Tariff Setting for Independent Hydro Power Producers in Perspective of Pakistan's Electric Power Market

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Certificate

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Dedication

This thesis is dedicated to a sustainable future, for all of man-kind

Acknowledgment

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Abstract

This thesis presents an overview of the economic regulation of the electric market in Pakistan, which can generally be categorized into three market segments, i.e. generation, transmission and distribution of electricity. In addition, it evaluates the currently employed mechanism for tariff setting for an important generation segment, the Independent Power Producers in the field of Hydro power generation, and proposes various recommendations to enhance transparency, simplicity, efficiency and stability in the tariff setting mechanism. Hence offering an attractive opportunity to the investors to invest in Pakistan’s energy market by reducing and controlling their risks as well as protect the interests of the consumers. Emphasis is concentrated on hydropower power generation, especially by the private sector Independent power producers. Tthe guidelines for tariff setting as given by the NEPRA is discussed for hydro-power generation sector. Tariff setting guidelines along with development of a tariff model is discussed. The major goal of the thesis is to analyze and discuss a tariff setting mechanism that attracts investors like foreign Independent Power Producers to invest in the market’s generation sector whilst eliminating regulation uncertainties and encouraging companies to elaborate their investment plans for the energy starved country's electric market and at the same time protects the end consumer interests as well. In order to illustrate the proposed approach, a case study is done, where the feasibility of an IPP (Star Hydro PVT LTD) is studied. Finally, an attempt is made to discuss the regulatory issues in the said sector. The difficulties in practical implementation of the defined theoretical framework that are and can be encountered are presented. The possible solutions to eradicate the potent irregularities are enumerated at the end of the thesis.

Key words: Hydro power generation, Independent power producers, tariff determination, financial modeling

List of Figures

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List of Journal/Conference Papers

- *Investing in Hydro Power for Pakistan's Energy Security" presented in the International Conference on Energy Systems and Policies, 2014
- ** Risk Evaluation and Analysis for Tariff determination of Independent HPP in context of Pakistan's electricity market" submitted for International Journal for Energy Systems and Policies, 2015

* Annexure 1

** Annexure 2

Abbreviations Used

AJ&K	Azad Jammu and Kashmir
BOO	Build-Own-Operate
BOOT	Build-Own-Operate-Transfer
CAPM	Capital Asset Pricing Model
CAS-En	Centre for Advanced Studies in Energy
CPI	Consumer Price Index
CPP	Capacity Purchase Price
EOI	Expression of Interest
EPC	Engineering, Procurement and Construction
EPP	Energy Purchase Price
FC	Financial Close
FSA	Fuel Supply Agreement
GENCO	Generating Company
GOP	Government of Pakistan
GWh	Gigawatt hour
IA	Implementation Agreement
IPP	Independent Power Producer
IRR	Internal Rate of Return
KESC	Karachi Electric Supply Corporation
KIBOR	Karachi Inter Bank Offer Rate
km	Kilometer
kV	Kilo Volt
KPK	Khyber Pakhtoonkhwa
LOI	Letter of Interest
LOS	Letter of Support
MW	Megawatts
NEPRA	National Electric Power Regulatory Authority
NTDC	National Transmission and Dispatch Company
NUST	National University of Sciences and Technology
O&M	Operation and maintenance
PAEC	Pakistan Atomic Energy Commission
PEPCO	Pakistan Electric Power Company
PPA	Power Purchase Agreement
PPIB	Private Power and Infrastructure Board
SHPL	Star Hydro Power Limited
SHYDO	Sarhad Hydel Development Organization
WAPDA	Water and Power Development Authority
WUL	Water Use License

Chapter 1

Introduction

1.1. The Power Sector

Electricity represents about 16% of the total energy consumption in Pakistan. The power sector, which comprises of the generation, transmission and distribution sector, is regulated under the NEPRA Act, 1997. NEPRA was exclusively powered an independent entity, a newly formed regulator, to regulate all sectors of the power sector. It has been empowered to grant licenses, to approve tariffs, and to establish codes and standards [1].

All power sector policies and relevant legislation is developed and implemented by the Ministry of Water and Power. Under the advice of the World Bank, in the early 1990's, The Government of Pakistan initiated the process of power sector reformation to de-regulate and restructure the power sector. The power sector restructuring and reforms, developed through different initiatives in different stages, is reflected today in the adopted policies. These were designed to attract participant investors from the private sector in a newly re-structured power sector [2].

Pakistan's power sector market, is still in its transition phase of de regularization, and today is semi-privatized and semi-deregulated. The country, as of today has a substantial amount of private sector led electricity generation. The evident success in attracting private sector generators was not without issues and most of the private sector Independent Power Producers IPP's ended up in disputes on contracts with the GOP. However, these disputes have been harmoniously settled with minimal possible changes and adjustments to the original contracts. Although, renovated and negotiated, the terms and conditions of the contracts made were eventually honored which provided a degree of ease in the present day investment environment [3].

The following visual graph depicts the current structure of Pakistan’s power sector market.

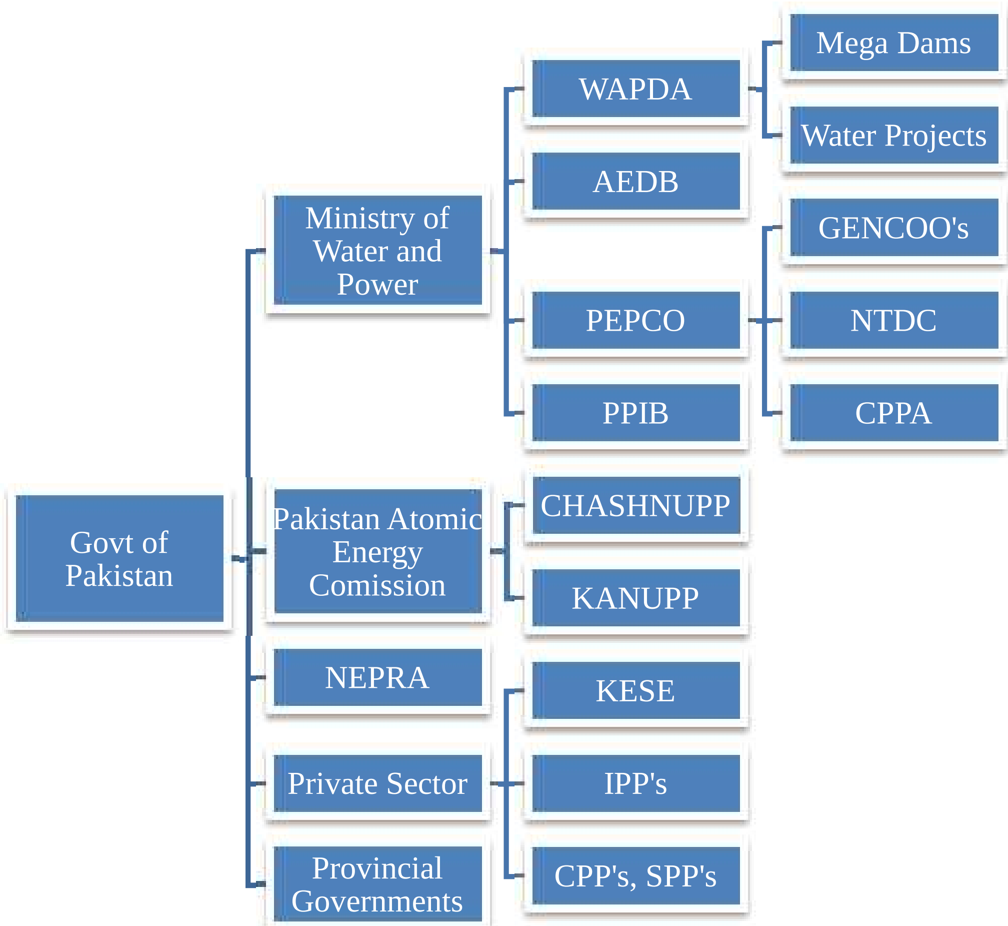

Figure 1: Pakistan's Power Market Structure

1.2. Evolution of Pakistan’s Electricity Market

Power Sector of Pakistan has remained under complete government control for most of the time since 1947 when the overall power generation capacity was around 60 MW to the present generation of 23538 MW. A Bulk of the power sector entities still work under government run organizations. Electric power sector in Pakistan comprises of a number of institutions which are then either directly or indirectly responsible for providing required technical and smooth operation of the tasks they are assigned to. The power market was controlled, regulated and monitored by WAPDA (Water and Power Development Authority) a Federal Semi-Autonomous Organization formed in the year

1958. Along with WAPDA, another vertically integrated entity, the KESC (Karachi Electric Supply Co-corporation) was responsible for operating in their region of concern i.e. Karachi.

With increased globalization and a shift towards privately-owned business enterprises, Pakistan also initiated its policy of gradually de-regulating the power sector. So far this process has achieved the following milestones [4].

- Dissolution of WAPDA into the following three sectors:
  - The state owned Generation companies (the GENCO's)
  - The National Transmission and Distribution Company (NTDC)
  - Regionally operating Distribution companies (the DISCO's)
- Establishment of a Regulatory authority, the National Electric Power Regulatory Authority (NEPRA)
- Privatization of the Karachi Electric Supply Corporation (KESC)
- Formation of the Private Power & Infrastructure Board (PPIB)

1.3. Energy Mix

Pakistan relies on fossil fuels to fulfill 65% of its power demand. Due to the depleting resources of indigenous natural gas and low calorific value of the domestic fuel, most of the power-plants are based on imported furnace oil, which currently happens to be a very expensive source of electricity generation. The following data provided by the Federal bureau of Statistics reflects the sources of energy production as compared to the global averages [5].

It is heartening to note that the country produces approx. 32% hydroelectricity compared to the world average of approx.15% in this traditional renewable sector.

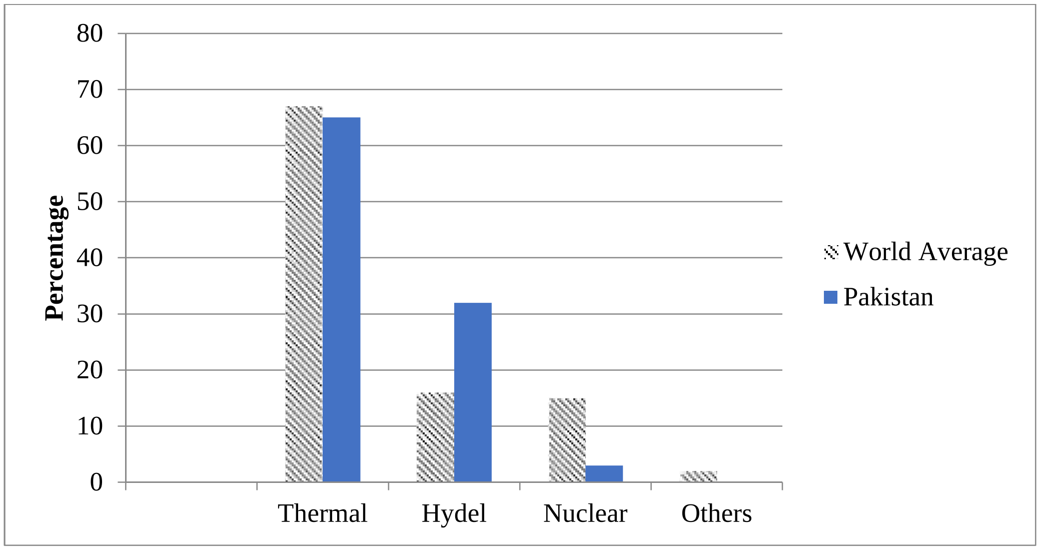

Figure 2: Energy Mix In Terms Of Percentage

1.4. Pakistan's Per Capita Energy Demand

The average per capita power consumption in Pakistan is about 456kWh, which happens to be 30% lesser than Asia (averaged at 646kWh) and is about 83% lesser than the global average (2596kWh). The main reason for very low per capita energy consumption is the installed generation capacity, which happens to be very low and the resultant power outages owing to under capacity generation. The PPIB estimates the gap between demand and supply to be around 5000 MW.

To catch up on the Asian average for per capita power consumption (assuming that it remains constant) in the next 5 years, with Pakistan's given annual population growth rate of 2 %, the power consumption needs to grow at a CAGR (compounded annual growth rate) of 9.2%. Alternately, for a stagnant power generation capacity for the next 5 years, with the current growth rate of population, Pakistan's per capita power consumption would drop to 380kWh hence resulting in a greater shortage of electricity [6].

1.5. Demand Supply Gap

Currently, Pakistan is facing severe shortage of electricity. Generation of electricity in the country has reduced by up to 30% in the recent years due to over-dependency on fossil fuel based electricity generation, which happens to be very costly. Load Shedding has become severe in Pakistan in the recent years.

Political instability, increase in demand, under-capacity generation, and poor efficiencies of the grid systems are a few of the reasons for the ever increasing gap between supply and demand, which has risen to over 5000 MW. The following graph shows the supply-demand statistics for years 2009-13 [7].

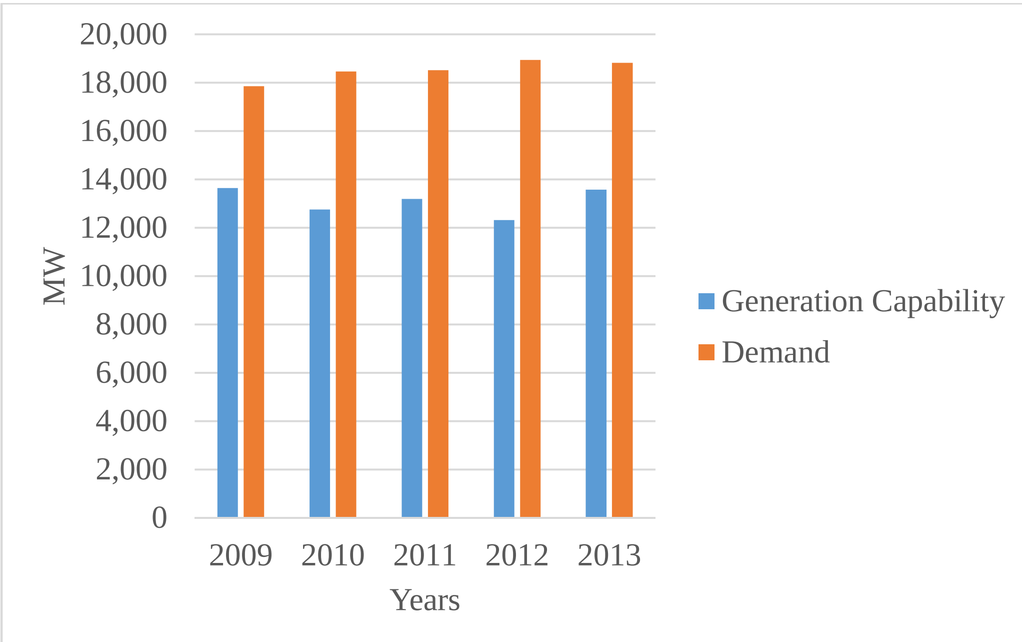

Figure 3: Yearly Demand Supply Gap

1.6. The Power Policy 2013

The 2013 National Policy was implemented with the vision,

“The country will develop the most efficient and consumer centric power generation, transmission, and distribution system that can meet the needs of her population and hence boosts its economy in a sustainable and affordable way.”

The policy sets the following targets to be achieved:

- To eliminate the demand-supply gap by the year 2017
- To decrease the cost of electricity generation from 0.12 $/kWh to 0.10 $/kWh
- To decrease the transmission and distribution losses from 25% to 16% by 2017.

- To increase electricity bill collection from 85% to 95% by 2017.
- Improvement in decision making and reduction in the time taken for decisions at the Ministry, and related departments.

The major strategy to achieve the above mentioned targets and goals is pivoted on attracting and utilizing local and foreign investments towards the rapidly expanding power generation market in Pakistan. However, foreign as well as local investments can only be encouraged if the sector is made attractive, profitable, secure and bankable [9].

In developing and implementing new projects for power generation, up-front or feed-in tariff (which shall set the upper ceiling tariff) is to be given preference. In addition, competitively bided projects are also to be employed in order to reduce generation costs.

The GOP wishes to increase hydro-power electricity generation capacity through medium and long term plans. Six hydro-power projects of 388 MW are to be completed by the start of the year 2015. The Patrind and Gulpur hydro-power projects are expected to achieve COD by December, 2017 and will add additional 247 MW to the national grid. An additional 1000 MW from the Neelum-Jhelum hydro-power project will come online by November, 2016. A number of other hydro-power projects are expected to be completed in 2017 and will start generating power. These include the fourth and fifth expansions of the Tarbela dam, which has the potential to add 1910 MW to the national grid.

Long term hydro-power projects such as Kohala (1000 MW), Diamer-Bhasha (4500 MW) and Bunji (7100 MW) are under consideration, whose completion would ensure energy security in Pakistan.

1.7. Solutions for the Solution of Current Energy Crises

The current Government came to power in Pakistan in 2013, and is aware of the wide-ranging power shortage problems but up till now, it has failed to tackle the issue head-on [10]. Although some initiatives have been taken, several others face hurdles in implementation, and more broadly speaking, the government is regarded to have taken too little action as yet [11][12]. A few recommendations are presented to help tackle the issue:

- The GOP must resolve the circular debt issue on emergency basis.
- The GOP must invest to cover up for transmission and distribution losses.
- Industries consume 33% of the total electricity produced. They should implement and ensure Energy Conservation Systems and Management measures.
- Industries need to step up and produce their own energy decreasing grid-dependence.
- The energy sector needs to be made more attractive for foreign investors.
- Efficiency of old gas plants should be enhanced, in order to conserve energy.
- The GOP must contemplate investing in Renewable energy resources.

1.8. Energy Costing

The EIA (International Energy Agency) values the following global average costs (including the construction, operations and maintenance, fuel costs etc.). Table 1 highlights the emergence of Nuclear power followed by Hydro-power to be the cheapest source of electricity across the globe.

Table.1: Global Average Energy Generation Costs

Global Average Electricity Generation Costs			
Fuel Mix	**At discount rate = 5%**	**At discount rate = 10%**	**Construction Cost**
	USD Cents/kWh		**USD/kW**
Coal	2.5 to 5	3.5 to 6	1000 to 1500
Gas	3.7 to 6	4 to 6.3	400 to 800
Nuclear	2.1 to 3	3 to 5	1000 to 2000
Wind	3.5 to 9.5	4.5 to 24	1000 to 2000
Hydro	4 to 8	6.5 to 10	2500 to 3500
Solar	15 to 16	20 to 22	2000 to 3000

1.9. Hydro Power Technologies

Hydro-power is considered to be a source of renewable energy, as it uses the natural hydrological cycle to generate electricity. As water flows down streams due to gravitational potential energy, it creates kinetic energy that can converted into electricity using hydraulic turbines that connect to a generator, hence generating electricity.

Hydro-power is a well proven and an advanced technology of electricity generation, with modern power plants providing the most efficient energy conversion processes (efficiency>90%), that is also an important environmental benefit. Hydro based power generation has the lowest operating costs off all generation sources and the longest service life of all. Normally, a typical hydro power plant remains in service for 40-50 years and can have operational lives of up to 100 years. The ‘fuel’ (water) is not subject to variations in market economy. Hydro-power electricity generation represents energy sufficiency for many countries in the world.

Hydro-power power generation is also vivacious from an operational point of view, since it needs almost zero "ramp-up" time unlike many other common combustion technologies. It can therefore vary the quantity of power supplied instantly in order to meet changing demands. With these attributes, i.e. Important load-following capability, voltage stability and peaking capacity, hydro-power ensures reliable electricity. In addition, hydro-electric pumped storage plants currently are the only significant way available for storage of electricity. Hence, hydro power provides boosted value to the electricity generation system being efficient, secure, and reliable.

1.10. Hydro Power Development in Pakistan

History of hydro power development in Pakistan dates back to 1925, when a 1 MW run-of-the river hydro power plant was set up in Renala Khurd, District Okara. Estimates show that Pakistan has a hydro-power generation potential greater than 60000 MW, of which, the majority is available in the North-West of Pakistan comprising of the KPK province and the AJK. Whereas, the exploited power potential is only around 6000 to 7000 MW, a mere 10-12 % of the total available potential.

The Government of Pakistan is keen to assist local and foreign investors to promote electricity generation by hydro-power means. However, a difficult issue is to estimate the market-specific risks, the related infrastructural and political issues. The most critical concerns of all is to decide if the investor would be able to find a certain low-risk profit considering all the related concerns with the development of the project.

The benefits offered by the hydro-power resources are of significant importance to the success of our experiment of deregulating the electric power sector. And with the present available potential and investor-friendly policies, it has a huge potential to attract foreign investments.

1.10.1. Resources and Potential

The installed capacity of the hydro-power generation facilities in the country is 6823 MW, out of which more than a half, i.e. 3849 MW is in the KPK province, 1699 MW in the Punjab province, 1039 MW in the AJK area and 133 MW in GB region.

Table. 2: Identified Potential on rivers

River	Identified Potential (MW)
The Indus	39717
Jhelum	5624
Swat	1803
Kunhar	1480
Kandiaah	1006
Punch	462
Other Rivers	9704

The major hydro-power resources are primarily located in the mountainous areas in northern region of the country i.e. KPK, AJK and GB. The scarce hydro-power resources in the south mainly consists of small to medium hydro-power plants built on barrages and canals, and usually are run of the river based plants. The table below shows the distribution of hydro-power potential in the Pakistani rivers [8].

1.10.2. Installations

The country currently generates 6823 MW (32% of total electricity) from its hydro-power plants. The breakup of the installed capacity of each of the plants is given in Table 3:

Table 3. Installed Capacities of Hydro-Power Plants

Currently running Hydro Power Plants	**Capacity (MW)**
Tarbela Dam	3478
Ghazi Brotha	1450
Mangla Dam	1000
Warsak Dam	243
Chashma	184
Dargai	20
Rasul	22
Shadi-waal	18
Nandi pur	14
Kurram Garhi	4
Renala	1
Chitral	1
Jagran	30
Khankhwar	72
Allaikhwar	121
Gomal Zam	17
Jabban	22
Duber khwar	130
Total Installed	6823
Up Coming Hydro Power Plants	
Diamar Bhasha	4500

Bunji	7100
Kohala	1100
Nelum Jhelum	1000

1.11. Advantages of Investment in Hydro-Power Sector

Besides a fairly decent projected economic growth, following are a few potent reasons to invest in Pakistan's hydro-power sector

- A significant amount of hydro power potential remains unexploited. Out of 60,000 MW of available potential, only a fraction (roughly 10%) is being exploited to generate power.
- The available hydro-power resources are very versatile in nature. They provide great investment opportunities in the form of run-of-the river, small, medium and mega storage based hydro-power projects.
- Currently, there exists a supply demand gap of 5000 MW in the country. The country is power starved, hence making it ideal for investors
- NEPRA offers a long term tariff for 25-30 years to the investors. Furthermore, the Independent power producers are not subjected to market risks.
- A good and stable ROE (Return on equity) is given to investors. For Hydro Power Producers, currently, the ROE ceiling is 17 %
- An attractive debt-equity ratio 70:30 (70 debt, 30 equity) is being allowed to Hydro-Power Producers.
- The tariff components are indexed for variations in USD and PKR parity based on the projected depreciation of the local currency.
- The GOP provides guarantee of the performance obligations for each of its related entities i.e. all provinces, the National Grid, the Power purchaser, etc.
- Financial Protection to the debt-lenders and sponsors is also provided if the project terminates. The GOP also provides guaranteed support against possible variations in taxes and duties.

- According to the Private Power Investment Board (PPIB), 21 new hydro-power projects are expected to be initiated in the following 10 years with a projected capacity of 5200 MW.

1.12. Power Project Process

The power project process is straight forward and one window operation is shown in the figure 4.

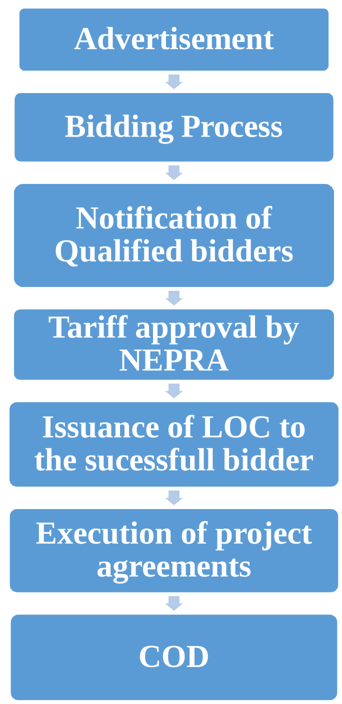

Figure 4: Power Project Process

1.13. Tariff Setting Mechanism

The NEPRA is required to determine electricity tariff so as to safeguard the interests of the power producer, the supplier as well as the consumers. Any raise in tariff requested by the producer can be allowed or rejected, after analyzing the financial statements.

The sequence indicated in figure 1.5 is followed for tariff determination.

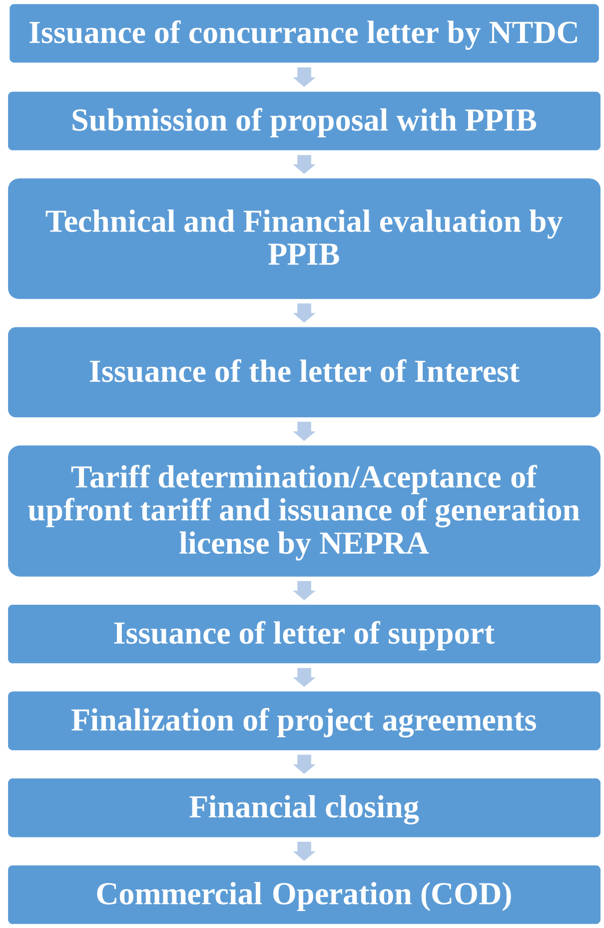

Figure 5: Tariff Determination Sequence

Summary

Pakistan, naturally is a country with rich hydrological resources, but unfortunately, investment in her energy market especially in hydro-power generation has been caught up in frenzy and paradoxes for the last two decades. The GOP is trying to facilitate private investors as much as possible in order to enhance hydro-power generation in the country, by providing attractive investment opportunities. We have presented an overall analysis of the country's power market and the opportunities it provides to investors in the hydro-power generation sector.

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Chapter 2

Literature Review

2.1. Introduction: A Synopsis of the Power Sector

For almost a decade now, the balance between the demand and supply of electric power in Pakistan has largely remained an unsolved issue. As of 2014, a large proportion of the demand remained unserved. Electricity generation shrunk by an astounding 50% due to the country's over reliance on imported fossil fuel. As a result, massive number of black-out hours followed suits causing economic and political un-stability in the country. The major causes of the crises appear to be the Government's policies subduing to the pressure created by the oil companies, the rapid increase in demand and the low generation efficiencies of the generation plants. By 2014, the total installed capacity was reported to be 22,800MW and a generation of 12,000-13,000 MW against an average demand of round 17,000 MW. Hence resulting in shortfalls ranging between 4000-5000 MW.

Before the de regulation of the Electric power market in Pakistan, Electricity was mainly generated, transmitted as well as distributed by two major vertically integrated public sector utilities, namely the WAPDA for the entire country except for Karachi and her suburbs and KESE in Karachi and adjoining areas. However, the privatization of the sector in the early 1990's resulted in the formation of a corporate entity, the Pakistan Electric Supply Corporation, the PEPCO [1]. We'll briefly discuss the various stake holders in the Power Sector.

2.2. Evolution of Pakistan's Electricity Market

The power sector of Pakistan has remained under complete government control for most of the time since the country's independence in 1947, when the overall power generation capacity used to be around a mere 60 MW to the present generation capacity of 23,800 MW. A majority of the power sector entities still work under the Government run organizations. Electric power sector in Pakistan comprises of a number of entities which are then either directly or indirectly responsible for providing required technical and smooth operation of the tasks they are assigned. The power market was controlled, regulated and monitored by the WAPDA (Water and Power Development Authority) a Federal Semi-Autonomous Organization formed in the year 1958. Along with WAPDA, another vertically integrated entity, the KESC (Karachi Electric Supply Co-corporation) was responsible for operating in Karachi and its surrounding areas [2].

With increased globalization and a shift towards privately-owned business enterprises, Pakistan also initiated its policy of gradually de-regulating the power sector. So far this process has achieved the following milestones:

- Dissolution of WAPDA into the following three sectors:
    - Generation Sector: The Generation Companies (GENCO's)
    - Transmission Sector: The National Transmission and Distribution Company (NTDC)
    - Distribution Sector, 10 Regional Distribution Companies (DISCO's)
- Establishment of a Regulatory body, i.e. the NEPRA
- Privatization of the Karachi Electric Supply Corporation (KESC)
- Establishment of the Private Power and Infrastructure Board (PPIB)
- Expansion of the Nuclear Generation Facilities under the Pakistan Atomic Energy Commission (PAEC)

2.3. Stake-holders in the Power Sector of Pakistan

Figure below presents an over view of the country's electric power market. Apparently, the said sector is in control (director indirect) of different government and non-government organizations [3].

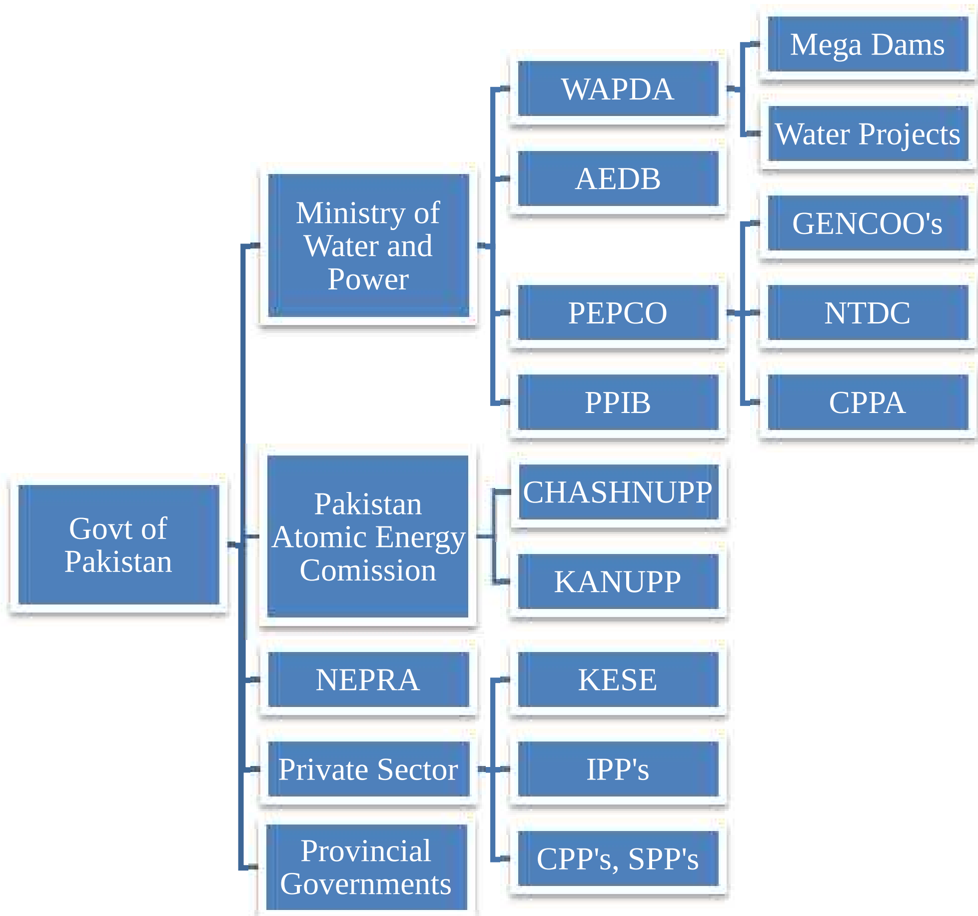

Figure 6: Pakistan Electricity Market

2.3.1. The Ministry of Water and Power

The said ministry has an over-all executive authority to all issues related to water and power in the country, and is responsible for all formations and implementations of policies and plans related to the of water and power resource development.

2.3.2. The Water and Power Development Authority (WAPDA)

WAPDA's role has reduced to the development of public owned hydel projects, and handling water resources of the country.

2.3.3. The Regional Distribution Companies (DISCO's)

The Distribution of electricity network is being operated by the following distribution companies in their respective regions

- The Islamabad Electric Supply Company (IESCO)

- The Multan Electric Power Company (MEPCO)
- The Peshawar Electric Supply Company (PESCO)
- The Quetta Electric Supply Company (QESCO)
- The Gujranwala Electric Power Company (GEPCO)
- The Lahore Electric Supply Company (LESCO)
- The Tribal Areas Electric Supply Company (TESCO)
- The Faisalabad Electric Supply Company (FESCO)
- The Hyderabad Electric Supply Company (HESCO)

2.3.4. The National Transmission and Dispatch Company (NTDC)

The NTDC is exclusively in charge for all transmission of electricity (except for the areas underneath the KESE jurisdiction) for a period of 30 years (starting from 2002) under a license from the NEPRA. In light of the license, the NTDC has been permitted to work:

- As a Central Power Purchasing Agency (CPPA): For procurement of produced power from the fossil fuel, as well as hydro generation companies (GENCO's) and Independent power producers for electricity transmission through its 132kV, 220 kV and 500 kV networks.
- As a System Operator: To ensure the safe, secure and steadfast operation, control and dispatch from the generation facilities.
- As a Transmission Network Operator: For O&M design, planning and development of its 500 kV, 220 kV and 132kV system of transmission.
- As a contract Registrar and Power Exchange Administrator (CRPEA): For recording & monitoring of the contracts related to system of bilateral trade in the sector.

2.3.5. Private Power and Infrastructure Board (PPIB)

The Private Power and Infrastructure Board (PPIB) was established in 1994 in order to facilitate local and foreign private sector investments in the power generation sector. The PPIB provides one-window facility to the investors on the behalf of the Government of Pakistan (the GOP), its ministries, and departments for all matters related to the power projects in private sector. The PPIB also provides technical and legal support to the Ministry of Water and Power, and guidance to the provincial and the AJ&K Governments in the matters related to development of hydro-power IPPs.

2.3.6. The Alternative Energy Development Board (AEDB)

The Alternative Energy Development Board functions under the Ministry of Water & Power and is responsible for development of power projects of up to 50 MW utilizing renewable energy resources of micro hydel, wind, solar and bio mass energy in the private sector [4].

2.3.7. Power Sector Departments in the Provinces and the AJ&K

Following departments under provincial and the AJ&K governments work for the development of power projects up to 50 MW in their respective jurisdictions:

- Punjab Power Development Board (PPDB) and Punjab Power Company Ltd. (PPCL) under Irrigation and Power Department, Government of Punjab
- Irrigation and Power Department, Government of Sindh
- The Sarhad Hydel Development Organization (SHYDO) under Energy and Power Department, Government of Khyber Pakhtunkhwa
- Irrigation and Power Department, Government of Baluchistan
- AJ&K Private Power Cell (AJ&K PPC) and AJ&K Hydroelectric Board (AJ&K HEB) under Electricity Department, Government of AJ&K
- Water and Power Department, Government of Gilgit-Baltistan

2.3.8. The National Electric Power Regulatory Authority (NEPRA)

The National Electric Power Regulatory Authority, NEPRA was established under the regulation of Generation, Transmission and Distribution of Electric Power Act 1997. The main functions of NEPRA are to

- Grant licenses for generation, transmission and distribution of electric power
- Prescribe and enforce performance standards for generation, transmission and distribution companies
- Tariff determination: Being a regulator, NEPRA is responsible for all matters related to the tariff of electric power in the country.

2.3.9. The Karachi Electric Supply Company (KESE)

The Karachi Electric Supply Company Limited was incorporated before the partition of India in 1913. The Government of Pakistan took control of the Company by acquiring majority shareholding in 1952. The Company was there after privatized in 2005. The Company is primarily engaged in generation, transmission and distribution of electric energy to industrial, commercial, agricultural and residential consumers to entire Karachi and its suburbs up to Dhabeji and Gharo in Sindh and Hub, Uthal, Vindhar and Bela in Baluchistan.

2.3.10. Pakistan Atomic Energy Commission (PAEC)

The Pakistan Atomic Energy Commission, PAEC is operating and maintaining the following Nuclear Power plants

- 137 MW Karachi Nuclear Power Plant (KANUPP)
- 300 MW Chashma Nuclear Power Plant-I (CHASNUPP-I)

The construction of Chashma Nuclear Power Project Unit-2 (CHASNUPP-2) is in process.

2.4. Hydro Power-An Introduction

Hydro-power is a renewable source of energy. It harnesses the natural water cycle, using its potential energy to produce electricity. Hydro-Electric power comes from flowing water, winter and spring Run-off Rivers and canals from mountain streams and natural or man-made reservoirs called dams. Water when flows due the force of gravity, can be used to run turbines and hence the generators that produce electricity.

The flow of water as it flows downstream processes kinetic energy that can be transformed into electrical energy using turbines. A hydro-Electric power plant converts this gravitational potential energy and kinetic energy into electricity by inducing water, often stored at a reservoir through a hydraulic turbine that runs a generator. The water thereafter exits the turbine returns to a stream or river bed through a channel called tail. Hydropower is highly dependent upon changes in amount of precipitation and elevation. High precipitation levels and large changes in elevation are required to generate significant amount of electricity.

Therefore, an area such as the mountainous North West areas of Pakistan (The KPK province, the GB and AJ&K) have more productive hydropower plants than plain area such as the Indus plains, which might have large levels of precipitation but are comparatively flatter [5].

2.5. Important Characteristics of Hydro-Power

Hydro Power resources are widely spread out throughout the globe. A significant potential exists in more than 150 countries across the world, and around 70% of the economically feasible potential remains unexploited. Most of this unexploited potential is present in developing and under developed countries.

Hydro power is an age old technology and is highly advanced, with modern HPP's functioning at the most efficient energy conversion processes (greater than 90%).

With its small response time, it is able to meet impulsive variations in electricity demand. The generation of peak load electricity from hydro power plants allows base load electricity to be generated from other less flexible sources, such as nuclear, solar and wind.

Hydro power plants have the lowest of operating costs and the longest of plant life, as compared to other large scale generating options. After an initial investment in the necessary civil works, the plant life of HPP's can be protracted economically by inexpensive maintenance and periodic replacement of electro-mechanical parts. Normally, a hydro power plant remains in service for 40-50 years, and its operational life can be doubled by periodic maintenances. The 'fuel' (water) is renewable, and is not subject to fluctuations in market economy. Hydro power represents energy independence for many countries [6].

2.6. Hydro Power, a Green Energy Resource

In today's world, about 83% of the primary source of energy is fossil fuel, oil, gas and coal or traditional wood. Such an extensive use of fossil fuel is associated to mega-scale greenhouse gas emissions, i.e. carbon di oxide gas from combustion and methane gas from the processing of natural gas and coal. It is a well-established fact that this is eventually leading the planet earth towards major climatic changes and dis-balance of the natural hydrological cycle.

Research has confirmed that the GHG emission factor for hydro-power plants in boreal ecological systems is usually 30-60 times less than that of fossil fuel based plants. Studies also show that if a mere half of the planet's economically feasible hydro-power potential is exploited for electricity generation, the GHG emissions would reduce by 13%. In addition to this, sulfur dioxide and nitrous oxide emissions (major causes for acid rain) can also be mitigated to a great extent.

A coal-fired power plant can emit up to 1000 times more deadly sulfur dioxide gas, as compared to a hydro power plant (taking into account all fuel required for construction work). Further, the particulate emissions from burning fossil fuel, in connection with respiratory diseases and environmental pollution costs more than USD 500/ton/year. The magnitude of impact of hydro-power therefore is tremendous [7].

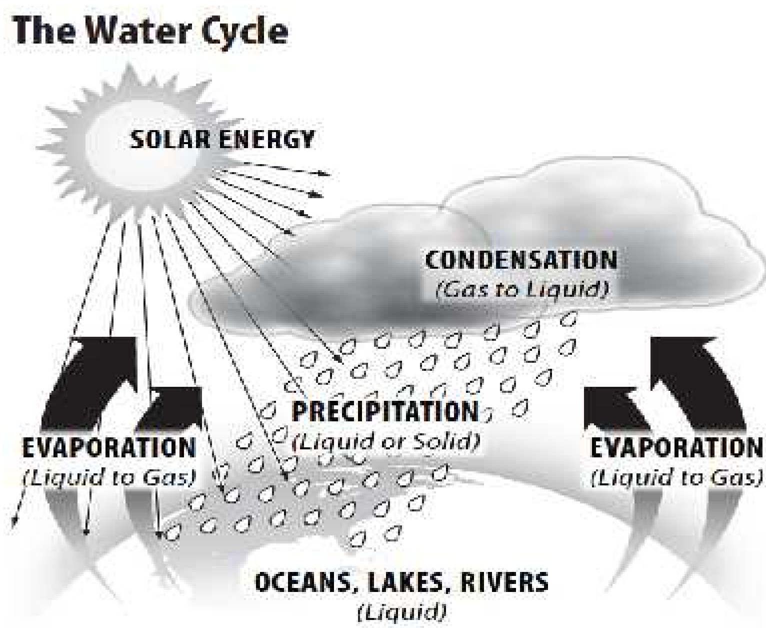

Figure 7: The Natural Hydrological Cycle

2.7. A Brief History of Hydro-Electric Power

During historic times, flowing water and wind were the only sources of mechanical power available to man-kind other than muscle power of both men and domesticated animals.

In the quiet recent past (and somewhat even today in rural areas) water wheels were used for grinding grain and for pumping water for drinking, irrigation and storage purposes. Water wheels of various types and sizes are still employed in many places across the globe. In the Northern Areas of Pakistan i.e. the KPK, the GB and AJ&K, water wheels are still in use for milling grains. Ancient water wheels can be classified into these types:

1. The Breast Shot type water wheel
2. The Under Shot type water wheel
3. The Over Shot type water wheel

The efforts of making water wheels more efficient, reliable, and consistent led to the development of Hydro-Electric power plants. In the attempts to increase the efficiency of water wheels (which had increased up to 60-70 % in the mid-1850s), extensive theoretical contribution by scientists to pave the way for a hydro-power revolution. After the development of the dynamo (generator) in the 1880's, the application of water turbines for the production of electricity became extremely popular. The 12.5 kW Hydro-Electric power plant on the Fox River New York, USA manifested the birth of commercial Hydro-Electric power generation. The simultaneous supply of electricity to a large number of consumers in parallel had been mastered in that very era. Enhanced designs for the turbines, generators and motors were being developed in rapid succession and the multi-phase motor proposed by the Electrical genius Nikola Tesla in 1888 marked the beginning of a new era in the generation and transmission of electricity.

Subsequently, several other small Hydro-Electric plants were installed to supply electricity to the consumers in a large number, in order to fulfill the local demand (generally consisting of illumination purposes and for small industry). The ability of Hydro-Electric power plants to supply electricity to large urban centers was made possible in the year 1891, when a long distance transmission line (177 km) was established between Lauffen and Frankfurt, Germany. With the ongoing improvements in performance of turbine and generator technologies and the development of high voltage-long distance transmission lines the development of large scale Hydro-Power plants that could supply to an extensive distribution grid became extremely popular. A similar trend was observed for thermal power plants, hence paving way to the start of the industrial revolution.

During the second half of the twentieth century, the development of hydro-electric power plants increased significantly after the exploitation of low head hydro-power potential commenced. On the current world wide standpoint, hydro-power is the most extensively used form of renewable energy, supplying more than 3000 TWh of electricity across the globe, accounting to 16% of the overall electricity supply in 2006 and even more than that as of today [8].

2.8. Qualities of Hydro-Electric Power Plants

Hydro-electric power is generated by converting the potential and kinetic energy of water by means of electro-mechanical conversion. The form is a very attractive source of energy since it:

- Is renewable and a sustainable form of energy
- Is clean as it does not cause pollution
- Does not produce any waste material or by products
- Is indigenously available
- Is an age old-mature technology
- Is reliable and highly efficient

Hydro-power generation can prove to be crucial for self-reliance in terms of energy for any country having a sufficient potential as being a completely indigenous resource. The hydro-power resources are usually infinitely renewable and are typically invulnerable to fluctuations and variations in the economic stability of that country. Since hydro-power projects are labor intensive, they can offer employment opportunity to a large number of people [9].

2.9. Fundamentals of Hydro-Power Conversion

Hydro-electric power is generated as a result of the conversion of potential and kinetic energy of the water into electrical energy by the use of electro-mechanical means, i.e. turbines and Generators.

Therefore, the hydro-power conversion (hydraulics) governs the conversion of kinetic and potential energy of water into electric energy.

Since, $$Work = Force \times Distance$$

$$dW = \rho \times g \times h \times dV \tag{3.1}$$

Where dW is the work done by mass of water, ρ is the density of water, g is acceleration due to gravity, dV is the volume of water and h is the vertical distance travelled by the volume of water (the head)

Now, Water Discharge = Volume flow per unit time

$$q = \frac{dV}{dt} \tag{3.2}$$

The power extracted from the water, in accordance with the work-power theorem, is the rate of work done. i.e.

$$Power = \frac{Work}{Time}$$

$$dP = \frac{dW}{dt}$$

$$dP = \rho \times g \times \frac{h}{dt} \times dV \tag{3.3}$$

Integrating over time;

$$P = \rho \times g \times q \times h \tag{3.4}$$

This equation gives the theoretical power extractable expressed in terms of $kgms^{-2}$.

Since, in SI system of units, $g = 9.8 m/s$, $\rho = 1 kgs^2m^{-4}$

$$P = 9.8 \times q \times h \times \eta \qquad (3.5)$$

Gross head is the total height (altitude) difference between the head water and tail water. Normally, the discharge through the turbine is merely a small fraction of the water that flows in the water stream. The altitude level of head water may differ in accordance to various geographical and design factors such as the storage level of the reservoir (when some sort of regulation is available) or in case of run-of-the river plants, the rate of water inflow. Similarly, the tail water level depends on various factors such as river discharge rate and the interaction with the down-stream reservoirs etc.

2.10. Classification of Hydro-Power Plants

Hydro-power can normally be classified on the basis of following parameters.

- Technology
- Energy Distributed
- Energy Demand
- Water Economy
- Energy Generated
- Design Head
- Topography

2.10.1. Classification on The Basis of Technology

Hydro-power plants can be classified into the following set of categories on the basis of difference in technology.

1. Plants utilizing the energy of flowing water
2. Pumped-storage plants
3. Plants utilizing tidal energy

2.10.1.1. Plants utilizing the energy of flowing water

This type of power plants can be divided into two main sub categories.

1. Plants with-out storage (Run-of-river)

2. Plants with storage (reservoirs)

2.10.1.1.1. Plants without storage (run-of-river)

These types of hydro power plants are built across flowing rivers and canals. No reservoir is built for water storage, therefore, electricity is produced from the instantaneous flow of water. These types of hydro-power plants significantly rely on water flow, and their production varies significantly with weather variations

A. Non-diversion run of the river plant

A reservoir (barrage or dam) is built across the river flow. The natural flow of the water in the river is passed through a penstock (the conveying pipe to the turbines).

None or a very little regulation and ability of storage of water is offered in this type of hydro-power plants.

Examples of such type of power-plants in Pakistan are:

- The Warsak hydro-power station built on river Kabul
- The Chashma hydro-power station.

B. Diverted run of the river plant

In this type of run of the river power plants, a diversion structure such as a barrage or a small dam is built across the flowing body of water, river or stream. The natural flow of water is hence diverted and directed to the turbine through a diverting channel like an open canal, a free flow tunnel, a pressure tunnel through a penstock.

The slope of the head race is usually kept flatter than that of the natural slope of the water body in case of open canal or free flow tunnel. Hence the difference in altitude between the headrace and the natural water stream increases. Selecting an optimum site for the power-house allows the exploitation of the available head.

An example of this type of hydro-power plant in Pakistan is the Ghazi-Brotha power plant, located on the Indus River, down streams of the Tarbela-Dam. Other examples include small hydro-power plants in the Northern Areas of Pakistan such as Darghai, the

Kargha Nalluh, the Gupis Gulmiti power plants on the Upper Swat Canal, and Pattika, Khel in the AJ&K.

2.10.1.1.2. Plants with storage

Natural or man-made water reservoirs are used to store water at an elevated height. This water is therefore used to run turbines and generate electricity. Hydro-power plants with storage capacity make the generation plant more reliable, by increasing their plant factors. The reservoirs can be multi-purpose. The water stored in them can be used for irrigation purposes, for power generation, flood control etc. Such reservoirs also make good recreational sites.

A. Non-diversion development

Constructing a reservoir across a flowing water body creates a shortage of water down streams hence increasing the depth of the water body hence decreasing the hydraulic gradient and creating a head. The storage in a reservoir varies in accordance with the water influx, and climatic conditions, which might vary periodically. Storage of water helps to regulate the quantity of water discharge by storing water during high-influx times, and augmenting it during the times of low water influx. The Tarbela dam on the Indus and the Mangla dam on Jhelum are examples of such type of power plants.

B. Diversion development

A diversion structure, like an intake, pressure or gravity tunnel, penstock or a surge tank are built leading to a reservoir, in order to divert the natural flow of water. The alignment of the tunnel is such that the total distance covered between the site of the storage site and the site of the power house is less than the natural course of the stream.

The storage in a reservoir varies in accordance with the water influx, and climatic conditions, which might vary periodically. Storage of water helps to regulate the quantity of water discharge by storing water during high-influx times, and augmenting it during the times of low water influx. The Allai Khwar hydro-power station on the Allai

Khwar Nullah, an offshoot of the Indus upstream of the Tarbela dam is an example of such type of power plants [10].

2.10.1.2. Pumped storage

Normally, two reservoirs at different elevation levels are constructed for this type of power plants. The reservoir at lower height is fed by a stream of natural flowing water. In some cases, instead of a reservoir, ocean water is also used.

The water in the lower pump, is then pumped to the higher reservoir when a surplus of energy is available. This water is stored in the higher reservoir, and is used to generate power during peak demand periods, or during the periods of water shortage. High capacity, water pumps are installed at the power houses for such type of power plants.

Owing to the characteristics of this energy system and the dis-balance between supply and demand, none of the pumped-storage power plants has been constructed in Pakistan as yet.

2.10.1.3. Tidal Energy

The tidal cycles in the ocean also offer potential to be utilized as a source of hydro-power. The variations in the height of high and low tides in some coastal areas across the globe are significantly high. This difference between the heights of a high tide and a low tide is termed as the tidal range. This tidal range can be modeled as a potent head, and can be utilized to run turbines and generate electricity. Such type of power plants with considerable amounts of electricity generation are operational in Canada, China, England and France. However, none has been set up in Pakistan so far [11].

2.10.2. Classification on the Basis of Energy Distribution

2.10.2.1. Isolated plants

Isolated plants independently provide electricity to a grid-network, without having to co-operate with other generating facilities. They supply electricity to isolated systems (usually including remote villages, factories, mills, mines etc).

Many small hydro-power plants in the Northern Areas of Pakistan are working as isolated plants, and do not connect to the central grid.

2.10.2.2. Co-operating (inter-connected) plants

Co-operating power plants provide energy to an inter-connected grid, which is simultaneously being fed by other power plants including other hydro-power plants, thermal and nuclear power plants etc. Almost all of the medium and large scale power plants in Pakistan connect and feed to the national grid system.

2.10.3. Classification on the Basis of Energy Demand

2.10.3.1. Base-Load Plants

These types of power plants have high efficiencies and capacity factors; hence provide electricity round the clock meeting the base demand of the grid network. These power plants are also termed as "base reserves". Usually these type of power plants include large scale nuclear and thermal power producing units

2.10.3.2. Peak-Load Plants

Unlike base-load power plants, peak load power plants produce their maximum capacity electricity during peak hours, in order to supply for peak demands. Peak demand occurs on daily basis, and can have monthly or seasonal cycles.Hydro Power plants, with high-heads being flexible in their operation are best suited to offer peaking duty. They can be turned ON and OFF more rapidly than nuclear or thermal plants hence allowing adjustments and adaption to demand variation.The operations of the Tarbela dam on river Indus, and Mangla dam on the Jhelum covers the peaking demand of the national grid in Pakistan.

2.10.4. Classification on the Basis of Water Economy

2.10.4.1. Single-Purpose Plants

In such type of hydro-power plants, water is used for the generation of electricity only. Other possible uses, such as storage or irrigation etc. are not considered.In Pakistan, examples of single-purpose plants are the Chashma, Ghazi Brotha and the Warsak dam.

2.10.4.2. Multi-Purpose Plants

These types of plants offer multiple uses to the water stored in the reservoir. Apart from electricity generation, these plants serve several other purposes, such as irrigation, water storage and supply, flood control etc. Mostly, irrigation happens to be the first priority of such plants. Examples of such power plants in Pakistan are the Tarbela and Mangla dam.

2.10.4.3. Subsidiary Plants

Subsidiary plants comprises of the reservoirs that are used for irrigation, water storage and supply etc. and other purposes. These plants generate a nominal quantity of electricity, however electricity generation is not the first priority of such plants. Examples of subsidiary plants in Pakistan are the Nandipur and the Shadiwal power plants.

2.10.5. Classification on the Basis of Energy Generated

Quite often, power plants are categorized on the basis of their capacity to produce electricity. The classification usually is done in the following way:

- Micro-Hydel Plants, with capacities less than 100 kW
- Mini-Hydel Plants, with capacities between 100 kW and 5 MW
- Small-Hydel Plants with capacities between 5 MW and 15 MW
- Medium-Hydel Plants with capacities between 15 MW and 50 MW
- High capacity Hydel Plants with capacities more than 50 MW

2.10.6. Classification on the Basis of Design Head

From a plant designer's perspective, classification of a hydro-power plant according to the available head is the most suited and logical method. Although, the classification may vary location to location, a generally defined limit is:

- Low-Head Plants, with a head of less than 15 m.
- Medium-Head Plants with heads ranging between 15 m and 50 m.
- High-Head Plants with heads greater than 50 m.

2.10.7. Classification on the Basis of Topography

Hydro-power plants can be classified on the basis of their topographic arrangements. They can be classified as:

- Low land power plants
- Hilly Area power plants
- Mountainous region power plants

2.11. Impacts of Hydro-Power Generation

Hydro power, although does not discharge any pollutants into the environment, yet it is not completely free from adverse effects on the environment. Efforts are being made to minimize the associated environmental problems, such as securing aquatic life, providing fish a safe passage and for water quality improvement. Safety of dams has been improved by the use of modern technologies, like the use of modeling and simulation of faults, and the use of remote sensing.

Significant amount of effort is being put in for R&D programs to improve plant efficiencies and their environmental performances in order to reduce costs and negative environmental impacts. Development of hybrid generation systems (Integration of hydro power generation technologies, with other renewable resources) is in progress. There is a need for further R&D to improve equipment designs, investigate various materials, improve power electronics and control systems, and to optimize generation as part of integrated water-management system [12].Hydro power research and development today is primarily being done in the following specialized areas:

- Fish Passage, Behavior, and Response
- Turbine-Related Projects
- Monitoring Tool Development
- Hydrology and water Quality
- Dam Safety
- Operations & Maintenance and water Resources Management

Summary

Beginning in 1987, the GOP planned on to increase private sector participation in the energy sector. Under this plan, the Water and Power Development Authority (WAPDA), the main electric utility in the country, would be unbundled into separate generation, transmission and dispatch, and distribution companies and gradually privatized. The private sector would be invited to construct and operate new thermal generation plants, and an independent regulator would be established. The synopsis of the power sector and its de-regularization was discussed in this chapter. Hydro power is a very important and attractive source of electricity generation. As compared to other technologies, it does not need a “ramp-up” time. It can vary the amount of power it is supplying to the system, almost instantaneously, hence a very good option for serving peaking demands. Owing to this attribute of load following, along with its peaking capacity, voltage stability and frequency control, hydro power plays a significant part to ensure reliable electricity generation. In addition to this, pumped storage hydro power plants are the only currently viable option to “store” electricity.The electric benefits provided by hydroelectric resources are of vital importance to the energy demands of the energy starved country, and for the success of our national experiment to deregulate the electric power industry.

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Chapter 3

Methodology

3.1. Introduction: NEPRA's Tariff Regime

The National Electric Power Regulatory Authority, NEPRA was established under the regulation of Generation, Transmission and Distribution of Electric Power Act 1997. The main functions of NEPRA are to

- Grant licenses for generation, transmission and distribution of electric power
- Prescribe and enforce performance standards for generation, transmission and distribution companies
- Tariff determination: Being a regulator, NEPRA is responsible for all matters related to the tariff of electric power in the country.

For tariff determination, following set of procedure, standards and laws are in practice

- NEPRA (Tariff Standards and Procedure) Rules, 1998
- NEPRA (Resolution of Disputes between Independent Power Producers and other Licenses) Regulations, 2003
- NEPRA Interim Power Procurement (Procedure and Standards) Regulations 2005
- NEPRA Competitive Bidding Tariff (Approval Procedure) Regulations, 2008
- NEPRA Up-front Tariff (Approval & Procedure) Regulations, 2011

3.2. Tariff Determination Guidelines

In order to restructure the tariff determination mechanism for Independent power producers, the Government of Pakistan under the NEPRA act 1997 issued the following guidelines to be followed.

- **Compliance with the Policies of the Government of Pakistan**

The nascent regulator, the National Electric Power Regulatory authority, the NEPRA is bound to conform to the policies defined by the Government of Pakistan, and any modifications, revisions or supplementation that might be induced from time to time.

- **Negotiation of Tariff**

In case, if an independent power producer wishes to submit an un-solicited bid for a project and wishes to negotiate for the tariff, NEPRA, in consultation with that IPP and the power purchase bodies has to determine the tariff structure.

- **Tariff Through Competitive Process**

The process of bidding is structured on the following two options

  - Bidding for a tariff
  - A Bench marked Upfront Tariff offer

Once tariff has been determined by NEPRA, it is not subjected to further review (except for Hydel Power Projects). The bidding process is structured and administered by the PPIB in consultation with the power purchaser, the Ministry of Finance and the NEPRA. The lowest offered levelized tariff is recommended to the Government for acceptance.

- **Up front Tariff**

NEPRA was advised to work on determining and announcing periodic upfront tariffs along with reference tariff tables, in order to make the mechanism more efficient and less time consuming. The announced up-front tariff is to be different for different technologies, taking into account various technological and financial parameters. The Independent Power Producers that opt for the defined up-front tariff regime are to be considered to have obtained NEPRA's approval for tariff definition

- **Financial Parameters Assumptions for Tariff Determination**

It is proposed that

  - A reasonable Internal Rate of Return (IRR) on invested equity is to be allowed to the IPP's.

- The rate of return on equity is to be calculated over the entire life of the power project, starting from the date of construction.
- The Return on equity should be equal to the long term interest rates.
- For projects built under, Build Own Operate Transfer (BOOT) mode, the investor shall be allowed to redeem the injected equity, after the completion of debt-servicing i.e. returning of all debts. The equity sis to be redeemed in equal installments from the time of completion of the debt services till the end of the concession period (end of project life). The effects of PKR-USD exchange rate variation are to be compensated for equity redemption. And the project is to be transferred to the Government of Pakistan at the end of the defined concession period, at a notional price of PKR 1.
- For projects built on Build Own Operate (BOO) basis, redemption of equity is not allowed.

- **Interest on Loans**

The bench mark rate of interest is defined as: **KIBOIR+300** basis points for tariff determination.

- **Debt Structuring**

The Independent Power Producers are offered incentives for better terms of debt financing. In case, if the power producer can arrange better financial terms by the date of financial closure, the over-all impact of reduction in the debt-servicing costs is to be shared on annual basis in the defined ratio, i.e. *Government of Pakistan: IPP = 60 : 40*

- **Indexation for Local and Foreign Loans**

Local and foreign loans may be indexed to the changes in the bench marked index rates like KIBOR and LIBOR etc. respectively.

- **Indexation of Tariff Components**

Various tariff components are to be indexed and adjusted for PKR-USD parity etc. are to be based on the pre-defined formulae and reference parameters.

- **Transparency of Tariff Calculations**

NEPRA is to provide complete details of the assumptions, various parameters, inputs and calculations along with the tariff table to the IPP.

- **Evaluation of Tariffs**

Levelized Tariff is to be evaluated on the basis of capacity purchase price and energy purchase price based on the defined parameters for the power plant.

3.3. Feed-In-Tariff

Feed-in-tariff is a tariff policy-mechanism designed to enhance investments being made in renewable energy technologies like Solar, Wind, Geo-thermal or even hydel by offering attractive long-term contracts to producers, typically based on the generation costs of each of the technologies 1]. The goal of this mechanism is to offer monetary compensation to producers by providing them with price certainty for power production and long-term contracts (mostly between 15-30 years) that help finance investments in the private sector [2]. FIT's usually provide with a guaranteed grid access, which means that the buyer is bound to purchase the produced energy at a pre-negotiated price. The purchase price (tariff) is usually cost-of-the-technology based [3].

Under such an agreement, eligible producers including domestic small-scale producers, public and private investors, rental power producers or corporates are a paid a cost-based price for the energy they supply to the grid. This enables a wide range of technologies to be developed and be integrated into the energy mix.

The tariff varies with technology, location and size and efficiencies. Performance based tariffs incentivize the producers to incorporate technology change, as to maximize their generated outputs and efficiencies [4].

As of 2010, the FIT policies have been enacted in over 50 countries of the world. An analysis by the European Commission, the IEA and the European Federation for Renewable Energy concluded that, "well-adapted FIT regimes are the most efficient and effective support schemes for promoting renewable power generation." [5].

3.4. Mechanism for Determination of Tariff for Hydro Power Projects

Pakistan has a tremendous potential for hydro-power electricity generation. According to estimates, 60000 MW of potent potential is available, consisting of a diverse category of plant types, including large, medium and small reservoir based, run of the river, high head and low head schemes in the mountainous North West, comprising of the KPK province the GB and the AJ&K and in the extended river and canal system of the Indus plain. However, the current installed capacity is a mere 10-11% of the identified potential i.e. 6,608 MW.

The ongoing energy crises demands induction of new hydro-power plants into the system in order to meet the ever increasing demand by increasing power production capacity, as well as to provide a favorable energy mix, with hydro being the plural of energy generation, making electricity production cheap and efficient.

However, due to their unique nature, hydro-power plants as compared to other sources of power generation present with copious amounts of risks, which prove to be a major hurdle for investors to invest in the sector.

In order to account for the various associated risks and financial uncertainties, the NEPRA has developed a mechanism which provides subsequent adjustments to the determined tariff at different stages of project development. Three significantly cost-uncertain distinct stages have been identified, namely:

- Costs at Feasibility stage
- Costs at Engineering Procurement and Construction stage
- Costs at the Commercial Operation Date (Final Costs)

This mechanism, therefore provides a three stage, redundant scheme for tariff determination, based on the predicted costs at the feasibility stage, accounting for risks and uncertainties during project development phase, and reflects the variations in costs in the EPC and final costs at the COD. Hence making hydro power projects less vulnerable to risks and uncertainties by making the tariff determination more efficient and reliable.

3.5. Need for Tariff Re -adjustment

Hydro power projects are significantly cost uncertain, due to which their construction costs cannot be accurately stated till their completion. The three stage tariff setting mechanism provides with a mechanism to eliminate such uncertainties in cost allowing adjustments to various components and their costs at subsequent stages of project development

3.5.1. The Feasibility Stage Tariff Determination

On the basis of the feasibility study of the project, initial tariff is determined in the 1st stage of the tariff determination scheme under the following guidelines:

1. Filing of Application for tariff

For tariff determination, the concerned Independent HPP is required to file a petition with NEPRA in a form and manners defined in the NEPRA laws.

2. Completeness of Feasibility Study

NEPRA is bound to admit the complete and accurate feasibility studies of the projects, which are supported with a statement by a panel of experts about the quality of the feasibility study and is performed following international practices while satisfying the terms of reference and the information required by the NEPRA.

In addition to the relevant information, the feasibility study must include:

- Break down of the major components of the project.
- Bill of Quantities (BOQ) and their corresponding costs, capacity and energy data and a reference tariff table.
- A detailed schedule of implementation and payments during the construction period.
- Details of the tariff reopeners.

Feasibility study includes significant details of the geo-technical investigations and the conclusions inferred regarding the characteristics of underground rock and soil along with the tunnel. A detailed report regarding the soil and rock classification is to be included in the feasibility study.

All formulae and calculations regarding costs and unit rates for all activities including rock evacuation, underground excavation, land reinforcements, fillings etc are to be included.

3. Recommendations of Provinces

NEPRA is to invite comments and consider the recommendations of the province (in which the project is to be located) before tariff determination. The considerations include comments on resettlement costs and land costs as claimed by the applying independent HPP.

3.5.2. The Engineering, Procurement and Construction (EPC) Stage

An Independent HPP, possessing NEPRA's approval for feasibility stage tariff determination can opt for seeking revision in tariff during the EPC stage by filing a petition with the NEPRA on the validation of cost variations to the regulators satisfaction. At this stage, NEPRA may carry out detailed prudence of cost variations, however, in case the applicant HPP backs its petition by competitive bids from a number of reputed contractors, without going into the detailed prudence of cost variations, NEPRA may accept the lowest of the bids

The Independent HPP's who did not obtain a tariff on feasibility stage costs, wishing to seek a tariff based on the EPC costs can also file a petition to NEPRA in accordance with the NEPRA laws.

Adjustments at EPC stage

Actual EPC stage costs, such as costs for Mechanical and Electric (M&E) works, costs for underground tunneling and hydraulic steel structuring etc. become more obvious and clear when extensive investigation is carried out. These classification of costs usually is beyond the scope of the feasibility level studies, hence provoking costs uncertainties, moving from feasibility studies to the EPC stage. In order to mitigate these uncertainties, the NEPRA currently allows the following adjustments to costs in this stage:

- **Cost Variations for the Construction of Tunnel(s)**

The cost of construction of a tunnel(s) is subjected to substantial disparities due to the on-site geological conditions. The variations may be due to the difference in rock/soil classifications encountered, as compared to those reported at the feasibility stage. Or, due to change in the cost for the unit rate for land escalation. However, no variations in the length of the tunnel is allowed, unless a change in design is inevitable.

- **Civil Works Costs Escalation**

NEPRA allows an increase in the cost of civil works, from the date approved by NEPRA when the tariff was determined. No change in the quantities pointed out at feasibility level are allowed.

- **Cost Variation in M&E Works and Hydraulic Steel Structure**

The costs encompassed in tariff determination at the feasibility stage are to be adjusted to permit cost variations in the EPC contract(s).

4.5.3. The Commercial Operation Date (COD)

As a part of the three stage tariff determination mechanism, final adjustments to costs are allowed by NEPRA at the COD in order to eliminate cost uncertainties. Upon filing of a petition for tariff adjustment at the COD stage in terms of NEPRA tariff determination, NEPRA will allow adjustments as elaborated thereafter.

Adjustment at COD

- **Geological Cost Variations for the Construction of Tunnel(s)**

Final revision in cost variations is allowed at the COD, for differences in rock and soil classification and for increase in unit cost for land escalation over approved construction time. Geological cost variations are subject to provision of verifiable references.

- **Civil Works Cost Escalation**

Escalation in units rates of land at actual will be allowed by NEPRA up to the time scheduled to achieve commercial operation.

- **Cost Variation in M&E Works and Hydraulic Steel Structure**

Adjustment is be allowed at COD on account of variations in costs of M&E works, or hydraulic steel structure work cost.

- **Cost Variations due to Resettlement Cost**

The feasibility study provides all details of resettlement costs and their schedule of payment. Any variations in land costs and resettlement costs are allowed provided the variations are certified by the government of the province where the project is located.

Summary

At COD, adjustment in tariff on the account of tariff reopeners is allowed, subjected to following of procedure as contained in the power purchase agreement. The prices of components subject to adjustment are to be given in the Statistical Bulletins (Published by Statistical Division, the Government of Pakistan). Where deemed necessary, statutory notifications and officially quoted price from public sector organizations like the Pakistan Engineering Council are used. The same is to be specified in the cost of the project included in the approved Feasibility Study. For a particular item, the same source is to be used throughout construction of the project. NEPRA may appoint consultants or experts to review and comment on any aspect of the project. The applicants are bound to facilitate any site visits and investigations that the Consultant/Expert may want to carry out.

References

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Chapter 4

Results and Discussions

4.1. Introduction

The goal of designing a financial model for a power project is to depict the various costs, recurring or non-recurring, as to calculate a levelized tariff which provides a return sufficient enough to attract investments covering the risk exposures borne by the investors. The main objective is to determine a levelized tariff over the defined life of the project. Cash flow projections show the feasibility of the project on the basis of NPV and IRR calculations. The levelized tariff hence is there after negotiated between the IPP, the NEPRA and the power purchaser (WAPDA/NTDC).

The following information can be analyzed in a financial model

- Balance sheet for the entire project life
- Nominal Tariff calculations for the entire project life
- Real tariff calculations for the entire project life
- Cost projections and nominal revenues for the entire project life
- Cost projections and real revenues for the entire project life
- Risk analysis for the entire project life
- Sensitivity Analysis

4.2. General Concepts in Reference to Hydro Tariff Determination

1. Additional Capitalization

It implies the capital expenditure incurred or projected to be incurred on a hydro power project, valued at subsequent stages and finalized after the date of commercial operation of the project and admitted by the regulatory commission after prudence check.

2. Auxiliary Energy Consumption

The magnitude of energy consumed by auxiliary equipment of the generating facility and transformer losses within the generating station at a hydro power plant, expressed as a percentage of the sum of gross energy generated at the generator terminals of all the units of the generating station.

3. Capital Cost

Capital cost for a project includes:

- The expenditure incurred or projected to be incurred
- Interest during construction and financing charges
- Any gain or loss on account of foreign exchange
- Risk variation during construction on the loan

4. Declared Capacity

The ability to deliver electricity in MW declared by such hydro power generation plant in relation to any time-block of the day or whole of the day, duly taking into account the availability of fuel or water.

5. Design Energy

It is the quantity of energy which can be generated in a dependable year with 95% installed capacity of the Hydro generating station.

6. Infirm Power

Electricity injected into the grid prior to the commercial operation of a unit or block of the generating station.

7. Installed Capacity

The sum of the name plate capacities of all the units of the generating station or the capacity of the generating station.

8. Operation and Maintenance Expenses

The expenditure incurred on operation and maintenance of the project, and includes the expenditure on manpower, repairs, spares, consumables, insurance, and overheads etc.

9. Plant Availability Factor (PAF)

The average of the daily declared capacities for all the days during that period expressed as a percentage of the installed capacity in MW less normative auxiliary energy consumption.

10. Capacity Index (CI)

$$Capacity\ Index = Declared \frac{capacity(MW)}{Max\ available\ capacity} \times 100$$

Where, Declared Capacity (DC) is the power that is expected to be generated next day based on availability of water & machine; and maximum available capacity (MAC) is the maximum power that a station can generate with all units running, under the prevailing water levels and flows over the peaking hours next day.

4.3. Tariff Determination Methodology for Hydro Power Plant

The Capital cost for a Hydro Power Plant consists of a significant chunk of the total costs and includes the following:

- The cost of land
- The cost of building and equipment
- The cost of installation
- The cost of designing and planning of the station.

The capital cost varies from site to site, depending on the location of the station and the type of the equipment in use. The Generating Company can obtain the required capital for financing their investment in the form of equity or debt or a mixture of both.

The Tariff for supply of electricity from a hydro generating power station for the recovery of annual fixed cost comprises of

- Capacity charge and
- Energy charge

1. Capacity Charge

The fixed component of the tariff is mostly dependent on the capital cost of the project. The fixed component of the tariff ensures that the investor (power producer) is able to recover the fixed expenses and earn a return on investment on the project, irrespective of the actual generation from the plant. Generally, for hydro power generating stations, significant amount of the costs are fixed in nature.

2. Energy Charge

The Energy charge are payable by each beneficiary for the total energy scheduled to be supplied to the beneficiary, during a time period (a calendar month, generally), at the computed energy charge rate (excluding free energy, if any)

$$Energy\ Charges(PKR)\ EC = Rate\ of\ energy\left(\frac{PKR}{kWh}\right) \times energy\ scheduled\ for\ a\ month(kWh)$$

4.4. Tariff Components

Tariff comprises of the energy purchase price (EPP) and the capacity purchase price (CPP) which are supposed to be quoted separately by the bidding IPP. The power purchaser is bound to pay the CPP whether the plant produces power or not. However, the EPP is paid on the basis of the actual MW's of produced power. Hydro-power tariff comprises of the following components

1. Capacity Purchase Price, CPP

Includes

- Fixed O&M costs
- Insurance costs
- Return on Equity
- With-holding tax
- Debt servicing
- Equity redemption (in case of BOOT projects)

2. Energy Purchase Price, EPP

Includes

- Variable O&M costs
- Water use charges

4.4.1. Capacity Components (Capacity Purchase Price CPP)

The capacity components and their description is mentioned as follows:

1. Fixed Operations and Maintenance Charges

This is a component of the CPP which is paid to the IPPs to cover their fixed O&M expenses. It includes salaries of the personnel, long term service contracts, vehicle O&M, lube and oil for repair and maintenance costs, etc.

2. Insurance Costs

This is the annual charge for insuring the plant against major disasters (unexpected failures, fire and other). The insurance costs are estimated to be 1% of the Engineering, Procurement and Construction (EPC) cost of hydro power projects.

3. Return on Equity and Equity Redemption

According to the Government policies, the investors are required to maintain at least a 20% stake in the project. Equity has to be redeemed since the project is developed on BOOT basis. Equity redemption starts once the debt is paid off completely.

4. Debt Servicing

Up to 75% of the project cost is financed by project finance. For tariff calculation, it is assumed that the complete debt is taken from local sources. The annual interest cost is taken into account. Let's say, for an offered interest rate is 3 month KIBOR + 3% with four (4) years of grace period and eight (8) years of maturity. This implies that interest payment and principal redemption starts after 4 years i.e. once the power plant becomes operational. Interest during construction is capitalized and added back to the principal amount. And the total project cost is calculated on the basis of the capitalized interest during construction.

4.4.2. Variable Components (Energy Purchase Price EPP)

The capacity components and their description is mentioned as follows:

1. **Water Use Charge**

The water use charge is to be paid by the Hydro IPP to the Government for use of water to generate electricity. The water usage charge per KWh and is fixed at the rate of PKR.0.15/KWh, as per the power policy 2002 and is indexed to the Wholesale Price Index (WPI).

2. **Variable Operations and Maintenance Charges**

These charges include the cost of running the power plant, mainly the cost of lube oil and other lubricants, as well as other minor maintenance expenditures during the day to day operations of the project. The annual O&M expense charged by the O&M operator is translated into PKR/KWh using total annual energy produced. Variable Operations and Maintenance charges are indexed with the exchange rate.

4.5. Reference Tariff Determination Financial Model

For the sake of understanding, a tariff model determined for Star Hydro Power Limited, SHPL was studied. The financial model for the said IPP is discussed in detail as follows:

4.5.1. The Information Sheet

The information sheet includes the main inputs to this financial model which are as follows:

- **Capacity:** The designed capacity of the hydropower plant (SHPL) is 150 MW.
- **Project Life:** The project is of 30 years duration on BOOT basis.
- **Plant factor:** The plant factor is the ratio of the average load supplied to the peak load in kilowatts in a specified period. For SHPL, the plant factor is listed to be 52.72%.
- **Loan Payment periods:** 8 years loan payment period, with 4 years of grace period during construction.
- **Equity Redemption Period:** Equity redemption is to start after the debt servicing and is spread over a period of 22 years (till the end of project life).
- **Total cost of the project:** The estimated total cost of the project is USD 223.36 million.

- **EPC Costs:** The EPC cost for this hydro power project is estimated to be USD 185 million.
- **Debt and Equity Ratio:** 75: 25.
- **Interest Rate:** The annual interest charge on the debt is 3 months KIBOR + 3 %.
- **ROE:** 18.11%
- **Components of Tariff:** The breakdown of capacity and energy components is provided below:

Table. 4: Break Down of Tariff Components

Capacity Charge (PKR/Kw/Month)	**First 8 years**	**Last 22 years**
Fixed O&M	88.67	88.67
Insurance	61.67	61.67
Return on Equity	525.89	539.75
Debt Services	519.71	0.00
Total Fixed Charges	**1195.94**	**690.09**
Variable Charge (PKR/kW/month)		
Water Usage Charges	0.15	0.15
Variable O&M Charges	0.016	0.016
Total Variable Charges	**0.166**	**0.166**

4.5.1.1. Real Tariff Structure (Without Indexation)

The inputs of the energy and capacity components are taken from the information sheet. The total tariff is calculated by first converting the capacity component units from PKR/KW/month to PKR/KWh and then adding this figure with the energy component. The plant factor of 52.72% has to be taken into account for appropriate conversion. The Power Policy poses a limit on the maximum percentage of the overall tariff that hydel IPPs can specify as capacity component: a limit of 60 to 66 % for CPP and 40 % to 34 % for EPP. This means the power purchaser can cover a maximum of 66 % of the total tariff by the capacity payments made to the IPP. So, the energy component is shown in the tariff schedule as 34 % of the tariff, while the capacity component is given as 66 %. Both of these components are shown separately in the tariff schedule.

4.5.1.2. Real Levelized Tariff Calculation

The levelized tariff is calculated by discounting the above mentioned real tariff schedule for 30 years at a discount rate of 12 % according to the Power Policy. This is used by NEPRA as a benchmark measure to compare electricity prices among the various IPPs.

4.5.1.3. Nominal Tariff Structure (With Indexation)

The power policy allows for escalation of certain components of the tariff against factors such as exchange rate, inflation, and KIBOR. These factors (indexations) can be formulated with the calculated real tariff in order to obtain a nominal tariff structure.

4.5.2. ROE during Construction Sheet

Equity is assumed to be invested equally in installments of PKR 847.19 million in four years of scheduled construction. No return can be made to equity holders because the project is not operational and the ROE during this period is capitalized with the original equity. After capitalization at the rate of 18.11% for four years of construction, the total equity becomes PKR 5,227 million. Once the project becomes operational, the ROE is disbursed to investors at the rate of 18.11%, on this amount.

Table. 5: ROE during Construction

All Amounts in Million PKR				
Year	**Start of year Equity**	**ROE**	**End year Equity**	**Equity Investment**
1	847.19	153.43	1000.62	847.19
2	1847.81	334.64	2182.45	847.19
3	3029.64	548.67	3578.30	847.19
4	4425.49	801.46	5226.95	847.19
At the end of four years total				**5226.95**

4.5.3. Equity Redemption Sheet

Equity redemption starts in the 9th year of operation after the debt has been paid off. Equity redemption is calculated based on equal annuity payments made for 22 years on the total equity at a discount rate equal to the return on equity provided to the investor. An equity redemption table similar to the amortization schedule has been created showing decreasing total equity reducing to zero at the end of the project. For the first 8 years ROE on the principal is fixed at PKR 946.6 million. Annual payments from the ninth year onward are equal to PKR 971.56 million. The principal gradually decreases to zero at the end of 30 years.

4.5.4. Debt Servicing Sheet

The amortization table of loan payments can be formulated. In this case, the annuity payments are to be made quarterly for the duration of the loan by SHPL to the lenders. However, these payments have to be annualized keeping in mind the time value of money to determine the tariff rate for each year for simplicity.

4.5.5. Revenue and Costs without Risks Sheet

After calculating the real tariff structure, the revenues and costs for each year can be calculated. To calculate revenues the yearly tariff is multiplied by the actual energy produced during that year. The actual energy produced each year is calculated by multiplying the actual plant factor with the installed capacity. For example, during the 1st year of operations total revenue is PKR 3,588 million (Given that 1st year Tariff is PKR 5.18/kWh, Annual plant capacity is 1,314 GW and plant factor is 52.72%).

Summary

The goal of designing a financial model for a power project is to depict the various costs, recurring or non-recurring, as to calculate a levelized tariff which provides a return sufficient enough to attract investments covering the risk exposures borne by the investors. The levelized tariff hence is there after negotiated between the IPP, the NEPRA and the power purchaser (WAPDA/NTDC).The Tariff for supply of electricity from a hydro generating power station for the recovery of annual fixed cost comprises of capacity charge and energy charge, which further can be split up into various segments, as discussed in this chapters and modeled financially for tariff-determination.

Conclusions

Electricity constitutes one of the most important components of infrastructure and plays a key role in national economic growth and development. Provision of electricity to a huge population base of Pakistan while meeting demand for increasing urbanization and industrialization poses a challenge for the Government of Pakistan. Therefore, public and private sector participation in power generation, transmission and distribution is envisaged in the Pakistan Power Policy, Interdependent power producers (IPP) are encouraged to undertake investment in hydro and thermal based power projects.

Undertaking a power project, especially the one based on hydro-power, entails significant amount of money, time, expertise and risk. Therefore, for any investor, a feasibility study entailing the financial viability of a hydropower project incorporating the tariff, revenue, cost and cash flows models as well as identifying the possible financing sources is of utmost important for determination of tariff for a Hydro Power IPP

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Recommendations

The findings of present work depict the mechanism of tariff determination for Independent hydro-power projects implemented by the NEPRA, taking into account, the electricity market structure in place. Furthermore, a financial model was formulated, based on the stipulations for the hydro power projects, in the Power Policy, 2002.

This work can be extended to other resources of electricity generation in the private sector, in order to formulate reference tariff models based on NEPRA guidelines.