
Control and Monitoring for Generator Feeders	
Control and Monitoring for 220 kV/132 kV Inter-connection Transformers	
132 kV/11 kV Station Service Transformers	

Source: Prepared by the Survey Team

(4) Protection

Actually, generator feeder line protections are installed in the same protection panels of transmission lines, which are connected to same bays of feeder lines, as shown in Table 4-16.

Table 4-16 Switchyard Protection System Work

Circuit	Present Condition
Protection for Transmission Lines	Conventional protection relay systems are installed in the switchyard control room.
Protection for Generator Feeders	
Protection for 220 kV/132 kV Inter-connection Transformers	
132 kV/11 kV Station Service Transformers	

Source: Prepared by the Survey Team

4.7.8 Control and Protection for Station Service System

(1) Alternative Current (AC) Power Supply

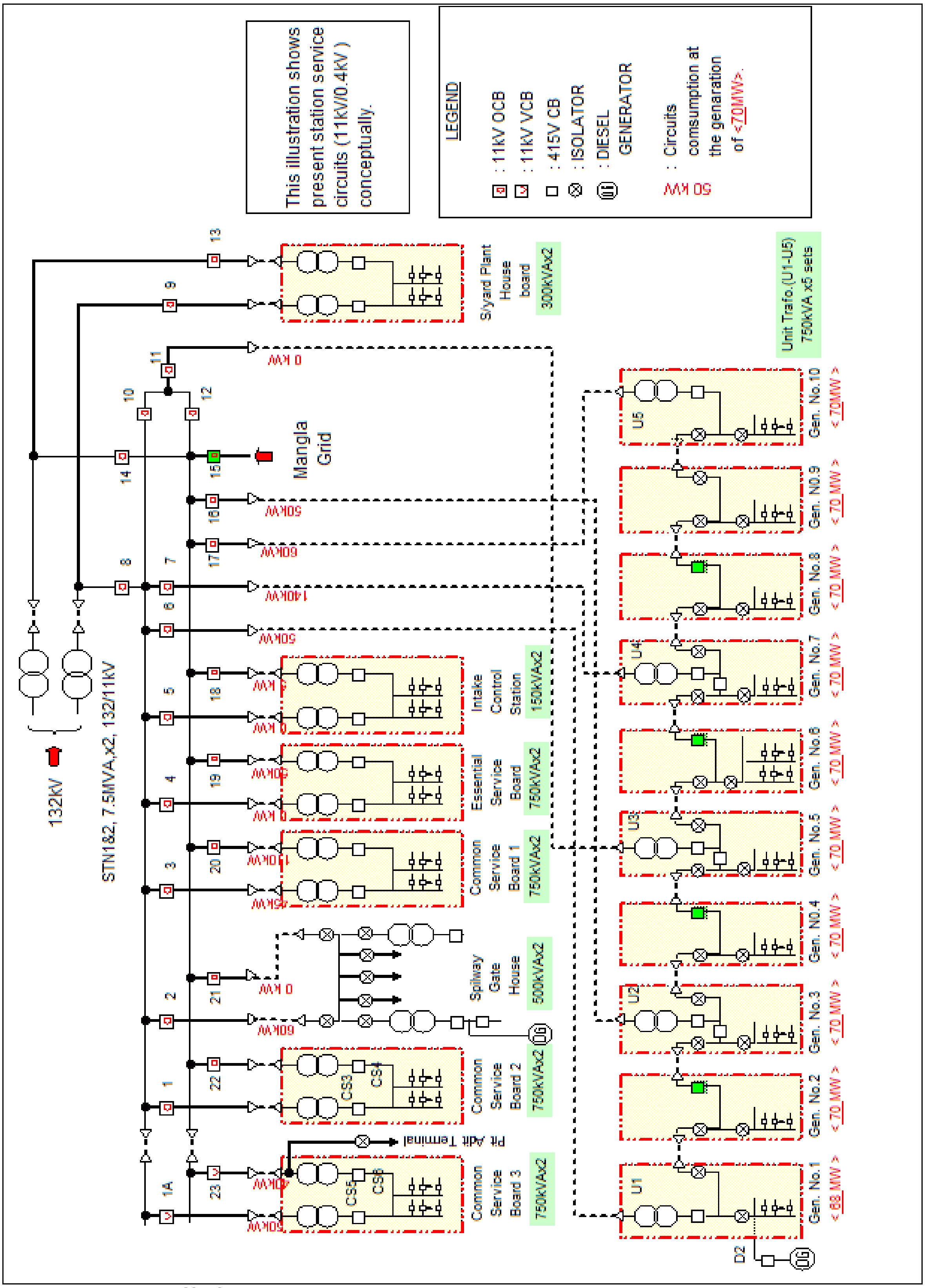
The 132 kV bus supply the power to two sets of station service transformers (132/11 kV-7.5 MVA), and each transformer supplies power to two split buses. In total, 19 transformers (11/0.4 kV) are connected to these buses, and the transformers supply the 400 V AC to the stations' facilities. The station service diagram is shown in Figure 4-16.

(2) Direct Current (DC) Power Supply

Mangla control system uses two levels of DC voltages. One is 230 V DC for control and device drive, and another is 50 V for status indication and alarming.

There are two DC 230 V battery systems. One system is for Units 1 to 6 and another system is for Units 5 to 10. One battery set consists of two banks (170 Ah - 2 sets) of batteries, and two sets of battery chargers.

Battery banks have been renewed during the last ten years. There is no requirement for replacing them.



Source: Prepared by the Survey Team

Figure 4-16 Actual Station Service Circuit

4.7.9 Photographs of Control and Protection

Photo 4-13
Control Room

Photo 4-14
Generator Synchronizing Relay

Photo 4-15
Governor and AVR Cubicle for Unit 1

Photo 4-16
Generator Protection Relay

Photo 4-17
11 kV Station Service Cubicles

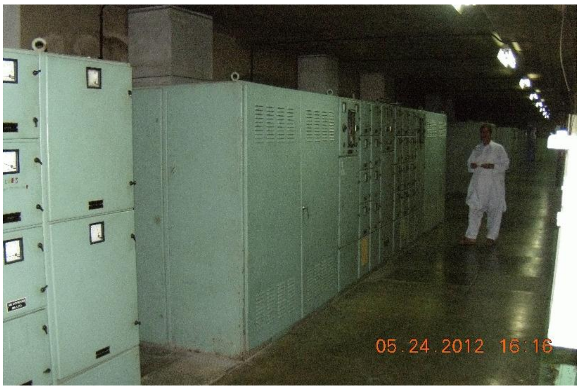


Photo 4-18
400 V Station Service Cubicles

Source: Prepared by the Survey Team

4.8 Switchyard

4.8.1 Outline of Switchyards

The 132/220 kV switchyard, as shown in Photo 4-19, is located at about 1.2 km southeast from the power station. The switchyard is an outdoor conventional type with one and half circuit breaker configuration.

The 132 kV and 220 kV bus are connected by three 132 kV/220 kV 138 MVA transformers with total capacity of 414 MVA.

Source: Prepared by the Survey Team

Photo 4-19 Switching Station

Two generators of Units 1 and 2 are connected to the 132 kV bus and the generators of Units 3 to 10, eight units in total, are connected to 220 kV bus through their generator step-up transformers.

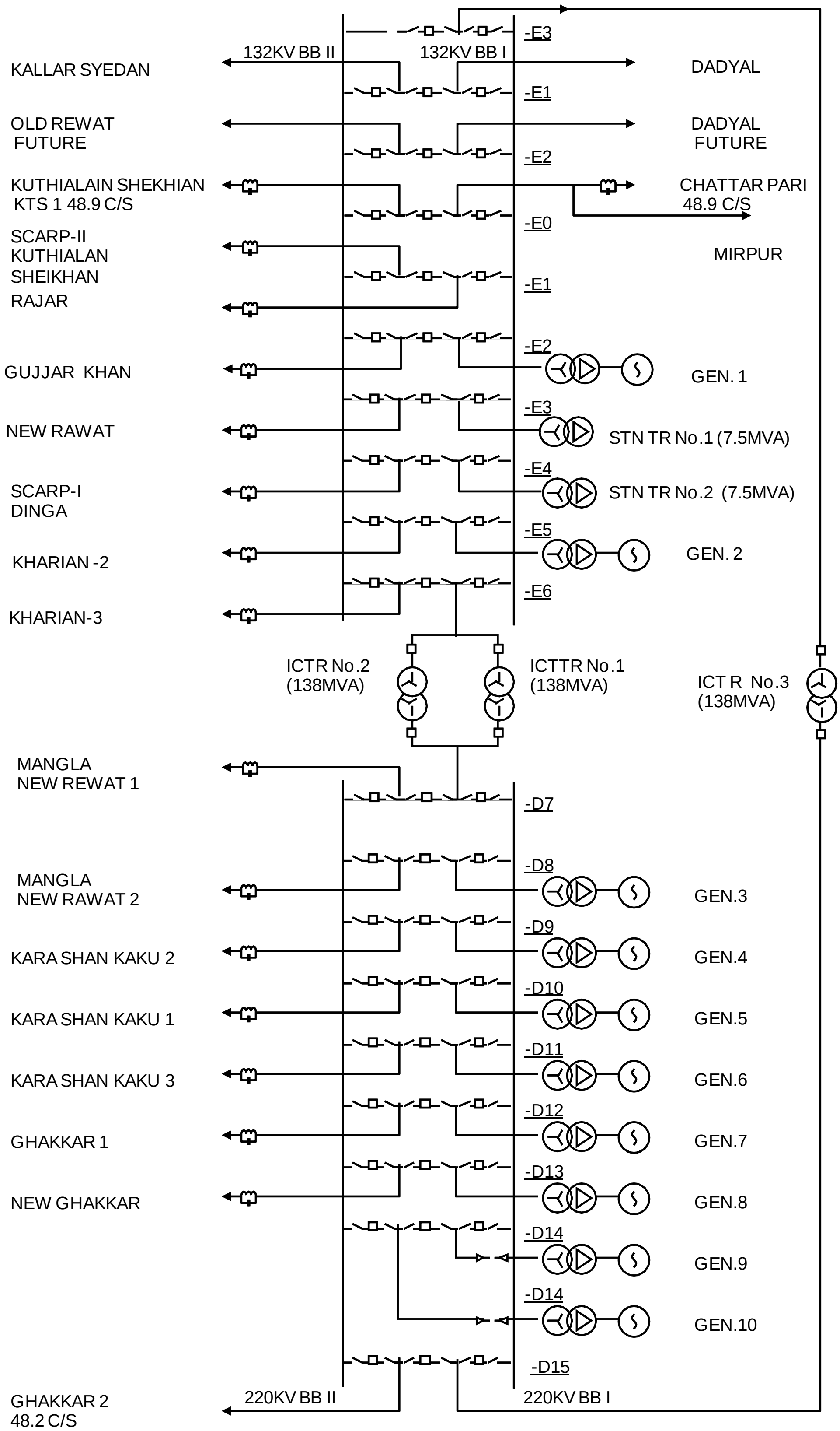
Eleven 132 kV and eight 220 kV transmission lines are emanated from the switchyard. Besides, two transmission bays are prepared in 132 kV for future expansion.

The single line diagram is shown in Figure 4-17, and the layout of transmission towers connecting the power station and switchyard is shown in Figure 4-18.

At present, Units 1 to 8 are connected by overhead line and Units 9 and 10 are connected by underground XLPE cable, which is planned to be changed to overhead line in the near future by NTDC to keep the reliability.

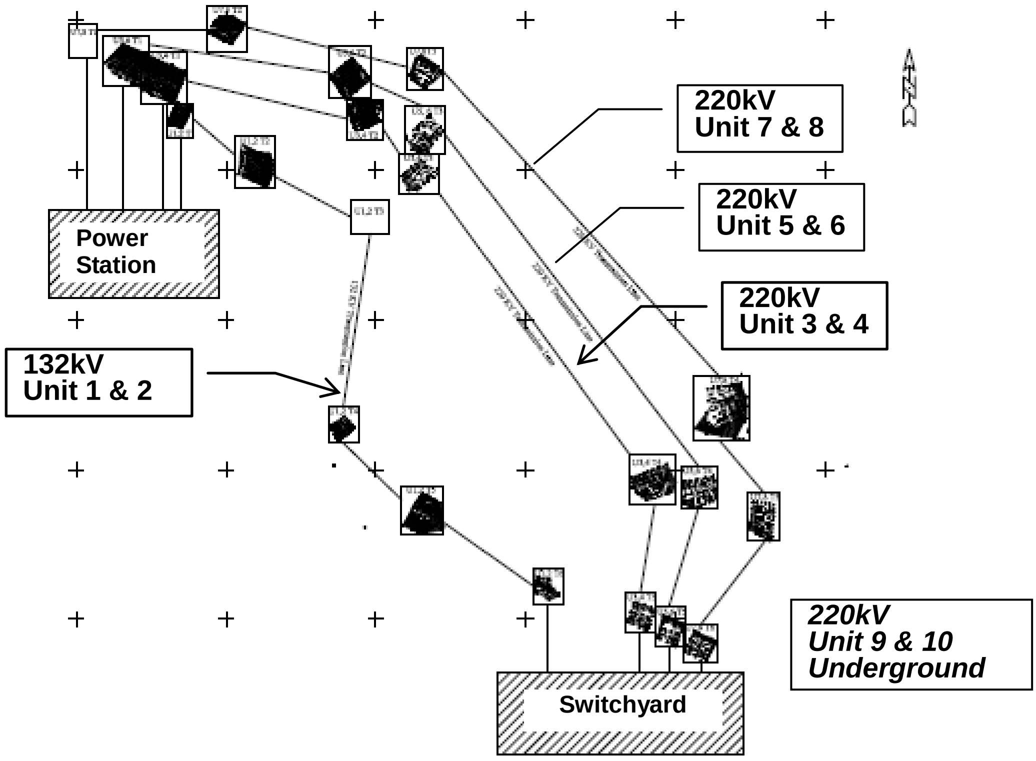
The switchyard consists of the following main equipment and associated systems:

- 132 kV and 220 kV Bus Bars
- Circiuit Breakers
- Disconnecting and Earthing Switches
- Current and Voltage Transformers
- Surge Arresters
- Line Traps
- 132/220 kV Interconnector Transformers
- 132/11 kV Station Service Transformers
- Steel Structure
- Protection Panels



Source: Prepared by the Survey Team

Figure 4-17 Single Line Diagram



Source: Prepared by the Survey Team

Figure 4-18 132 kV and 220 kV Overhead Line between Power Station and Switchyards

The section photo of the cable trench between power station and switchyard is shown in Photo 4-20. Previously, all power cables for Units 1 to 10, 11 kV station service power cables, and control/protection/measurement cables have been installed in the trench. After the fire that happened in 2008, power cables for Units 1 to 8 were converted to overhead line.

Source: Prepared by the Survey Team

Photo 4-20 Power Flow of 220 kV to 132 kV in Switching Station in 2010

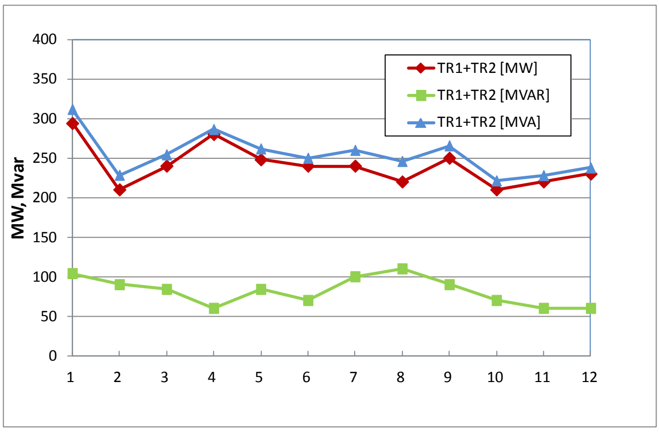
4.8.2 Generator Connection to Switching Station Bus

The power flow in the switchyard is always one-way, namely, 220 kV to 132 kV, through the 220 kV/132 kV inter-connecting transformer.

In January 2010, 310 MW power flow was recorded, which exceeded the capacity of two 138 MW transformers (276 MW in total). Then, one 138 MW inter-connecting transformer was additionally installed by the end of 2011 for sufficient capacity.

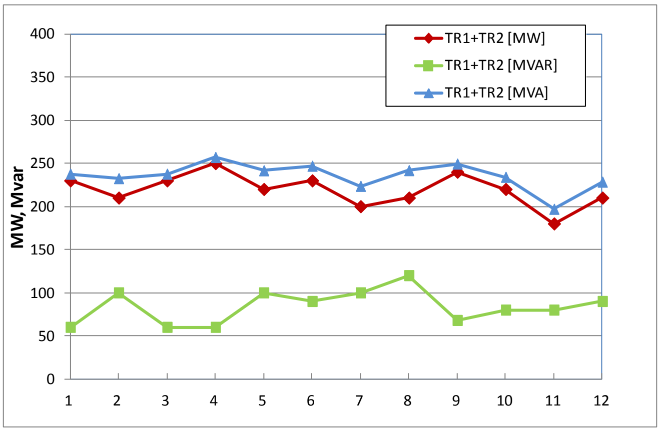
At present, Units 1 and 2 are connected to 132 kV bus in the switchyard and Units 3 to 10 are connected to 220 kV via 13.2/132 kV and 13.2/220 kV step-up transformers installed in the power station, respectively.

Monthly maximum power flows of 220 kV to 132 kV in 2010 and 2011 are shown in Figures 4-19 and 4-20, respectively. Maximum power flows vary from 200 MVA to 250 MVA. About 310 MVA was recorded in January 2010.



Source: WAPDA (Mangla Hydro Power Station)

Figure 4-19 Power Flow of 220 kV to 132 kV in Switching Station in 2010



Source: WAPDA (Mangla Hydro Power Station)

Figure 4-20 Power Flow of 220 kV to 132 kV in Switching Station in 2011

With the enhancement of the generator, the connection change is recommended, which is discussed in Chapter 5.

4.8.3 Switchgears

There are 27 and 29 (total 56) circuit breakers for 220 kV and 132 kV side, respectively. The circuit breakers were originally air-blast type. However, they are in the process of being replaced with SF6 type breakers.

As of May 2012, 21 and 24 circuit breakers for 220 kV and 132 kV, respectively, have already been replaced to SF6 type. Then, 6 and 5 circuit breaker for 220 kV and 132 kV, respectively, are scheduled to be replaced in the near future.

4.8.4 Replacement Required with the Enhancement Project

After discussing with the manager of the switchyard, the following points need to be studied:

The results of studies and the recommendations are discussed in Chapter 5.

1) Bus Bar for 220 kV and 132 kV
   After enhancement of the generating capacity, current capacity of bus bars shall be studied.

2) Current Transformer Capacity
   After enhancement of the generating capacity, ratio of the current transformers shall be studied.

3) Transmission Line Capacity
   After enhancement of the generating capacity, ratio of the current transformers shall be studied.

4.9 Existing Conditions for Mangla Dam

4.9.1 Meteorology Feature

There are four seasons in Pakistan, i.e.: winter with cold and dry season from December to February, spring with hot and dry season from March to May, summer with hot, rainy and monsoon season from June to September, and autumn as transition period from October to November. Pakistan’s climate consists of the desert climate (BW) in the central southern area, steppe climate (BS) in the northern area, and temperate climate in summer rain (Cw) in the northern mountainous area. There are five meteorological stations upstream of Mangla Dam (see Table 4-17) and the monitoring of temperature, humidity, precipitation, evaporation, insolation time, and wind direction/velocity is done by WAPDA. The data is kept by the Surface and Water Division of Hydrology (GM of Planning and Design: Mr. Irshed Ahmad) of WAPDA.

Table 4-17 Location of Meteorological Stations Maintained by WAPDA

Station	River Basin	Latitude	Longitude	Elevation
Domel	Upper Jhelum	34°22′04″	73°28′08″	686 ft (209.1 m)
Pallandri	Lower Jhelum	33°43′10″	73°41′06″	1,402 ft (427.3 m)
Kotli	Poonch	33°29′05″	73°52′52″	610 ft (185.9 m)
Kallar	Kanshi	33°25′00″	73°22′00″	518 ft (157.9 m)
Mangla Dam	Local	33°07′28″	73°38′00″	282 ft (86.0 m)

Source: WAPDA P&D Division

Table 4-18 shows the maximum and minimum mean temperatures of each month at the meteorological stations during the last ten years.

Table 4-18 Monthly Temperatures (Unit: ºC)

1) Domel Station

Month	1	2	3	4	5	6	7	8	9	10	11	12
Max	16	18	24	29	33	35	34	33	33	30	24	18
Min	2	3	8	13	16	20	20	22	17	12	7	2

2) Pallandri Station

Month	1	2	3	4	5	6	7	8	9	10	11	12
Max	14	15	21	26	30	30	28	27	27	25	21	16
Min	1	2	6	11	14	17	19	19	14	11	7	3

3) Kotli Station

Month	1	2	3	4	5	6	7	8	9	10	11	12
Max	18	19	26	32	36	37	33	32	32	30	25	20
Min	2	6	9	14	20	22	23	23	18	13	8	2

4) Kallar Station

Month	1	2	3	4	5	6	7	8	9	10	11	12
Max	19	20	27	32	37	37	35	33	33	30	26	21
Min	4	6	12	16	21	23	23	23	19	16	11	4

5) Mangla Station

Month	1	2	3	4	5	6	7	8	9	10	11	12
Max	19	22	28	34	40	38	35	34	34	32	27	22
Min	4	7	13	18	22	24	25	24	22	16	10	4

Source: WAPDA P& D Division

The meteorological station of Mangla Dam recorded 40ºC as the maximum temperature in May and 4ºC as the minimum temperature in December and January.

The precipitation in the catchment area of Mangla Dam is shown in Table 4-19.

Table 4-19 Monthly Rainfall (Unit: mm)

1) Domel Station

Month	1	2	3	4	5	6	7	8	9	10	11	12	Total
Monthly Mean	100	158	104	86	77	145	273	183	89	38	39	72	1364
Hourly Max	72	141	74	43	43	88	155	159	81	61	45	101	-

2) Pallandri Station

Month	1	2	3	4	5	6	7	8	9	10	11	12	Total
Monthly Mean	93	161	87	61	42	126	257	167	70	40	26	51	1181
Hourly Max	66	178	69	86	58	59	194	125	51	64	51	68	-

3) Kotli Station

Month	1	2	3	4	5	6	7	8	9	10	11	12	Total
Monthly Mean	70	112	77	38	43	95	209	184	63	28	18	38	975
Hourly Max	65	125	65	40	71	56	72	74	36	50	27	65	-

4) Kallar Station

Month	1	2	3	4	5	6	7	8	9	10	11	12	Total
Monthly Mean	50	90	58	52	29	76	194	106	67	33	30	52	837
Hourly Max	70	96	38	51	27	83	273	98	107	80	51	39	-

5) Mangla Dam Station

Moth	1	2	3	4	5	6	7	8	9	10	11	12	Total
Monthly Mean	34	54	43	26	30	90	204	188	60	16	12	26	783
Hourly Max	33	70	42	51	56	48	133	72	59	25	22	83	-

Source：WAPDA P& D Division

For the annual precipitation, the Domel and Plandari stations have 1343 mm and 1109 mm, respectively. Precipitation in Kotli, Kallar, and Mangla Dam stations were 975 mm, 793 mm, and 783 mm, respectively, which constituted comparatively less rain.

The tendency of precipitation from 2001 to 2010 in the Mangla Dam basin is indicated in Table 4-20**.**

Table 4-20 Tendency of Precipitation from 2001 to 2010

(mm/year)

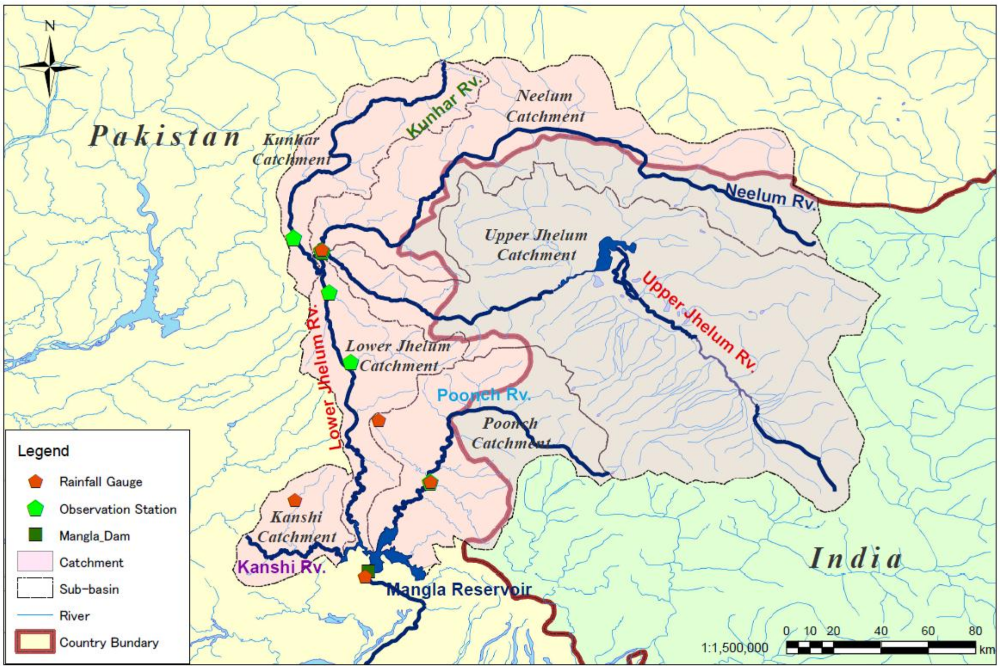
Year	Meteorological Station					Average
	Domel Sta.	Pallandri Sta.	Kotli Sta.	Kallar Sta.	Mangla Sta.	
2001	926	1,180	-	734	573	853
2002	1,087	881	817	858	534	835
2003	1,607	1,432	1,016	1,026	884	1,193
2004	1,474	1,056	881	961	825	1,039
2005	1,566	650	743	457	-	854
2006	2,187	1,112	1,411	1,099	1,049	1,372
2007	1,132	1,081	1,003	145	948	862
2008	1,795	1,284	1,298	1,056	879	1,262
2009	51	1,093	625	567	527	573
2010	1,608	1,319	977	1,027	825	1,151
Average	1,343	1,109	975	793	783	-

Source：WAPDA P& D Division

According to the above table, the precipitation in 2005, 2007, and 2009 in the Mangla Dam basin did not compare much with the other years. Accordingly, climate change was not observed in the last ten years.

4.9.2 Basin of Mangla Dam

The river system in the Mangla Dam basin consists of Neelum, Kunhar, Upper Jhelum, Lower Jhelum, Poonch, and Kanshi rivers (see Figure 4-21) and these catchment areas are indicated in Table 4-21.



Source: Prepared by the Survey Team

Figure 4-21 Basin of Mangla Dam

Table 4-21 Catchment Area of Mangla Dam Basin

River Name	AJK (Pakistan Side)			AJK (Indian Side)			Total		
	mile^2	km^2	(%)	mile^2	km^2	(%)	mile^2	km^2	(%)
Neelum	1,875	4,854	32.6	965	2,498	13.5	2,840	7,352	22.0
Kunhar	940	2,434	16.3	-	-	-	940	2,434	7.3
Upper Jhelum	312	831	5.6	5,218	13,509	73.3	5,530	14,340	43.0
Lower Jhelum	1,930	4,997	33.5	-	-	-	1,930	4,997	15.0
Poonch	690	1,786	12.0	940	2,434	13.2	1,630	4,220	12.7
Total	5,747	14,902	100.0	7,123	18,44	100.0	12,870	33,343	100.0
(%)	44.7			55.3			100.0		

Source: WAPDA F/S Report

The inflow area from AJK India side was 55.3% of total catchment area and its 73.3% came from the Upper Jhelum River. The inflow area from the Pakistan side was 44.7% and its 32.6% came from Neelum River and 33.5% from Lower Jhelum River.

There are six major observation stations for monitoring and flood warning in the Mangla Dam basin as shown in Table 4-22.

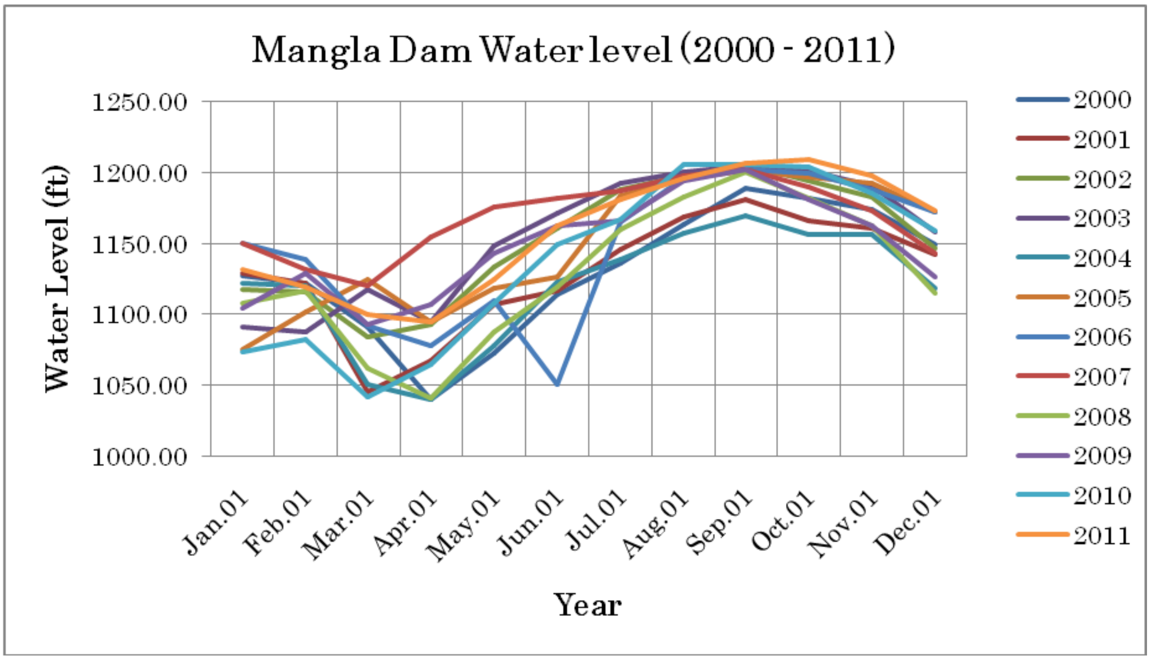
Table 4-22 Six Observation Stations for Monitoring in Mangla Dam Basin

Station	River	Latitude	Longitude	Elevation	Lag Time
Muzaffarabad	Neelum	34:21:32	73:28:18	787 m	8.25 hrs
Talhatta	Kunhar	34:24:52	73:21:45	877 m	8.75 hrs
Domel	Upper Jhelum	34:22:04	73:28:08	209 m	8.00 hrs
ChattarKlass	Lower Jhelum	34:12:18	73:29:52	632 m	6.50 hrs
Azad Pattan	Lower Jhelum	33:56:27	73:34:43	543 m	2.50 hrs
Kotoli	Poonch	33:29:05	73:52:52	186 m	1.00 hr

Note: The lag time is the arrival time of the flood from the station to Mangla Dam.
Source : WAPDA Hydrological Section of Mangla Dam

4.9.3 Water Level of Mangla Dam

The water level at Mangla Dam from 2000 to 2010 is shown in Figure 4-22. According to the figure, the water level in March, April, and May becomes low due to the dry season and the water is utilized for irrigation.



Source : WAPDA Hydrological Section of Mangla Dam

Figure 4-22 Mangla Dam Water Level since 2000

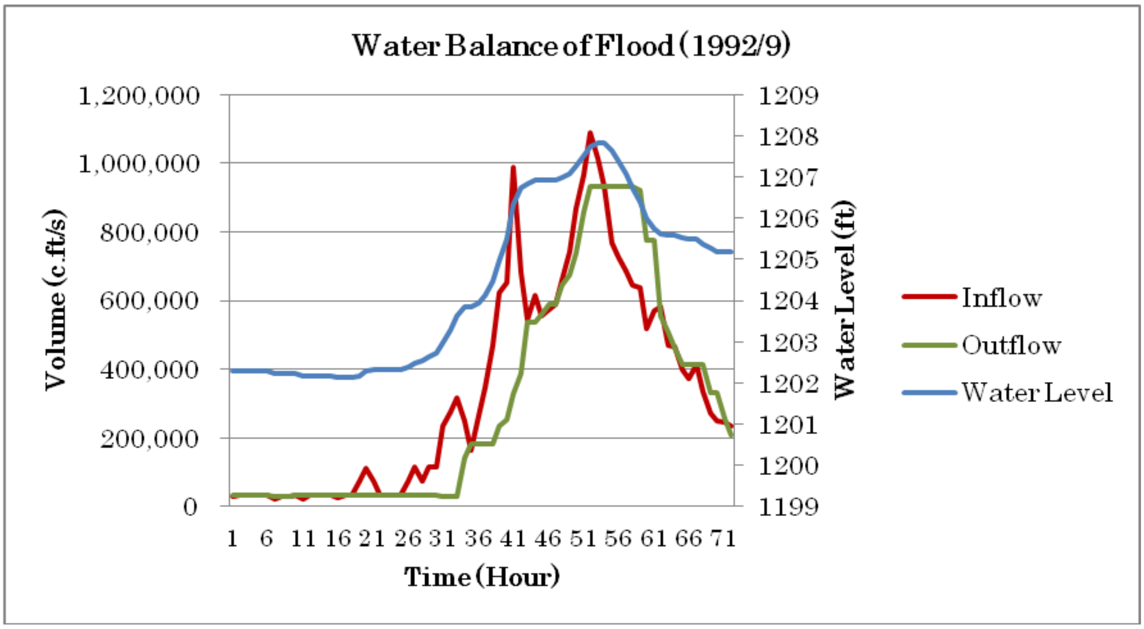
The monitoring stations have records of river discharges and water level. The historical floods are indicated in Table 4-23.

Table 4-23 Historical Floods

Year	Date	Lag Time	Inflow (cfs)	Inflow (m^3/s)
1928	17 Jul.	49 hrs	600,000	16,980
1978	6 Aug.	63 hrs	396,475	11,220
1988	7 Dec.	94 hrs	425,515	12,042
1992	11 Sep.	77 hrs	1,090,000	30,847
2010	31 Jul.	85 hrs	267,181	7,561

Note: The lag time means the time from start of rainfall in the area to occurrence of flood at Mangla Dam.
Source : WAPDA Hydrological Section of Mangla Dam

In case of 1992, the total inflow volume into the Mangla Dam was estimated at 38,347 acre foot (AF) (47.3 million m^3) and the outflow to the Jhelum River was estimated at 40,373 AF (49.8 million m^3) (see Figure 4-23).



Source：WAPDA Hydrological Section of Mangla Dam

Figure 4-23 Water Balance Flood in September 1992

4.9.4 Dam/Reservoir Condition (Annual Inflow and Sedimentation)

The design levels of Mangla Dam and the reservoir capacity are indicated in Table 4-24.

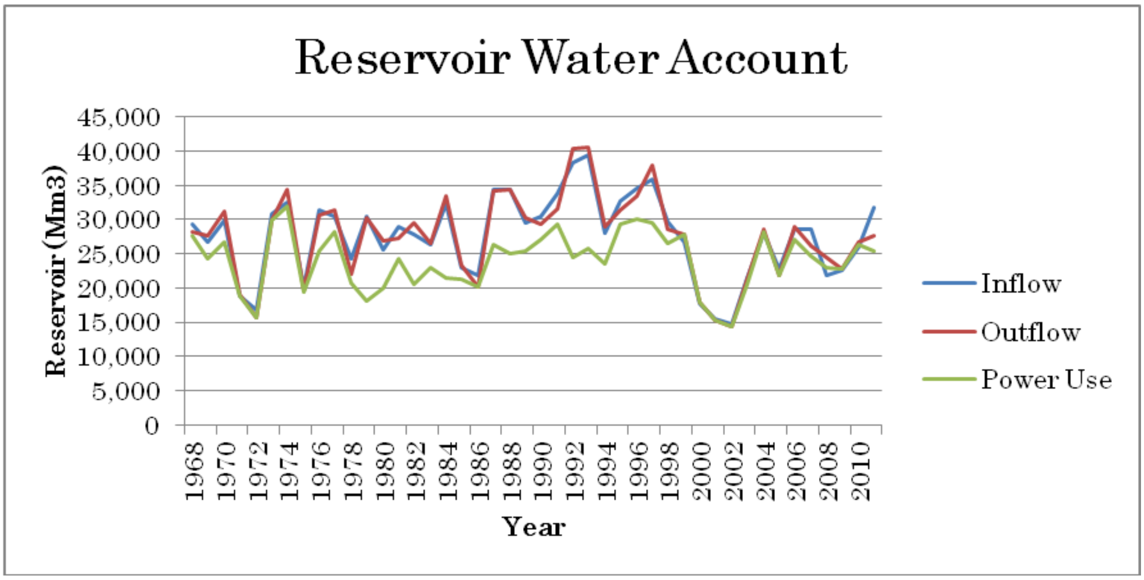
Table 4-24 Outline of Mangla Dam Level

Item	Original Design	After Dam Raising	Comparison
Reservoir			
Max. Water Level	366.5 m (1,202 ft)	378.7 m (1,242 ft)	+12.2 m
Min. Water Level	317.1 m (1,040 ft)	317.1 m (1,040 ft)	+0.0 m
Reservoir Capacity	5,553 million m^3 (4.5 million AF)	9,132 M m^3 (7.4 MAF)	+3,579 million m^3
Dam Body			
Crest Height	138.5 m (454 ft)	147.6 m (484 ft)	+9.1 m
Crest Length	3,350 m (10,300 ft)	3,400 m (11,150 ft)	+50 m
Intake Level	376.2 m (1,234 ft)	386.0 m (1,266 ft)	+9.8 m
Additional Capacity	-	3,550 million m^3 (2.88 million AF)	-
Annual Generation	-	644 GWh	-

Source：WAPDA Hydrological Section of Mangla Dam

4.9.5 Water Balance of Reservoir

Mangla Dam's reservoir capacity was estimated at 5,553 million m^3 before raising and the balance between inflow and outflow during the operation from 1968 to 2011 is shown in Figure 4-24. The averages of inflow and outflow were 27,600 million m^3 (22.376 million AF) and 27,545 million m^3 (22.331 million AF), respectively. The outflow used for the power generation was estimated at 23,981 million m^3 (19.442 million AF) on average and it is supplied for irrigation after generation as per intent of Indus River System Authority (IRSA). Also, the water volume released during big floods was 3,729 million m^3 (3.023 million AF) on average through the main spillway.

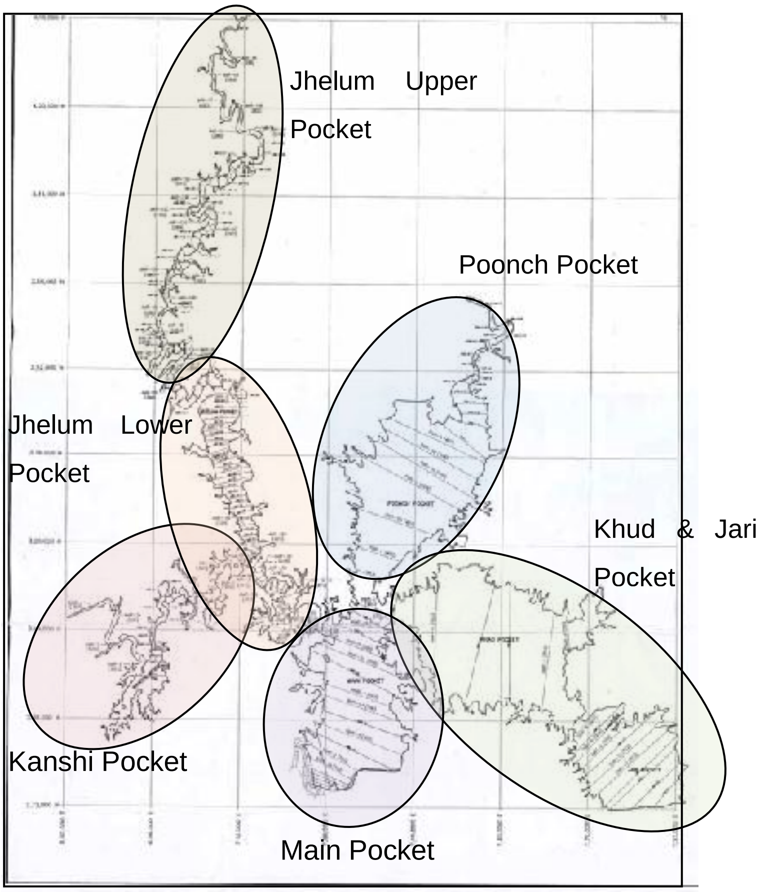


Source：WAPDA Hydrological Section of Mangla Dam

Figure 4-24 Reservoir Water Account (1968 to 2010)

4.9.6 Sedimentation of Mangla Dam

The contribution of sediments in the reservoir from different rivers in the catchment area is given in Table 4-24. The hydrographic survey for sediment was carried out 11 times after the construction of Mangla Dam. The sediment pockets are shown in Figure 4-25.



Source: Prepared by the Survey Team

Figure 4-25 Sediment Pocket at Mangla Dam

Table 4-25 Deposited Sediment Volume at Each Pocket (Unit: million m^3)

Year	Upper Jhelum	Lower Jhelum	Kanshi	Poonch	Main	Khud & Jari	Total
1967	16.10	3.76	2.28	11.10	4.56	-	37.81
1968	16.10	3.76	2.28	11.10	4.56	-	37.81
1969	16.10	3.76	2.28	11.10	4.56	-	37.81
1970	16.10	3.76	2.28	11.10	4.56	-	37.81
1971	26.93	3.18	1.27	10.43	2.76	-	44.58
1972	26.93	3.18	1.27	10.43	2.76	-	44.58
1973	26.93	3.18	1.27	10.43	2.76	-	44.58
1974	13.72	6.82	4.48	13.62	1.69	18.53	58.86
1975	13.72	6.82	4.48	13.62	1.69	18.53	58.86
1976	13.72	6.82	4.48	13.62	1.69	18.53	58.86
1977	13.72	6.82	4.48	13.62	1.69	18.53	58.86
1978	13.72	6.82	4.48	13.62	1.69	18.53	58.86
1979	5.48	7.00	1.55	3.98	3.54	5.78	27.33
1980	5.48	7.00	1.55	3.98	3.54	5.78	27.33
1981	5.48	7.00	1.55	3.98	3.54	5.78	27.33
1982	5.48	7.00	1.55	3.98	3.54	5.78	27.33
1983	5.48	7.00	1.55	3.98	3.54	5.78	27.33
1984	3.92	10.04	1.77	6.94	6.82	3.36	32.86
1985	3.92	10.04	1.77	6.94	6.82	3.36	32.86
1986	3.92	10.04	1.77	6.94	6.82	3.36	32.86
1987	3.92	10.04	1.77	6.94	6.82	3.36	32.86
1988	3.92	10.04	1.77	6.94	6.82	3.36	32.86

1989	12.73	10.29	2.15	6.01	17.77	2.90	51.85
1990	12.73	10.29	2.15	6.01	17.77	2.90	51.85
1991	12.73	10.29	2.15	6.01	17.77	2.90	51.85
1992	12.73	10.29	2.15	6.01	17.77	2.90	51.85
1993	12.73	10.29	2.15	6.01	17.77	2.90	51.85
1994	-2.42	-0.84	0.54	9.08	36.55	-1.09	41.83
1995	-2.42	-0.84	0.54	9.08	36.55	-1.09	41.83
1996	-2.42	-0.84	0.54	9.08	36.55	-1.09	41.83
1997	-2.42	-0.84	0.54	9.08	36.55	-1.09	41.83
1998	-2.99	-0.36	1.04	7.04	22.98	-0.32	27.38
1999	-2.99	-0.36	1.04	7.04	22.98	-0.32	27.38
2000	-2.99	-0.36	1.04	7.04	22.98	-0.32	27.38
2001	-7.78	-7.30	14.25	13.20	12.47	3.00	27.83
2002	-7.78	-7.30	14.25	13.20	12.47	3.00	27.83
2003	-2.57	0.88	0.42	-2.21	16.43	2.25	15.19
2004	-2.57	0.88	0.42	-2.21	16.43	2.25	15.19
2005	-2.57	0.88	0.42	-2.21	16.43	2.25	15.19
2006	9.10	0.19	0.57	-0.27	11.31	-1.01	19.90
2007	9.10	0.19	0.57	-0.27	11.31	-1.01	19.90
2008	9.10	0.19	0.57	-0.27	11.31	-1.01	19.90
2009	9.10	0.19	0.57	-0.27	11.31	-1.01	19.90
2010	9.10	0.19	0.57	-0.27	11.31	-1.01	19.90
Total	328.05	179.93	100.60	304.33	521.55	155.19	1,589.65
Ratio	21%	11%	6%	19%	33%	10%	100%

Source：WAPDA Hydrological Section of Mangla Dam

According to the monitoring reports of Mangla office of WAPDA, there are three major pockets for the sediment volume such as Main Pocket, Jhelum Upper Pocket, and Poonch Pocket. The total sediment from 1967 to 2010 was measured at 1,589.65 million m^3 and the average sedimentation per year was estimated at 36.13 million m^3. The maximum sedimentation was observed in 1978 and 1993 from the hydrographic surveys for sediment. However, the sedimentation volume was decreasing after 2000 due to stability of the riverbed and the catchment area slopes.