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Modeling of Existing and Candidate Hydro Power Plants Generation Expansion Planning using Wien Automatic System Planning-IV Model

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ABSTRACT

This paper follows comprehensive methodology for overcoming energy crisis in Pakistan. Pakistan's existing and candidate hydro power plants potential is taken into account for Power Generation Expansion Planning. The modeling of hydro power plants is carried out in a more significant way for long term expansion time 2013-2035. Several energy parameters are understood by cogent and impeccable correlation between Loss of Load Probability, Forced Outages and Energy Not Served Costs etc. Moreover, the simulated results obtained from the above modeling procedure were evaluated with a help of characteristics of hydropower plants. Characteristics of hydro power plants include forecasted inflow of energy, storage capacity, average minimum generation, operation and maintenance costs etc. The hydro power plants model achieves the objective function of least cost plan using WASP-IV. It adopts linear programming, dynamic programming and regression analysis techniques to find objective function. Furthermore, Capacity Generation Mix Supply is prepared for the projected demand of energy. The research is characterized as flexible, generalized and more significant as compared to other system models.

KEYWORDS: Forced Outage, Reserve Margins, Loss of Load Probability (LOLP), Energy Not Served Costs and Capacity Generation Mix Supply.

INTRODUCTION

To overcome Energy requirement is the most vital task for eliminating great number of predicaments. There are many energy resources such like conventional and non conventional. The conventional energy sources are fossil fuel that couldn't be replenished. The non-conventional energy is renewable source energy. Hydro can be taken as a non-conventional energy source. Pakistan's existing power sector has 21103 MW of installed capacity in 2012. Hydro power plants installed capacity is 6,654 MW. Hydro power plants have a capacity up-to 100000 Mega Watt in Pakistan. Although there are many energy resources but Hydro power remains unique amongst all the energy resources. It has limited bottlenecks compared to other environmental polluting resources. Hydro power is considered green energy resource sustaining the marine life, agriculture sector and clean water storage.

As there are numerous methodologies adopted to perform Power Generation Expansion [1]. It is done so due to the shortage of electricity demand and substantial increase in the population. There is a need to install new power plants to overcome the energy demand. Our cynosure in this research paper is the hydro power plants. The paper comprises the modeling techniques using WASP-IV model for Power Generation Expansion Planning (PGEP) [2]. Several characteristics are modeled for hydro power plants that are required following some necessary calculations. After achieving desired modeled results, they are given to WASP-IV model modules. It follows the dynamic and linear programming techniques to generate many optimized number of configurations which prepares least cost expansion plan along with other energy parameters.

This paper is divided into four sections. First section gives the proposed structure of research methodology using WASP-IV model. Second section consists of energy parameters modeling along with existing and candidate hydro power plants. Third and fourth section provides simulated results, in depth analysis and conclusion along with the future prospects.

Related Work

Several models are applied [3 and 4], but each model has its own limitation regarding its expansion time, cost and expansion plants etc. Further, it finds the most significant least cost generation expansion for the given time period of 2013-2035. So here we develop models that match the energy demand projections with generation mix supply with focus on hydro power plants, for the years 2013-2035. Our research modeling of hydro power plants

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focuses on the existing hydro power plants as well as candidate hydro power plants (to be added in the future expansion generation). These primitive models have certain limitations with respect to their time and energy parameters sensitivity analysis that are based on optimization techniques.

Motivation

The modeling of existing and candidate hydro power plants for Pakistan is of paramount significance. In Pakistan, there is a lot of hydro potential. It is considered to be green energy resource. If it is utilized to the fullest, Pakistan can revive its economic conditions sufficiently. Moreover, it will help to diminish our problems linked to the certain economic parameters. So the contribution of cost effective Hydro Power Plants to Pakistan's Power Sector will lead to optimized solution of energy crisis. It is done with a help of Power Generation Expansion Planning.

1. Proposed Flow Chart of the Model

1.1 WASP-IV Simulation Flow Chart

First of all the several papers relevant to our research were studied for developing strong cogent and impeccable literature review. The data was collected regarding modeling of hydro power plants in WASP-IV model. Further the data was implemented in the model to get optimized simulated results. Analysis and conclusion were based on their in depth sensitivity analysis.

System modeling for power generation expansion is carried out via WASP-IV Model. The research and system modeling of hydro power plants is based upon the flow chart given below in figure.1 [2].

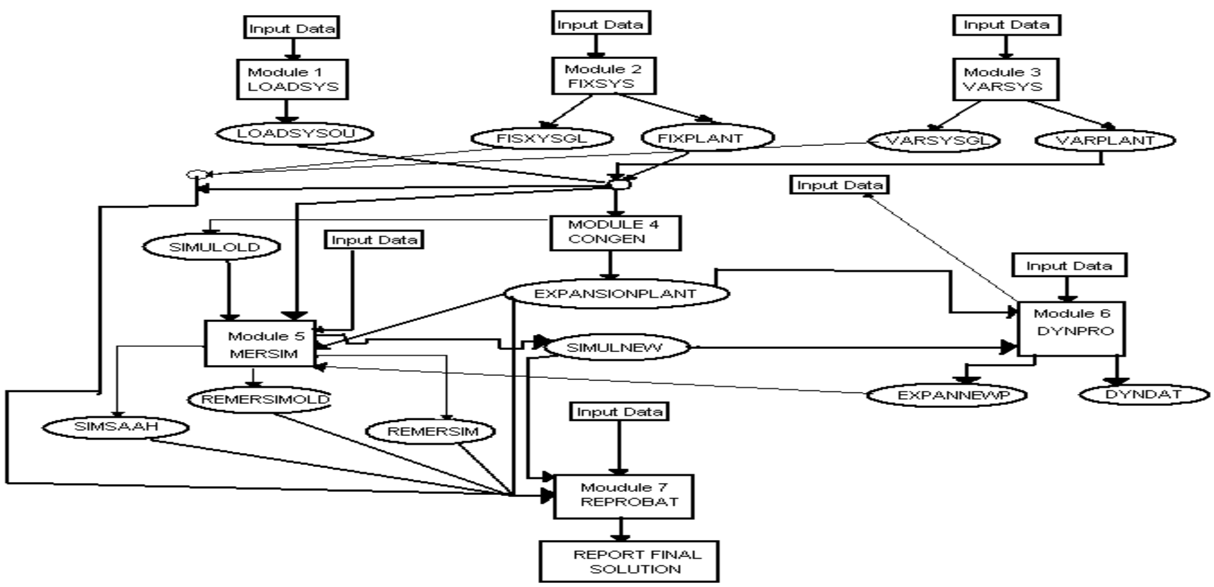

Figure.1 "WASP-IV computer code Flow Chart"

The above flow chart for our research shows that the input data is collected and modeled, and then given to LoadSy, FixSy and VarSy module. After execution it generates large number of configurations by ConGen module. These configurations are then merged and simulated by MerSim module. The DynPro module follows the dynamic programming methodology for cost optimization. It repeats the process until the desired least cost expansion is achieved. In ReproBat module, the optimized results are generated in ".rep" file.

2. System Modeling of Hydro-Thermal Power Plants

2.1 Energy Factors and Functions

2.1.1 Optimization Cost Function

The cost function to be optimized in WASP-IV [2] is given by equation 1, the basic minimized cost function is represented depending on certain constraints as described below:

$$Bj = \sum_{t=1}^{T}[\bar{I}(j,t) - \bar{S}(j,t) + \bar{F}(j,t) + \bar{L}(j,t) + \bar{M}(j,t) + \bar{O}(j,t)] \ldots\ldots (1)$$

Where:

Bj is the main objective function along with the expansion plan j, and t is the time in years (e-g; 1, 2, ... , T), T shows the length of the study period (total number of years), and the bar over the symbols represent the discounted values to a reference date at a given discount rate i. The function in equation (1) shows capital investment costs (I), fuel costs (F), salvage value of investment costs (S), fuel inventory costs (L), non-fuel operation, maintenance costs (M) and cost of the energy not served (O). Those functions are further dependant on other variable factors.

2.1.2 Forced Outage Rate

The forced outage rate (FOR) of each generating unit is essential in calculating the risk index. The forced outage rate is defined as in equation. 2:

$$\mathrm{FOR} = \frac{\mathrm{FOH}}{\mathrm{FOH} + \mathrm{SH}} * 100\ (\%) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where, FOH = Forced Outage Hours
SH = Service Hours

Numerous factors have effect on FOR of generating units which can vary the numbers. These factors include unit size, fuel type, duty cycle, and operational and maintenance practices. There can be significant variation in FOR values from different sources. They are governed by a combination of factors. So it is difficult to explain variation in values. Moreover, the values of FOR should be obtained from a large enough sample over a long period of time so as to represent the expected value of reliability with a reasonable degree of accuracy, for reliability evaluation and generation planning purposes.

2.1.3 Reliability Criteria Factors

The timing of new capacity additions required in the future is determined by the reliability criterion. At present our country is experiencing huge shortage of power, reliability of system is not a primary concern for Pakistan. It is therefore planned to add capacity to meet demand requirements at a lower but acceptable reliability level. It is important to consider proper reliability criterion to decide the capacity addition requirement every year over the planning horizon. Two reliability criteria are commonly used for development of generation expansion plans. These are as follows:

Loss of Load Probability (LOLP): LOLP is the risk associated with having insufficient Generation to meet the forecasted load demand. It is generally expressed in hours/years.

Expected Un-served Energy (EUE): Energy measurement, which is not supplied in expected terms over the year is EUE. It is usually expressed in GWh per year.

2.1.4 Loss of Load Probability (LOLP) Analysis and Addition of Peaking Units

The risk associated with insufficient generation to meet the load, is calculated as a Loss of Load Expectancy (LOLP) in days per year or hours per year. As an option, peaking plants are added automatically in such a way that the system reliability is at least equal to a given reliability index.

The interval load duration curves technique is generally done for LOLP analysis. The maintenance of the hydro units is done deterministically and the maintenance of the thermal units is scheduled either manually or automatically. To schedule maintenance automatically [5], the program starts by scheduling the units in descending order of size and locating maintenance in interval having the highest reserve. If the unit requires more than one interval of maintenance then consecutive intervals with the highest reserve are located in order to schedule unit maintenance.

Starting with the original load duration curve and using the following recursive formula, we convolve each unit with the load duration curve as given in equation 3. with the help of [6].

$$\mathrm{ELDCi}\,(x) = \mathrm{pi.ELDC}(i-1)(x) + \mathrm{qi.ELDC}(i-1)(x - \mathrm{Ci}) \ldots\ldots\ldots\ldots\ldots (3)$$

As qi is Forced Outage Rate (FOR) of the i-th unit.
pi = 1 - qi, it is the availability rate of i-th unit.
ELDCi (x)is Equivalent Load Duration Curve after convolution of the ith unit.
Ci is the capacity of the ith unit.

The loss of load probability for a system having n units with total installed capacity, C, is shown in equation 4.

$$\mathrm{LOLP} = \mathrm{ELDCn(C)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Peaking units are added until the desired reliability is achieved incase LOLP is greater than the system designed criteria. When the annual LDC is used, an approximation is made for the maintenance of units. For calculating LOLP, the firm capability of the hydro is usually used, but the other capabilities can be examined if desired. The module uses the load duration curves [7] to calculate the risk associated with having Expected Un-served Energy Costs. The energy produced by the thermal units can be calculated by either one of two ways [6]:

1. Simplified Method

This method is illustrated in the following figure.2. The energy produced by a unit is the area under the duration curve. The unit capacity is de-rated by the unit forced outage rate and to account for unit maintenance, the unit capability is also generally de-rated by the planned outage rate.

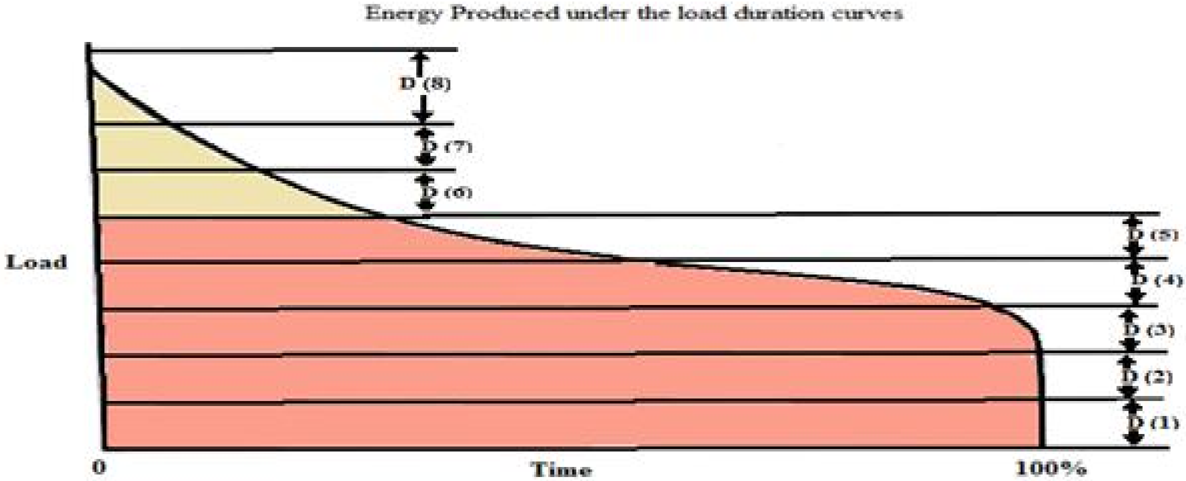

Figure.2 “Energy produced under the load duration curves”

The de-rated capacity (Di) is given by equation.5 below:

$$Di = Ci\,[1-(PORi + FORi)]\ldots\ldots\ldots\ldots\ldots(5)$$

Where,

Ci is the unit net capacity, PORi is the planned outage rate and FORi is the forced outage rate.

2. Probabilistic Method

The method takes the outage rate of the unit into account probabilistically as illustrated in the following figure.3. In the LOLP analysis, each unit is convolved with the load duration curve using the recursive formula given in equation (1). When a unit is stacked, the load level increases by the unit size for a duration proportional to the forced outage rate of the unit and to the time the unit is used in that load state.

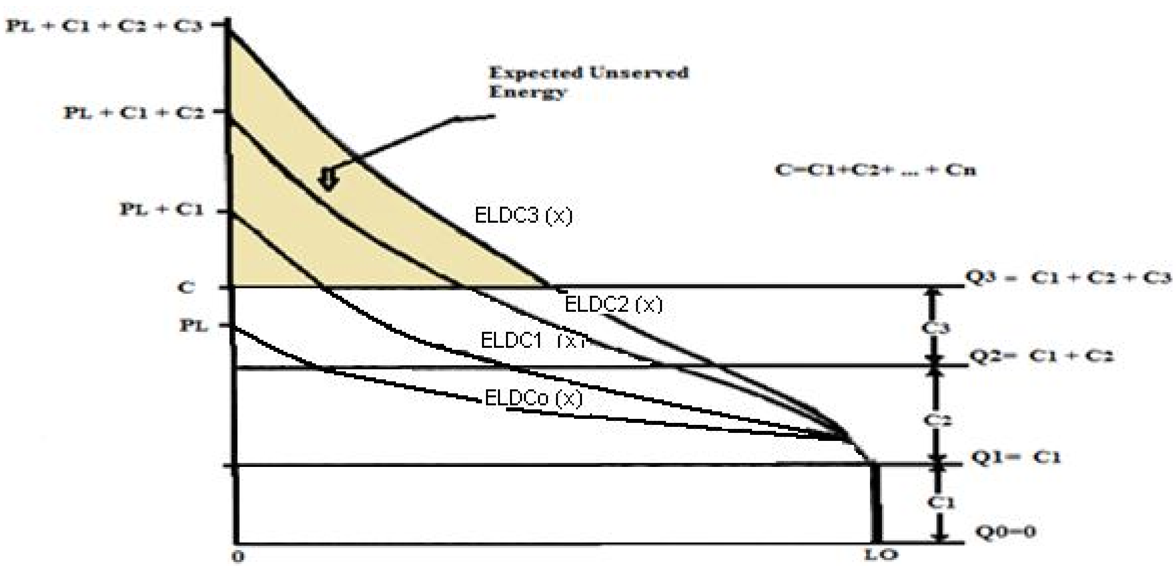

Figure.3 “Energy produced by unit i, area under the load duration curve by unit availability”

The energy produced by unit i (Ei) is the area under the load duration curve multiplied by the unit availability. It is given by equation. 6. in [6].

$$Ei = Pi \int_{Q(i-1)}^{Qi} ELDC(i-1)(x)dx \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ (6)}$$

Where Qi and Qi-1 are the load levels at which the unit is stacked.

There will always be some un-serviced energy on a probabilistic basis. After stacking the n available thermal units having a total capacity of C, the expected un-serviced energy (UE) is given by equation. 7:

$$UE = \int_{c}^{PL+C} ELDCi\,(x)dx \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ (7)}$$

Whereas PL is the peak load.
Unit maintenance is treated either automatically or manually as described in the LOLP Analysis.

2.1.5 Energy-not-served costs

The energy not served costs are given by equation. 8 below [2]:

$$O(j,t) = (l+1)^{-t-0.5} * \sum_{h=1}^{NHYD} \left[\left(a + \left(\frac{b}{2}\right) * \left(\frac{Nt,h}{EAt}\right)\right) + \frac{c}{3} * \left(\frac{Nt,h}{EAt}\right) \right] * N(t,h) * \alpha h \ldots\ldots\ldots\ldots (8)$$

where: a, b, and c are constants ($/kWh) given as input data.

N(t,h) is the amount of energy-not-served (kWh) for the hydro-condition h in year t and EAt is the necessary energy demand (kWh) of the system in year t.

As stated in equation 1, the cost components of the objective function (Bj) are presented in a simplified form. In fact, the above expressions have been derived considering each expansion candidate as a single unit (hydro, thermal or nuclear etc) whereas in WASP-IV the expansion candidates are defined as plants and the number of units (or projects) from each plant to be added in each year is to be determined by the WASP study.

2.2 Modeling of Hydro Power Plants

The modeling of hydro power plants involves two types of modeling. First of all we performed the modeling of Existing hydro power plants and secondly, modeling of Candidate hydro power plants. While modeling the hydro power plants, many insufficiencies were encountered regarding their characteristics so they are dealt with their evaluated parameters. The modeling of hydro power plants was carried out with the help of [8, 9, 10, 11, 12, 13 and 14].

2.2.1 Modeling of Existing Hydro Power Plants

The existing hydro power plants that are already installed in Pakistan up till the year 2012 are shown in the figure.2.3. The existing installed hydro capacity is 6935 MW. Furthermore, Minimum generation (Giga Watt-hour), average capacity and fixed operation and maintenance cost ($/KWh-month) are accumulated. The table 2.1 shows Existing Hydro Power Plants.

Table 2.1 Existing Hydro Power Plants

Existing Hydro Power Plants	
Hydro Power Plants	**Plant Capacity**
Small Hydro	122
Chashma	184
Jagran	30
Malakand III	81
Mangla	1000
Warsak	243
Tarbela	3478
Ghazi Barotha	1450
Jinnah	96
Allai Khwar	121
Duber Khwar	130
Total Installed Capacity =	6935 MW
(Hydro Power Plants)	

The necessary parameters such as inflow energy and live storage capacity [15, 16, 17, 18 and 19] are converted to Inflow energy (GWh/period) and Storage Capacity (GWh) as seen in figure.2.3 with the help of [20 and 21].

Characteristics of Existing Hydro Power Plants

The modeling of Existing hydro power plants for FixSys Module is carried out on the basis of their characteristics and parameters as discussed in [22, 23 and 24], vis-à-vis as the thermal power plants; the characteristics were evaluated with the help of their parameters and [25, 26, 27 and 28].
The characteristics of existing hydro power plants for FixSys Module are evaluated and shown in table. 2.2.

Table. 2.2 Modeling Characteristics of Existing Hydro Power Plants

Characteristics of Existing Hydro Plants for FixSys Module						
	Hydro Power Plant		=Small Hydro			
	Installed Capacity (MW)		=122 MW			
	Storage Capacity (GWh)		= 227.894 GWh			
	Fixed O& M Costs ($/KWh-month)		= 0.0025			
	Inflow Energy (GWh)		Min. Generation (GWh)		Average Capacity (MW)	
Period 1	443.93	GWh	74.25	GWh	91.5	MW
Period 2	443.93	GWh	74.25	GWh	91.5	MW

The characteristic of existing hydro power plants are:

- Installed Capacity (MW)
- Storage Capacity (GWh)
- Fixed Operation and Maintenance costs ($/KWh-month)
- Inflow Energy (GWh)
- Minimum Generation (GWh)
- Average Capacity (MW)

One of the parameters such as, installed capacity (MW) of the existing hydro power plants is given in [6] along with its other parameters i-e; Annual Firm Energy, and Fixed Operation and Maintenance costs in US $/KWh-year (to be converted into US $/KWh-month). Average Capacity (MW) is assumed to be 75% of the installed capacity. And the Minimum Generation (GWh) is half of the firm annual energy. Moreover, it is calculated for a period (six months) as defined in the beginning by the user. The inflow energy and storage capacity etc are modeled with the help of [22, 29, 30 and 31].

2.2. 2 Energy Conversion Parameters

Before calculating the modeling parameters of hydro power plant, one must know the energy conversion parameters as shown in table.2.3, evaluated in Microsoft Excel with the help of [23, 30, 32, 33, and 34].

Table. 2.3 Energy Conversion Parameters designed for WASP-IV model

Energy Conversion Parameters	
1 cusec	= 1.98 AF/day
1cusec	= 0.028317 m^3/sec
1 AF/year	= 0.00138127 cusec
1m^3/sec	=12674.88AF/period
1 MCM/day	= 454.22306 KW (KWh/h)
1 MCM /day	= 454.22306 MW (MWh/h)
1 MCM/day	= 0.45422306 GWh/h
1 MAF	= 1233.481 m^3 /day
1 AF /day	= 0.01428 m^3 / sec
0.005556 MCM/period	= 0.018926 GWh/day

It is not possible to measure the amount of water flowing into the rivers and dams with such an great quantity. So there are certain measuring techniques to measure the immense amount of water. It is measured in cusec, m^3/sec or MAF (Million Acre Feet). The basic and common unit which enables us to measure the water flow is so called 'cusec'. It means that one cubic foot water flows in a second or twenty eight liters of water per second. The water quantity is measured in terms of acre foot which means the quantity of water required to flood one acre of level ground to a depth of one Foot. For very large quantities of water the term million acre feet (MAF) is used which equals to million acre feet. In case of hydro power plants, if one cusec of water is dropped from a height of 100 feet then it has potential energy to generate nearly 8.5 KW of electrical power.

2.2.3 Calculation of Storage Capacity (GWh)

The storage capacity (GWh) required in FixSys module for Hydro power plants is calculated for each existing hydro power plant. The calculation is carried out for already installed hydro power plants in Pakistan via their water flow energy parameters as discussed in energy conversion parameters. The live storage capacity of each hydro plant is converted into MCM (Million Cubic Meter) according to its desired time period. And then from Million Cubic Meter (MCM) it is converted into the desired storage capacity (GWh) [35] and [36]. The conversion is performed in Microsoft excel as seen in table 2.4.

Table 2.4 Calculation of Storage Capacity (GWh)

Calculation of Storage Capacity (GWh)	
0.00018 MAF = 0.222027 MCM	0.0055556 MCM = 0.000105 GWh
X (Enter value) 7.2 = **8881.063 MCM**	8881.063 MCM = **168.1185 GWh**

2.2.4 Calculation of Inflow Energy (GWh/period)

The Inflow energy (GWh) is evaluated with the help of conversion of water flow for each hydro power plant as in table 2.5. The water flow for hydro power plants is either given in cusecs or m^3/sec [37] and [38], then m^3/sec (cubic meter /second) is converted to AF/sec (Acre Foot/ second). After converting the energy parameters with different escalating factors, MCM/period (Million Cubic Meter /period), we convert it to the inflow energy Gega Watt-hour/Period (GWh/period).

Table. 2.5 Calculation of Inflow Energy (GWh)

Calculation of Inflow Energy (GWh)	
1 cusec = 0.028317 m^3/sec	1m^3/sec =12674.88AF/period
1428 cusecs = 40.43668 m^3/sec	40.43 m^3/sec =506995.2 AF/period
180 AF/period = 0.222027 MCM/period	0.005556 MCM/period = 0.000105 GWh/period
506995.2 AF / period = 625.3689 MCM/period	625.3689 MCM/period = **11.83823 GWh/period**

When all the characteristics of existing hydro power plants are modeled for each hydro power plant in a FixSys Module, we model candidate hydro power plants.

2.2.5 Modeling of Candidate Hydro Power Plants

After achieving characteristics of existing hydro power plants, we calculate the characteristics of candidate hydro power plants. They are evaluated with the help of their parameters. The Candidate hydro power plants are future hydro power plants which are to be added in the future time span as defined for power generation expansion period. The Capacity (MW) of candidate hydro power plants which are to be installed in future in their respective years is 38298 MW. Furthermore, Minimum generation (GWh), average capacity and fixed operation and maintenance costs ($/KWh-month) are also accumulated as in [9, 39, 40 and 41].

The characteristics of candidate hydro power plants are same as of existing hydro power plants. The characteristics are in table. 2.6. For each candidate hydro power plant, their necessary parameters are also evaluated.

Table 2.6 Modeling Characteristics of Candidate Hydro Power Plants for VARSYS Module

	Characteristics of Candidate Hydro Power Plants for VARSYS Module						
	Hydro Power Plant =		Khan Khwar				
	Installed Capacity (MW) =			172	MW		
	Storage Capacity (GWh) =			49.03457	GWh		
	Fixed O& M Costs =			1.175			
	($/KWh-month)						
	Inflow Energy (GWh)		Min. Generation (GWh)			Average Capacity (MW)	
Period 1	10.3584	GWh	26.25		GWh	137.6	MW
Period 2	10.3584	GWh	26.25		GWh	137.6	MW

The table. 2.7 shows the candidate hydro power plants which are to be added in future along with their parameters i-e; live storage capacity (MAF) and Inflow energy (m^3/sec) as discussed earlier for existing hydro power plants and further can be studied in [42, 43, 44 and 45].

Table 2.7 Candidate Hydro Power Plants

Candidate Hydro Power Plants			
Hydro Power Plants	**Plant Capacity** (MW)	**Hydro Power Plants**	**Plant Capacity** (MW)
Taunsa	120	Yugo	520
Khan Khwar	172	Dasu	4320
Neelum Jhelum	969	Bunji	7100
Diamer Basha	4500	Akhori	600
Golen Gol	106	Lower Spat Gah	496
Kurram Tangi	83	Palas Valley	665
Tarbela 4 Ext	960	Pattan	2800
Doyian	490	Thakot	2800
Keyal Khwar	122	Dudhnial	800
Phander	80	Yulbo	3000
Basho	26	Tungas	2200
Harpo	33	Skardu	1650
Lawi	70	Kalabagh	2776
Total Installed Capacity of Candidate Hydro Power Plants = 38198			

Similarly the candidate hydro power plants characteristics are evaluated in Microsoft excel.

3. Implementation

In FixSy and VarSy module existing and candidate hydro power plants are defined by clicking “Add Plant”. All existing and committed hydro power plants are defined in the FixSy and VarSy module. There are two types of hydro power plants i-e Type-A and Type-B. For each type of hydro power plant, Operation and Maintenance Costs are defined. Moreover, it specifies year of operation in which hydro power plant is to be operated, installed capacity (MW), Storage Capacity (GWh) of hydro power plant, Inflow Energy i-e the energy which relies on the water flow to the dams, Minimum Generation from the hydro power plant and Average Capacity (MW) that a hydro power plant produces. All these mentioned parameters are modeled with the help of [14, 46 and 47] for each existing hydro power plant as shown in figure.4 for WASP-IV Module.

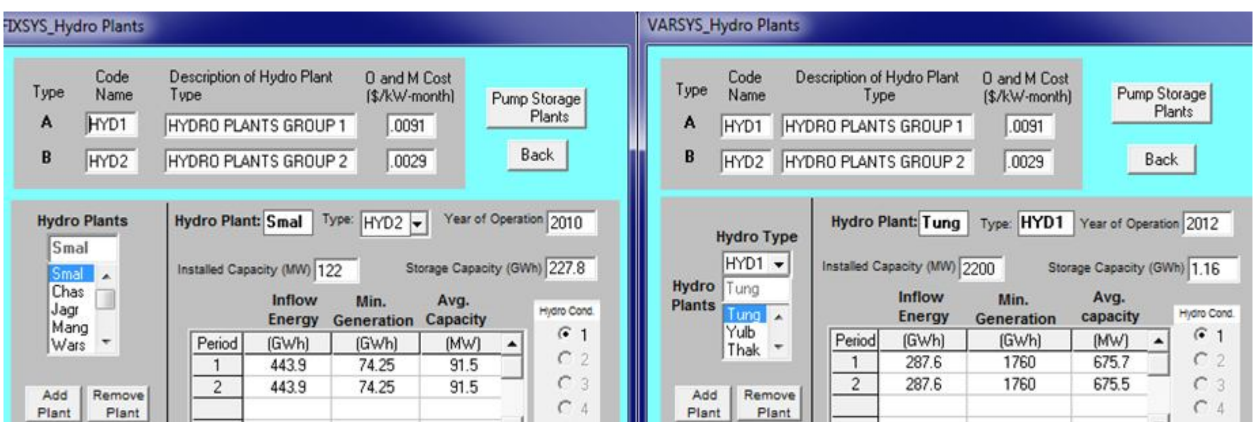

Figure.4 “Existing and Candidate Hydro Power Plants Characteristics in FixSy Module”

These are the characteristics of Existing and Candidate Hydro power plants which are given to FixSy and VarSy Module of WASP-IV after modeling several parameters of all the hydro power plants.

The ConGen Module is configuration generator. It generates many optimized configurations for all the hydro thermal power plants defined in the VarSy Modules. In Congen Module, it requires minimum and maximum reserve margins for all the power plants and critical hydro condition which is already defined in common case data. During power generation expansion, all the candidate power plants are in the row. Below lies the previous year of expansion and current year of expansion. Numerical values in the boxes represent number of units of the power plants either to be added or are already added.

Once the configurations of all the power plants are generated then they are merged into each other for further operations research. The characteristics of MerSim Module are base year, number of Fourier coefficients, spinning reserves requirements either variable or constant, group limitation calculations, loading order of plants during simulations and calculations that are based upon plant by plant and unit by unit loading order, spinning reserve contribution by Hydro power plants i-e Type A and Type B. As in variable spinning reserves requirements, SPNRES is calculated as a function of the largest unit capacity block already loaded (CAP) and the period peak load (PKMW) in equation.1.

$$SPNRES = SPNVAL * CAP + PEAKF * PKMW \ldots\ldots.(1)$$

Multiplier coefficients SPNVAL and PEAKF are user defined multiplier coefficients also we define Data for Future Years adopting the data collection methodologies similar to [48].

4. RESULTS

The results are generated in .rep batch file of WASP-IV for each module. In Microsoft Excel, the characteristics of existing and candidate hydro power plants are also evaluated for FixSys and VarSys module of WASP-IV. Each cell is pre-defined with the formula. And it recalls the values from many other cells in the Microsoft excel where necessary calculations are carried out. In such a way, great number of existing and candidate hydro power plants calculations is achieved in a very efficient way.

Table 4.1 and 4.2 shows the evaluated characteristic of existing and candidate hydro power plants which are to be installed in Pakistan for period 2013-2035.

Characteristics of Existing Hydro Power Plants

Table 4.1 Characteristics of Existing Hydro Power Plants

Characteristics of Existing Hydro Power Plants						
Hydro Power	**Plant Capacity**	**Fixed O & M Costs**	**Min. Generation**	**Average Capacity**	**Storage Capacity**	**Inflow Energy**
Plants	**(MW)**	**$/KWh-month**	**(GWh)**	**(MW)**	**MW**	**(GWh)**
Small Hydro	122	0.0025	74.25	91.5	227.894	443.93
Chashma	184	0.0125	179.5	138	16.811	439.97
Jagran	30	0.0083333	18.25	22.5	28.01	9.48
Malakand III	81	0.0083333	49.25	60.75	31.28	11.96
Mangla	1000	0.0016667	639.75	750	31.989	128.22
Warsak	243	0.0041667	128.5	182.25	0.5907	144.72
Tarbela	3478	0.0033333	1673	2608.5	226.026	1760.049
Ghazi Barotha	1450	0.0091667	873.5	1087.5	170.4535	473
Jinnah	96	0.0083333	32	72	67.2474	2173.92
Allai Khwar	121	0.0083333	40	90.75	284.86	5.62
Duber Khwar	130	0.0083333	46.75	97.5	2.1715	7.3988
Installed Capacity =	**6935**					
(Hydro Power Plants)	**MW**					

Characteristics of Candidate Hydro Power Plants

Table 4.2 "Characteristics of Candidate Hydro Power Plants"

Characteristics of Candidate Hydro Power Plants						
Hydro Power	**Plant Capacity**	**Fixed O & M Costs**	**Average Capacity**	**Min. Generation**	**Storage Capacity**	**Inflow Energy**
Plants	**(MW)**	**$/ KWh-month**	**(MW)**	**(GWh)/period**	**(GWh)**	**(GWh)/period**
None	None	None	None	None	None	None
Khan Khwar	172	1.175	137.6	26.25	49.03457	10.3584
Neelum Jhelum	969	0.575	775.2	286.25	107.409	91.74631
Diamer Basha	4500	1.45	3600	841	182.128	96.77
Golen Gol	106	1.025	84.8	21	46.69	8.8786
Kurram Tangi	83	4.55	66.4	43.75	19.38	873.95
Tarbela 4 Ext	960	0.625	768	250	142.43	218.71
Munda	740	1.025	592	262.25	13.057	60.96
Keyal Khwar	122	1.683333	97.6	27	168.11	6.511029
Phander	80	0.733333	64	19	7.004	11.83823

Basho	26	1.158333	20.8	8	175.123	1.035845
Harpo	33	1.108333	26.4	11.25	133.0938	1.627757
Lawi	70	2.5	56	19.75	112.079	5.919117
Dasu	4320	1.508333	3456	1255.75	26.85	769.4852
Bunji	7100	0.491667	5680	2156.75	203.1432	562.3161
Akhori	600	4.583333	480	85.25	256.84	1036.437
Lower Spat Gah	496	1.758333	396.8	173	121.41	8.8786
Palas Valley	665	1.433333	532	233.5	49.03	465.83
Pattan	2800	1.816667	2240	957	25.68	667
Thakot	2800	1.816667	2240	957.75	21.01	858.727
Dudhnial	800	1.9	640	244	23.34	86.41911
Yulbo	3000	2.858333	2400	875.75	2.8	292.9931
Tungas	2200	2.425	1760	675.75	1.167	287.6691
Skardu	1650	6.341667	1320	499	123.75	281.454
Yugo	520	7.316667	416	147.75	91.74	100
Kalabagh	2776	0.775	2220.8	2315	142.3	327.9191
Taunsa	120	1.891667	96	128	74.71	447
Doyian	490	1.091667	392	423.25	109.744	554.325
Total Installed Capacity (MW) =	**38198**	**MW**				

The nominal installed capacities (MW) for hydro power plants are shown in figure.5accordance to their fuel types.

FIXED SYSTEM
SUMMARY OF INSTALLED CAPACITIES
(NOMINAL CAPACITIES (MW))

HYDROELECTRIC	HYD1		HYD2		THERMAL FUEL TYPE										TOTAL
					0	1	2	3	4	5	6	7	8	9	
YEAR	PR.	CAP	PR.	CAP	Inte	NG	FO	LCoa	ICoa		Dies	Uran			
2013	8	5124.	3	1603.	0.	6714.	7894.	30.	0.	0.	25.	660.	0.	0.	22050.
2014	9	5254.	5	1820.	0.	7417.	7874.	30.	0.	0.	25.	1340.	0.	0.	23760.
2015	9	5254.	6	1903.	0.	7960.	8446.	30.	0.	0.	25.	1340.	0.	0.	24958.
2016	10	5338.	7	2872.	0.	7960.	8843.	30.	0.	0.	25.	1340.	0.	0.	26408.
2017	11	6748.	7	2872.	0.	7820.	8820.	30.	0.	0.	25.	1340.	0.	0.	27655.
2018	11	6748.	7	2872.	0.	7820.	9420.	30.	0.	0.	25.	1340.	0.	0.	28255.
2019	11	6748.	7	2872.	0.	7820.	9420.	30.	0.	0.	25.	1340.	0.	0.	28255.
2020	11	6748.	7	2872.	0.	7686.	9150.	30.	0.	0.	25.	2340.	0.	0.	28851.
2021	11	6748.	7	2872.	0.	7598.	9067.	30.	0.	0.	25.	2340.	0.	0.	28680.
2022	11	6748.	7	2872.	0.	6858.	8790.	30.	0.	0.	0.	2280.	0.	0.	27578.
2023	11	6748.	7	2872.	0.	6858.	8790.	30.	0.	0.	0.	2280.	0.	0.	27578.
2024	11	6748.	7	2872.	0.	6424.	8790.	30.	0.	0.	0.	2280.	0.	0.	27144.
2025	11	6748.	7	2872.	0.	6424.	7905.	30.	0.	0.	0.	2280.	0.	0.	26259.
2026	11	6748.	7	2872.	0.	6424.	7905.	0.	0.	0.	0.	2280.	0.	0.	26229.
2027	11	6748.	7	2872.	0.	6424.	7284.	0.	0.	0.	0.	2280.	0.	0.	25608.
2028	11	6748.	7	2872.	0.	6424.	6988.	0.	0.	0.	0.	2280.	0.	0.	25312.
2029	11	6748.	7	2872.	0.	5605.	6988.	0.	0.	0.	0.	2280.	0.	0.	24493.
2030	11	6748.	7	2872.	0.	5605.	6137.	0.	0.	0.	0.	2280.	0.	0.	23642.
2031	11	6748.	7	2872.	0.	5350.	6137.	0.	0.	0.	0.	2280.	0.	0.	23387.
2032	11	6748.	7	2872.	0.	5350.	6137.	0.	0.	0.	0.	2280.	0.	0.	23387.
2033	11	6748.	7	2872.	0.	5350.	6137.	0.	0.	0.	0.	2280.	0.	0.	23387.
2034	11	6748.	7	2872.	0.	5350.	6137.	0.	0.	0.	0.	2280.	0.	0.	23387.
2035	11	6748.	7	2872.	0.	5350.	6137.	0.	0.	0.	0.	2280.	0.	0.	23387.

Figure.5 “Nominal Capacities of Hydro Power Plants”

The ConGen module of WASP-IV generates the minimum and maximum number of configurations along with their reserve margins percentage for each expansion year in figure.6. Total 4745 no. of configurations are generated for all the expansion years. Amongst them, 1068 number of configurations are generated for hydro power plants for expansion time period.

RES. PERMITTED EXTREME CONFIGURATIONS OF ALTERNATIVES

YEAR	CON	RES. MAR-GIN	NUTH	GTUR	CC07	COL6	HYD1	HYD2
2013	1	-10	0	0	0	0	0	0
		5	0	0	0	0	0	0
2014	1	-10	0	0	0	0	0	0
		5	0	0	0	0	0	0
2015	4	-10	0	0	0	0	2	0
		10	0	1	0	0	3	0
2016	27	0	0	0	0	0	2	0
		10	0	1	1	2	4	0
2017	98	0	0	0	0	1	2	0
		10	0	1	1	3	4	2
2018	137	0	0	0	0	2	2	0
		10	0	2	1	4	4	2
2019	186	0	0	0	0	3	5	0
		10	0	2	1	5	8	2
2020	204	0	0	0	0	4	7	1
		10	0	2	1	6	10	3
2021	211	0	0	0	0	5	7	1
		10	0	2	2	7	10	3
2022	375	0	0	0	0	6	8	4
		10	1	3	3	8	10	6
2023	286	0	0	1	2	7	10	7
		10	1	3	5	9	12	8
2024	302	0	0	2	4	8	11	9
		10	1	4	6	10	13	11
2025	285	0	0	2	5	10	11	12
		10	2	4	7	11	13	13
2026	200	0	2	4	6	10	11	14
		10	3	6	8	11	13	15
2027	401	0	3	4	7	11	14	15
		10	4	7	9	13	16	16
2028	396	0	4	5	7	12	17	17
		10	5	8	9	14	18	19
2029	438	0	4	5	8	13	17	20
		10	6	8	10	15	18	22
2030	282	0	5	8	8	13	18	22
		10	6	11	10	15	19	23
2031	213	0	6	[illegible]	10	15	20	24
		10	8	11	12	17	20	26
2032	144	0	9	10	12	17	20	24
		10	10	13	14	19	20	26
2033	144	0	11	10	12	20	20	25
		10	12	13	14	22	20	26
2034	250	0	11	14	12	22	20	26
		10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2035	160	0	10	13	16	25	20	27
		10	12	17	22	28	20	27

4745 TOTAL NUMBER OF CONFIGURATIONS GENERATED

Figure.6 "Configurations generated for each year of power generation expansion"

MerSim simulates system operations for each configuration and for each period in the year and each hydrological condition (merges and simulates). It determines energy generated by each generating unit in each period, capacity factors, fuel costs, operation and maintenance costs, LOLP (with maintenance), Energy not served. It utilizes the methodology of the loading order, spinning reserves, probabilistic simulation and then saves previous calculations for further results.

The figure.7 displays the result of annual addition during Power Generation Expansion Period (PGEP) along with the Loss of Load Probability (%) for each expansion year. LOLP (%) decreases, as the expansion year proceeds further. It is due to satisfying the reliability criteria. The total capacity to be installed in future 2013-2035 is 85119 MW. During expansion time period; 47 hydel power plant units are to be installed as shown in figure.7.

OPTIMUM SOLUTION

ANNUAL ADDITIONS: CAPACITY(MW) AND NUMBER OF UNITS OR PROJECTS

FOR DETAILS OF INDIVIDUAL UNITS OR PROJECTS SEE VARIABLE SYSTEM REPORT

SEE ALSO FIXED SYSTEM REPORT FOR OTHER ADDITIONS OR RETIREMENTS

NAME :			NUTH	GTUR	CC07	COL6	HYD1	HYD2
SIZE (MW):			1000.	155.	707.	600	0.	0.
YEAR	%LOLP	CAP						
2013	19.529	0.						
2014	10.915	0.						
2015	4.628	1055.		1			3	
2016	0.151	2039.			1	2	1	
2017	0.069	836.				1		2
2018	0.133	755.		1		1		
2019	0.197	2344.				1	4	
2020	0.068	1815.				1	1	1
2021	0.208	1807.			1	1	1	
2022	0.309	3708.	1	1	1	1		3
2023	0.257	3544.			2	1	2	2
2024	0.201	3657.			1	1		2
2025	0.056	4950.	1			1		2
2026	0.028	4009.	1	2	1			3
2027	0.012	5186.	1	1	1	2	2	1
2028	1.542	5622.	1		1		4	2
2029	0.002	7596.	1			2		3
2030	4.579	7272.		3	1		1	2
2031	3.281	5614.	2		2	2	1	2
2032	1.844	5234.	2	4	2	2		
2033	2.001	5800.	2			3		1
2034	3.419	5527.		4	1	3		1
2035	1.187	6749.			7	3		
TOTALS		85119.	12	17	22	28	20	27

Figure.7 "Optimized Solution achieved by showing the Annual Addition of Hydro Power Plants for the PGEP period"

The Energy not Served (ENS) in GWh, Loss of Load Probability (%), Reserve Margins (%), Hydro power plants installed capacity is given in figure.8. The Energy Not Served and LOLP (%) decreases as the reserve margins (%) increases.

SUMMARY OF
FIXED SYSTEM PLUS OPTIMUM SOLUTION
(NOMINAL CAPACITY IN MW, ENERGY IN GWH)

YEAR	PUMPED STORAGE PUMP PR.	PUMPED STORAGE PUMP CAP	HYDRO ELECTRIC HYDR PR.	HYDRO ELECTRIC HYDR CAP	TOTAL THERMAL CAPACITY	TOTAL CAP	SYSTEM RES. %	SYSTEM LOLP. %	ENERGY NOT SERVED HYDROCONDITION 1
2013	0	0	11	6727	15323	22050	-2.3	19.529	1717.5
2014	0	0	14	7074	16686	23760	0.9	10.915	744.4
2015	0	0	18	8057	17956	26013	5.6	4.628	202.1
2016	0	0	21	9242	20260	29502	13.0	0.151	2.8
2017	0	0	24	10888	20697	31585	15.7	0.069	1.2
2018	0	0	24	10888	22052	32940	14.3	0.133	2.3
2019	0	0	28	12632	22652	35284	15.8	0.197	3.5
2020	0	0	30	13847	23848	37695	17.6	0.068	1.4
2021	0	0	31	14347	24984	39331	15.9	0.208	4.5
2022	0	0	34	15593	26344	41937	15.2	0.309	7.5
2023	0	0	38	17123	28358	45481	16.4	0.257	6.1
2024	0	0	40	19473	29231	48704	15.9	0.201	4.7
2025	0	0	42	22823	29946	52769	16.5	0.056	1.2
2026	0	0	45	24815	31933	56748	15.8	0.028	0.8
2027	0	0	48	26939	34374	61313	15.6	0.012	0.8
2028	0	0	54	30854	35785	66639	16.2	1.542	275.6
2029	0	0	57	36250	37166	73416	18.4	0.002	1.0
2030	0	0	60	42350	37487	79837	18.0	4.579	1439.3
2031	0	0	63	43350	41846	85196	17.1	3.281	919.5
2032	0	0	63	43350	47080	90430	15.9	1.844	466.9
2033	0	0	64	45350	50880	96230	15.1	2.001	550.9
2034	0	0	65	47750	54007	101757	13.7	3.419	1195.1
2035	0	0	65	47750	60756	108506	13.5	1.187	327.1

Figure.8 "Nominal Capacity (MW) for Hydro during PGEP along with Energy Not Served, Loss of Load Probability (%), and Reserves (%)"

The expected generation by plant type (GWh) for hydro power plants is given by figure.9 below.

SUMMARY OF
FIXED SYSTEM PLUS OPTIMUM SOLUTION
EXPECTED GENERATION BY PLANT TYPE (GWH)

YEAR	HYDROELECTRIC HYD1	HYD2	TOTAL	THERMAL FUEL TYPES 0 Inte	1 NG	2 FO	3 LCoa	4 ICoa	5	6 Dies	7 Uran	8	9	TOTAL	GR. TOTAL
2013	23378	7776	31154	0	49872	49491	205	0	0	45	4288	0	0	103901	135055
2014	23997	8898	32895	0	54618	45151	205	0	0	24	9093	0	0	109091	141986
2015	26750	9227	35977	0	59930	43897	205	0	0	12	9093	0	0	113137	149114
2016	27862	14377	42239	0	64594	33003	9311	0	0	0	9093	0	0	116001	158240
2017	31502	15312	46814	0	63515	32153	13864	0	0	0	9093	0	0	118625	165439
2018	31502	15312	46814	0	64779	35588	18417	0	0	0	9093	0	0	127877	174691
2019	37696	15312	53008	0	64654	34902	22970	0	0	0	9093	0	0	131619	184627
2020	45429	16209	61638	0	62827	26117	27522	0	0	0	16160	0	0	132626	194264
2021	46864	16209	63073	0	67587	26680	32074	0	0	0	16160	0	0	142501	205574
2022	46864	21281	68145	0	69727	22193	36625	0	0	0	23909	0	0	152454	220599
2023	49069	24376	73445	0	79087	19060	41174	0	0	0	23909	0	0	163230	236675
2024	49069	33605	82674	0	81569	20829	45728	0	0	0	23909	0	0	172035	254709
2025	49069	46842	95911	0	80179	16351	50277	0	0	0	31850	0	0	178657	274568
2026	49069	55034	104103	0	85928	16915	50082	0	0	0	39792	0	0	192717	296820
2027	50204	62519	112723	0	88930	12866	59187	0	0	0	47734	0	0	208717	321440
2028	53513	72669	126182	0	93260	12992	59183	0	0	0	55675	0	0	221110	347292
2029	53513	100071	153584	0	80734	9371	68284	0	0	0	63617	0	0	222006	375590
2030	54899	128987	183886	0	82838	10004	68279	0	0	0	63617	0	0	224738	408624
2031	55245	134797	190042	0	85938	7060	77373	0	0	0	79500	0	0	249871	439913
2032	55245	134797	190042	0	95212	5154	86476	0	0	0	95384	0	0	282226	472268
2033	55245	143496	198741	0	90844	4914	100079	0	0	0	111267	0	0	307104	505845
2034	55245	154220	209465	0	100895	6007	113732	0	0	0	111267	0	0	331601	541066
2035	55245	154220	209465	0	126766	3843	127441	0	0	0	111267	0	0	369317	578782

Figure.9 "Expected Generation by Plant Type (GWh)"

The total domestic and foreign cost for hydro power plants is 5552 Million US $ as shown in figure.10.

EXPECTED COST OF OPERATION
TOTAL COST
DOMESTIC AND FOREIGN
COST BY FUEL TYPE (MILLION $)

TYPE OF PLANT: YEAR	TOTAL	Inte	NG	FO	LCoa	ICoa		Dies	Uran			HYD1	HYD2	ENS
2013	14357.0	0.0	4722.5	7796.7	18.1	0.0	0.0	13.8	21.2	0.0	0.0	51.0	16.0	1717.5
2014	13253.1	0.0	5300.8	7067.1	18.1	0.0	0.0	7.7	44.5	0.0	0.0	52.3	18.1	744.4
2015	13426.6	0.0	6350.4	6714.4	18.1	0.0	0.0	4.0	57.4	0.0	0.0	61.3	19.0	202.1
2016	13078.0	0.0	7401.7	4900.8	602.7	0.0	0.0	0.4	77.5	0.0	0.0	63.4	28.6	2.8
2017	14108.5	0.0	8185.9	4808.7	895.0	0.0	0.0	0.3	108.8	0.0	0.0	77.5	31.0	1.2
2018	16257.2	0.0	9370.8	5430.3	1187.3	0.0	0.0	0.4	157.7	0.0	0.0	77.5	31.0	2.3
2019	17725.0	0.0	*******	5354.6	1479.5	0.0	0.0	0.4	234.1	0.0	0.0	94.9	31.0	3.5
2020	17910.0	0.0	*******	4469.8	1771.7	0.0	0.0	0.3	321.0	0.0	0.0	104.8	33.1	1.4
2021	20399.6	0.0	*******	5253.3	2064.0	0.0	0.0	0.4	250.2	0.0	0.0	109.8	33.1	4.5
2022	21256.7	0.0	*******	4930.0	2356.1	0.0	0.0	0.0	319.6	0.0	0.0	109.8	45.5	7.5
2023	23247.8	0.0	*******	4800.4	2648.0	0.0	0.0	0.0	261.3	0.0	0.0	116.3	54.2	6.1
2024	25925.6	0.0	*******	6035.5	2940.4	0.0	0.0	0.0	217.5	0.0	0.0	116.3	77.6	4.7
2025	25441.1	0.0	*******	4928.6	3232.4	0.0	0.0	0.0	309.4	0.0	0.0	116.3	111.0	1.2
2026	26750.6	0.0	*******	5439.2	3215.0	0.0	0.0	0.0	401.3	0.0	0.0	116.3	130.8	0.8
2027	26856.0	0.0	*******	4460.2	3799.5	0.0	0.0	0.0	493.2	0.0	0.0	119.6	148.7	0.8
2028	28676.9	0.0	*******	4876.3	3799.3	0.0	0.0	0.0	585.1	0.0	0.0	128.8	178.5	275.6
2029	23963.2	0.0	*******	3690.9	4383.6	0.0	0.0	0.0	677.0	0.0	0.0	128.8	232.3	1.0
2030	26301.1	0.0	*******	4286.8	4383.3	0.0	0.0	0.0	677.0	0.0	0.0	133.8	288.0	1439.3
2031	25405.5	0.0	*******	3245.9	4967.2	0.0	0.0	0.0	860.8	0.0	0.0	134.6	297.2	919.5
2032	26219.0	0.0	*******	2591.3	5551.7	0.0	0.0	0.0	1044.6	0.0	0.0	134.6	297.2	466.9
2033	27473.7	0.0	*******	2670.6	6425.4	0.0	0.0	0.0	1228.4	0.0	0.0	134.6	317.1	550.9
2034	32079.5	0.0	*******	3407.9	7301.9	0.0	0.0	0.0	1228.4	0.0	0.0	134.6	341.0	1195.1
2035	33305.2	0.0	*******	2443.1	8181.5	0.0	0.0	0.0	1228.4	0.0	0.0	134.6	341.0	327.1
TOTALS	513416.8	0.0	308314.0	109602.4	71239.9	0.0	0.0	27.8	10804.0	0.0	0.0	2451.4	3101.0	7876.1

Figure.10 "Expected Cost (Million US $) of total Domestic and Foreign for Hydro Power Plants"

5. Analysis and Conclusion

After achieving our results, we conclude the research findings based upon on their in depth analysis. The existing and candidate power plants were reckoned to meet the energy demand by satisfying the reliability criteria. All the characteristics of hydro power plants were counted. Further, the power generation expansion was carried out. It involves the state-of-the-art modeling technique using WASP-IV model.

The desired research on modeling hydro power generation expansion plan for 2013-2035 is significant in several ways. It meets the required energy demand (GWh), calculating all the costs by adopting optimal trajectory path using dynamic programming, Loss of Load Probability, Energy not Served, setting up required reserve margins (MW).

After attaining crucial results, more significant analysis and conclusion can be drawn regarding Pakistan's power sector. It adheres to accomplish the different concocted hydro power plants' installed capacity (MW) for future expansion time period, as given in table. 5.1

Table. 5.1 Future Installed Electricity Generation Capacity

Year	2013	2020	2025	2030	2035
Total Installed Capacity Hydro (MW)	6727	15750	29104	43230	47750

5.1Generation Mix Supply

Figure.11 represents Generation Capacity Mix Supply. It is the most optimized and feasible generation expansion attained by our research ascertains for the power generation expansion plan (year- 2013-2035).

The share of hydro power plants along with their respective year of generation expansion is also evaluated in (MW). Power Generation Expansion Planning (PGEP) for the years 2013-2035 exhibits 47750 MW for Hydro (44 %).

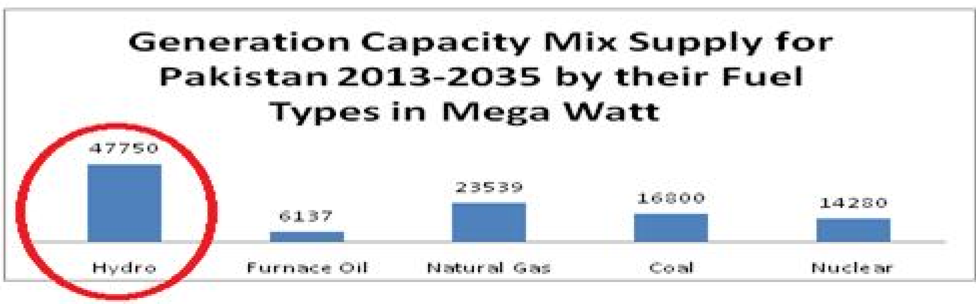

Figure.11 "Generation Capacity Mix Supply for Pakistan 2013-2035 by their Fuel Types in Mega Watt (MW)"

Future Work Prospects

Other group limits can be imposed on the annual electricity generation. Hydro power plants can be integrated with existing and candidate thermal power plants of Pakistan. Increase in the number of periods in a year, can substantially increase the accuracy of Power Generation Expansion. And alternate modeling simulation softwares could be used such as LEAP, EnergyPlan etc. to get load and energy demand forecast on weekly basis.

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REFERENCES

[1] Muhammad Fahad Shinwari, Muhammad Latif , Naveed Ahmed, Hassan Humayun, Dr. I.M Qureshi, Dr. Ihsan ul Haq and Dr. Yasin Chohan, " Optimization Model using WASP-IV for Pakistan's Power Plants Generation Expansion Plan", IOSR-JEEE, Vol.3, Issue. 2, PP. 39-49, Nov. 2012.

[2] International Atomic Energy Agency, ―Wien Automatic System Planning (WASP) package - A computer code for power generating system expansion planning, version WASP-IV user's manual, IAEA, Vienna, 2006.

[3] S. Jebaraj and S. Iniyan, "A review of energy models", Renewable & Sustainable Energy Reviews, Vol. 10, PP. 281-311, 2006.

[4] R. B. Hiremath, S. Shikha and N. H. Ravindranath, "Decentralized energy planning; modeling and application", Renewable & Sustainable Energy Reviews, Vol. 11, PP. 729-752, 2007.

[5] M. Nejati, N. Amjady, H. Zareipour, "A New Stochastic Search Technique Combined with Scenario Approach for Dynamic State Estimation of Power Systems", IEEE Transactions on Power Systems, Vol. 27, Issue. 4, PP. 2093 – 2105, January 2012.
[6] Generation Planning, National Transmission and Despatch Company Limited, Pakistan, 2011.
[7] Wang, B.; Li, Y. and Watada, J., "Supply Reliability and Generation Cost Analysis Due to Load Forecast Uncertainty in Unit Commitment Problems", IEEE Transactions on Power Systems, Vol. 23, Issue. 3, PP. 2242 – 2252, August 2013.
[8] Prakash Thimmapuram, Thomas D. Veselka, Vladimir Koritarov, Sónia Vilela, Ricardo Pereira and Rui Figueiredo Silva, " Modeling Hydro Power Plants in Deregulated Electricity Markets: Integration and Application of EMCAS and VALORAGUA", UChicago Argonne, LLC, Operator of Argonne National Laboratory, Argonne, 2006.
[9] Robert, G. ; EDF Hydro Eng. Centre, Le Bourget du Lac, France and Michaud, F , "Hydro power plant modeling for generation control applications", IEEE, ACC Conference, PP. 2289 – 2294, June 2012
[10] Gyan Ranjan Biswal, R. P. Maheshwari and M. L. Dewal, "Modeling, Control, and Monitoring of S3RS-Based Hydrogen Cooling System in Thermal Power Plant", IEEE Transactions on Industrial Electronics, Vol. 59, PP.562-570, Jan. 2012.
[11] Noor Azliza B.T Ibrahim, "Modeling of Micro Hydroelectric system Design", MS Thesis, University Tun Hussein Onn, Malaysia, July 2012.
[12] I. Khan, A. Mahmood, N. Javaid, S.Razzaq, R.D. Khan, M. Ilahi, "Home Energy Management Systems in Future Smart Grids", Journal of Basic and Applied Scientific Research , Vol.3, PP. 1224-1231, 2013.
[13] N. Javaid, M. Ilahi, R. D. Khan, L. Ali, U. Qasim and Z. A. Khan, "Evaluating Wireless Reactive Routing Protocols with Linear Programming Model for Wireless Ad-hoc Networks", Journal of Basic and Applied Scientific Research, Vol. 3, PP. 1170-1181, 2013.
[14] Levron, Y.; Guerrero, J.M. and Beck, Y., "Optimal Power Flow in Microgrids with Energy Storage", IEEE Transactions on Power System, Vol. 28, Issue. 3, PP. 3226 - 3234, August 2013.
[15] Deependra Kumar Jha, Naoto Yorino, Yoshifumi Zoka, Yutaka Sasaki, Yuki Hayashi, Kazunoni Iwata and Ryuji Oe, "Backward Search Approach to Incorporate Excess Stream Inflows in SDP Based Reservoir Scheduling of Hydropower Plants", IEEE, PP. 1-6, Hiroshima, Japan, 2009.
[16] Kai Heussen, Stephan Koch, Andreas Ulbig and Goran Andersson, "Energy Storage in Power System Operation: The Power Nodes Modeling Framework", IEEE, PP. 1-8, 2010.
[17] Sachin Mishra, S.K. Singal and D.K. Khatod,, "Effect of Variation of Penstock Parameter on Mechanical Power", International Journal of Energy Sciences, IJES, Vol.2, Issue. 3, PP. 110-114, 2012.
[18] A. Motamedi, H. Zareipour, W. D. Rosehart, "Electricity Price and Demand Forecasting in Smart Grids", IEEE Transactions on Smart Grid, Vol.3, No. 2, PP. 664-674, June 2012.
[19] Skoulikaris, Ch., Ganoulis, J., and J.M. Monget, "Integrated modeling of a new dam: a case study from the "HELP" Mesta/Nestos River", 18th World IMACS/MODSIM Congress, Cairns, PP. 13-17, July 2009.
[20] Fredrik Olsson and Mark Pearson, "Modeling the total inflow energy to hydropower plants- a study of Sweden and Norway", Lund University, March 2005.
[21] Rajib Datta and V. T. Ranganathan, "A Method of Tracking the Peak Power Points for a Variable Speed Wind Energy Conversion System", IEEE Transactions on Energy Conversion, Vol. 18, Issue. 1, PP. 163-168, Mar. 2003.
[22] Poullikkas A., "Implementation of distributed generation technologies in isolated power systems", Renewable and Sustainable Energy Reviews, Vol. 11, PP. 30-56, 2007.
[23] Shyh-Jier Huang, "Application of Genetic Based Fuzzy Systems to Hydroelectric Generation Scheduling", IEEE Transactions on Energy Conversion, Vol. 14, No. 3, PP. 724-730, September 1999.
[24] E. D. Castronuovo and J. A. P. Lopes, "On the optimization of the daily operation of a wind-hydro power plant," IEEE Trans. Power Syst., Vol. 19, No. 3, PP. 1599–1606, Aug. 2004.
[25] Hubert Abgottspon, "Mid-Term Hydro Power Planning for Energy and Ancillary Services", Master's Thesis, Zurich, 2009.
[26] A. Hainoun, "Construction of the hourly load curves and detecting the annual peak load of future Syrian electric power demand using bottom-up approach", ELSEVIER, International Journal of Electrical Power & Energy Systems, Vol. 31, Issue 1, PP. 1-12, January 2009.
[27] G. C. Bakos, "Feasability study of a hybrid wind-hydro power-system for low-cost electricity production," Appl. Energy, Vol. 72, no. 3/4, PP. 599–608, 2002.

[28] Khodayar, M.E.; Shahidehpour, M. and Wu, L., "Enhancing the Dispatchability of Variable Wind Generation by Coordination With Pumped-Storage Hydro Units in Stochastic Power Systems", IEEE Transactions on Power Systems, Vol. 28, Issue.3, PP. 2808 - 2818 , August 2013.

[29] Francine Menzel, Gaianê Sabundjian and Rita de Cássia Mutarelli, "Study of The Environmental Costs to Nuclear Power Plants using the Program Simpacts", International Nuclear Atlantic Conference – INAC,2011

[30] Paul Denholm and Gerald L. Kulcinski, "Life Cycle Energy requirements and greenhouse gas emission from large scale energy storage systems", ELSEVIER, Energy Conversion and Management, Vol. 45, Issue. 13-14, PP. 2153-2172, August 2004.

[31] Kollas I.G. and Mirasgedis S., "Health and Environmental Impacts of the Hydroelectric Fuel Cycle", Int. J. Risk Assessment and Management, Vol. 3, PP. 23-40, March 2002.

[32] Hongqing Fang, Long Chen, Nkosinathi Dlakavu and Zuyi Shen, "Basic Modeling and Simulation Tool for Analysis of Hydraulic Transients in Hydroelectric Power Plants", IEEE Transactions on Energy Conversion, Vol. 23, Issue. 3, PP. 834-841, Sept. 2008.

[33] N. Javaid, S. Hayat, M. Shakir, M. A. Khan, S. H. Bouk, Z. A. Khan, "Energy Efficient MAC Protocols in Wireless Body Area Sensor Networks-A Survey", Journal of Basic and Applied Scientific Research, Vol. 3, PP. 770-781, 2013.

[34] L. Vega, "Ocean Thermal Energy Conversion", Encyclopedia of Energy Technology and the Environment, John Wiley & Sons, Inc., New York, 2005.

[35] Surface Water Storage and Hydro Power, Handbook on Water Statistics of Pakistan, PP. 109-115.

[36] Ayaz Ahmed, Henna Iftikhar and G.M. Chaudhry, "Water Resources and conservation Strategy of Pakistan", PP. 1-17, 2009.

[37] Izhar-ul-Haq, "Hydro Power Potential of Pakistan", Pakistan.

[38] Optimal Control of Multiple Reservoirs System under Water Scarcity by Iftikhar Ahmed, Institute of geology, 2009.

[39] Milanovic, J.V. and Mat Zali, S., "Validation of Equivalent Dynamic Model of Active Distribution Network Cell", IEEE Transactions on Power System, Vol. 28, Issue. 3, PP. 2101 - 2110, August 2013.

[40] Naveed Ahmad, Mureed Hussain, Naveed Riaz, Fazli Subhani, Sajjad Haider, Khurram. S. Alamgir and Fahad Shinwari, "Flood Prediction and Disaster Risk Analysis using GIS based Wireless Sensor Networks, A Review", of Basic and Applied Scientific Research, Vol. 3, Issue. 8, PP. 632-643, August 2013.

[41] Amita Mahor and Saroj Rangnekar,, "Short Term Optimal Generation Scheduling of narmada Cascaded Hydro Electric System", Hydro Nepal, Issue. 7, PP. 71-80, July 2010.

[42] Deane, J.P.; McKeogh, E. and Gallachoir, B.P.O., "Derivation of Intertemporal Targets for Large Pumped Hydro Energy Storage with Stochastic Optimization", IEEE Transactions on Power Systems, Vol. 28, PP. 2147 - 2155, August 2013.

[43] C. Bueno and J. Carta,, "Technical economic analysis of wind-powered pumped hydro-storage systems. Part II: Model application to the island of El Hierro", Solar Energy, Vol. 78, no. 3, PP. 396–405, 2005.

[44] United States Department of Energy, National Hydrogen Energy Roadmap, November 2002.

[45] Randi Cameron Field, "Multi-Objective Optimization of Folsom Reservoir Operation", Master of Science Thesis , University of California, September 2007.

[46] G. N. Bathurst and G. Strbac, "Value of combining energy storage and wind in short-term energy and balancing markets", Electric Power Syst. Res., Vol. 67, Issue. 1, PP. 1–8, 2003.

[47] A. B. Alaya, A. Souissi, J. Tarhouni and K. Ncib, "Optimization of Nebhana Reservoir Water Allocation by Stochastic Dynamic Programming", Water Resources Management, Kluwer Academic Publishers, The Netherlands, Vol. 17, PP. 259-272, 2003.

[48] Muhammad Fahad Shinwari, Naveed Ahmed, Hassan Humayun, Ihsan ul Haq, Sajjad Haider and Atiq ul Anam, "Classification Algorithm for Feature Extraction using Linear Discriminant Analysis and Cross-correlation on ECG Signals", SERSC-IJAST (Korea), Vol. 48, PP. 149-162, Nov. 2012.