SAARC Study

Optimum Power Generation Mix for Sustainable Power Sector in South Asia

November 2015

SAARC ENERGY CENTRE, ISLAMABAD

Contents

Foreword

Utilities across the globe are striving for balancing the ever increasing load with the limited power generation. The best industry practices require the utilities to maintain certain balance among different types of power generating sources being utilized. Power system control and dispatch functions of a utility are dynamic functions, hence, utilities keep on struggling for optimizing their generation mix. While deciding for types of new generating facility, decision makers consider a number of factors such as indigenous fuel, base load characteristics, closer location to the load center, cost of the technology and fuel, etc. However, fuel diversity is considered as a vital factor with respect to energy security and network reliability. It is, therefore, required to maintain a variety of fuel types, with certain quantity of each fuel type, in the generation mix.

In order to highlight the importance of an optimized power generation mix in South Asia, SAARC Energy Centre (SEC) initiated this short term, Study “Optimum Power Generation Mix for Sustainable Power Sector in South Asia” through its Action Program FY 2015. The study outcome is expected to ensure efficient usage of the available generation capacity and to increase overall efficiency of power system of SAARC Member States.

The study is an in-house effort by Salis Usman, Research Fellow (Energy Efficiency) and was peer-reviewed by Aziz ur Rehman former General Manager, National Power Control Centre, Pakistan National Transmission & Dispatch Company and by Ihsanullah Marwat, Research Fellow (Energy Efficiency). The purpose of this study is to provide a reference document on optimal generation mix with respect to each SAARC Member State and to facilitate power sector engineers and planners on optimal dispatch scenarios, based on the latest data pertaining to generation and demand. The Study focuses on the current challenges to the power system with respect to controlling and scheduling the available generating plants for improving the system security and reliability while considering the economic dispatch.

SEC looks forward to the comments and suggestions from the professionals to add further value to the study report besides seeking proposals for future interventions to be undertaken by the SEC especially in the perspective of energy efficiency and smart grid.

Muhammad Naeem Malik
Director, SEC

Executive Summary

Apart from undertaking of energy conservation and efficiency techniques through demand side management programs, utilities are also required to add new generation capacities under a well-integrated and cohesive program. Similarly smart dispatch of available power is critical for networks security and reliability. At the moment, each of the SAARC Member States reflects a unique scenario and it stands at a different level with respect to achieving the objectives of system security and reliability. Consequently, Member States need to take benefit form the best industry practices as well as learning from the experiences of each other. The fundamental purpose of setting up technical arms of SAARC such as SAARC Energy Centre was to promote the welfare of the people of South Asia, strengthen collective self-reliance, and promote active collaboration and mutual assistance in the economic, social, cultural, technical and scientific field. Overall objective of this study aligns with the SEC's purpose; idea is to assess the prevailing practices and situation of SAARC Member States with respect to development and dispatch of power generation facilities.

Setting the perspective, the Study defines power generation mix and provides unique characteristics of different methods for generating electricity based on different fuels including fossil fuels, hydro, nuclear, wind, solar, biomass and geothermal. The objective of this chapter is to highlight that ultimate dependency on one or two types of fuel by one country does not corresponds to the best industry practices.

Through an exclusive chapter, the Study pinpoints prevailing power generation mix of the whole world as well as South Asia and each of the SAARC Member States with the help of providing data as of the year 2014 comprising of fuel sources, installed capacity in megawatts and %age contribution of each of the fuel source; also represented through pie charts for better understanding and comparison. Fuel sources include fossil fuel, wind, nuclear, hydro and others (solar, biomass, etc.)

The core section of the Study, included as 'Diversity Status of SAARC Member States' takes up the analysis of power system of each country with respect to fuel diversity. For this purpose, power sector background, country's historical power development, progressive situation of installed capacity (2011 – 2014) and energy generated and country's potential multiple options for balancing the power generation mix are discussed for each of the eight Member States. This chapter reflects how each Sout Asian nation has taken up its addition of egenration facilities during the last four years, where do they stand in terms of fuel divesity and megattas. The crus of this chapter is the discussion on potential options of new generating facilities for balancing the generation mix which is provided for each of the Member States.

Capitalizing on the availability of relevant data for Pakistan, the Study has included case studies on major fuels i.e. hydro, coal, wind and solar exclusively for Pakistan. The Study ignores fossil fuel since it is not indigenous in case of Pakistan and it already enjoys a big share (over 65%) in the generation mix of the country. Discussion on the importance of balanced addition of four fuels provides food for thought for the planners and decision makers with respect to balancing the power generation mix of the country.

In a bid to facilitate enhanced control over power system and enhance the system efficiency by optimizing the existing power network elements, the Study includes recommendations for automation of power control function of the power system. Minimum requirements and features of the automation options are also recommended for adaption by the SAARC Member States.

Finally, the Study concludes with the Way Forward and Recommendations. The Study reveals that power generation mix of each of the SAARC Member States is variably unbalanced. In order to induce and manage fuel diversity by maintaining industry standard balance among the fuel types, country specific recommendations are provided. The Study also furnishes important recommendations for economizing and strengthening the power system with respect to smart grid technologies, black start generation facilities, poor efficiency of power houses, demand side load management, system automation for the power control and dispatch function.

Chapter 1 Introduction to the Study

1.1 Background

South Asia is endowed with a variety of abundant natural energy resources like water, coal, gas, wind, solar, thermal, geothermal etc. The Region has a sufficient electric power generating capability with natural resources including estimated hydro power of 296,431 MW, coal reserves of 133,237 Million Tons, natural gas reserves of 85 Tcf and large renewable potential of Wind (378,594 MW), Solar (365,639 MW) as well as Biomass. Despite of rich energy recourses, many SAARC Member States are facing acute shortage of electric power leading to frequent black outs. SAARC Member States have tapped approximately all the available resources to produce electricity except Maldives where electricity is being generated by imported diesel only. International practices for efficient electric power system are invariably dependent on optimization of Power Generation Mix [1]. Diversified portfolio of electrical power mix plays a vital role in terms of stability and reliability of supply to consumers. The dispatch and control of electrical energy through associated electrical transmission network system is extremely complex and requires perpetual exercises based on various factors such as unforeseen supply shortfalls at extremely short timescale, varying demand conditions, generation economics, base load characteristics, disparity in Power Purchase Agreements (PPAs), etc.

Power system of any electric utility is continuously monitored and controlled by power dispatch engineers and power planners who are primarily responsible to schedule, control and dispatch the available diversified energy portfolio to ensure secure, safe, reliable and economical operation of the power network. The ultimate goal of power system controller is to identify and implement the most economic dispatch of generation facilities available in the power system.

With increasing trend of cross border trade and thereof awareness and implementation of bilateral and regional power trade, no country would remain in the state of island mode; role and responsibilities of power system controllers will thus increase many fold. Increase in number and variety of supply sources will result in increased complexity of the scheduling and dispatch functions.

Consequently, in order to move toward making the power sector of SAARC region more stable, secure and sustainable by identifying and suggesting changes to the existing generation mix, the study for optimizing the generation mix has been launched.

1.2 Objective

Aim of this Study is to provide a broad overlook with respect to optimal generation mix of each SAARC Member State and to facilitate power sector engineers and planners on optimal dispatch scenarios, based on the latest data pertaining to power generation/installed capacities. The Study focuses on the current challenges to the power system with respect to controlling and scheduling the available generating units for improving the system security and reliability while managing the economic dispatch.

1.3 Methodology

With the objective to optimize the existing generation mix portfolio, a combination of quantitative and qualitative research technique has been applied for this study, using the latest data available on internet, interviewing the accessible organizations, considering international best practices, undertaking data analysis, suggesting recommendations and the way forward.

1.4 Terms of Reference

Broad terms of reference of the study are as follow:

a. Review and comment the current generation mix of SAARC Member States in view of the international practices while considering the prevailing generation mix in SAARC Member States as case studies.

b. Make recommendations for optimal generation mix and discuss their pro and cons.

c. Look into possibilities of automation option for power system control in SAARC Member States based on the latest facilities and advancement pertaining to the smart grid technologies.

1.5 Rationale for the Study

In order to meet its energy needs, each country uses its power generation resources with in different proportions. This is what we call the power generation mix [1]. Depending upon the available resources including fossil fuels (oil, natural gas and coal), nuclear energy, waste and many types of renewable energy (hydro, wind, solar, biomass and geothermal), this combination varies significantly from country to country.

With respect to any country, the composition of generation mix is dependent on various parameters such as i) indigenous resources of primary energy; ii) quantum of power demand and iii) government's relevant policy dimensions e.g. seeking investments through lucrative incentives.

This particular study has been launched to discuss and explore options for optimizing the generation mix process of the SAARC Member States while considering the system adequacy and reliability at the most economical cost. Of course, in view of the dynamic scenarios of available resources, policies and demand, optimizing of generation mix remains a continuous quest. It is expected that the study outcome would help the SAARC professionals in understanding and analyzing the current generation mix while comparing it with the other Member States and experimenting changes in the generation capacities in a bid to optimize it with reference to essential system parameters.

Optimizing the generation mix is meant to increase the overall energy efficiency besides complementing the reliability, security of power system and improve competitiveness in the power sector resulting economic growth of the county and bring affordability of electricity tariff to the end consumers.

The aim of the study is to facilitate the power system control engineers and planners in scheduling and dispatching power at optimum level, considering optimum scenario of diversified energy portfolio in SAARC Member States to enhance the security, reliability and economics of supply.

The term energy mix refers to the breakdown of final consumption of all sort of primary energy resources by a country or a region. However, power generation mix is the ratio of all types of energy recourses used to generate electrical energy. The composition of the generation mix varies from country to country and contrast can be gauged by examining the breakdown of power generated by a particular country. All SAARC Member States with the exception of Bhutan reflect diversity in their power generation mix; in Bhutan, all electric power (for local needs as well as for exporting) is generated through hydro resources. Power generation mix widely affects the tariff, reliability, security of power system and country economy and Annual GDP indirectly.

2.1 Electrical Power Generation Mix

Energy sources are mainly divided into two categories, i.e. renewable and non-renewable. Worldwide most of the electricity is generated by using non-renewable and the remaining through renewable resources. Non-renewable resources come out of the ground as liquids, gases and solids. These include crude oil (petroleum), natural gas, propane and coal, also known as fossil fuels since they are formed from fossils (remains or impressions of organisms of past geologic ages). Another non-renewable source is nuclear fission power. These sources cannot be replenished in a short period of time. On the other hand, renewable resources are not subject to depletion in a human timescale. These sources include the sun rays, waves, rivers, tides, wind, biomass and the heat from radioactive decay in the Earth's core. Generally, the process of generating electricity goes through several transformations, as there is little primary energy directly convertible into electricity.

2.2 Methods of Generating Electricity

Electricity is vital to modern life. It powers our lights and appliances at home. It makes possible many industrial processes. It is used to power trains and to charge electric vehicles. Every form of electricity generation has its strengths and weakness. The global demand for electricity is rapidly increasing, and in future electricity generation will importantly comprise of diversified options, although these must be of low carbon since greenhouse gas emissions are to be reduced.

For many decades, almost all the electricity consumed in the world has been generated from three different sources i.e. fossil fuels, hydro and nuclear. Renewable energy sources currently hold a relatively small share of the world's electricity generation, although this share is growing fast. A glimpse of some prominent resources used for power generation is given below:

2.2.1 Fossil Fuel

Fossil fuel based power plants burn carbon fuels such as coal, oil or gas to generate steam that drives large turbines to produce electricity. These plants can generate electricity reliably over long periods of time. However, by burning carbon fuels they produce large amounts of carbon dioxide, which affects climate change. This process can also produce other pollutants, such as Sulfur Oxide, which contributes in causing acid rain. Fossil fuel plants require huge quantities of coal, oil or gas. These fuels may need to be transported over long distances for generating power. The price of fuels can rise sharply at times of shortage, leading to unstable generation costs.

2.2.2 Hydropower

Hydropower is a process where flowing water is used to spin a turbine that is connected to an electricity generator. There are two systems in which hydropower can be divided:

a. Dams: Flowing water is got accumulated in reservoirs or dams. The water falls through a tunnel and applies pressure against the blades of a turbine. The blades drive the generator and produce electricity.
b. Run-of-River: The force of the river current applies pressure to the blades of a turbine and produces electricity.

Large hydro power plants generate electricity by storing water in vast reservoirs behind massive dams. Water from the dams flows through turbines to generate electricity, and then goes on to flow through rivers below the dam. Hydro dams can generate large amounts of electricity. However, dry periods may drain the reservoirs. The flooding of reservoirs behind dams and slowing of the flow of the river below the dam can have a serious impact on the ecology around the dam. The number of sites suitable for new dams is naturally limited.

Hydropower also faces a controversy when classifying it into a renewable resource. It is produced from elemental, natural, and recurrent resources like rainfall and snowfall. Its fuel is not depleted during the production of electricity. However, environmentalists say that the construction of dams as well as the change of course in rivers causes irreversible damages to the wildlife and the ecosystems.

2.2.3 Nuclear Power

Nuclear power plants use the heat produced by nuclear fission to generate steam that drives turbines like in fossil fuel plants. Such a plant has a reactor that contains a core of nuclear fuel, primarily enriched uranium. When continuous fission takes place, it forms a chain reaction and releases heat. However, no greenhouse gases are produced in this fission process, and only small amounts are produced across the whole fuel cycle. Nuclear fuel can be used in a reactor for several years. The used fuel must be stored and then either recycled to make new fuel or carefully disposed-off. Nuclear fuel is radioactive and toxic and it is extracted from open-pit underground mines. After the uranium is mined, it is sent to a processing plant so it can be concentrated into a useful fuel (called uranium oxide pellets). This is known as the uranium enrichment process and it generates radioactive waste. The enriched fuel is then transported to the nuclear power plant. These power plants can run 24/7 for many months without interruption, providing reliable and predictable supplies of electricity. Nuclear generation is one of the safest and least environmentally damaging forms of electricity generation.

2.3 Renewables

Electricity generated from resources such as geothermal, biomass, solar, wind, and low-impact hydro facilities is called green power as it has almost no greenhouse effect. Renewable energy sources are also termed as an alternative solution (alternative to the conventional resources such as fossil fuel) to the supply of energy.

Renewable sources such as wind, solar and small scale hydro produces electricity with no greenhouse gas emissions at the point of generation and very low amounts of greenhouse gas emissions across their entire lifecycle. The cost of electricity generation from many renewables tends to be higher (mainly due to higher upfront cost) than other forms of generation, often requiring subsidies to compete with other forms of generation, although these costs are coming down. Many renewables do not produce electricity predictably or consistently causing intermittency. Electricity generation from wind turbines varies with the wind speed, and if wind is too weak or too strong no electricity is produced at all. The output of solar panels is reliant on the strength of the sunshine, which depends on the time of day and the amount of cloud cover. This means that renewables have to be backed up by other forms of electricity generation, often fossil fuel generation with their resultant greenhouse gas emissions. Different renewable energies playing vital role in producing green electrical powers are briefly described as under:

2.3.1 Wind Power

Wind power uses the energy contained in the wind for practical purposes like generating electricity, charging batteries, grinding grain or pumping water. A wind turbine works quite similar to a windmill; various wind turbines operate together in wind farms to produce electricity for utilities. Home owners or remote villages also use smaller turbines to produce energy. Wind power is a renewable resource and environmentally friendly as well.

2.3.2 Solar Power

Solar power is obtained from the energy of the sun. Solar technologies use the sun's energy and light to provide heat, light, hot water, electricity, and even cooling. The energy from the sun is not always available and it is widely scattered, however, solar power is renewable and environmentally friendly. There are several solar technologies, for example:

a. Photovoltaic (PV) solar cells, which directly convert sunlight into electricity.

b. Buildings are designed to incorporate design features that promote passive solar heating, cooling and day lighting. For example, using large South-facing windows and building materials that absorb and slowly release the sun's heat. All of these methods do not use mechanical means; passive solar designs can lower heating bills by 50%.

c. Concentrating solar power is a technology that uses reflective materials like mirrors to concentrate the energy from the sun. The heat energy obtained can be converted to electricity.

d. Solar Hot Water and, Space Heating and Cooling: Solar hot water heaters use the sun to heat water or fluid in collectors.

2.3.3 Biomass Power

Bio-energy technologies use renewable biomass resources - wood, municipal solid waste (garbage), and agricultural waste (like corn cobs and wheat straw) - to produce different types of energy, like electricity, liquid, solid and gaseous fuels, chemicals, heat, and other materials. In the United States, bio-energy has the second place after hydropower in renewable category. It is also a renewable resource and environmentally friendly as well.

2.3.4 Geothermal Power

Heat contained within the earth can be recovered and put to work. This heat is called geothermal energy. Geothermal power is originated beneath the surface of the earth. It comes from buried heat energy. There are five forms of geothermal energy but today, only hydrothermal reserves and earth energy are being used. People have used the geothermal resource for centuries and it is the world's largest energy resource. Geothermal power is a renewable resource and it is environmentally friendly. Geothermal power is produced when enough heat rises close to the surface of the earth and heats underground water causing steam that can be used at steam-turbine plants. Unlike a coal generating plant, a geothermal plant does not produce emissions of sulfur dioxide, carbon dioxide and nitrogen oxides.

Chapter 3 World's Diversified Electrical Energy Portfolio

3.1 Diversified Electrical Energy Portfolio

The nature has endowed our earth and its residents with abundant resources of water, coal, nuclear, gas, wind, solar, thermal, and geothermal energy. Throughout the world, these energy resources are utilized in primary shape directly or in converted formation. Electrical energy is the secondary form of energy generated from different kind of primary energy sources. The generation of electrical energy from different means results in diversified portfolio pattern having its own pros and cons.

The diversified electrical energy generation poses a serious challenge for the utility and especially for dispatch engineers at control center (besides power planners), scheduling the power system for smooth operation and maintenance purpose. The diversity phenomenon requires increased ability of control engineers to stabilize the power system while managing network security, safety and reliability in the most economical manner. Consequently, GDP of the country is also affected by the composition of generation mix. For understanding the whole scenario, it would be appropriate to observe the breakup of electricity generating capacity by energy source with respect to the whole world as well as to South Asia [2].

The world portfolio of electrical energy generated or generation mix by fuel is provided in Table 3.1 indicating generation up to 64% by Fossil Fuel, 17% by Hydro, 7% by Nuclear and 12% by renewable means. The South Asian position has been indicated through Table 3.2 indicating 71% power by Fossil Fuel, 17% by Hydro, 2% by Nuclear and about 10% from renewable resources which shows less intensity of electricity generation by renewable resources. Individual position of SAARC Member States is reflected in Table 3.3 to 3.10 respectively [2].

3.2 World Generation Mix Scenario 2014

Table 3.1: Total World Power Generation Capacity 2014 [2]

World Power Generation Capacity from all Energy Sources 2014 (MW)			
S. No.	**Fuel Sources**	**Installed Capacity**	**%age Contribution**
1	Wind	341,860	6%
2	Others	367,140	6%
3	Nuclear	375,770	7%
4	Hydro	976,190	17%
5	Fossil Fuel	363,8400	64%
	Total (MW)	**5,699,360**	

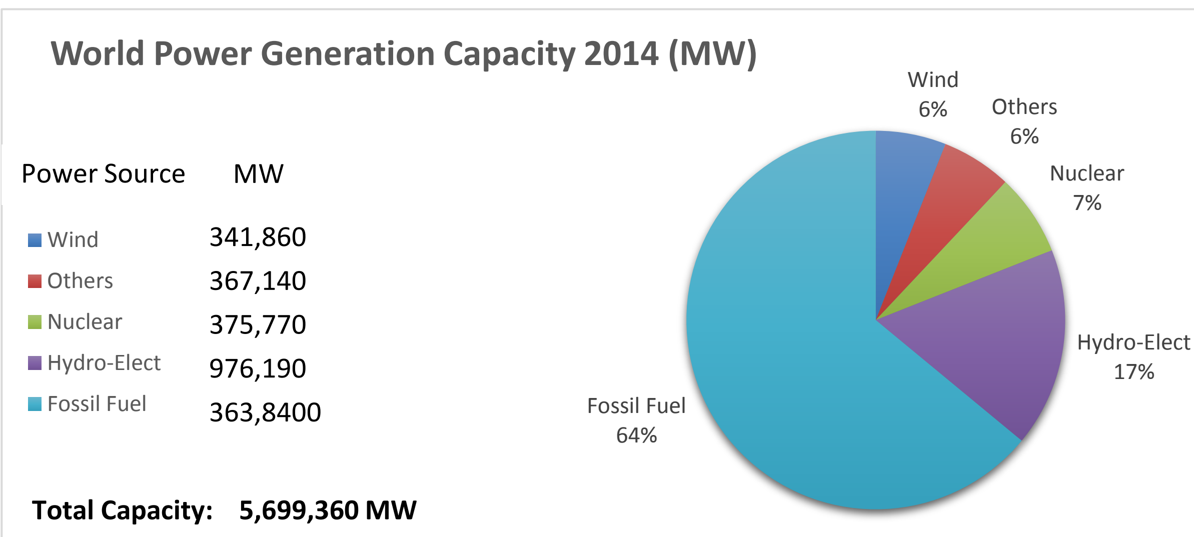

Figure 3.1: World Power Generation Capacity 2014 (MW)

3.3 South Asia Power Generation Mix Scenario 2014

Table 3.2: Total South Asia Power Generation Capacity 2014

South Asia Power Generation Capacity from all Energy Sources 2014 (MW)			
S. No.	**Fuel Sources**	**Installed Capacity**	**%age Contribution**
1	Wind	22,680	7%
2	Others	7,240	3%
3	Nuclear	5,990	2%
4	Hydro-Electric	53,970	17%
5	Fossil Fuel	222,760	71%
	Total (MW)	**31,2640**	

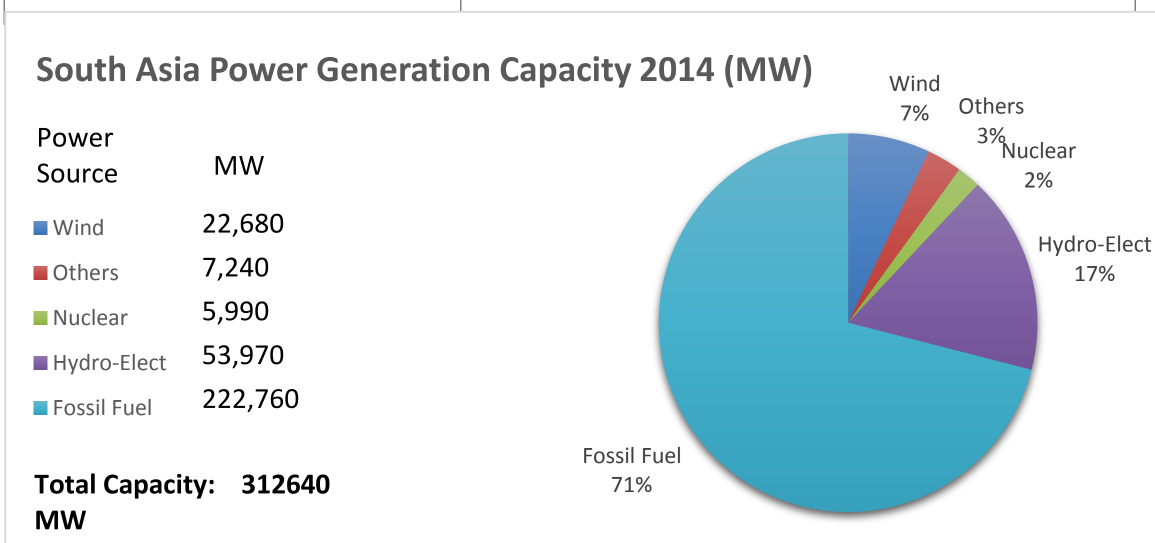

Figure 3.2: South Asia Power Generation Capacity 2014 (MW)

3.4 Afghanistan Power Generation Mix Scenario 2014

Table 3.3: Total Afghanistan Power Generation Capacity 2014 [2]

Afghanistan Power Generation Capacity from all Energy Sources 2014 (MW)			
S. No.	**Fuel Sources**	**Installed Capacity**	**%age Contribution**
1	Wind	0.1	0%
2	Others	-	0%
3	Nuclear	-	0%
4	Hydro-Electric	400	95%
5	Fossil Fuel	20	5%
	Total (MW)	**420**	

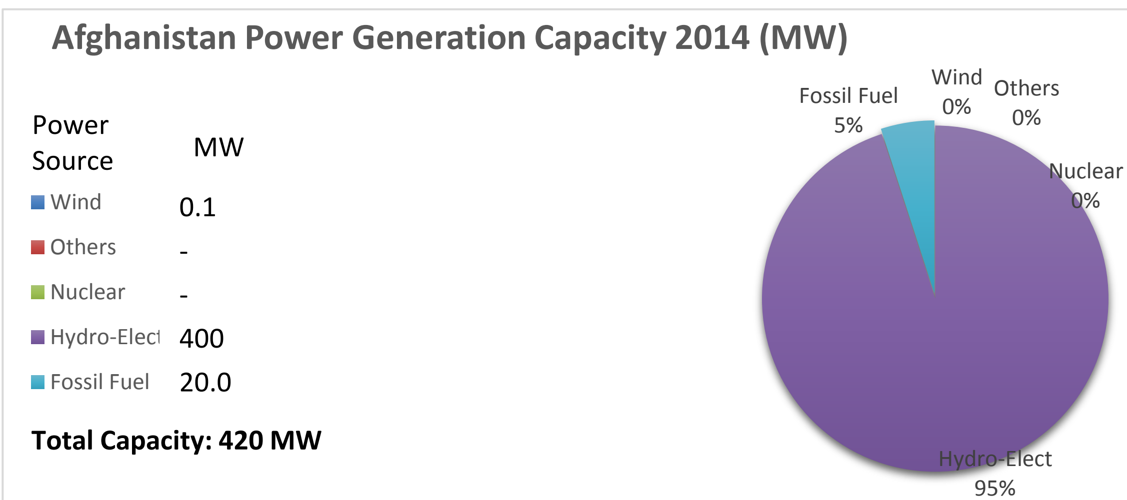

Figure 3.3: Afghanistan Power Generation Capacity 2014 (MW)

3.5 Bangladesh Generation Mix Scenario 2014

Table 3.4: Total Bangladesh Power Generation Capacity 2014

Bangladesh Power Generation Capacity from all Energy Sources 2014 (MW)			
S. No.	**Fuel Sources**	**Installed Capacity**	**%age Contribution**
1	Biomass & Waste	-	0%
2	Nuclear	-	0%
3	Hydro-Electric	230	2%
4	Fossil Fuel	9,270	98%
Total		**9,500**	

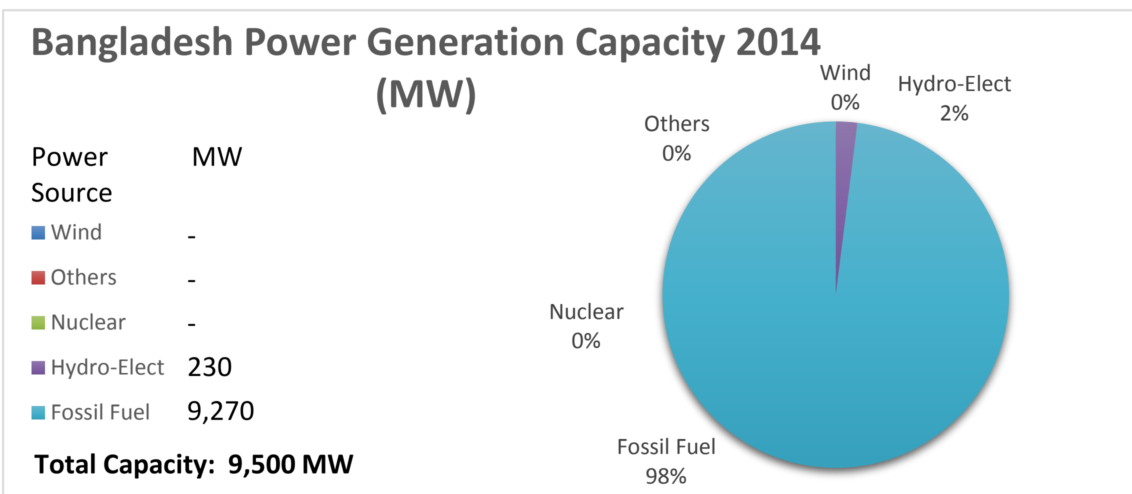

Figure 3.4: Bangladesh Power Generation Capacity 2014 (MW)

3.6 Bhutan Generation Mix Scenario 2014

Table 3.5: Total Bhutan Power Generation Capacity 2014

Bhutan Power Generation Capacity from all Energy Sources 2014 (MW)			
S. No.	**Fuel Sources**	**Installed Capacity**	**%age Contribution**
1	Wind	-	0%
2	Others	-	0%
3	Nuclear	-	0%
4	Hydro-Electric	1,480	99%
5	Fossil Fuel	10	1%
Total (MW):		**1,490**	

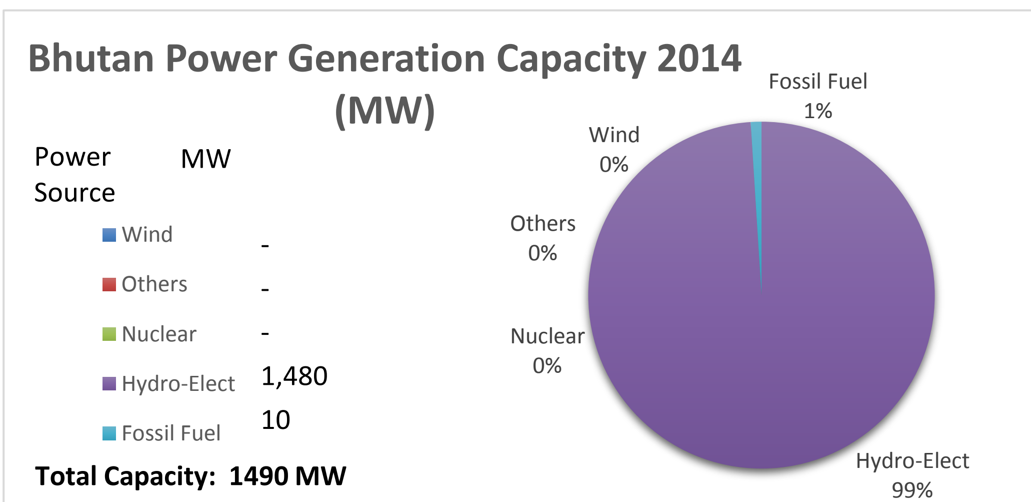

Figure 3.5: Bhutan Power Generation Capacity 2014 (MW)

3.7 Indian Generation Mix Scenario 2014

Table 3.6: Total India Power Generation Capacity 2014 [2]

Indian Power Generation Capacity from all Energy Sources 2014 (MW)			
S. No.	**Fuel Sources**	**Installed Capacity**	**%age Contribution**
1	Wind	22,460	8%
2	Others	7,240	3%
3	Nuclear	5,300	2%
4	Hydro-Electric	42,800	16%
5	Fossil Fuel	192,290	71%
	Total (MW):	**270,090**	

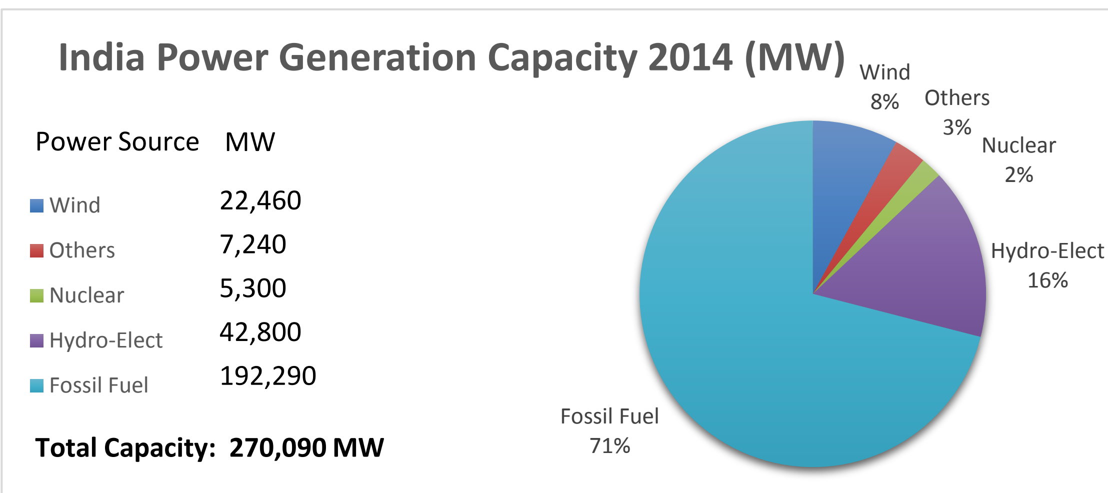

Figure 3.6: India Power Generation Capacity 2014 (MW)

3.8 Maldives Generation Mix Scenario 2014

Table 3.7: Total Maldives Power Generation Capacity 2014

Maldives Power Generation Capacity from all Energy Sources 2014 (MW)			
S. No.	**Fuel Sources**	**Installed Capacity**	**%age Contribution**
1	Fossil Fuel	240	100%
2	Wind	-	0%
3	Others	-	0%
4	Nuclear	-	0%
5	Hydro-Electric	-	0%
	Total (MW)	**240 MW**	

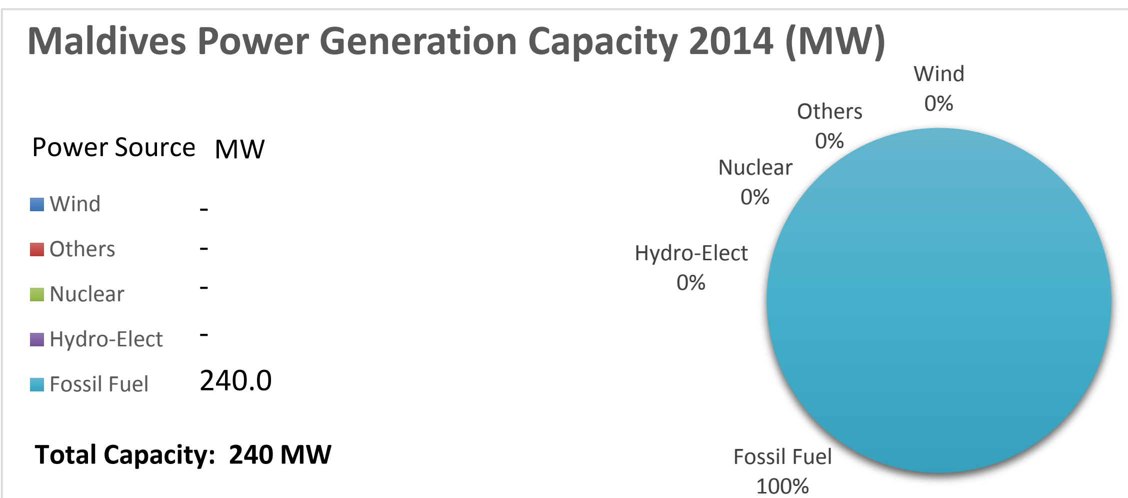

Figure 3.8: Nepal Power Generation Capacity 2014 (MW)

3.9 Nepal Generation Mix Scenario 2014

Table 3.8: Total Nepal Power Generation Capacity 2014 [2]

Nepal Power Generation Capacity from all Energy Sources 2014 (MW)			
S. No.	**Fuel Sources**	**Installed Capacity**	**%age Contribution**
1	Wind	-	0%
2	Others	-	0%
3	Nuclear	-	0%
4	Hydro-Electric	700	92%
5	Fossil Fuel	63	8%
	Total (MW)	**763**	

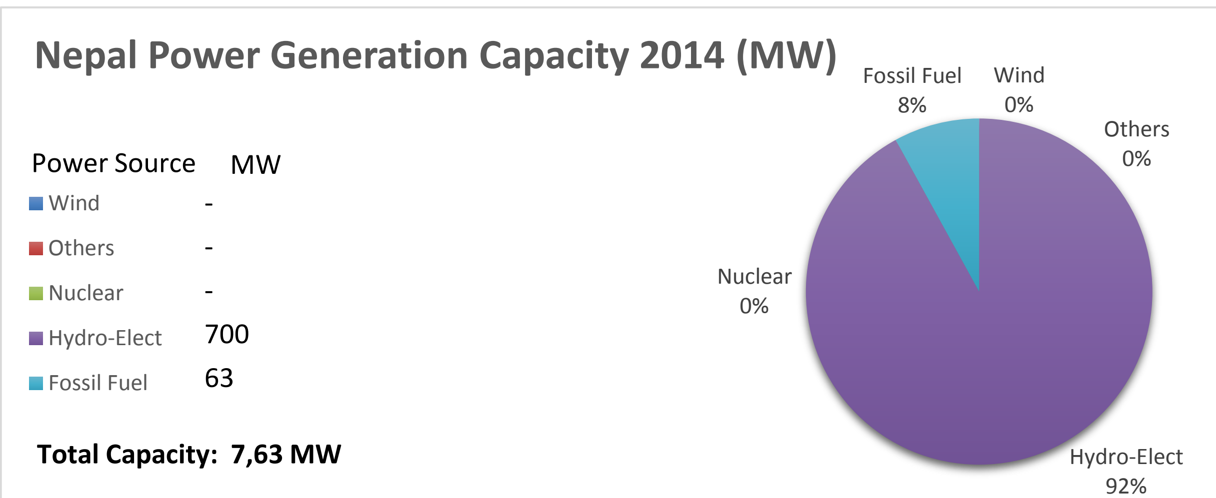

Figure 3.8: Nepal Power Generation Capacity 2014 (MW)

3.10 Pakistan Generation Mix Scenario 2014

Table 3.9: Total Pakistan Power Generation Capacity 2014 [2]

Pakistan Power Generation Capacity from all Energy Sources 2014 (MW)			
S. No.	**Fuel Sources**	**Installed Capacity**	**%age Contribution**
1	Wind	106	0.5%
2	Others	-	0%
3	Nuclear	787	3%
4	Hydro-Electric	7,097	28%
5	Fossil Fuel	16,963	68%
	Total (MW)	**24,953**	

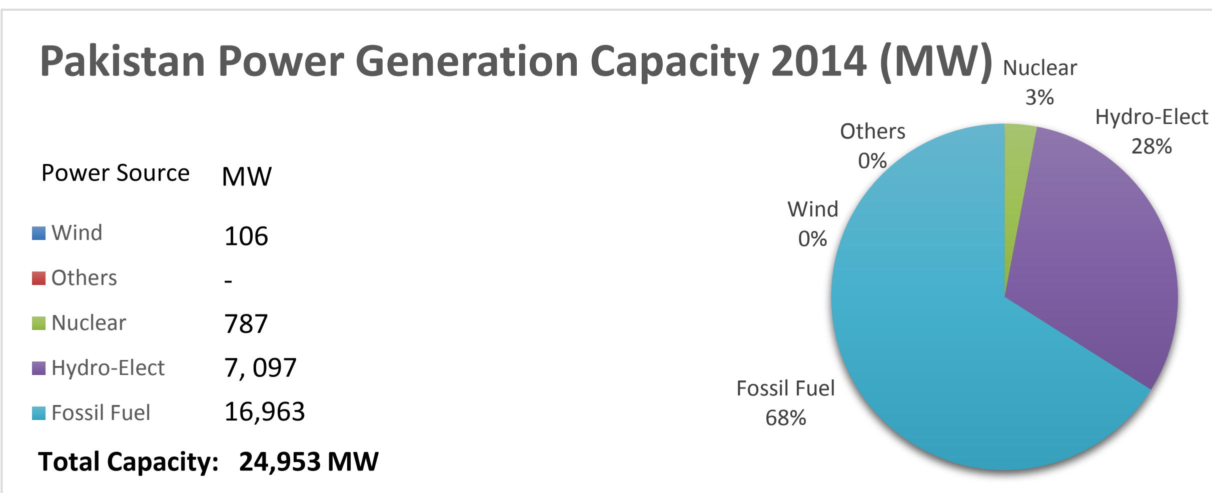

Figure 3.9: Pakistan Power Generation Capacity 2014 (MW)

Sri Lanka Power Generation Capacity from all Energy sources 2014 (MW)

3.11 Sri Lanka Generation Mix Scenario 2014

S. No.	Fuel Sources	Installed Capacity	%age Contribution
1	Renewables	152	4%
2	Biomass & Waste	-	0%
3	Nuclear	-	0%
4	Hydro-Electric	1,665	42%
5	Fossil Fuel	2,115	54%
	Total (MW)	**3,932**	

Table 3.10: Total Sri Lanka Power Generation Capacity 2014

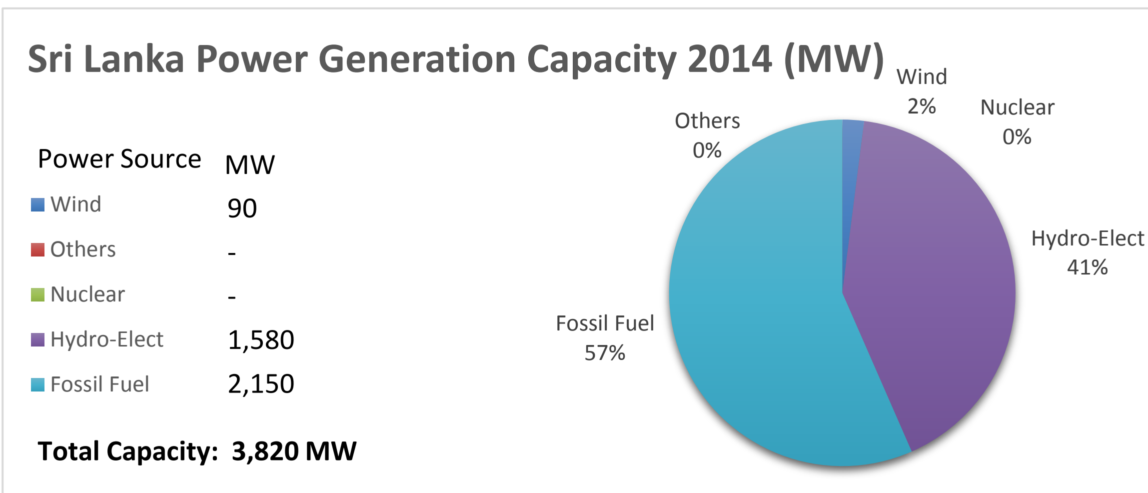

Figure 3.10: Sri Lanka Power Generation Capacity 2014 (MW)

Chapter 4 Diversity Status of SAARC Member States

4.1 Afghanistan

4.1.1 Power Sector Background

Afghanistan's power network presently consists of isolated transmission systems in different areas including North East Power System (NEPS), South East Power System (SEPS), the Turkmenistan System and the Herat System. Afghanistan imports power from Uzbekistan, Tajikistan, Iran and Turkmenistan. More cross border links are expected in future. The energy network isolated systems deliver electricity to only about a quarter of Afghan households. Electricity access varies widely from 0% in rural areas to as high as 90% in urban areas. Increasing energy supply and expanding the energy grid to under-served areas is a national priority. While over 75 percent of the population in large urban areas like Kabul, Kandahar, Herat, and Mazar-e-Sharif have electricity. Less than 10 percent of the rural population has access to grid-connected power. Large parts of Kabul, Mazar-e-Sharif and Pul-e-Khumri have a 24-hour power supply. These cities are part of the North East Power System (NEPS), which imports 150 MW from Uzbekistan throughout the year, supplemented by 150 MW from Tajikistan during the summer. Without low-cost, reliable grid power, population centers either go without power or rely on limited amounts of high-cost and unsustainable diesel-generated power. Afghanistan's current energy supply consists of 77 percent imported power, 21 percent hydro power and 2 percent diesel-generated power.

In the year 2002, only 6 [3] percent of Afghans had access to reliable electricity. Today, 18 percent do have, including more than 2 million people in Kabul who now benefit from electric power 24 hours a day. In addition to building hydro-electric and solar facilities, Da Afghanistan Breshna Sherkat (DABS) is on a path to become fully self-sustaining. DABS collected $ 220 Million from the sale of electricity in 2012, an increase of 67 percent while comparing with 2010.

Afghanistan has one of the lowest rates of electricity usage in the world. It is within the bottom 10 percent globally (around 100 kilowatt hours per year per capita consumption). The reliability of the grid, particularly in Kabul, has improved significantly over the past few years. But load shedding and outages are still a sufficiently common occurrence. The total currently transmission lines capacity is: 326 MW from Uzbekistan, 164 MW from Iran, 433 MW from Tajikistan and 77 MW from Turkmenistan.

4.1.2 Afghanistan Historical Power Development

Afghanistan Energy Infrastructure, generation, transmission and distribution were almost destroyed over the past three decades due to the war and conflict. The government of Afghanistan corporatized the National Electricity Service Department i.e. DABS into an independent state owned utility. As such, all assets, staff and other rights and obligations were transferred to DABS on May 2008. Electricity generation in the history of Afghanistan is quite old and hydro plants were built between 1950 [4] and mid-1970s, which include Sarbobi, Naghlu, Jajki and a number of others plants. Some plants, operational since 2002, include Pupil, Kumhri, Draunta and Brashna Kot dam.

Southern region of Afghanistan is lacking adequate electricity due to issues with Kajak power plant. Third turbine of 16.5 MW capacity is being planned which will certainly improve electricity condition in Southern region especially in Kandhar and Lashkar.

4.1.3 Installed Capacity and Energy Generated [2]

Table 4.1.1: Afghanistan installed capacity (MW) from 2010 to 2014

Year	2010		2011		2012		2013		2014	
	(MW)	(%)	(MW)	(%)	(MW)	(%)	(MW)	(%)	(MW)	(%)
Fossil Fuel	220	37	220	37	220	35	120	23	20	5
Hydro	370	63	370	63	400	65	400	77	400	95
Total (MW)	**590**	**100**	**590**	**100**	**620**	**100**	**520**	**100**	**420**	**100**

Table 4.1.2: Afghanistan Generation Mix Generation (GWh) from 2010 to 2014

Year	2010	%	2011	%	2012	%	2013	%	2014	%
Oil	140	15	190	23	130	15	70	10	10	2
Hydro	750	82	590	71	710	82	640	89	580	98
Gas	-	-	10	1	-	-	-	-	-	-
Coal	30	3	40	5	30	3	10	1	-	-
Total	**920**	**100**	**830**	**100**	**870**	**100**	**720**	**100**	**590**	**100**

It is evident from Table 4.1.2 that in Afghanistan generation energy mix is not diversified and is highly unbalanced which requires due attention from the perspective of diversification in the generation mix.

4.1.4 Afghanistan Multiple Options for Generation Mix

Afghanistan population has very low access to electricity. Only 33% of the total pupation is connected to national grid majority of population turn their night into day without electricity. Insecurity and weak national economic position is the main hindrance to exploit indigenous available large potential for renewable energy to meet its growing electricity need and balance its energy mixed position. Afghanistan can produce thousands megawatts (MW) of electricity from its own natural resources. At present 1,150 MW is being consumed in the country out of which only approximately 420 MW is being generated locally while rest is being imported from neighboring countries. The demand of electricity at present is 5,000 MW. The indigenous resources are water, solar and wind having a combined potential to produce 314,500 MW [4]. Each of the sources is discussed in brief as under:

- **Solar**

Solar Energy is the biggest source of power for Afghanistan. About 222,000 MW of electricity could be generated from solar energy in the country. At least 300 days are counted as sunny in the year and the remaining 65 days are cloudy. So it is a large and unique potential of Afghanistan to generate enormous amount of electricity from solar panels.

- **Wind**

Wind energy is second major electricity generating source in the country. Around 67,000 MW of electricity could be generated by wind turbines in Afghanistan. Farah province has the potential to generate 18,000 MW of electricity from wind. At least 12,000 MW could be generated in Herat province, 10,000 MW in Nimroz and 1,800MW in Helmand.

- **Hydro**

Hydropower is another big source of power generation in Afghanistan. The country has an overall hydro potential of generating about 23,000 MW of electricity.

- **Other Non-renewable**

Other non-renewable sources available in the country are gas and coal through which cheap energy can be produce. About 2,500 MW can be produced from gas. A project of 200 MW is underway for electricity generation through coal.

The government has granted licenses for electricity generation, utilizing ingenious fuel that may improve the generation mix position and improve security and safety of power system, besides providing sustainable electric supply to the people of Afghanistan.

4.2 Bangladesh

4.2.1 Power Sector Background

Bangladesh is one of the world's most densely populated nations. An average household in Bangladesh consists of 4.5 household members and have an overall income of BDT 9,648, or about BDT 2,130 per head. The average per capita income level of consumers below the upper poverty line is BDT 1,271 per month, for those below the lower poverty line its only BDT 1,102.84 per month on national level. Lack of access to modern energy services is one of the reasons for poverty and low economic development. Almost 75% of Bangladesh's 161 million citizens live in rural areas [5]. In 2015, around 68 % of the Bangladesh population is connected to the electricity grid. In 2010, the Bangladesh Bureau of Statistics mentioned 90% access in urban areas and only 42% access in rural areas. The electricity supply is not reliable; supply does not meet the demand. However, as far as possible, load shedding is scheduled [6]. Current installed capacity (September 2015) including public, private and import is 11,877 MW with de-rated capacity of 11,282 MW and a maximum output delivered was 6,675 MW [7]. National grid of Bangladesh is facing load shedding of 600 – 1,200 MW. A situation which deteriorates during irrigation seasons, when the demand-supply gap reaches up to 1,500 MW. Domestic and industrial sectors consume about 43% and 44% electrical energy respectively, i.e. a total of about 87% of power consumption occurs in these two sectors. Out of this, a large part of electrical energy is consumed by light load. Maximum demand-supply gap occurs primarily during the evening.

To materialize the government's vision of electrifying the entire country by 2020 through grid expansion, large scale electrification, renewable energy sources in particular solar energy will have to play a vital role for off-grid electrification. In 2013, the International Renewable Energy Agency (IRENA) ranked Bangladesh as having the sixth-largest renewable energy–related workforce in the world with 114,000 jobs.

4.2.2 Bangladesh Historical Power Development

Bangladesh is a developing country and classified as the eleventh emerging market. The economy is increasing rapidly. The GDP growth was noticed 7.2% during 2015 as compared to 6.1% during 2014, however, Bangladesh is facing challenges of energy shortage and infrastructure deficits. Electricity is being generated by fossil fuel and also by hydro resources. Different types of power plants generate electricity and synchronize it with the national grid. There are some isolated diesel power stations at remote places and islands which are not connected with the national grid. Terminal voltages of different generators are 11 KV, 11.5 KV and 15.75 KV.

In the Eastern Zone (Eastern side of river Jamuna), electricity is generated from indigenous gas and a small percentage through hydro power. In the Western Zone, coal and imported liquid fuel is used for generation of electricity. The fuel cost per unit generation in the Western Zone is much higher than that of the Eastern Zone. Therefore, as a policy, low cost electricity generated in the Eastern Zone is transferred to the Western Zone through the 230 kV East-West Inter connector transmission line. The power system of national grid along with transmission data detail is given in Figure 4.2.1

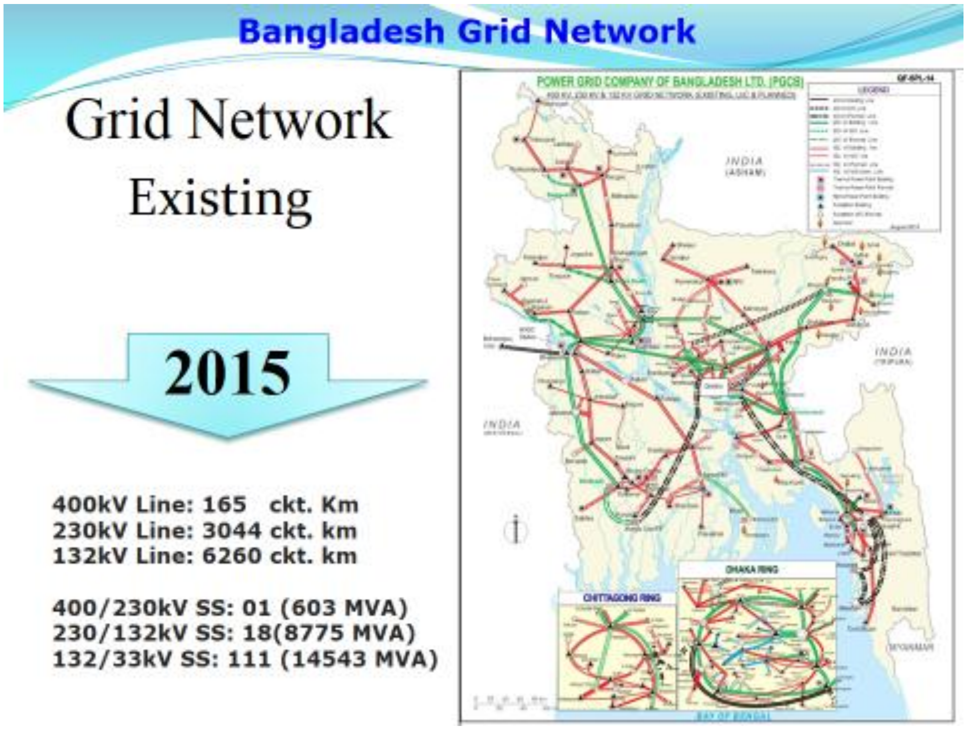

Figure 4.2.1: Bangladesh Grid Network

4.2.3 Installed Capacity and Energy Generated

Table 4.2.1 Bangladesh Installed Capacity from 2010 to 2015 [2]

Year	2010	%	2011	%	2012	%	2013	%	2014	%	2015	%
Hydro	230	4	230	3	230	3	230	3	230	2	230	2
Fossil	5,041	96	6,409	97	7,870	97	8,295	97	9,270	98	11,373	98
Total	**5,271**	**100**	**6,639**	**100**	**8,100**	**100**	**8,525**	**100**	**9,500**	**100**	**11,603**	**100**

Historical Installed Capacity along with Peak Load Recorded is shown in Figure 4.2.2

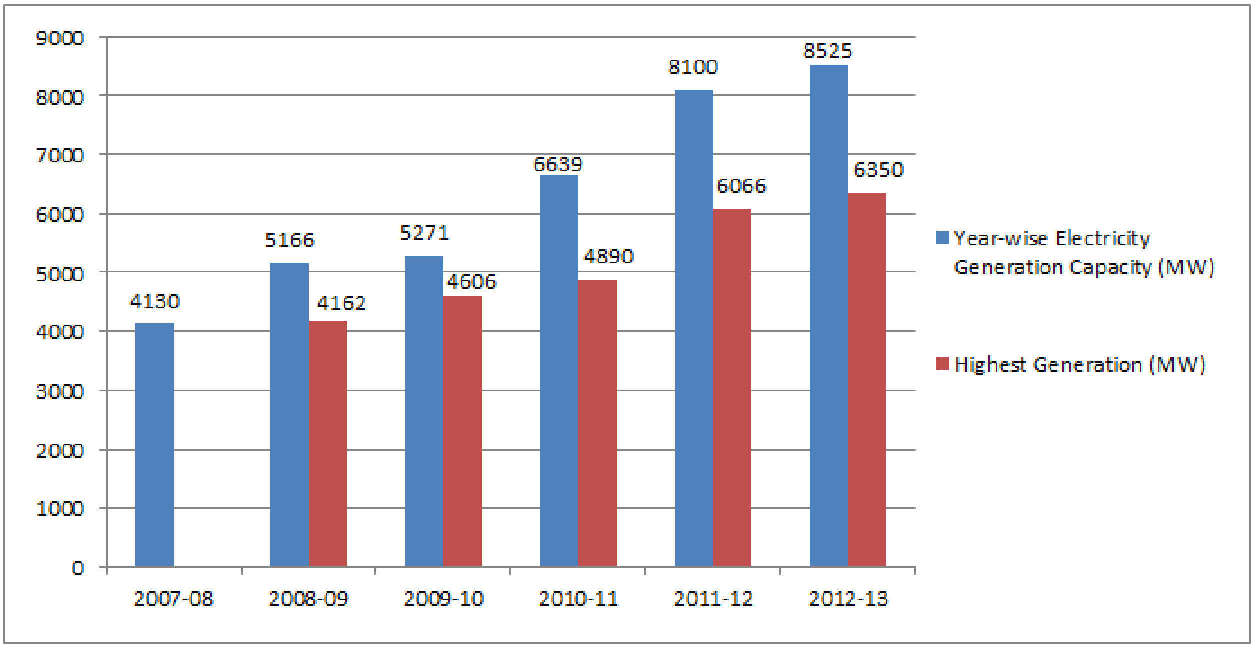

Figure 4.2.2: Bangladesh Historical Capacity and Peak Load Recorded 2007-2013

Table 4.2.2: Bangladesh Generation (GWh) from 2010 to 2014 [2]

Year	**2010**	**%**	**2011**	**%**	**2012**	**%**	**2013**	**%**	**2014**	**%**
Oil	1,840	5	1,970	5	2,370	5	2,370	5	2,370	5
Hydro	1,640	2	1,740	4	1,870	4	1,440	3	1,110	2
Gas	35,990	91	37,880	89	45,529	90	47,240	91	47,240	91
Coal	680	2	730	2	880	2	930	2	980	2
Total	**40,220**	**100**	**42,380**	**100**	**50,709**	**100**	**52,060**	**100**	**51,810**	**100**

It is evident from the above data that Bangladesh generation mix is not satisfactory and is highly unbalanced (dominated by gas) which requires due attention to diversify the generation mix.

4.2.4 Bangladesh Multiple Options for Generation Mix

In Bangladesh, electricity is mainly generated by utilizing both non-renewable and renewable sources. Non-renewable, fossil fuels including natural gas resource are supported by oil, hydro and coal plants. Renewable and nuclear plants are also being promoted. 500 MW power is being imported from India through a 400 kV cross border link since end of 2013. Due to power deficit, additional cross border link with India has been planned to enhance the amount of import up to 1,000 MW. In the following paragraphs, the Bangladesh development of generation mix and its hindrance are discussed.

- **Hydro Power**

Large scale hydro power is not possible in Bangladesh; only micro and mini hydro have limited potential in Bangladesh, with the exception of Chittagong and the Chittagong Hill tracts. Hydropower assessments have identified some possible sites from 10 kW to 5 MW but no appreciable capacity has yet been installed. There is one hydro power plant at Kaptai established in the 1960s with present installed capacity of 230 MW.

- **Solar Energy**

Solar photovoltaic (PV) systems have been established in Bangladesh and are in use throughout the country with having a capacity of 122.2 MW (April 2014) and over 2.9 million household-level installations, Scaling-up of solar PV systems, assisted by the development partners, are being implemented through different organization as Bangladesh Power Development Board (BPDB), Local Government Engineering Department (LGED), Infrastructure Development Company Limited (IDCOL), Rural Electrification Board and some private organizations are involved in solar energy programs. There is a strong potential for solar energy within the country. Dissemination of Solar Home System (SHS) being promoted mainly by IDCOL, private sector companies and NGOs based on the direct-sale approach.

- **Wind Energy**

Wind Energy, also being promoted in Bangladesh, has a good potential but mainly in coastal areas, and in offshore islands with strong wind regimes. These coastal settings offer good opportunities for wind-powered pumping and electricity generation. Presently there are 2 MW of installed wind turbines at Feni and Kutubdia.

- **Biomass**

Bangladesh has strong potential for biomass gasification based electricity. More common biomass resources available in the country are rice husk, crop residue, wood, jute stick, animal waste, municipal waste, sugarcane bagasse, etc. This technology can be disseminated on a larger scale for electricity generation.

- **Biogas**

Biogas mainly from animal and municipal wastes may be one of the promising renewable energy resources for Bangladesh. Presently there are tens of thousands of households and village-level biogas plants in place throughout the country. It is a potential source to harness basic biogas technology for cooking and for rural and peri-urban electrification to provide electricity during periods of power shortfalls.

- **Other Renewable Source**

Other renewable energy sources include bio-fuels, gasohol, geothermal, river current, wave and tidal energy. Potential of these sources are yet to be explored.

Bangladesh is required to expedite the program already launched for the development of existing projects well in time and explore further avenues to enhance its generation mix. Meanwhile Bangladesh has signed a protocol deal with Russia on October 21, 2011 after a series of talks on cooperation in the field of peaceful usage of nuclear energy as the country plans to install a nuclear power plant in Pabna district, some 216 Km northwest of capital Dhaka which will certainly diversify the generation mix and will facilitate the power system control along with reliability and security.

4.3 Bhutan

4.3.1 Power Sector Background

Almost all the power generation in Bhutan is from hydro resources except some small diesel plants. Electrical energy is the key component for the development of country; Bhutan is focused to trade it with neighboring countries. Bhutan has developed a number of Hydro projects and is in excess of energy normally but in dry winter season, it becomes importer of power. During summers, surplus hydropower is exported to India. And during lean water period in winter, when hydropower capacity drops, Bhutan faces power shortages and imports power from India. Bhutan has no petroleum or natural gas except some coal reserves of about 1.3 million tons, which are not yet utilized. Now government has started to explore alternative energies such as Solar, Wind and Biogas due to vulnerability of water supply and climate change [8].Bhutan also operates several small hydroelectric projects, with output capacities ranging between 12 MW and 0.36 MW [9].

4.3.2 Bhutan Historical Power Development

In view of the low cost energy source and it's criticality for Bhutan's economy, the government began to develop hydro projects in the early 1960s with India's assistance. The first major expansion of hydroelectric facilities started in 1975 on the Wang Chhu between Thimphu and Phuntsholing known as the Chukha Hydro Project. It helped in boosting the nation's fledgling industrial development. The 336-megawatt Chukha Hydropower Station came on line in 1986 and was synchronized with the Indian grid same year, and additional capacity became available in 1988. It was planned that Bhutan would sell all excess power to West Bengal. Bhutan also hoped to re-import some of that power through the Indian power grid into Southern districts. The Chukha project was important not only because it supplied electric power to Western and Southern districts but also because it provided a major source of income for the government. In 1981, Bhutan generated 22 million kilowatt-hours of energy from hydroelectric sources. Another major plant in southwest Bhutan, the 18 MW Jaldhaka hydroelectric plant, provided electricity locally and exported the balance to India's West Bengal. In 1989, out of the total Bhutan's government-installed power generation capacity of 355 megawatts, nearly 95 percent was supplied by Chukha; with that a total of some 20 principal towns and 170 villages had been electrified.

By 1991, besides the Chukha project, government installations included seven mini hydroelectric plants, each averaging 7,350 kilowatt capacity; twelve micro hydroelectric plants, each averaging 340 kilowatts capacity; and eight diesel powered generation stations each averaging 6,000 kilowatts capacity. Because domestic consumption was low (just over 16 megawatts, more than 80 percent of which was consumed by industry), ample power was exported to India. This not only halved domestic electricity costs, but also generated revenues from electricity sold to India nearly equal to the total government revenue from all domestic sources. Smaller enterprises, such as the 1.5-megawatt Gyetsha Mini-Hydro, which was inaugurated in 1989, brought badly needed power to Bumthang. Another major plant, a proposed 60-megawatt plant at Kurichu in eastern Bhutan, was included in the Sixth Development Plan (1987–92).

4.3.3 Installed Capacity and Energy Generated

Bhutan's installed capacity in (MW) from 2010 to 2014 is given in Table 4.3.1.

Table 4.3.1: Bhutan installed capacity (MW) from 2010 to 2014 [2]

Source	2010	%	2011	%	2012	%	2013	%	2014	%
Fossil Fuel	10	1	10	1	10	1	10	1	10	1
Hydro	1,480	99	1,480	99	1,480	99	1,480	99	1,480	99
Solar	-	-	-	-	-	-	-	-	-	-
Total availability	**1,490**	**100**	**1,490**	**100**	**1,490**	**100**	**1,490**	**100**	**1,490**	**100**

Table 4.3.2: Bhutan Generation (GWh) from 2010 to 2014

Source	2010	%	2011	%	2012	%	2013	%	2014	%
Fossil Fuel	-	-	-	-	-	-	-	-	-	-
Hydro	7,250	100	6,970	100	6,740	100	6,120	100	5,560	100
Solar	-	-	-	-	-	-	-	-	-	-
Total Production	**7,250**	**100**	**6,970**	**100**	**6,740**	**100**	**6,120**	**100**	**5,560**	**100**

It is clear from Tables 4.3.1 and 4.3.2, that Bhutan's energy sector is mainly dependent on hydro power and lacks diversity. For the security of power system, addition of energy from other renewable sources such as wind, solar, biomass, geothermal is necessary to strengthen the generation mix.

4.3.4 Bhutan Multiple Options for Generation Mix:

- **Hydro**

There is no oil and gas or fertile land in Bhutan however nature has endowed Bhutan with resource of hydro power, mountainous topography and climatic characteristics. The vast hydro potential has been assessed around 30,000 MW. While technically feasible is 23,760 MW which translates into a mean annual energy production capability of around 100,000 GWh. The hydro power has been taped for additional benefits other than fulfilling local energy needs of the county. Both India and Bhutan have made highly successful partnership by ensuring mutual benefit. By now Bhutan has exploited only 6%, i.e. 1,614 MW of available electrical energy through hydro. Bhutan's electricity demand is around 400 MW and 75% energy is exported to

India and has plan to developed 10,000 MW up to 2020. All surplus energy will be delivered to India.

- **Solar/Wind**

Bhutan is also endowed with other natural energy resource such as Wind and Solar. Bhutan has a highly skewed generation mix, with hydro forming nearly 98% of its generation capacity, which puts its energy security at considerable risk and exposes it to environmental vulnerabilities, such as changes in hydrological regime due to climate change. The major challenge for Bhutan is to address the environmental and social issues associated with large-scale hydropower development and a more balanced and optimal energy portfolio that should conform to the philosophy of Gross National Happiness (GNH) and its objectives. Bhutan has considerable solar resource for development of Photovoltaic Solar Power Projects, the potential has been assessed 58,300 MW. 5% of the Bhutan total land is viable for solar development, however due to its mountainous terrain, limited grid connectivity, and low population density, very few regions can be considered for a utility scale solar power project. Areas like Sarpang, Samtse, Chukha and Paro have been marked as to be viable for generating 5 MW plants. Bhutan Wind potential has been estimated theoretically 3,670 MW while considering only land of class 3 or greater. Each square kilometer land accommodates 5 MW of installed capacity with individual 1.5 MW turbines.

The Bhutan power system is at risk of highly skewed generation mix with hydro as the primary resource for power generation and energy produced is least diversified. Bhutan will have to develop projects based on alternate energies. For future generation, renewable energy technologies may provide solution for better generation mix. Bhutan should tap its natural resources of Solar, Wind, Waste to energy and other new technologies to achieve and maintain optimal generation mix.

4.4 India

4.4.1 Power Sector Background

India has electricity generating capacity of 1,362 MW at the time of independence. Only Hydro and Coal power plants were in operation. Power was restricted to a few urban centers; rural areas and villages did not had electricity access. The power sector developed significantly after Independence. The distribution and generation sectors both were run by private utility companies. Afterwards State Electricity Boards (SEBs) were formed in all the states. The power sector developed initially slowly, however, grew remarkably in the successive five year plans and progress has led to extensive use of electricity in all the sectors of economy. Installed capacity of Power Plants (Utilities) kept on growing and increased to 89,090 MW (1998) from meager 1,713 MW in 1950. Similarly, the electricity generation grew rapidly from about 5.1 billion units to 420 Billion units. The per capita consumption of electricity in the country also increased from 15 kWh to about 338 kWh in about 48 years, which is about 23 times. Due to facilitation provided in Electricity (Supply) Act, 1948, the electricity industry developed rapidly in the public sector. The Electricity (Supply) Act, 1948, provided an elaborated institutional frame work and financing norms for the performance of the electricity industry in the country.

Electricity, in India is considered as the key to economic development and power sector development have been given top priority right from the launch of first five years' plan in 1950. As a result of that power sector grew remarkably and progress has led to extensive use of electricity in all the sectors of economy. Both Central and State governments frame policies and laws for the power sector. Both state own and privately own companies are significant player in electrical sector with private sector growing faster than the other. Central Transmission Utility (CTU) is responsible for Inter State Transmission System (ISTS). State Transmission Utilities are responsible for Intra state transmission in their respective States. Indian power grid is a geographically dispersed network having installed capacity of 271,722 MW and transmission line of 306,685 circuit kilometer as of September 2015. The generating capacity is mix and diversified of thermal generation, hydro generation, nuclear generation and also non-conventional generation like wind, biomass, waste etc. The thermal capacity is concentrated in the eastern part while hydro capacity is concentrated in south and extreme north part of India. The electricity is transported from these concentrations to load centers via transmission systems comprising 1,200 kV, 765 kV, 400 kV, 220 kV and 500 kV HVDC Bi-pole networks.

Operation of such complicated and vast system required a central coordination and information system through supervisory control and data acquisition (SCADA) which has been functional at national and regional level. National Load Dispatch Centre (NLDC), Regional Load Dispatch Centre (RLDC) and State load Dispatch Centre (SLDC) are responsible for system operations.

4.4.2 India Historical Power Development

In the history of subcontinent 1879 is the year to be remembered as introduction of electric light in Calcutta managed by Calcutta Electric Supply Corporation. The company was initially registered in London and then transferred to Calcutta in 1870. After success of electricity in Calcutta, power was thereafter introduced in Bombay. First demonstration of electric lighting in was presented at Crawford Market in 1882 and Bombay Electric Supply & Tramways Company (BEST) set up a generating station in 1905 to provide electricity for the tramway. The first hydroelectric project in India was installed in 1897. The first electric streetlight in Asia was lit on 5th August 1905 in Bangalore. The government of India truly involved in the generation of electricity and bulk transmission of power and took effective steps toward development of energy sector especially power sector from 1974 with the start of fifth five year plan. The efforts were supplemented at state level for setting up large power project of coal and hydro to meet the growing power requirement of country.

National Thermal Power Corporation (NPTC), now known as NTPC Limited was established later in 1989 with the aim to construct, operate and maintain the inter-State and interregional transmission systems in all India latterly called Power Grid. The size of the generating unit that has been used in the country in coal based power stations has progressively increased from about 15 MW prior to the era of planned development to 500 MW at present. Now Electricity sector in India had an installed capacity of 271,722 MW as of 30 September 2015 [10]. Renewable plants constituted 28% of total installed capacity and Non-Renewable Power Plants constituted the remaining 72%. The gross electricity generated by utilities is 1,106 TWh (1,106,000 GWh) and 166 TWh by captive power plants during the 2014–15 fiscal [11]. During the year 2014-15, the per capita electricity generation in India was 746 kWh.

India at present has a deficit of electricity about 3.6% [10]. Table 4.4.1 shows the region wise supply, demand and surplus/ deficit position of all India.

Table 4.4.1: Region wise supply, demand and surplus/deficit position of all India [12]

All India (Anticipated) Power Supply Position in FY2015-16						
Region	**Energy**			**Peak Power**		
	Requirement (MU)	**Availability (MU)**	**Surplus(+)/ Deficit(-)**	**Demand (MW)**	**Supply (MW)**	**Surplus(+)/ Deficit(-)**
Northern	355,794	354,540	-0.40%	54,329	54,137	-0.40%
Western	353,068	364,826	3.30%	48,479	50,254	3.70%
Southern	313,248	277,979	-11.30%	43,630	35,011	-19.80%
Eastern	124,610	127,066	2.00%	18,507	19,358	4.60%
North-Eastern	15,703	13,934	-11.30%	2,650	2,544	-4.00%
All India	**1,162,423**	**1,138,346**	**-2.10%**	**156,862**	**152,754**	**-2.6 %**

Table 4.4.2: India Historical installed Capacity (MW) from 1947 to 2015 [12]

Installed Capacity	Thermal (MW)				Nuclear	Renewable (MW)			Total (MW)
as on	Coal	Gas	Diesel	Sub-Total		Hydro	Other	Sub-Total	
31-Dec-47	756	-	98	854	-	508	-	508	1,362
31-Dec-50	1,004	-	149	1,153	-	560	-	560	1,713
31-Mar-56	1,597	-	228	1,825	-	1,061	-	1,061	2,886
31-Mar-61	2,436	-	300	2,736	-	1,917	-	1,917	4,653
31-Mar-66	4,417	137	352	4,903	-	4,124	-	4,124	9,027
31-Mar-74	8,652	165	241	9,058	640	6,966	-	6,966	16,664
31-Mar-79	14,875	168	164	15,207	640	10,833	-	10,833	26,680

Installed Capacity	Thermal (MW)				Nuclear	Renewable (MW)			Total (MW)
as on	Coal	Gas	Diesel	Sub-Total		Hydro	Other	Sub-Total	
31-Mar-85	26,311	542	177	27,030	1,095	14,460	-	14,460	42,585
31-Mar-90	41,236	2,343	165	43,764	1,565	18,307	-	18,307	63,636
31-Mar-97	54,154	6,562	294	61,010	2,225	21,658	902	22,560	85,795
31-Mar-02	62,131	11,163	1,135	74,429	2,720	26,269	1,628	27,897	105,046
31-Mar-07	71,121	13,692	1,202	86,015	3,900	34,654	7,760	42,414	132,329
31-Mar-12	112,022	18,381	1,200	131,603	4,780	38,990	24,503	63,493	199,877
31-Mar-14	145,273	21,782	1,200	168,255	4,780	40,532	31,692	72,224	2,45,259
23-Sep-15	169,118	23,062	1,200	188,898	5,780	41,267	35,777	77,044	271,722

4.4.3 Installed Capacity and Energy Generated [2]

Table 4.4.3: India installed capacity (GW) from 2010 to 2014

Year	2010	%	2011	%	2012	%	2013	%	2014	%
Others	2.6	1	3.9	1	4.8	2	6.0	3	7.2	3
Nuclear	4.2	2	4.4	2	4.4	2	5.3	2	5.3	2
Wind	13.1	6	1.6	6	18.4	7	20.1	8	22.5	8
Hydro	40.1	20	43.3	18	42.8	17	42.8	17	42.8	16
Fossil Fuel	147.2	71	171.1	72	184.3	72	175.3	70	192.3	71
Total	**207.2**	**100**	**224.3**	**100**	**254.7**	**100**	**249.5**	**100**	**270.1**	**100**

Table 4.4.4: Indian Energy Generation (GWh) from 2010 to 2014 [2]

Year	2010	%	2011	%	2012	%	2013	%	2014	%
Wind	20	2	26	3	28	3	32	3	35	3
Others	28	3	26	3	28	3	29	3	31	3
Nuclear	20	2	29	3	30	3	29	3	33	3
Hydro	122	14	142	14	125	13	131	13	129	12
Gas	108	12	102	10	102	10	89	9	80	8
Coal	606	67	672	61	670	68	720	70	800	72
Total	**904**	**100**	**997**	**100**	**982**	**100**	**1,031**	**100**	**1,118**	**100**

It is clear from above that share of electrical energy by fuel in India's generation mix is supportive for control of power system. However for enhanced efficiency, the share of each type of energy should be at least 5% and India requires to expand its power sector keeping in view the generation mix scenario as per best practices to get proper diversified generation mix so that improvement in electricity tariff structure along with improvement in security, reliability and safety of electric supply in the country in achieved.

4.4.4 Multiple Options for Indian Generation Mix

- **Hydro**

Nature has endowed India with water resource and mountainous topography suitable for exploitable and technically feasible potential of hydro electrical energy. The viable hydro potential has been assessed to be about 84,000 MW. Also 6,780 MW can be explored from Small, Mini, and Micro Hydro schemes. Further, 56 sites with an aggregate installed capacity of 94,000 MW have been identified for pump storage schemes to cater for peak electricity demand and water pumping for irrigation needs. India is the 5th largest country in the world in terms of exploitable potential of hydro energy. India is sixth largest country of the world in terms of hydro energy generation. Hydro energy sector is dominating in India and directly under control and supervision of State, but this sector is going to grow faster with the participation of private sector for developing the hydro potential located in the Himalaya mountain ranges of India but hydro potential at Godavat, Mahandi and Normad river basin has yet not been exploited due to resistance from local tribes. India has option to increase share of Hydro energy in its generation mix scenario, however its share is toward reduction since few year and energy produced by fossil fuel is dominating.

- **Nuclear**

India presently has Installed capacity of 5,780 MW and 32,455 million units are generated annually by nuclear fuel. Installed capacity by nuclear fuel is 3% and energy generation is 3.75%. In the electricity generation, India started nuclear power plant development in 1964 and succeeded in development of nuclear energy under the umbrella of Indian department of Atomic Energy which is a public sector organization with the mandate to implement and operate nuclear power stations for India's electricity sector. State owned company has planned 63 GW generation capacity up to 2032 to meet with increasing electricity demand of India. India has estimated 64,000 to 150,000 tons of Uranium (the nuclear fuel) making it 5th largest rich country in Uranium. Thus having the potential to increase the share if electricity from nuclear fuel in their generation mix. India must develop more nuclear power projects to enhance its share in total generation mix at least 5% to manage and maintain optimum diversity.

- **Solar**

India has vast area of land suitable for electricity generation from Solar. The available land has the solar intensity of 5,000 trillion kWh per year with solar power potential of 0.25 kW/ m^2/ day. In India there is unlimited scope to generate electricity by solar means and to replace all fossil fuel requirement (coal, diesel, gas) and hydro electricity generation. However there is limitation of solar energy in the total scenario and 5% share is recommended, suitable for diversified generation mix.

- **Wind**

Wind is another indigenous source of renewable energy in India which the nature has endowed upon India. India is the 5th largest producer globally in power generation through wind energy. The India has huge potential of power generation through wind energy. Only state of Gujarat is estimated to have maximum gross potential of 10.6 GW. Installed wind capacity at present is 23,864.91 MW as on July 2015. Wind energy contribution in energy mix at present is 8% yet its share needs to be increased to 10% at least.

- **Coal**

India the largest country of South Asia, blessed with huge domestic reserves of coal; depends on coal base power generation to meet it substantial needs for electricity. Economic and security drivers are likely to ensure coal's dominance in India's energy scenario and especially in the electricity sector for many more years to come. Coal-based electricity is primarily generated from conventional sub-critical pulverized coal technologies, and most of these plants operate with low conversion efficiencies of coal to electricity. The poor performance of coal-based power plants in India is attributed to diverse factors and is required to compel India to reduce electricity generation by coal and increase share of renewable electricity generation to control on one side to prevent environmental pollution and on the other hand secure diversified generation mix for more secure and reliable power system.

- **Others Indigenous Sources**

Beside traditional ways of harvesting electrical energy, India also has potential to generate power from other renewable sources. The country is rich in biomass potential and it has been assessed 16,880 MW of electricity that can be generated by utilizing biomass technology.

Electricity can also be generated by bagasse cogeneration and has the potential of 5,000 MW. Municipal waste is another source and about 2,700 MW power can be generated by this indigenous source.

All indigenous sources of electric power generation are favorable and India has potential and technology to benefit from these resources and diversify its generation mix to get better control on power system and more balance in mix energy generation to secure its power system.

4.5 Maldives

4.5.1 Power Sector Background

Maldives is composed of geographically separate islands; country consist of total 1,190 small island out of which only 358 are used, local inhabitants have occupied 195 islands and remaining out of 358 are being utilized as tourist resorts. Owing to their dispersed nature, each island in Maldives has an individual electricity generation and distribution system which provides metered service to its residents. Maldives has no conventional energy resources (e.g., oil and gas) for meeting its energy needs. Basically, the country utilizes imported petroleum fuels to meet all of its energy needs. Bulk of these fuel imports is diesel fuel oil (DFO), which is mainly used for power generation both by the State Electric Company Limited (STELCO) and close to 1,000 other electricity generators in the outer islands. Thus 100% power generation in Maldives is on diesel fuel oil which is imported. In most of the islands, this system is operated by government owned utilities, although there are also private community operators such as Island Development Committees (IDCs), Non-Government Organizations (NGOs) and other private owners in some instances.

4.5.2 Maldives Historical Power Development

Electricity business started in 1949 in Maldives with the installation of diesel power generating plant in Male' by STELCO. This first plant at Mali started providing electricity with just one generator set with a capacity of 14 kW. Since then the generation capacity has been increased according to the demands of consumers, through various expansion projects. Each inhabited island in Maldives has its own electric power generation system and other basic infrastructure. However, regular and continuous electric power supply is available in only 24 of the inhabitant islands. These 24 islands have power generation provided by the government-owned company, STELCO. The remaining islands have at least 5 to 12 hours electricity service. Energy demand in Maldives is rapidly growing with an annual growth rate of approximately 11% . In the outer islands, the company provides electricity using small diesel generating sets and, low and medium voltage distribution networks. The total generating capacity both in Male' and outer islands at present is 240 MW. Power generation is unequally distributed among the islands, particularly between Male', Villigili and outer rural islands. The capital alone accounts for approximately 72% of all the generated power for inhabited part of the country. Out of the total generated electricity 48.3% is produced in the tourist resorts which constitute the main source of income for the islands.

4.5.3 Installed Capacity and Energy Generated

Table 4.5.1: Maldives installed capacity (MW) from 2010 to 2014 [2]

Source	2010	%	2011	%	2012	%	2013	%	2014	%
Oil	175	100	190	100	200	100	217	100	240	100
Wind	-	-	-	-	-	-	-	-	-	-

Solar	-	-	-	-	-	-	-	-	-	-
Total Availability	**175**	**100**	**190**	**100**	**200**	**100**	**217**	**100**	**240**	**100**

Table 4.5.2: Maldives Generation (GWh) from 2010 to 2014 [2]

Source	2010	%	2011	%	2012	%	2013	%	2014	%
Oil	240	100	260	100	280	100	300	100	330	100
Wind	-	-	-	-	-	-	-	-	-	-
Solar	-	-	-	-	-	-	-	-	-	-
Total Production	**240**	**100**	**260**	**100**	**280**	**100**	**300**	**100**	**330**	**100**

It is clear from above data that there is no diversity in the energy produced by Maldives, however it can be achieved only through wind and solar energy for which priority has already been adapted by the government as per energy policy 2005 to increase national energy security by diversifying energy resources.

4.5.4 Maldives Multiple Options for Generation Mix

The primary source for generating electrical energy is fossil fuel and normally energy is produced by diesel generators. The following renewable resources are also available in Maldives.

- **Electricity Provision with Renewable Energy Technology**

Three potential renewable resources in the Maldives are: (1) Solar; (2) Wind; and (3) Biomass. Currently, there are just a few applications of solar photovoltaic cells such as to power navigation lights and outer island telecommunication systems. Maldives is blessed with renewable energy resources. This creates serious economic and financial difficulties and puts the security of energy supply at risk. Developing appropriate measures will secure the constant supply of energy and serve the long term goal of reducing GHG emissions as well as improving the standard of living of the people. The solar intensity is 5.2 Wh/m^3 / day and wind speed is 6.5 to 6.7m/s at 50 m height. Solar energy is abundant in the Maldives as it is a tropical country lying at the equator with an average surface temperature of 30-32 degree Celsius. Solar energy potential assessed is 793 MWH/year.

4.6 Nepal

4.6.1 Power Sector Background

Electricity in Nepal is being controlled by Nepal Electricity Authority (NEA), a state owned authority. Current electricity supply is unreliable, insufficient, and expensive. Despite having 83,000 MW of theoretical hydroelectric potential, about 42,000 MW of which is technically and economically viable, current realization remains hardly above 700 MW. The supply problems impose a number of costs on society, including economic inequity, health and environmental impacts, and economic losses due to unreliable connectivity and productivity losses.

Approximately 63 percent of the population has access to electricity. There is an acute shortage of electricity and even residents in capital city of Kathmandu experience outages several times a day for up to 16 hours during the dry season. These electricity shortages have led to a heavy reliance on biomass burning for energy in rural Nepal, which has negative health and environmental impacts, particularly on women and children of the area.

Peak power demand in Nepal reached 1200.98 MW during 2013/14, and is likely to increase by around 10 percent annually. Energy consumption and number of consumers are increasing at 9%. Beside the national grid, thousands of small installations (diesel generating sets, solar home systems, small island mini grids, etc.) are also installed in Nepal. 478 MW of hydropower capacity is owned by NEA while 255 MW is privately owned and operated.

4.6.2 Nepal Historical Power Development

The history of electricity development of Nepal has crossed 100 years since the start of construction of Pharping hydro power (500 KW) in 1911. Today, Nepal has an electric power installed capacity of 787 MW (in 2015) in Integrated Nepal Power System (INPS). Out of total electric power, about 91% is contributed from hydroelectric plants and rest of 9% is supported from diesel plants. The existing largest hydroelectric plant in the country is Kaligandaki-A (144 MW). The generated electric power has been transmitted through 132 KV single and double circuit transmission line of 1562.9 km, 66 KV single circuit, double circuit of 354.72 km. The country has a total substation capacity of 1415.10 MVA to date.

4.6.3 Installed Capacity and Energy Generated

Table 4.6.1: Nepal installed capacity (MW) from 2010 to 2014 [2]

Source	2010	%	2011	%	2012	%	2013	%	2014	%
Fossil Fuel	50	7	50	7	50	7	32	4	63	8
Hydro	660	93	680	93	700	93	700	96	700	92
Solar	-	-	-	-	-	-	-	-	-	-
Total Availability	**710**	**100**	**730**	**100**	**750**	**100**	**732**	**100**	**763**	**100**

Table 4.6.2: Nepal Generation (GWh) from 2010 to 2014 [2]

Source	2010	%	2011	%	2012	%	2013	%	2014	%
Oil	-	-	-	-	-	-	1,000	24	2,000	41
Hydro	3,170	100	3,450	100	3,490	100	3,170	76	2,880	59
Solar	-	-	-	-	-	-	-	-	-	-
Total Production	**3,170**	**100**	**3,450**	**100**	**3,490**	**100**	**4,170**	**100**	**4,880**	**100**

It is clear from Tables 4.6.1 and 4.6.2 that Nepalese energy sector is mainly dependent on hydro energy and has least fuel diversity; for the security of power system, addition of energy from other renewables sources such as wind, solar, biomass, geothermal is necessary to strengthen the generation mix.

4.6.4 Multiple Options for Nepalese Generation Mix

- **Hydro**

Nepal has very huge hydro power potential that has been assessed 83,000 MW while technically feasible and economical viable are 42,000 MW. Nepal has explored only 2% of the country indigenous hydro and is facing acute shortage of electricity and load shedding because of non-development of new projects. Harnessing more hydro energy will not only provide Nepal with opportunity to meet with existing demand but it can reduce the electricity cost and excess energy produced can also be exported to stable the country economy.

- **Wind**

Nepal has potential area for the wind power and as a whole it is estimated about 6,074 km^2 with wind density about 300 watt/ m^2. It has an estimated potential of generating 3,000 MW from wind energy. Despite of this huge potential for wind energy, yet only significant amount has been harnessed as off-grid.

- **Solar**

Nepal is also rich in Solar potential and has per day 6.8 sunshine hours with intensity of solar insolation ranging from 3.9 to 5.1 kWh/ m^2-day. The average solar potential of Nepal is 800,00GWh/ day. If Nepal utilize only 0.01% of its overall solar potential i.e. at 8 GWh/day, annual electricity produced will be 2,920 GWh; which is more than present total power generation of Nepal.

Alternate energy potential of Nepal is very encouraging and may balance the country electricity shortage, stabilize power system with optimized generation mix besides helping to boost the economy.

4.7 Pakistan

4.7.1 Power Sector Background

Electricity in Pakistan is generated, transmitted, distributed and retailed supply by two vertical integrated public sector utilities: Pakistan Electric Power Company (PEPCO) for all Pakistan except franchised area of K-Electric/ Karachi Electric Supply Company (KESC). National Transmission and Dispatch Company Ltd. (NTDC) being withholding company of PEPCO is responsible for receiving Power from Generation Companies (GENCOs, IPPs, and WAPDA's Hydro-Electric Power Plants) and dispatches it to distribution companies (DISCOs). NTDC also has interconnection with K-Electric/KESC. NTDC operate and maintain a power system at national level of 500 kV, 220 kV and 132 kV transmission network comprising substations and transmission lines throughout Pakistan.

The operation of national network along with associated substations and power plants is controlled by a Load Dispatch System comprising a National Power Control Centre (NPCC) at Islamabad and two regional Control Centers (RCCs) one for the North region and the other for South region.

NPCC is responsible for monitoring and controlling of all power plants, 500/220 kV substations, 500/220 kV transmission network and 132 kV network associated with power plants. NPCC is equipped with state of the art SCADA system. Distribution Control Centers (DCCs) are being established at all DISCOs for controlling and monitoring at distribution level.

The overall power system (NTDC & DISCOs) comprises 132 kV, 220 kV, 500 kV integrated network known as national grid connected with power plants owned by GENCOs, WAPDA Hydro-electric Power and IPPs. The grid is not interconnected with other countries yet, however, there is consideration and planning for inter connection to neighboring countries in future to enable Pakistan entering in power trade era. Currently, Pakistan is importing a small amount of 80 MW from Iran but the location is isolated.

As of 2014, total installed capacity was 24,953 MW, net de-rated capacity of 22,935 MW and average generated capability of 16,350 MW against the computed demand of approximately 21,674 MW [2] resulting net deficiency of 5,324 during peak hours. The total installed capacity is not sufficient to cope with increasing demand. Demand has outstripped supply of electricity and country is presently facing demand-supply gap coupled with consistent growth in demand that clearly indicates the need and market for enhancement of current Power generation capability.

4.7.2 Pakistan Historical Power Development

Pakistan is a developing country with annual GDP growth rate equal to 4.24% (2014) [13]. Pakistan power system network is available as Figure 4.7.1.

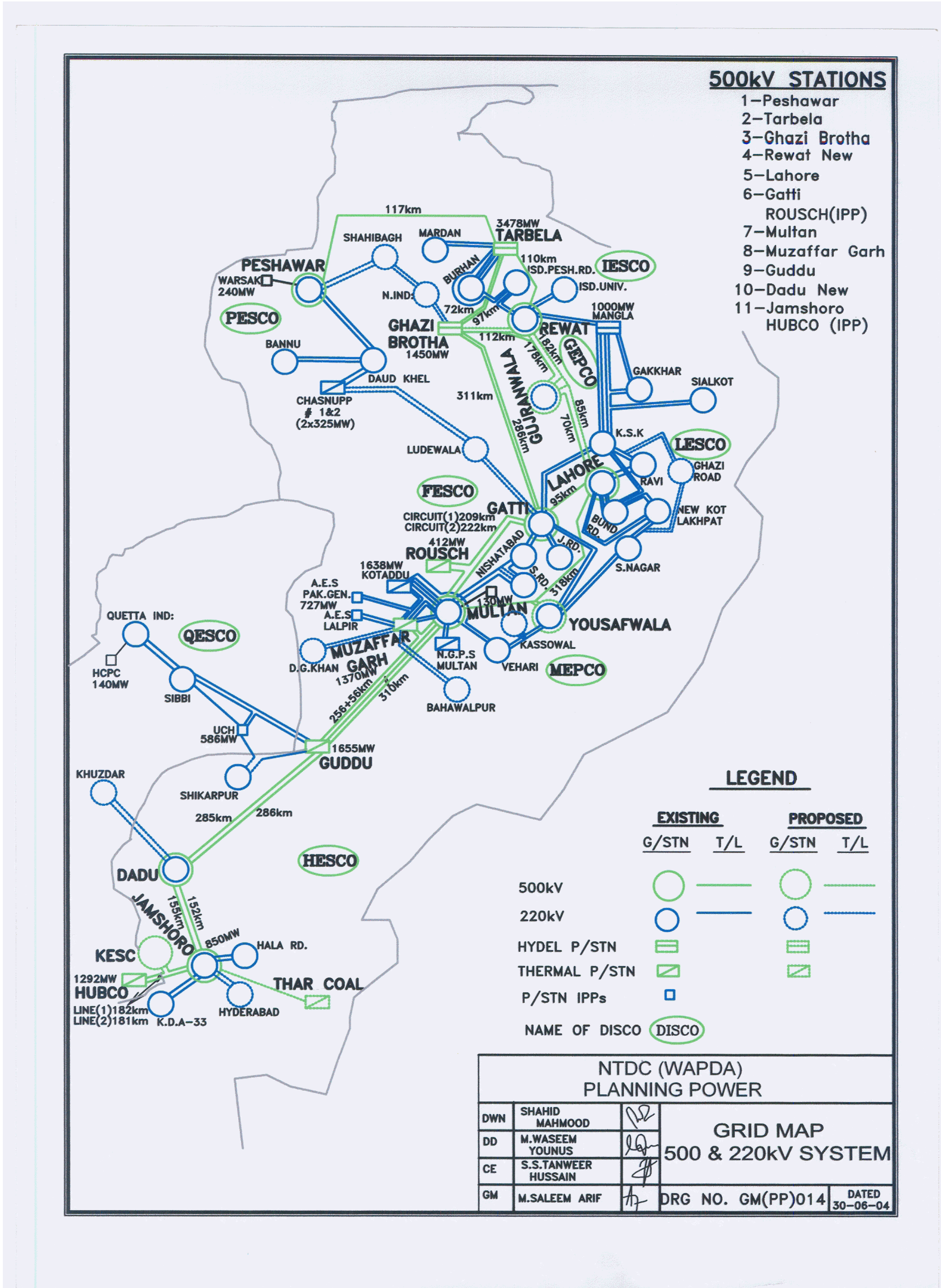

Figure 4.7.1: Pakistan Power System Network

The geographical location of power system is longitudinal in nature, all hydro resources and existing electricity plants are located toward North while major fossil fuel and wind generation is located in South with lower thermal generation in the middle, while load center is mainly in mid of the country; therefore, Pakistan faces high transformation losses and high risk of energy security. Pakistan transmission system data is given in Table 4.7.1 below:

Table 4.7.1: Pakistan Transmission System Data [14]

Description	500kV	220kV	132kV	66 & 33 kV
No. of Sub Stations	12	33	595	146
Length of Transmission Line (Km)	5,147	8,605	27,108	9,033
MVA Capacity	15,750	19,674	34,228	2,404

Table 4.7.2: Historical Peak Load, Computed Peak and Surplus/Deficit (MW)

Fiscal year ending 30th June	Available capacity (MW)	% availability Growth	Computed peak (MW)	% Peak Growth	Surplus/deficit (MW)
2001-2002	10,894		10,459		435
2002-2003	10,959	0.6	11,044	5.29	-86
2003-2004	11,834	7.39	11,598	4.77	236
2004-2005	12,792	7.48	12,595	7.91	197
2005-2006	12,600	-1.52	13,847	9.04	-1,247
2006-2007	13,292	5.2	15,838	12.57	-2,546
2007-2008	12,442	-6.83	17,398	8.96	-4,956
2008-2009	13,637	8.76	17,852	2.54	-4,215
2009-2010	13,445	-1.42	18,467	3.38	-5,022
2010-2011	13,193	-1.91	18,521	2.86	-5,328
2011-2012	13,733	3.93	20,058	7.66	-6,325

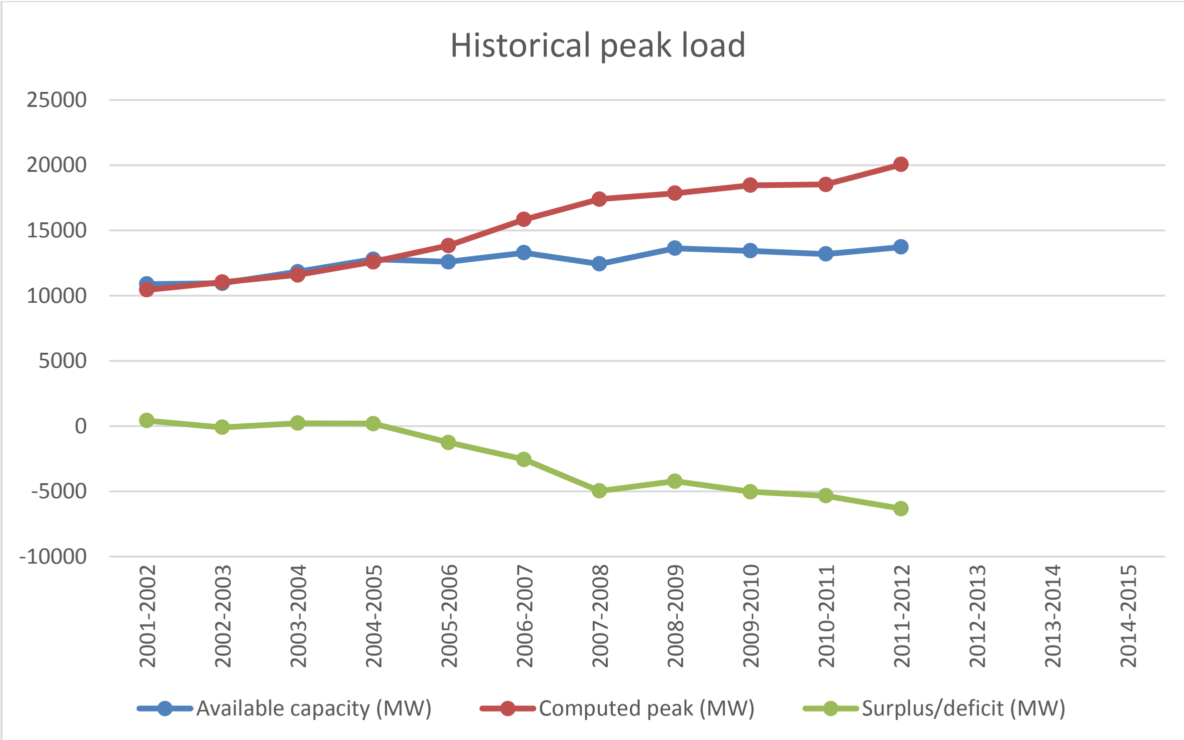

Figure 4.7.2: Historical Peak Load, Computed Peak and Surplus/Deficit

From the Table 4.7.2, it is clear that Pakistan average availability growth from 2001-02 to 2014-15 is 1.77% while average growth in computed peak for the same period is 6.49%, indicating worse scenario in electrical energy generation and need special attention and priority to boost the electrical generating capacity and country economic growth thereof.

4.7.3 Installed Capacity and Energy Generated

Total Pakistan Installed capacity at present 25,722 MW with de-rated capacity is 23,410 MW.

Table 4.7.3: Pakistan installed capacity (MW) from 2010 to 2014 [2]

Year	2010	%	2011	%	2012	%	2013	%	2014	%
Wind	-	-	-	-	50	0	50	0	106	0
Nuclear	420	2	720	3	720	3	690	4	787	3
Hydro	6,740	30	6,750	29	6,780	30	6,780	31	7,097	31
Fossil Fuel	15,200	68	15,450	67	15,280	67	14,110	65	16,963	66
Total	**22,360**	**100**	**22,920**	**100**	**22,830**	**100**	**21,630**	**100**	**24,953**	**100**

Table 4.7.4: Pakistan Power Generation Status from 2010 to 2014

Year	2010	%	2011	%	2012	%	2013	%	2014	%
Others	90	0	100	0	90	0	90	0	120	0
Oil	31,250	35	31,700	35	29,240	33	30,240	33	31,240	34
Nuclear	2,560	3	3,840	4	5,270	6	4,390	5	46,000	5
Hydro	31,490	35	28,230	31	29,549	33	32,450	36	33,369	36
Geothermal	400	0	400	0	400	0	400	0	400	0
Gas	24,320	27	25,990	29	23,969	27	23,219	26	23,219	25
Total	**90,109**	**100**	**90,260**	**100**	**88,519**	**100**	**90,790**	**100**	**92,949**	**100**

4.7.4 Multiple Options for Pakistan Generation Mix

Pakistan is a developing country and can optimally be powered only by mix energy sources but development of each source faces practical and/or political problems. The primary energy demand is expected to rise by 50% from 2015 to 2021 based on the annual rate growth worked out from 2000-2014 data, which seems a tough asking. The forecast for load is shown in Table 4.7.5. Relying on only hydro and oil will aggravate the problem and restrict to achieve progress in harnessing alternative energy for meeting energy short fall. In the following paragraphs, the historical development of generation mix and its hindrance will be discussed.

Table 4.7.5: Load Forecast NTDC, K-Electric/KESC and Country (MW) [14]

Year	NTDC	K-Electric/KESC	Country
2011-12	19,400	3,021	22,199
2012-13	20,401	3,240	23,407
2013-14	21,556	3,484	24,792
2014-15	22,761	3,762	26,261
2015-16	24,081	4,157	27,896
2016-17	25,352	4,592	29,647
2017-18	26,810	5,069	31,562
2018-19	28,353	5,387	33,604
2019-20	30,036	41,44	35,822
2020-21	31757	6752	38127

- **Hydro**

Pakistan is a water-rich country and nature has endowed Pakistan unique opportunity to exploit approximately 60,000 MW of hydro potential power to meet its energy requirement [15]. Most of this potential lies in Khyber Pakhtunkhwa, Northern Areas, Azad Jammu and Kashmir and Punjab. Total installed hydro capacity in the country is 7,097 MW (12% of the hydro power potential) and abundant hydro potential is still untapped which needs to be harnessed, while further exploring has been become politicize despite of the facts that there has been consensus among the stake holders that hydro power is the most important tool for Pakistan to achieve a sustainable energy future.

After the creation of Pakistan, the country faced numerous problems including dearth of electrical power. Hydropower development in the Indo-Pak subcontinent started in 1925, with the construction of the Renala 1 MW hydropower station. After a decade, the 1.7 MW Malakand-I hydropower station was built, which was later upgraded to a 20 MW capacity. Subsequently, in 1953, the 20 MW Dargai hydropower station was commissioned. At the time of independence, Pakistan inherited a very small power base with a capacity of only 60 MW for its 31.5 million people. At the time of creation of WAPDA in 1958, the country's total hydro capacity was enhanced to 119 MW. By the Indus Water Treaty in 1960, it was decided that Pakistan is entitled to 142 MAF (Indus 93, Jhelum 23 and Chenab 26) of water utilization. Subsequently, 240 MW Warsak, 1,000 MW Mangla and 3,478 MW Tarbela hydropower projects were constructed. Afterwards, only one addition could materialize i.e. Ghazi Barotha at District Attack Punjab of 1,450 MW Run-off-the-river project. Now the government has adapted serious step and Neelum-Jehlum Hydro project 969 MW, Tarbela Extension IV-1410 MW, Tarbela Extension V 1320MW and Karot Hydro Project 720 MW are in implementation phase and expected to be completed during next two years. In addition, Diamir Basha Dam 4320 MW, Dasu Dam 4,500 MW and Kohala 1,000 MW are in early completion stage and need policy continuation to be completed within the stipulated time frame [16].

In case of hydro since no fuel is used the variable portion of electrical energy tariff remains on low side as compared with other sources of energy and thus become shock observer to keep control on end consumer tariff, resulting in socio economic uplift of the country. Although hydroelectricity is considered to be cheap, however huge upfront investment is involved and for country like Pakistan big projects are not possible without financial help of international development agencies. Hydro energy is no doubt cheap, renewable, green, flexible and easily controllable compare to fossil fuel and nuclear, however, electricity generation from hydro is dependent upon availability of water which can't be controlled and varied. Drought may also affect electricity generation indirectly affecting price of energy. Further, primarily purpose for building dam in Pakistan remains irrigation and electricity is produced as a byproduct. Flow of water is being controlled by IRSA, therefore, electricity generation varies largely depending on indent of water release from reservoirs. The %age sharing of hydro in total generation mix varies at large scale and it remains in the range from 20% to 44 % throughout the year. The optimize position and most beneficial months are May to October.

- **Furnace Oil and Diesel**

Another important source of generating power in Pakistan is through of fossil fuels which include hydrocarbon (oil, natural gas, coal). The electricity produced by fossil fuel plants work as base load plants as generation by hydro is highly variable depending on flow and availability of water and especially in winter season its share become nominal thus generation of electricity by hydrocarbon play vital role. Usually furnace oil is used for generation of electricity which is the residual product of crude oil, chiefly consumed in power plants. Few plants run on dual fuel and also use diesel as fuel to produce electricity in emergency and acute shortage of electricity.

Oil is the major handicap in Pakistan economy as it is mostly imported in the shape of crude oil and finished product e.g. diesel, petrol; import bill of the country ranges approximately around 25% of trade bill [13].

The present decline in oil price is a blessing and chance for power sector for improved capacity utilization and government will get some respite from monstrous circular debt. To find long-term and sustainable solution for power sector, lesson learned from the history of Pakistan power sector should be taken into account while preparing the future power policy. Lower power prices scenario presents an opportunity to find a sustainable energy solution through optimizing of generation mix.

- **Nuclear**

The electricity generated by process of nuclear fission called nuclear energy is very sophisticated yet hazardous technology. At present, Pakistan generates 2% of its total production by nuclear means whereas world share of nuclear generation mix is 7%.

Pakistan’s first nuclear power plant was commissioned in 1972 with capacity of 137 MW at KANUP, Karachi to provide electricity to the mega city of Karachi only. Since then it is in operation and performing successfully, besides providing electricity, has also provided country nuclear researchers with an important case study.

In 2000 the 300 MW Chashma Nuclear Power Plant CHASNUPP-I started functioning while CHASNUPP-II was commissioned in 2011 with 325 MW generating capacity. CHASNUPP-III and IV 340 MW each power plant are expected to be completed in 2016 and 17 respectively. With the completion of these plants, share of nuclear energy will surpass 5% of generation mix.

- **Coal**

For Pakistan, another indigenous means of generating electricity is coal. The first discovery was made in 1980 at Lakra and Sonda-Jherruck, Sindh. However, Power generation by coal in Pakistan’s generation mix is negligible compared to the world average of 41% while 56%, 66% and 42% in India, China and USA respectively. The only coal power plant of 300 MW was established at Lakhara, however, it has lost its capacity and at present delivering only 35 MW. Thus electricity production through coal in Pakistan is a missing link in generation mix despite of so early discovery of coal in country. Whatever the reason may be, least attention has been given to the production of electricity by coal. The Thar coalfield was discovered in 1991, possesses among the largest coal deposits in the world, despite of passage of more than two decade, Thar coal potential has not been tapped due to multiple reasons.

The financial crises of 2008 also victimized the coal prices, prompted the local business community to pitch imported coal as a quick fix. Gadany Power Park also came into the limelight to offset the power supply demand gap. Government has started implementing its strategy to convert existing oil fired power plants to imported coal and subsequently to the indigenous coal. In any case, such developments will increase the share of coal generation electricity in overall generation mix of the country.

- **Natural Gas**

The most economical way of generating electricity after hydro power is by natural gas. Pakistan produced 25 % of its total energy generation mix by natural gas in 2014. The discovery of gas as indigenous source of energy was made in 1959 at Sue, a small town in Baluchistan and it became so popular among the masses that the term Sue gas is still used as a synonym for natural gas. With this discovery, laying down of a country wide high pressure transmission and low pressure distribution gas pipe line started and Pakistan today possess one of the world's most extensive inland natural gas supply infrastructure with total length of 140,000 enough to circle the whole world 3 time. Pakistan major gas field discoveries are at Mari, Khandkot, Qaderpur, Zamzama, Swan, Gurgiuri etc.

Over the period, the gas utilization expanded to the industrial, fertilizer as well as power sector. Due to important factors such as low cost, efficiency, environmental nature of natural gas relative to other fossil fuel along with guaranteed foreign currency return, power generation by natural gas has been preferred over any other fuel. Gas plants also helped in the bankability of power projects and attracted investment. Power plants already running on furnace oil were converted to duel fuel and switched to natural gas to help and keep the import bill low and electricity bill macroeconomic and microeconomic under control.

With accelerated usage of gas from 1,742 MMCFD in 1998-99 to 3,181 MMCFD in 2004-05, depletion of natural gas reservoir started. The present gas production is approximately 4,000 MMCFD. The supply-demand gap is 1,000—1,500 MMCFD which is expected to increase if no due attention is given to such important problem [17].

In 1996, Interstate Gas System Limited was established with a mandate to import gas through IPI (Iron-Pakistan-India) pipe line project, which was then expanded to include Turkmenistan-Afghanistan-Pakistan-Iran (TAPI) pipeline project. Government of Pakistan undertook a short term strategy to import LNG or RLNG Regasification of Liquefied Natural Gas to meet the power short fall. Despite all hurdles and limitations, natural gas remains one of the country's strengths with the capacity to support economy and to bring down poverty level. In order to increase local reserve pool, aggressive exploration activities are needed.

- **Wind and Solar Energy**

The nature has endowed Pakistan with huge quantity of both wind and solar renewable energies resources. The country had in roads in recent years in harnessing wind energy by utilizing wind corridor of Gharo and Jhimpir in Sindh. 250 MW has already been added to the national grid and a number of plants are in pipe line so the share of wind energy will be increased in generation mix. However, wind farming is highly capital intensive even though there is no fuel cost, the wind energy tariff is not consumer friendly mainly because of the high upfront technology cost. The intermittent nature of energy produced by wind and its technical complexity somewhat destabilizes central transmission system and limits the role of wind energy to a secondary source.

There is also a huge potential of solar energy i.e., about 100,000 MW in Pakistan. In Punjab, solar has been given due consideration; a solar power park being proposed with capacity of 1,000 MW at Bahawalpur district, while 100 MW has already been commissioned. Like wind, solar energy also needs high upfront cost but it can be offset by the absence of fuel cost to some extent. In a bid to meet fast growing electricity demand in Pakistan, all indigenous resources are to be utilized which require long term planning.

4.8 Sri Lanka

4.8.1 Power Sector Background

Sri Lanka is a developing country and its economy is growing at very high rate approximately 7% annually, correspondingly the demand of electricity is also increasing at an amazing rate. Ceylon Electricity Board (CEB) and eight independent power producers in Sri Lanka are responsible for generation of electricity by using hydropower and petroleum fuels. About fifty privately-owned renewable energy-based small power producers, mostly small hydropower are also involved in electricity business. CEB operates the high voltage (HV) transmission system and grid substations. Both CEB and Lanka Electricity Company (LECO) distribute electricity.

In order to meet the country's electricity demand, most of the power generation is through oil, hydropower and increasingly through coal. Preliminary electricity is generated by three sources, thermal power, hydro power and non-conventional renewable resources which are solar and wind. Sri Lanka is also looking for some alternatives for electric power generation, as thermal being much costly. It is also exploring new possibilities of utilizing renewable resources and enhancing LNG facilities. In addition, it is looking for cross border electrical trade with India to reduce dependability on oil base production. CEB has demonstrated its keenness to grow the generation pool to ensure that there is sufficient power as demand grows in its Long Term Generation Expansion Plan.

4.8.2 Sri Lanka Historical Power Development

Hydroelectricity is primarily the oldest way of generating electricity in Sri Lanka and is the only indigenous source utilized in appropriate size to produce electricity. Electricity was introduced in Sri Lanka in 1895 by M/s Baustead Brothers. Over 500 small hydro schemes exist in the country with first major project come into existence in 1950 with capacity of 25 MW. Now 10 major projects have been installed at four rivers Basins e.g. Kelani, Mahaweli, Kaluand Walawe. Seri Lanka has hydro potential of 2,000 MW out of which 1,580 MW has been tapped and a number of projects have been in pipe line to harness the 100% potential. At present, installed capacity is 3,932 MW, 42% being hydro generation and 58% is being generated by thermal and renewable sources. Hydroelectric power generation has been constantly under development since the introduction of the national grid, but its market share is currently declining because suitable new sites are scarce. Victoria Dam (210 MW) remains the largest among hydroelectric sources.

4.8.3 Installed Capacity and Energy Generated

Table 4.8.1: Sri Lanka installed capacity (MW) from 2010 to 2014 [2]

Source	2010	%	2011	%	2012	%	2013	%	2014	%
Hydro power	1,382	49	1,401	45	1,584	48	1,528	47	1,665	42
Thermal	1,390	49	1,690	54	1,638	49	1,635	50	2,115	54
Other renewables	45	2	50	1	90	3	99	3	152	4
Total Availability	**2,818**	**100**	**3,141**	**100**	**3,312**	**100**	**3,262**	**100**	**3,932**	**100**

Table 4.8.2: Sri Lanka Power Generation (GWh) from 2010 to 2014

Source	2010	%	2011	%	2012	%	2013	%	2014	%
Hydro Power	5,634	52	4,622	40	3,292	28	6,926	58	4,534	37
Thermal	4,995	47	6,785	59	8,339	71	4,772	40	7,508	61
Other renewables	86	1	121	1	169	1	262	2	315	2
Total Production	**10,715**	**100**	**11,528**	**100**	**11,801**	**100**	**11,960**	**100**	**12,357**	**100**

The generation mix of Sri Lanka surely needs optimization. Although more than 80% of the indigenous source of hydro generation has been achieved, however, the potential of wind and solar energy is available and to increase reliability, safety and security, the electricity generation from wind and solar is essential to improve induce diversity in the generation mix and improve control of the power network.

4.8.4 Sri Lanka Multiple Options for Generation Mix

- **Hydro**

Sri Lanka is endowed with natural potential of hydro power. The country's hydro potential has been assessed up to 2,000 MW, out of which 1,580 MW has already been tapped. Hydro energy has been providing low cost electricity to the country and has played major role in development since its first generation in 1950.

- **Wind**

Sri Lanka is a country where wind energy is available in substantial quantity. Three major regions have been identified North-West Coasted, Central Highlands and part of Sabaragamuwa and Uva provinces. It has been assessed that 6% of the total land area is suitable for wind power generation out of which 5,000 km^2 is good to excellence windy area. This windy area has potential of 20,000 MW installed capacity.

- **Solar**

Sri Lanka receives an abundant supply of solar radiation throughout the year as it is situated close to equator. As per National Renewable Energy Laboratory (NREL) research, the country has solar potential (solar radiation varies 4-4.5 $kwh/m^2/day$) over flat part of dry zone which account for two-third of land area. Thus substantial potential exists in dry zone. Taking into consideration land availability, solar exploitation has been estimated up to 6,000 MW.

Although in Sri Lanka, sustainable energy projects are working and providing clean and reliable supply. Hydropower, wind and solar power are playing vital role in country's generation mix but Sri Lanka cannot give up fossil-based fuels entirely due to increasing power demand and managing fuel diversity.

5.1 Case Study 1: Hydro Energy

While looking into the current generation mix of Pakistan, it is clear that share of electricity produced by each fuel type is not optimized in terms of cost and diversity. The progressive installed capacity (MW) indicating growth in generation mix from 2000 to 2015 is shown in Table 5.1.1. Sustained increase in thermal power is not coincident and cohesive with best industry practices and is creating worst scenario for control engineers at NPCC and power planners for scheduling existing power plants, associated substations and transmission network. First major type to be focused is the hydro power share in generation mix which requires due attention and planning systematic growth with increasing load demand.

Table 5.1.1: Progressive Installed Capacity Fuel Wise (MW) [14]

Fiscal Year	Hydro	%	Thermal	%	Wind	%	Nuclear	%	Solar	%	Total
2000	4,825	33.4	9,619	66.6	0	0	0	0	0	0	14,444
2001	5,039	32.4	10,170	65.5	0	0	325	2.1	0	0	15,534
2002	5,039	31.9	10,455	66.1	0	0	325	2.1	0	0	15,819
2003	5,039	31.9	10,455	66.1	0	0	325	2.1	0	0	15,819
2004	6,493	37.4	10,549	60.7	0	0	325	1.9	0	0	17,367
2005	6,493	37.3	10,577	60.8	0	0	325	1.9	0	0	17,395
2006	6,493	37.3	10,577	60.8	0	0	325	1.9	0	0	17,395
2007	6,474	36.9	10,727	61.2	0	0	325	1.9	0	0	17,526
2008	6,555	36.8	10,947	61.4	0	0	325	1.8	0	0	17,827
2009	6,555	36.4	11,142	61.8	0	0	325	1.8	0	0	18,022
2010	6,555	34.7	12,012	63.6	0	0	325	1.7	0	0	18,892
2011	6,627	31.6	13,709	65.3	0	0	650	3.1	0	0	20,986
2012	6,627	32.3	13,222	64.5	0	0	650	3.2	0	0	20,499
2013	6,928	33.2	13,222	63.4	50	0	650	3.1	0	0	20,850

Fiscal Year	Hydro	%	Thermal	%	Wind	%	Nuclear	%	Solar	%	Total
2014	7,097	32.1	14,251	64.5	106	0	650	2.9	0	0	22,104
2015	7,097	31.6	14,251	63.5	337	2	650	2.9	100	0	22,435

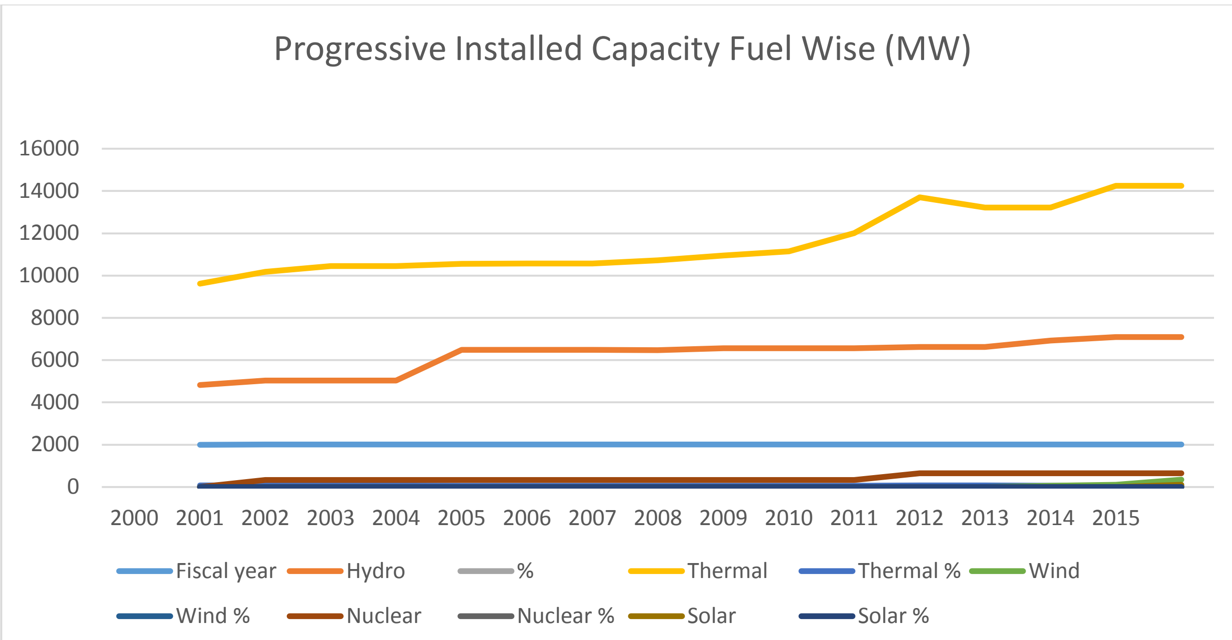

Figure 5.1.1: Progressive Installed Fuel Wise Capacity

Table 5.1.2: Progressive Energy Fuel Wise (GWh) [14]

Fiscal Year	Hydro	%	Thermal	%	Wind	%	Nuclear	%	Solar	%	Total
1980	8,718	71.9	3,406	28.1	0	0	0	0	0	0	12124
1981	9,046	68.5	4,160	31.5	0	0	0	0.0	0	0	13206
1982	9,526	64.5	5,242	35.5	0	0	0	0.0	0	0	14768
1983	11,366	68.9	5,126	31.1	0	0	0	0.0	0	0	16,492
1984	12,825	71.0	5,230	29.0	0	0	0	0.0	0	0	18,055

Fiscal Year	Hydro	%	Thermal	%	Wind	%	Nuclear	%	Solar	%	Total
1985	12,248	65.2	6,532	34.8	0	0	0	0.0	0	0	18,780
1986	13,807	65.6	7,251	34.4	0	0	0	0.0	0	0	21,058
1987	15,255	64.5	8,379	35.5	0	0	0	0.0	0	0	23,634
1988	16,694	60.8	10,762	39.2	0	0	0	0.0	0	0	27,456
1989	16,981	58.7	11,924	41.3	0	0	0	0.0	0	0	28,905
1990	19,930	57.9	14,502	42.1	0	0	0	0.0	0	0	34,432
1991	18,302	53.1	16,137	46.9	0	0	0	0.0	0	0	34,439
1992	18,652	49.0	19,419	51.0	0	0	0	0.0	0	0	38,071
1993	21,116	51.8	19,680	48.2	0	0	0	0.0	0	0	40,796
1994	19,441	45.9	22,960	54.1	0	0	0	0.0	0	0	42,401
1995	22,863	49.6	23,268	50.4	0	0	0	0.0	0	0	46,131
1996	23,210	47.5	25,653	52.5	0	0	0	0	0	0	48,863
1997	20,862	41.1	29,924	58.9	0	0	0	0.0	0	0	50,786
1998	22,064	41.4	31,199	58.6	0	0	0	0.0	0	0	53,263
1999	22,452	41.8	31,235	58.2	0	0	0	0.0	0	0	53,687
2000	19,288	34.5	36,575	65.5	0	0	10	0	0	0	55,873
2001	17,259	29.5	39,631	67.8	0	0	1565	2.7	0	0	58,455
2002	19,056	31.3	40,142	66.0	0	0	1662	2.7	0	0	60,860
2003	22,350	34.9	40,304	62.9	0	0	1386	2.2	0	0	64,040
2004	27,477	39.8	39,985	57.9	0	0	1559	2.3	0	0	69,094
2005	25,671	34.9	45,445	61.8	0	0	2,295	3.1	0	0	73,520

Fiscal Year	Hydro	%	Thermal	%	Wind	%	Nuclear	%	Solar	%	Total
2006	30,855	37.5	49,054	59.7	0	0	2,170	2.6	0	0	82,225
2007	31,942	36.4	53,780	61.2	0	0	1,944	2.2	0	0	87,837
2008	28,667	33.2	54,948	63.7	0	0	2,455	2.8	0	0	86,269
2009	28,183	33.4	54,909	65.1	0	0	1,057.5	1.3	0	0	84,377
2010	28,492	32.0	58,084	65.3	0	0	2,095	2.4	0	0	88,920
2011	31,990	35.3	55,386	61.1	0	0	2,930	3.2	0	0	90,575
2012	28,642	31.9	56,369	62.8	0	0	4,413	4.9	0	0	89,720
2013	30,033	34.0	54,221	61.4	5.5	0	3,640.5	4.1	0	0	88,275
2014	32,239	33.9	57,955	60.9	133.6	0	4,401.6	4.6	0	0	95,148

It is clear from the above data that in the beginning the country has produced hydro electrical energy in bulk with a share of 72% in the generation mix, which kept on decreasing with time and current share of hydro power in generation mix is just 33%, which is not so good and supportive in generation mix position for the country having enough indigenous water resource with a hydro potential of 60,000 MW against present installed capacity of around 7,000 MW. The role of hydro power in generation mix is very important not only because of tariff effective but from control point of view, it plays vital role because of its ramping rate which is very high and generation can be increased by hundred MWs in minutes as compared to thermal where ramping rate is very low 5 to 10 MW per minute and it becomes very difficult to meet balance in power system due to any sudden tripping of power plant or transmission line and thus the security safety and reliability of power system become risky and power system may face blackout. The current load demand and forecasted load demand up to 2022 is indicated.

Table 5.1.3: Historical Peak Load and Growth Rate [14]

Year	Computed Peak Load (MW)	Growth Rate (%)
2003-04	11,598	9.94
2004-05	12,595	14.38
2005-06	13,847	9.85

Year	Computed Peak Load (MW)	Growth Rate (%)
2006-07	15,838	2.61
2007-08	17,398	3.44
2008-09	17,852	0.29
2009-10	18,467	2.26
2010-11	18,521	-0.6
2011-12	18,940	9.29
2012-13	18,827	1.9
2013-14	20,576	5.34
2014-15	20,966	5.34
2015-16	22,085	5.34
2016-17	23,264	5.34
2017-18	24,506	5.34
2018-19	25,815	5.34
2019-20	27,196	5.34
2020-21	28,648	5.34
2021-22	30,177	5.34
Average Annual Growth Rate (%)		**5.34**

It is evident that power demand will rise to 30,177 MW in 2022 and the share of hydro energy must be at least 50% to facilitate control engineers over power system. Therefore, it is recommended that at least 25,000 MW of hydro power plants are to be added in generation mix up to 2022 to increase its share to 50% for safe, secure and stable power system. The hydro projects in pipeline are as listed below with capacity of 5,007.8 MW. These projects are required to be completed on fast track.

Table 5.1.4: Priority Hydro Projects of Pakistan [14]

Serial No.	Name of Project	Capacity (MW)
1	Kuran Tangi	83.4
2	Tarbela 4th Extension	1,410
3	Noulang Dam	4.4
4	Nelum Jehlum	996
5	Golan Gol	106
6	Mahl	590
7	Rajwani	132
8	Nekherdam Paur	80
9	Turtonus	58
10	Atmaqam	350
11	Sukiki Nari	840
12	Gul Pur	110
13	Patrind	148
14	Kotli	100
Total	**5,007.8 MW**	

Further to these, the long term projects like, Bungi, Dasu, Patan, Munda, Plas Valley, Spat ghah, Akori and Shyk dam are to be expedited and strictly followed so that at least additional 17,321 MW could be added to the system to achieve the target of 50% share in generation mix. This will not only help to optimize the generation mix, improve control over power sector and strengthen economy of Pakistan.

5.2 Case Study 2: Coal Energy

Another cheaper source for producing electrical energy is Coal while in Pakistan's generation mix, Coal energy is the missing link. Practically, it has no share in current generation mix. Only one plant of 300 MW was established at Lakhra in early 80s, however, now its capacity has been reduced to 35 MW. The electricity produced by coal in world generation mix is approximately 41%, while China, India, UK and USA are producing 76%, 60%, 40% and 39% of their electricity by coal respectively. Coal is indigenous source of fuel available for Pakistan, however, benefit of this black gold is not reflecting to economy and requires immediate attention. At least 20% share of coal energy is required to gain optimal generation mix so that security, safety and reliability of power system are improved. Pakistan has proven reserves of 185.175 billion tons of indigenous coal and it is ranked as the world's 6th largest. Pakistan can produce 50,000 MW of electricity by coal. Recently, a number of projects have been announced by the government, however, Pakistan will required 6,000 MW of coal energy by 2022 and this requires pre-planning and due attention. Induction of coal energy will not only facilitate the power control but cost of electrical energy will also be reduced and thus electricity tariff will be positively affected resulting in overall economic growth of the country.

5.3 Case Study 3: Wind and Solar Energy

Pakistan is rich in renewable energy resource mainly wind and solar. Pakistan has a potential of 100,000 MW from solar and 50,000 MW from wind, however, these have sizable effect and technical limitation while Grid Code of Pakistan capped these energies up to 5%. At present the share of wind and solar energies are nominal, only 250 MW for wind and 100 MW Solar plants are active which are producing less than 1% electricity in generation mix of Pakistan. The number of projects for wind and solar have been approved by PPIB and are under execution stage. With the completion of these projects, share of these renewables may increase to 2% in the generation mix of Pakistan, however as per load growth 3,000 MW more energy will have to be planned and added to the power system to gain diversity and stable power system. Although at present heavy investment is involved in establishing wind and solar power plants and present energy cost may affect the end user tariff, however due to no fuel cost and being environment friendly, energy produce by these sources are preferred option. While with the improvement in technique and technology the cost and intermittent effect may be mitigated. The diversified effect of renewable component in the total generation mix play vital role in controlling the power system.

5.4 Case Study 4: Thermal Energy

The electricity generated by thermal power plants is very important as these work as base load plants and are necessary for power system like Pakistan during winter and dry seasons when flow of water drops down to a very low level and hydro energy is at off peak position, thermal energy play a vital role despite of the fact having low ramping rate, bad environmental affect, yet mandatory for a power system like Pakistan. Thermal energy is the most expensive and polluted energy and efficiency of furnace oil based power plants is also very low. WAPDA's thermal plants are operating with very low efficiency; some plants are operating at 27% efficiency. The share of thermal energy in generation mix of Pakistan is highly unbalance due to shortage of electrical energy and sudden change of power policy in 1994 to erect thermal power plants operating on furnace oil to meet energy shortage, however, the unprecedented hike in oil prices from 2007 to 2012 did disturb the import bill of Pakistan and energy prices increased abnormally despite of subsidy provided by Government in electricity tariff, resulted in circular debt of billions of rupees. However, prevailing low oil prices have provided Pakistan with an opportunity to stable the power sector. At present, thermal energy share in Pakistan's generation mix is 56% which is abnormally high as compared to any other country. Pakistan will have to control the thermal share of energy in its total generation mix thus having control over circular debt and diversify its generation mix as per best industry practices for the survival of power sector.

Chapter 6 Power System Automation

6.1 General

In view of the ever growing demand of electricity and at the same time having various constraints in enhancing the power generation capacity, it is imperative to increase the overall efficiency of the power system. This need has motivated the concept of smart grid. A smart grid is the next generation power system that involves modern technology, smart processes and effective, 2-way communication across all the functions of power system; the overall objective of the smart grid is to deliver energy saving, cost reduction and increase reliability, along with security by enabling new strategies to manage power system. The SAARC Member States are also required to adapt latest developments achieved in smart grid technology. State of the art Supervisory Control and Data Acquisition (SCADA) and Energy Management System (EMS) are fundamental tools of a smart grid with respect to power system control function. These not only facilitate enhanced control over power system but will also increase the efficiency by optimizing the existing power network elements to get maximum benefit in term of time reduction in system black out, power outages, prior fault diagnoses and improve the power system reliability, security, safety and dependability. The power system control centers of all SAARC Members States must be provided a Load Dispatch System based on the state-of-the-art technology so that:

a. Power system control and monitoring can be performed more efficiently.
b. Timely operation decisions are taken to minimize outages and losses.
c. Power system stability, security, safety and reliability are enhanced.

The SCADA and EMS system provided for SMS should have at least but not limited to the following automatic options with proven track of capability to fulfil the requirement of a modern Load Dispatch Centre for power transmission network as well as the power plants for supervision and control by power control engineers. In this section, minimum requirements and features of the automation options are recommended for adaption by the SAARC Member States.

6.2 Basic Software Requirement

Basic features for SCADA/EMS software should be modular to facilitate future system amendment and extension. The user interface should be consistent for different modules and software should be able to work in the distributed computing environment. The SCADA/EMS should support Electric Power Research Institute (EPRI) common information model (CIM) and Control Center Application Programming interface (CCAPI) initiatives.

6.3 Energy Management Software Function

The selection of the software modules for EMS for providing the necessary energy management and scheduling functions should consider the present situation and future evolution of electrical energy market. Although market based electrical energy trading might be hypothetical to a certain degree but it should not be assumed that the present situation would remain unchanged.

Following functions are recommended to be included in the overall system:

a. SCADA Functions
b. Energy management (EM) functions
c. Study mode functions
d. Network application (NA) functions (network oriented EMS functions)
e. Supervisory Control Functions
f. Load Shedding Functions

Chapter 7 The Way Forward and Recommendations

1. Power generation mix of each of the SAARC Member States is high to moderately unbalanced; Member States are required to reconsider the share of each of their generation sources to transform their generation mix with diversified energy pattern, improve energy efficiency in terms of electricity tariff and security of supply.

2. In South Asia, electricity is produced by using different fuels available indigenously or otherwise imported. Each type of fuel used to generate electricity has its own merit and demerits, with certain limitations. The presence or absence of electricity produced by any type of fuel signifies certain pros and cons. Missing of power generation produced by any fuel type may not only unsecure the power network but may also disturb cost and affordability of electricity, which will affect the economy and GDP of the country.

3. South Asian Reign is indigenously rich with all kind of energy sources with abundant quantity, more than sufficient to meet the electricity requirement of the region. In view of the best industry practices, electricity produced in SAARC Member State need to be diversified with respect to fuel type. Electrical energy generated by each type of fuel plays vital role in shaping the generation mix, without balancing these, country’s power system will be at risk and unsecure.

   Focusing on the benefits of renewable energy, if total electrical energy is produced by wind power, available in most of the Member States in bulk quantity, the result will be totally black out whenever wind intensity goes out. Similarly solar energy has the drawback of zero production at night and no storage device can be arranged at reasonable cost to cater the country’s night load demand.

   Hydro power has the merit of easily control, having high ramping rate and peaking capability to facilitate the power control function. Being cheap, it also reduces the electrical energy tariff; however its generation is directly dependent on water flow and is subject to seasonal variations. Dry season can create reverse energy pattern.

   Generating electrical energy by nuclear technology is no doubt cheap, ensuring confirmed power available but it is dangerous, hazardous and risky. Waste of residual fuel requires special disposal processes.

   Electricity produced by coal large in quantum, less in terms of cost but is associated with pollution and greenhouse effect; thus limiting the share of coal power to a certain extent. Electrical energy production by gas is also suitable and cheap addition in generation mix but availability of gas remains an issue to ponder on.

   Electricity generation from oil is expensive and also pollutes the atmosphere, however, an oil power plant works as base load plant and also helps to stabilize the power system especially during peak load hours and emergency.

Other means used for generating electricity are less common e.g. biomass, municipal waste, geothermal and tidal have less contribution in generation mix scenario, therefore, there is no restriction on the production of electricity from these resources.

4. While focusing on individual Member States, Afghanistan needs to reduce its reliance on import of power for optimizing its generation mix. For this purpose, options such as hydro, gas, coal, solar, wind are required to be undertaken for electricity generation. Bangladesh case is quite different than other Member States. Due to lack of indigenous resources, Bangladesh has been forced to opt for import of power from India. Hefty investments in hydro power in Bhutan are also on the way. Power import, up to a certain limit, will help Bangladesh in optimizing its generation mix. In Bhutan, electricity is surplus against the country's own demand during summers and excess is exported to India while in winters electricity has to be imported to balance the load. India to some extent has balanced generation mix, however, there is space for improvement; solar and wind should preferably have a contribution of 5% each in generation mix. Maldives power production is on oil and it is an electricity deficient county. Nepal is a hydro dependent country. Coal power remains the missing link in Pakistan generation mix. Sri Lanka needs optimization potentially through addition of electrical power from coal and renewable resources.

5. Considering the best industry practices, hydro power playing a vital role, in the perspective of system stability, security and reliability, must be at least 35% of the total generation mix (depending on the available resources). Coal can produce cheap energy and also plays important role but its share should be restricted up to 25% due to adverse impacts on natural environment. Electricity produce by gas is very clean and helpful addition in generation mix from control and security point of view. Its share should be around 20% in generation mix for proper diversification of energy. Other means for production of electricity including biomass, waste, geothermal and tidal energy should be up to 3% of the total generation mix. 5% share from nuclear generation in generation mix is the requirement of a modern power system.

6. Smart grid technology is the modern way to control power networks that combines the power sector functions through two way communication with power control center to optimize the power generation, transportation and distribution of electrical energy and hence fetches energy saving, cost reduction and, increased reliability and security by enabling new strategies to manage the power system. SAARC Member States should adopt smart grid technology to optimize the utilization of available resources and increase the efficiency of existing facilities.

7. It has been noticed during the course of this study that SAARC Member States lack black start generation facilities which are highly critical for control engineers; in case of black out, a black start plant not only reduces restoration time but also enhances the safety of supply. SEC may investigate the situation by launching a short term study to identify the available black start power plants viz-a-viz regulatory obligations as defined in the relevant grid code besides highlighting the importance of black start plants.

8. Efficiency of power houses in South Asia have been noticed quite poor as compared to international standards, which is attributed to various reasons including machine manufacturing standards, aging of machines, fuel quality, obsolete/lack of compliance of operating and maintenance processes, etc. Special attention is required to enhance efficiency of the machines as this will increase power factor, load factor and overall power system efficiency to meet higher demand without installing additional capacity.
9. Demand side load management caries vital importance; energy efficient processes and devices can result in reduction of power demand significantly. SAARC Member States are required to revamp their policies on demand side management since it will also complement the diversity of the generation types.
10. System automation for the function of power control with minimum facilities as stated in Chapter 6 ‘Power System Automation’ of this report is recommended to be implemented for all the Member States. Though Bhutan, India and Pakistan already have the modern SCADA system, however, its application/provision is limited to transmission network while distribution function is usually manual. Complete automation will certainly help the utilities in ensuring the power system secure and reliable.

References

[1] [Online]. Available: http://www.planete-energies.com/en/medias/close/about-energy-mix.

[2] [Online]. Available: http://www.tsp-data-portal.org/Breakdown-of-Electricity-Generation-by-Energy-Source#tspQvChart.

[3] [Online]. Available: https://www.usaid.gov/news-information/frontlines/energy-infrastructure/powering-afghanistan.

[4] [Online]. Available: http://rta.org.af/en/index.php/economic/662-afghanistan-has-potential-to-generate-314,500-mw-electricity-minister.

[5] [Online]. Available: https://energypedia.info/wiki/Bangladesh_Energy_Situation.

[6] [Online]. Available: https://www.desco.org.bd/index.php?page=load-shedding.

[7] [Online]. Available: http://www.bpdb.gov.bd/bpdb/index.php?option=com_content&view=article&id=5&Itemid=6.

[8] [Online]. Available: http://bhutanobserver.bt/2637-bo-news-about-looking_beyond_hydropower.aspx.

[9] [Online]. Available: http://bhutanobserver.bt/708-bo-news-about-bpcls_first_small_hydropower_plant.aspx.

[10] [Online]. Available: http://www.cea.nic.in/reports/monthly/installedcapacity/2015/installed_capacity-11.pdf.

[11] [Online]. Available: http://www.indiaenvironmentportal.org.in/files/file/growth_2015.pdf.

[12] [Online]. Available: https://en.wikipedia.org/wiki/Electricity_sector_in_India#Installed_capacity.

[13] [Online]. Available: http://www.tradingeconomics.com/pakistan/gdp-growth.

[14] P. N. T. a. D. Company. [Online]. Available: http://www.ppib.gov.pk/Power%20System%20Statistics%202013-14.pdf.

[15] [Online]. Available: http://aaj.tv/2015/03/pakistan-has-hydropower-potential-to-generate-60000-mw-electricity-asif/.

[16] "National Power Expansion Plan 2011-2030 Final Report".

[17] [Online]. Available: http://www.shamrockconferences.net/og2013/presentations/ShahzadIqbal.pdf.

[18] S. Iqbal, "http://www.shamrockconferences.net/og2013/presentations/ShahzadIqbal.pdf".

List of Abbreviations

DABS	Da Afghanistan Breshna Sherkat
DCC	Distribution Control Center
DFO	Diesel Fuel Oil
DISCOS	Distribution Companies
GDP	Gross National Product
GENCOs	Generation Companies
GW	Giga Watt
GWh	Giga Watt Hour
IDC	Island Development Committee
IPPs	Independent Power Producer
IRENA	International renewable Energy Agency
MW	Mega Watt
MWH	Mega Watt Hour
NEEPCO	North Eastern Electric Power Corporation
NEPS	North East Power System
NGOs	Non-Government Organizations
NHPC	Hydro Electric Power Company
NJTC	Nathpa Jhakri Power Corporation
NLDC	National Load Dispatch Center
NPCC	National Power Control Center (Pakistan)
NPTC	National Power Transmission Corporation
NTDC	National Transmission and Dispatch Company (Pakistan)
NTPC	National Thermal Power Corporation
PV	Photovoltaic (Cell)
RCC	Regional Power Control Center
RLDC	Regional Load Dispatch Center
SCADA	Supervisory Control and Data Acquisition
SEPS	South Electrical Power System

SHS	Solar Home System
SLDC	State Load Dispatch Venter
SMS	SAARC Member States
THDC	Tehri Hydro Development Corporation
WAPDA	Water and Power Development Authority (Pakistan)

List of Data Tables

List of Figures