Generation Expansion Planning Towards Sustainable Development

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Abstract*: *This paper presents Generation Expansion Planning (GEP) problem towards Sustainable Energy Development (SED) for a hypothetical test power system. GEP is a highly constrained and non-linear optimization problem. In early days, the electric power generation is mostly from conventional types of plants emit Green House Gases (GHG) and other pollutants lead to environmental pollution. Due to higher depletion rate of fossil fuels and pollution impacts, it is important to consider Renewable Energy Sources (RES) such as wind, solar, biomass etc., for planning the future power system. In this study, Long-range Energy Alternative Planning (LEAP) soft tool has been used for solving the GEP problem towards SED. The various strategies involved in the SED are substitution of fossil fuels by various RES, energy savings on the demand and improve in efficiency of generating units. In this paper, GEP problem is solved for thirty years from 2017-2046. The various scenarios such as Demand Side Management Scenario (DSMS), Fuel Substitution Scenario (FSS), and Increase in Process Efficiency Scenario (IPES) are considered separately in addition to BASE Case Scenario (BCS). In all scenarios, the system performance factors like installed capacity required, emission of pollutants, reliability and total costs are analyzed.

Index Terms*: *Emission, Generation expansion planning, Reliability, Renewable energy sources, Sustainable energy development.

I. INTRODUCTION AND LITERATURE REVIEW

Electric energy is one of the most important sources for social and economic development and improved quality of life in all nations. The growth in electricity consumption is essentially associates with the development in economy. Electricity demand increases according to the population growth, higher per capita consumption, and hasty development of industrial & commercial sectors, higher Gross Domestic Product (GDP) growth and structural changes in the economy of all countries [1]. Therefore the proper planning of power system is essential to meet the demand accordingly.

GEP is a problem of finding 'WHAT' type of generating units to be commissioned and 'WHEN' the generating units to be committed accessible, over a long-range planning horizon [2]. The main objective of GEP is to diminish the total investment cost with a given reliability level. As GEP is a highly constrained, nonlinear, discrete optimization problem, it is a extremely thought-provoking problem for the power system planners [3, 4]. The solution for this GEP problem may be obtained by complete enumeration of each possible combination of constraints. Now a days power system planner are interesting in solving this problem to make the system as sustainable. Sustainable Energy Development strategies involve most important changes like substitution of fossil fuels by various Renewable Energy Sources [5,6], appear the most proficient and effective solutions intended for clean and green, energy savings on the demand side [7,8] and improve in efficiency of existing generating units [9,10]. Subsequently, large-scale renewable energy execution tactics must include strategies for incorporating renewable sources in coherent energy systems influenced by energy savings and Efficiency measures [11–14]. The sustainable activities are such that they meet the current requirements without abolishing the ability of future generations with equilibrium among economic, social and ecological requirements [15]. The Demand Side Management (DSM) involved for dropping peak demand so it can postponement building the further capacity. It can use for deferring high investment in electrical system like Generation, Transmission and Distribution networks and also makes available noteworthy economical, reliability and environmental benefits.

The DSM activities can be classified in two categories:

- Energy reduction technique programs —The procedures that are more efficient buildings or equipment for dropping demand.
- Load side management programs — During peak times the load pattern and heartening carries less demand.

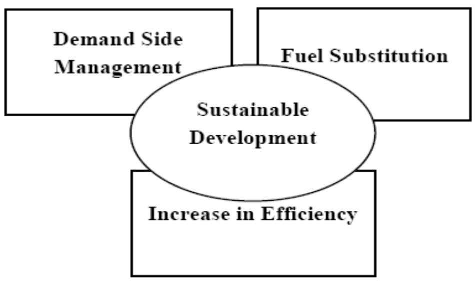

Fig. 1. Concept of Sustainable Energy Development

In this study the first category used for an action. For consumers, DSM offers a chance to diminish their energy bill through efficiency and conservation measures [16].

The concept of Sustainable Energy Development is shows in Fig. 1. In this paper, the long-term generation planning for a hypothetical test power system has been carried out with the available potentials of resources using LEAP software.

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The repose of the paper as follows. The chapter 2 delivers implementation in LEAP. The Chapter 3 describes results obtained by LEAP such as Installed Capacity, Environment analysis, Reliability analysis and Net present value. Chapter 4 concludes.

II. IMPLEMENTATION IN LEAP

The Long-range Energy Alternatives Planning system (LEAP) is an extensively recycled device for energy policy investigation and climate change moderation valuation established at the Stockholm Environment Institute (SEI) [17]. In this study, LEAP is used to solve Generation expansion preparation for a hypothetical test power scheme for the period of 2017-2046.

A. Exogeneous capacity

The test power system contains four types of plants which are Oil, Natural Gas, Coal, Nuclear power plants. The cost and technical data of the existing plants are taken from [18]. The technical and economic information of existing plants are

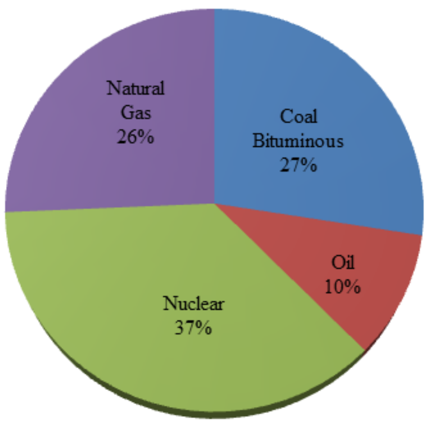

Fig. 2. Fuel mix ratio in the base year.

illustrate in Table 1. The test power system has the total installed capacity of 5450 MW in which coal contributes 27%, LNG contributes 26%, Nuclear power shares 37% and oil plants contribute 10% of total installed capacities. Fig. 2 shows the fuel mix ratio in the base year.

Table 1. Technical And Economic Data Of Existing Plants

Sl. No.	Name of the plants (Fuel Type)	Capacity (MW)	Operating Cost ($/KWh)	Fixed O & M Cost ($/Kw-Month)	Forced Outage Rate (%)
1.	Coal	1500	0.045	2.59	9.0
2.	Nuclear	1,000	0.021	7.77	9.0
3.	LNG	1400	0.036	1.098	3.0
4.	Oil	550	0.024	1.417	6.0

B. Endogeneous Capacity

In Table 2 illustrate the technical and economic data of upcoming candidate plants. For BCS, DSMS and IPES scenarios, all the plants are considered for imminent expansion. For FSS scenario, all the plants except Coal Bituminous and Coal Lignite power plants are considered as expansion candidates to meet the future load growth.

Table 2. Technical And Economic Data Of Candidate Plants

C. Energy growth

The energy required by the demand for the planning period 2017-2046. The peak demand available in the base year (2017) is 5000 MW also the total energy demand is 43800 GWh. The annual energy growth is assumed as 8% for scenarios BCS, FSS and IPES. For DSMS, it is assumed as 7.2% due to 10% energy saving by the various demand side management activities. The expected energy demand in 2046 is 4,08,097 GWh for all scenarios except DSMS. For DSMS, it will be 3,28,945 GWh in 2046. Fig.3. shows the energy demand for all scenarios.

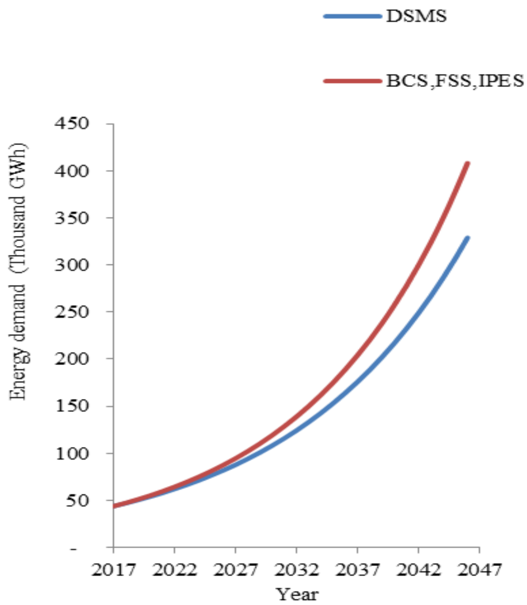

Fig. 3. Energy demand for all scenarios.

III. RESULTS AND DISCUSSIONS

The concerns of the three maintainable technological changes have been analyzed by using LEAP software. In this chapter, results obtained by LEAP such as Installed Capacity, Environment analysis, Reliability analysis and Net present value are conferred for BCS, DSMS, FSS and IEPS scenarios.

A. Installed capacity

Fig. 4 shows the installed capacity required for all scenarios during 2017-2046. The connected capacity for every scenario compared with BCS. The connected capacity of hypothetical power system is 5450 MW in the year 2017. In the year 2046, the installed capacity of the scenarios BCS, DSMS, FSS and IEPS are 58,160 MW, 46,650 MW, 61,150 MW and 58,650 MW.

Compared to BCS, the DSMS has 80.21% of installed capacity required in BCS. i.e., 19.79% is condensed by remedy actions takes place on the consumer side like

Sl. No	Name of the plants	Capital cost (k$/MW)	Fixed OM cost (k$/MW)	Variable OM cost ($/MWh)	Availability (%)	Scenarios			
						BCS	DSMS	FSS	IPES
1	Coal Bituminous	37.80	4.47	73.33	85	√	√	×	√
2	Solar	3873	27.75	0	40	√	√	√	√
3	Coal Lignite	37.80	4.47	73.33	85	√	√	×	√
4	On shore wind	2213	39.55	0	19	√	√	√	√
5	Nuclear	5530	93.28	2.14	90	√	√	√	√
6	Natural Gas	917	13.17	3.60	65	√	√	√	√
7	Bio mass	4114	105.63	5.26	30	√	√	√	√
8	Off shore wind	6230	74.00	0	50	√	√	√	√

√- considered for future expansion
×- not considered for future expansion

replacement of incandescent lamps and fluorescent lamps by LED/CFL lamps and by using energy efficient tube lights (Fluorescent lamps with electronic chokes) lead to considerable energy savings and hence the installed capacities. In FSS, the total installed capacity required is 61150 MW in 2046which is 5.14% higher than BCS. The FSS the thermal plants (coal based plants) are replaced by renewable power plants. In IEPS, it is increased by 0.84%.

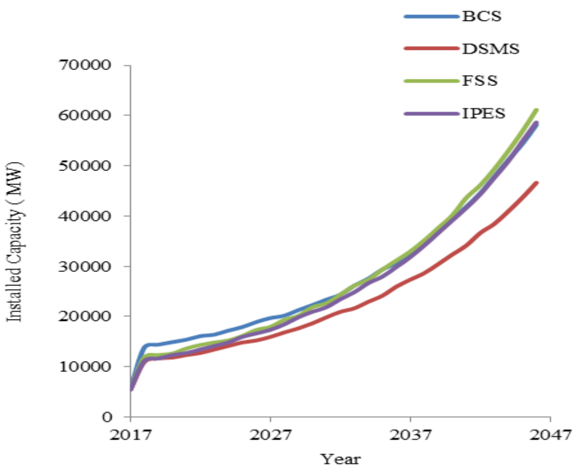

Fig. 4. Installed capacity required for all scenarios.

A. Environment analysis

In future for organization a power scheme, it is important to analyze the emissions from the thermal plants. In this category one hundred year Global Warming Potential (GWP) is quantitatively estimated by using data base in the LEAP software. Fig. 5. shows the total GHG emissions from the power plants during the study period. In BCS, the cumulative GHG emissions are 2821 Million Metric Tonnes CO2 Equivalent. In DSMS, it is reduced by 22.75% when compared to BCS. In FSS, it is expected to have less value of GHG emissions due to replacement of thermal plants by RES type plants like wind, solar and biomass. In this scenario, the total emissions are 792.7 Million Metric Tonnes. It is reduced by 71.9% when compared to BCS. The pollutants from thermal plants can also be reduced by increasing its process efficiency (8-10%). In IPES, it is reduced by 17.54% compared to BCS. Among the scenarios considered in this analysis, FSS plays important role in reducing the pollutions and saving the environment.

B. Reliability analysis

As The ability of scheme to meet the load demand to require dependability. It is the probability of providing consumers with continuous power supply. It can be measured by various indices in the power system engineering. In this study purpose, Energy Not Served (ENS) is recycled to estimate the reliability of the power scheme. The lower value of ENS indicates the better performance (good reliability) of the system and vice versa. The Fig. 6. shows the ENS value for all scenarios considered in this study. It has been noted that the reliability of the system is poor if FSS is considered. Because the Forced Outage Rate (FOR) of RES based plants are quite high and hence less power generations. In BCS, the value of ENS value is 36773.38 GWh in2046. These values are 32005.22 GWh, 131557.45 GWh and 38484.21 GWh for DSMS, FSS and IPES respectively at end of the planning period. When compared to BCS, in DSMS, the reliability is improved by12.96%. But in FSS, the value of ENS is 257.75% increased and hence the reliability of the system is poor. The value of ENS is comparatively reduced if it is compared with FSS. It is increased by 4.65% when compared to BCS. In the base year of study (2017), the value of ENS is zero GWh. The value of ENS is zero during the period 2017-2040 for BCS and 2017-2037 for DSMS and 2017-2027 for FSS and 2017-2038 for IPES.

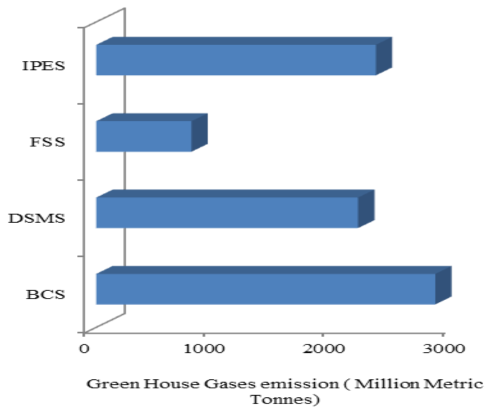

Fig. 5. Total GHG emissions during the planning period.

C. Net Present Value

The net present value of the power scheme is known as overall cost of the system. In BCS, the value of NPV is 147 Billion USD. The values of NPV are 140.9 Billion USD, 164 Billion USD and 145.1 Billion USD for DSMS, FSS and IPES respectively. The NPV of the FSS is too high compared to all scenarios. It is increased by 11.62% when compared to BCS. This is due to huge capital cost of RES based plants. In DSMS and IPES scenarios the NPV values have been decreased by 4.13% and 1.29% respectively when compared to BCS. Fig. 7. shows the NPV values of all scenarios.

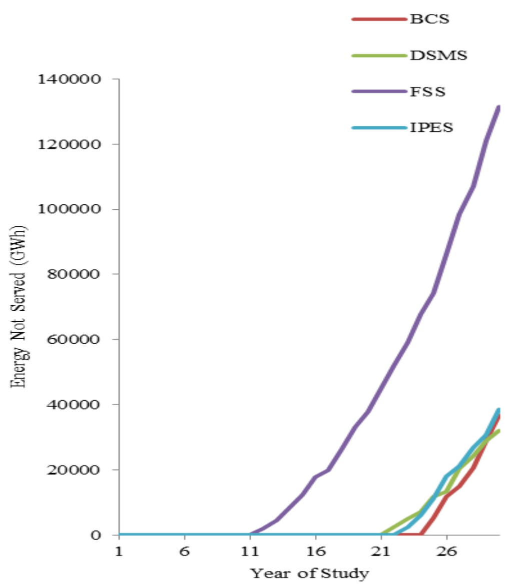

Fig. 6. ENS values of all scenarios.

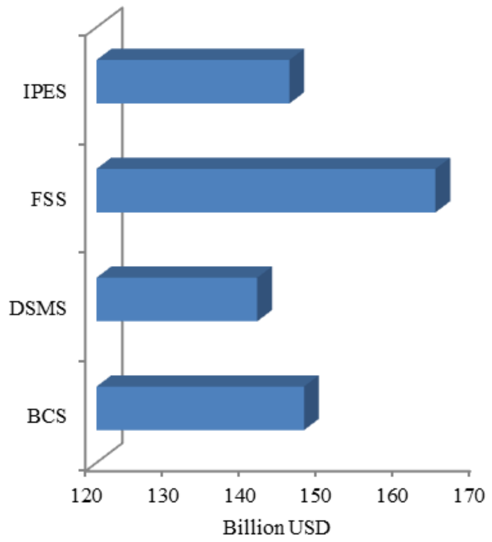

Fig. 7. Net Present Value of all scenarios.

IV. CONCLUSIONS

The Generation Expansion Planning (GEP) problem is solved in this paper towards the sustainable energy development for hypothetical power scheme for the period (2017 to 2046) of thirty years. In addition to Base Case Scenario (BCS) the various scenarios such as Demand Side Management Scenario (DSMS), Fuel Substitution Scenario (FSS), and Increase in Process Efficiency Scenario (IPES) are evaluated in terms of installed capacity, GHG emissions, reliability and the total scheme cost. The BCS scenario is considered as reference for all scenarios. With DSMS, the reliability of the power system can be improved to 12.56% and the total installed capacity can be reduced by approximately 20%. With FSS scenario, the GHG emissions can be concentrated by more than 70%. When compared to reference case, in IPES scenario, the GHG emissions can be concentrated by 17.54%. It has been concluded that by implementing load management, fuel substitution and efficiency also increasing in the thermal plants simultaneously the ENS value and environmental pollution can be further reduced.

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