Cost Analysis and Implementation of Smart Grid in Pakistan

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Abstract: In Pakistan the transmission system has capacity of 22,000MW and demand is 25,000MW, it means our present transmission system cannot bear more energy production. The renewable energy sources of Pakistan have the potential to generate the energy more than the demand. Renewable energy sources of Pakistan are hydropower, wind, solar and biomass. Also under the project of CPEC electricity of 10,400 MW will be added in the country. Rising population of Pakistan is increasing the demands of diapers; the recycling of waste diapers will produce 5000kcal/yr, energy which is useful for both industrial and domestic sectors. Main two problems of implementation of smart grids are cost and management. OELC method is used for calculating loads and costs; also OELC scheme proposes the solution to control the cost problems. Cost benefit analysis (CBA) give complete picture of investments and benefits. Case study with Pakistan's potential for renewable sources is discussed. There is cost to benefit ratio of 1.9 for Pakistan, so this is cost effective process. As there are three main parts of electricity system (generation, distribution, billing), the smart planning at these parts will manage the whole system. Pakistan is at its initial level of implementation of smart grid so with the proper planning and mutual collaboration of departments will make Pakistan an energy abundant country.

Keywords: *CPEC, smart grids, renewable energy, OELC, CBA*

I. 1. Introduction

Demand of electricity for Pakistan is 25,000MW, but its supply and transmission is 22,000 MW for both sectors i.e., residential and industrial. It means if more electricity is produced in some way, the system of transmission will not be able to resist it beyond 22,000 MW [1]. The system of supply and transmission of electricity in Pakistan is one of the impoverished in the world. Due to ineffective power supply system in the Pakistan 35 to 40 billion per year are being lost. The present grids are unable to bear the loads and also don't affiliate the DRES (distributed renewable energy sources). Constructing the more substations and lines will not cover the shortfall of energy. So to fulfill the demands of electricity there is need of reconstruction of electricity's structure. By converting present system of power management into smart grid system will increase generation of renewable energy [2].

Renewable energy can eliminate the energy crisis of Pakistan as it has potential. The abundant sources of renewable energy like biomass, solar, wind and hydra have the potential to generate the environmental friendly energy in the Pakistan. This means there are many opportunities for smart grid in Pakistan to overcome the crisis [3]

Actually smart grid technologies are used to fix the gap problems in between the demand and supply by reducing the losses and automating the supply and transmission of power. This is also important as under the project of (CPEC) $15.5 billion worth of projects like coal, solar, wind and hydropower will add the energy of 10,400 MW in the national grid. The main issue lies in the management and up gradation of supply and transmission. Metering is also a problem. Smart grid technologies can resolve these problems [4].

II. Background

Although Pakistan is rich in renewable sources, but from past 19 years Pakistan is facing many problems of power sector due to inefficient use of available sources and the demand of energy is rising on daily basis. In the year 2010-2011 there was an increase in hydro-electricity of 14.4% and the decrease in thermal by 2.4% and the consumption of electricity increased by 4.9% as shown in the fig-1 and fig-2. And in the fig-3 hide stations of power are given. [5] [6] [7].

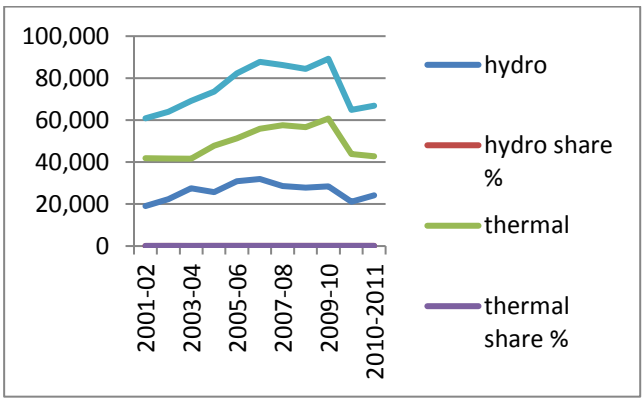

Figure 1. IPPs and imports are included in total generation

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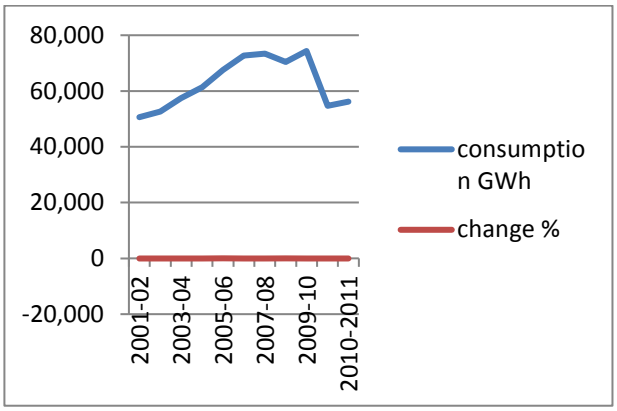

Figure 2 increase in hydro and decrease in thermal

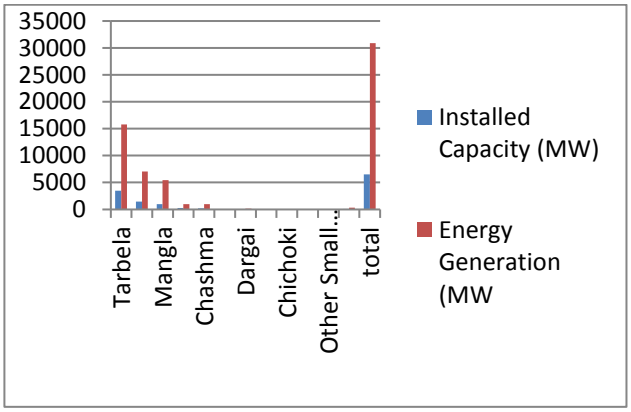

Figure 3 increase in consumption of electricity

Above discussion shows that WAPDA and KESC have been hosted by incapability, bad governance, bureaucracy, and interference of politics since their founding. The amount of transmission and supply losses were 30-40 %. This was due to low investment in the field of transmission as power robbed by groups and individuals.

In the result of this ineffectiveness, governments of that times added important subsidies into them to maintain the end user tariff viable for minimizing political damage. For preventing these problems, and motivated by donors like WB, now Pakistan is willing to start new energy projects with use of available renewable source.

I. Renewable Energy in Pakistan

The aim of Pakistan is to achieve 5-6% of its energy from the renewable sources (eliminating the hydropower) by the 2030. An overview of renewable energy in Pakistan is given below in table 1A [8].

Table A: Potential of Renewable sources in Pakistan	
Wind energy	In the region of southern Sindh and Baluchistan, the wind speed is 5-7 m/s. For energy of wind the potential capacity is 122.6 GW/yr., which is twice the current country's power generation level.
Solar PV	The estimated solar potential is 100,000 MW.
Biomass	Pakistan has world's largest irrigation system. Availability of biomass is approximately: • Solid waste 50,000 tones • Crops residue 225,000 tones • Animal manure 1 M tones
Hydropower	It has been proved the cheapest source of electricity.

A. *Diaper biomass fuel (New Idea)*

Recycling of waste diapers will produce biomass fuel. It takes 500 years to fully decompose the waste diapers, also this waste adding environmental pollution day by day, if recycling of waste is done by cutting, shredding, size reduction and pelleting then amount of energy will be **5000kcal/kg**. This energy can be used for both industrial and domestic sectors [9].

B. *Main challenges to smart grid*

Basically the smart grid is broad, interlinked systems, with latest equipment's and implementations, so this technology requires complete investigations about circumstances before its practical. Some main challenges for Pakistan are:

- Smart grid is expensive technology
- Management

II. How to Reduce Cost

The mechanism of OELC is proposed by the researchers for optimizing the cost and load of electricity. In this method in the peak duration of the day the demand of the electricity is directed by keeping several electricity suppliers in the strategy, encompassing domestic mini grid also adjoining mini micro grids of smart homes. For decreasing the price of electricity for the end consumers, collection of bids is done from several ways of electricity against pending programming language of each user. For managing the demands, priority is given to lower cost resources then come expensive sources. With the help of analysis of simulation, comparison of OELC with two more system is done; pricing of dynamic load shifting and system having no OELC [10].

A. *Method of OELC:*

There are six steps of OELC method.

1. Algorithm of weighted average prediction is used for calculating the demand of electricity for users [11].
2. OELC-1 will calculate the price to manage from domestic mini micro-grid
3. A cluster is made by gathering the smart homes
4. In every smart home all the OELC-1 are controlled by the centered OELC-2
5. All three above calculated costs will be compared by the OELC-2

6. In the last step the bill of each consumer of the electricity is calculated [12].

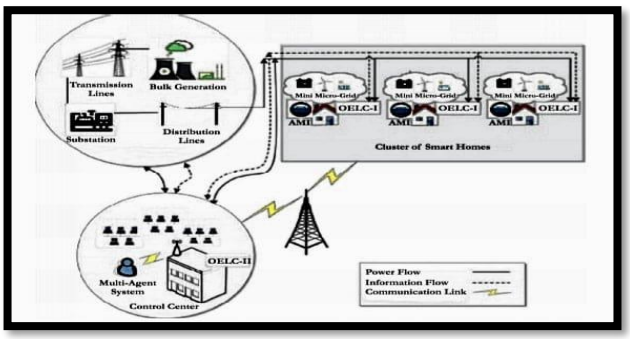

Figure 4 OELC scheme

A. *Results*

Above steps proposed the scheme for reducing the cost. For results of Simulation and OELC performance on the above steps, following assumptions were made:

- Energy requirement for all home users is slightly different from one another.
- Time slots of 24hrs were considered for whole simulation.
- Electricity cost is greater at the day start and in the evening time

I. CBA (COST BENEFIT ANALYSIS)

CBA gives a complete picture of investments and the results of these investments. It is simple and rigorous analysis. It helps in taking evidence based decisions. Methods and assumptions are transparent. It has flexibility for sensitive inputs; we can change inputs for knowing the different results. Economic effectiveness is calculated by the NPV method.

II. DEFINING PROJECT

III. FUNCTION TECHNOLOGIES MAPPING

IV. FUNCTIONS TO ADVANTAGES MAPPING

V. ADVANTAGES MONETIZING

VI. COSTS QUANTIFYING

VII. COMPARISON OF COSTS AND ADVANTAGES

VIII. SENSITIVE ANALYSIS[13].

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A. *Case study:*

The demand of electricity for Pakistan will grow 55GW to 60 GW till 2040. And aim of Pakistan is to achieve 5-6% from renewable sources till 2040 (wind and solar PV). In this case study we will discuss cost and benefits of upgrading the PV and wind system. We assume goal of 6% renewable energy will not change. The CBA gives importance to modern grid features. It supposes an up gradation of PV and wind with smart inverter. These inverters give grid friendly features. It will roll out with renewable sources for achieving the 6% renewable energy target, supposing the project roll out time 15 years.

I. DEFINING PROJECT

For Pakistan smart grid project is hypothetical based power system and our intent is to given an example of every step instead of complete CBA.

A. *Benefits Cost = project cost of SG + cost of enabled renewables*

Benefits = project benefits of SG + benefits of enabled renewables [14].

Table B: Benefit values

Advantages	**NPV**	**Level of uncertainty**	**Primary inheritor**
Reduced service cost of ancillary	6,240	Medium	Utility
Investments of deferred distribution	3300	Medium	Utility
Reduction in equipment failures	8	Medium	Utility
Reduction in cost of distribution operations	0	Low	Utility
Reduction in electricity losses	17000	Medium	Utility
Reduction in electricity cost	0	Low	Customers
Reduction in sustained outages	29000	H	Customers
Reduction in major outages	0	H	Customers
Reduction in cost of restoration	70	H	Utility
Reduction in momentary outages	0	L	Customers
Reduction in sags and swells	0	M	Customers
Reduction in emission of co2	9600	M	Society
Reduction in Sox, Knox and PM10 emission	1100	M	Society
Reduction in blackouts	0	H	Society

1) *Discussion*

The values of profits are USD 95M and the cost value is USD 48M. The values of benefits are greater than costs so the system will be called cost-effective. In the table 1A, in the NPV benefits the largest components are reduced sustained outages and reduced losses of electricity [15].

Table C: Cost values

Cost	NPV(thousand)	Level of uncertainty	Primary beneficiary
Latest PV inverters	3300	L	Owners of PV and utilities
Latest wind turbines	1500	M	Owners of wind turbines and utilities

A. *Smart controls:*

Wind turbines and PV inverters are upgraded with smart advanced grid.

B. *Map technology:*

In the first column all objectives are provided. Checkmarks are indications of objectives of that technology.

C. *Baselines of the study:*

Renewable energy benefits are predefined; we are comparing them with conventional system having no predefined objectives and benefits

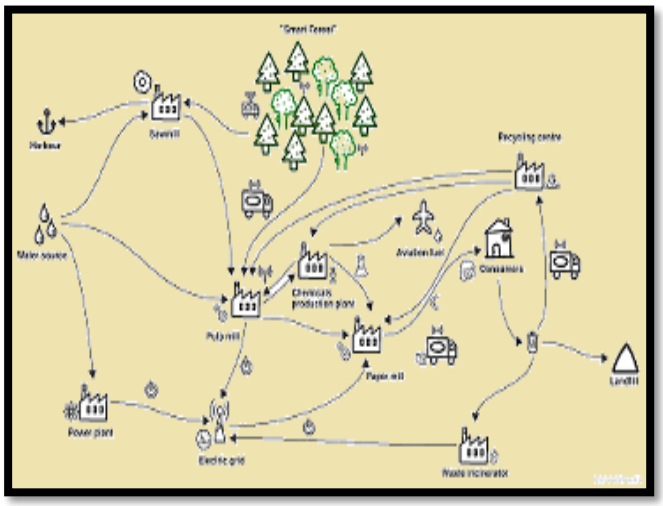

Figure 5 : Smart grid system

Table D: Map technologies to objectives

Objectives	Technology of PV inverters	Technology of wind turbines
Limitation of fault current		
Monitoring and visualization of wide area	✓	✓
Rating of dynamic capability		
Flow controlling	✓	✓
Adapt protecting		
Auto switching of feeder		
Auto control of voltage and VAR	✓	✓
Inspection		
Increased protection		
Management		
Transferring of load		
Optimization of use of customers electricity		

A. *Map objectives to advantages*

As predefined renewable approach is used for Pakistan's case study, so benefits of solar and wind power are not applicable in CBA. That's why these are not discussed in the following table.

Table E: Map objectives to benefits

Advantages	Objective: Monitoring and visualization of wide area	Objective: Flow controlling	Objective: Auto control of voltage and VAR
Optimization of generator operation			
Reduction in investment			

of generators capacity			
Reduced service cost of ancillary	✓		
Reduction in cost of congestion			
Investments of deferred transmission			
Investments of deferred distribution	✓	✓	✓
Reduction in equipment failures		✓	✓
Reduction in equipment cost of maintenance			
Reduction in distribution cost of operation		✓	✓
Reduction in cost of meter reading			
Reduction of electricity theft			
Reduction in losses of electricity		✓	
Reduction in cost of electricity		✓	
Reduction in sustained outages		✓	
Reduction in major outages	✓	✓	
Reduction in momentary outages	✓		
Reduction in sags and swells			✓
Reduction in emission of co2			✓
Reduction in Sox, Knox and PM10 emission			✓
Reduction in cost of fuels			
Reduction in blackouts of wide scale	✓	✓	
Wind generation enabling	NA	NA	NA
solar generation enabling	NA	NA	NA

A. *Uncertainty level categories*

Table F: Uncertainties

Uncertainty level	**description**
L	It has 80% probability for the actual value to be within the ± 20% of the estimates
H	It has 80% probability for the actual value to be within the ± 40% of the estimates
M	In this category estimates are difficult to calculate. With the level of 95% confidence, the level of precision is viewed at ± 100%.
Not possible to quantify	In this category advantages are so uncertain that they can only be shown as magnitude-estimates. [16].

II. MONETIZED OBJECTIVES

Table 1-A shows supposed values for the case study of Pakistan and 2-D shows all the estimated uncertainty levels. We have supposed many assumptions for monetizing input values. A full CBA has been shown which gives monetized advantages. One of the examples is, we have used PV inverter with the control of volt-VAR which will ignore the 200 switch capacitors.

All the benefits in the 1st year will give zero advantage. Advantages will increase gradually with more installations and in the 15 years we will get maximum values. Sustained outages are biggest advantages with USD, but it is also noted that it has high uncertainty level. Second largest benefit is electrical losses.

III. QUALITATIVE ADVANTAGES

These advantages include the training and experiences of utility workers. These skills will be transferred to future projects of smart grids.

IV. QUANTITATIVE ADVANTAGES

- Gives an idea of following costs
- Initial cost
- Implementation cost
- Operational cost
- Qualitative cost

V. COMPARISON OF ADVANTAGES AND COSTS

In our case study we have found 8 non-zero benefits as shown in table A.

Table G: NPV of Cost

Cost	NPV(M USD)
Latest inverters of PV	-33
Latest inverters of wind turbines	-15
total	-48

Note: as these are costs, values are negative.

Net benefits (95-48.0) = USD 47M. The ratio of benefits to cost is (95/47) = 1.9. So the project is cost effective.

I. SENSITIVE ANALYSIS

By changing the value in outage reduction from USD 3/kwh to .10/kwh the value of NPV will be USD 28M to –USD 2M.

Table H: Comparison in perspective of society and utility [17].

Perspective	Reduced outage Assumed value	Reduced outage NPV	Final NPV
Societal	USD 3/kwh	USD 28 M	USD 25M
Utility	.10/kwh	USD 1 M	-2M
Total			-38M

I. SMART GRID MODEL:

For the development of smart grid, it is mandatory to add power system integration along with the technology of the telecommunication and a sensor system [18]. Required equipment's of smart grid are given below:

Sensors	Computers	Smart grids having communications	Control devices

The structure of communication authorized the passaging of information in between all the parts of power system (fig-2) in between single computers and centre computers, and in between consumers and sellers.

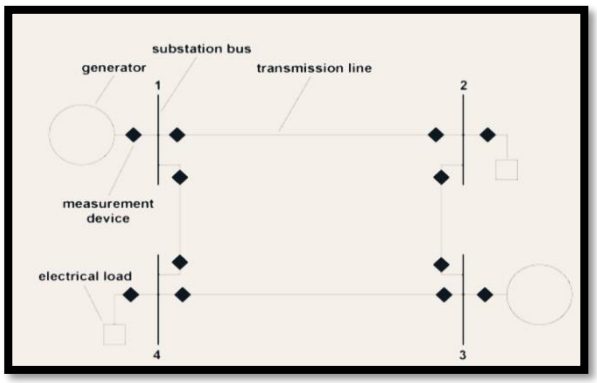

Figure 6 : Smart grid system

The structure of communication authorized the passaging of information in between all the parts of power system (fig-2) between single computers and center computers, and in between consumers and sellers.

Figure 7 (Bruce F. Wallenberg, Massed Amin.)

Three main parts of electricity supply system are:

- Power generation
- Distribution
- Power Billing
- Generation:

Addition of latest power plants in the grid is requirement of the time. But there should be cooperation in between the new plants and in the existing plants. Fortunately Pakistan has resources of wind and solar energy. Area of Tharp Desert and Sindh is suitable for wind energy. Enhanced operations of grid will result in lower cost of power sources and throughput will be increased by effective overflow in the power lines. This enlarged power capacity lowers the overcrowding which alternatively lowers the cost of generation for users. This milestone known as AAM (advanced asset management) [19]. It works with resources at their equipped level and manages their life cycles by

interconnecting systems with automated based sensor. Greater competent routing of discrete power units is allowed by smart grids, with lesser non-functional or dissipated generators. In overall, smart grids lower the generations and minimize the expenditures.

A. ***Transmission:***

ATO (advanced transmission operations) [20] will be provided by the smart grid technology, the objective of ATO is to manage the reliability and efficiency also to control the clogging. ATO consists on the automation of substation, super safety and managing of the grid and with the approach of up gradation integration of all above mentioned tools. Flexible devices of the AC transmission control are modern system that can change the direction of flow in the transmission lines [21].

B. ***Distribution:***

For distribution automated approach is used which helps in inspecting the loads that need to be close. Power systems of recent times are managed by the humans, helped by the systems of advanced computers; it will trigger the signals of distribution system and start the switching with slight time gap. This is significant in the emergency conditions. Execution of loads on the basis of selectivity can also be done by smart grid [22].

C. ***Consumer level***

Nowadays majority of consumers get information through their bills, this information is usually delivered after the days when decision has been taken, whether to on the equipment at lower or higher level. But smart metering gives its consumers information about recent tariffs, usage of electricity, and expenditures. And these are automated meters [23].

D. Conclusion:

The reality is implementation of smart grid in Pakistan needs broad planning as it is not project of one time and broad vision shows that it's a promise of long term. If we look at the present system there are many power-hungry digital systems that are rising, so there is need of improved structure of present energy system for longer energy stability. Studies also show that power grid transformation in the next 20 years will increase the GDP growth and will reduce emissions of carbon.

Many countries in the world are engaging in the grid technology. But for Pakistan the implementation is in its initial stages so it requires a broad planning. With the proper planning and mutual collaboration of departments will make Pakistan an energy abundant country.

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