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ENERGY PLANNING FOR INDIA WITH FOCUS ON COST OF COAL BASED POWER GENERATION

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ABSTRACT

Presently, the thermal based power plants caters majority of the demand of power in developing countries like India. Development of an electricity allocation model will help in the proper allocation of the energy sources in meeting the future electricity demand in such countries. In this paper, an energy planning model has been developed that minimizes the cost of power generation and determines the optimum allocation of different energy sources for the centralized and decentralized power generation in India with special emphasis on cost factor for the coal power plants. The electricity distribution pattern is obtained for the year 2020. The results indicate that the electricity generation mix would be 15,800 GWh (4 %) from the coal based plants. The OEAM model is validated by the sensitivity analysis. This study can be used by the policy makers for framing energy policies in developing countries.

Keywords: coal, energy planning, energy scenario, sensitivity analysis.

INTRODUCTION

The challenge of supplying electricity in the world, particularly in India is expected to increase in a very rapid manner due to the industrial growth and population. Currently, India is generating electricity with capacity of nearly 249,488 MW as of end June 2014. Every year, the need of power is increasing. Also, India is having a limited source of commercial energy sources, it can be said that renewable energy systems can be installed at a reasonable social cost. Even though the present cost of the power generation from the renewable energy sources is higher when compared to the conventional energy sources, there is a possibility for further decrease by achieving higher energy conversion efficiencies and by locating suitable sites where renewable energy sources could be trapped effectively and efficiently. An electricity planning model would facilitate the effective utilization of energy sources for the electricity generation. The scenario based on the cost of coal based power generation to improve the quality of life in India have been proposed and discussed in this paper.

A review of various energy planning models has been presented. De Musgrove (1984) had used the MARKAL, a linear programming model having total system discounted cost as the objective function and oil conversion and demand as constraints, to analyze minimum discounted cost configurations for the Australian energy system during the period 1980-2020[1]. A linear programming model had been studied by Ellis *et al* (1985) for the development of acid rain abatement strategies in Eastern North America [2]. Satsangi and Sarma (1988) studied the possible options for meeting the energy needs of the economy for India for the year 2000-01 [3]. Pasternak *et al* (1990) had developed an optimization model for the economic evaluation of energy conservation projects with an emphasis on initiation time [4]. The mathematical programming energy-economy-environment (MPEEE) model had been formulated by Suganthi and Jagadeesan (1992) [5]. A linear optimization model and a multi-attribute value model had been proposed by Mustafa Tiris *et al* (1994), to evaluate the long-term energy, economy and environment interactions for Turkey [6]. Jebaraj and Iniyan (2006) have studied the various kinds of energy models [7]. Benjamin K. Sovacool and Bulan (2012) investigated the energy security and hydropower development in Malaysia with the focus on the drivers and challenges facing the Sarawak Corridor of Renewable Energy (SCORE) [8]. Pierluigi Mancarella had discussed the overview of concepts and evaluation models in multi-energy systems (2014) [9]. In this work, Optimal Electricity Allocation Model (OEAM) has been proposed with special emphasis in the cost of coal based power generation.

METHODOLOGY

The OEAM model optimizes and choses the optimum energy options for the electricity generation on the criteria such as cost, resource potential, demand, efficiency, emission and carbon tax. The main objective function in the model is the minimization of the cost of power generation. The other parameters are used as constraints in the model. The fuzzy based linear programming problem is formulated with the objective function and constraints and mathematically represented as below.

$$\text{Minimise } Z = \sum_{j=1}^{1} \sum_{i=1}^{l} \left(C_{ij} X_{ij} \right) \quad (1)$$

Subjected to constraints

$$\text{Potential}: \sum_{k=1}^{19} \left[\sum_{i=1}^{m} \left(X_{ij} \right) \right] \leq P_k \quad (2)$$

$$\text{Demand}: \sum_{j=1}^{1} \left[\sum_{i=1}^{l} \left(X_{ij} \right) \geq D_j \right] \quad (3)$$

$$\text{Efficiency}: \sum_{j=1}^{1}\left[\sum_{i=1}^{l}\left(\eta_{ij} X_{ij}\right) \geq D_j\right] \quad (4)$$

$$\text{Emission}: E_n \sum_{k=1}^{19}\left[\sum_{i=1}^{m}\left(X_{ik}\right) \leq T_n\right] \quad (5)$$

$$\text{Carbon Tax}: E_n \sum_{k=1}^{19}\left[\sum_{i=1}^{m}\left(X_{ikr}\right) \leq T_n R\right] \quad (6)$$

Where η is the efficiency of the energy system, E_n is the emission constant (g/GWh), l is the number of energy systems for power generation, X is the quantum of energy (GWh), m is the number of system in respective resources, C is the unit cost of the energy system, D is the energy demand (GWh), k is the resources, P is the potential of sources (GWh), T_n is the target emission level (g/year), r is the carbon tax (Rs/ton), R is the projected carbon tax in 2020 (Rs/ton), I is the various energy systems and j is the power generation option. The constraints efficiency, emission and carbon tax do not have single value and therefore, they are used as fuzzy linear constraints. But, demand and potential are treated as ordinary linear constraints since they have exact values. The trapezoidal shaped membership function is selected for the fuzzy linear constraints.

The electricity demand during 2020 in India is forecasted by means of artificial neural network as 993,385 GWh. The present electricity supply is 565,102 GWh. Hence; the energy gap for the year 2020 is determined as 428,283 GWh. This energy gap should be met by the various energy options with focus on the emission and carbon tax and the cost of power generation. There are twenty different energy systems namely coal, gas, diesel, nuclear, hydro, biodiesel, biomass gasifier, wind, biogas, solid waste, cogeneration, solar PV, ethanol, solar thermal, OTEC, tidal, geothermal, mini hydel, fuel cell and MHD are considered in the energy planning model to meet the electricity demand.

RESULTS AND DISCUSSIONS

The OEAM electricity model gives the optimum allocation for energy sources in India for the year 2020. The proposed electricity generation mix is shown in Figure-1. It is found that the hydel power plants amount to 191,100 GWh, which is nearly 44 % of the total electricity

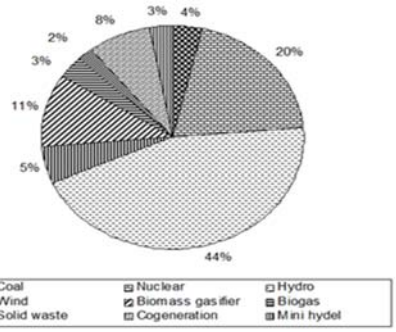

Figure-1. Energy mix for electricity generation for the year 2020.

demand, the nuclear power plants contribution is around 85, 400 GWh (20 %). But, the coal based power plants contribute to only 15,800 GWh, which is only 4 % of the total electricity need. Also, the power generation from diesel and gas based plants is very less when compared with the other conventional power plants. Altogether, the contribution from the conventional power plants for electricity generation is about 68 %. The remaining 32 % of demand is met by the renewable energy sources like wind, biomass, biogas plants, solid waste, cogeneration and mini hydel based power plants. The power generation from the bio-diesel-based plants, ethanol, solar, OTEC, tidal, geothermal, fuel cell and MHD are not chosen in the model. However, the model selects the above systems at the time of various scenarios.

COAL POWER: SCENARIO

An analysis has been conducted by varying the unit cost of power generation by coal-based thermal power plants and its implication is shown in Figure-2. It was compared with baseline scenario, which was already developed. The baseline scenario was developed with existing data without varying. It is represented as 100% (Base) in the scenario. The cost data is increased and decreased in stages from 100%. It is observed that there is no change in the power generation mix for 25%, 50% and 75% reduction in the cost for thermal power generation and 25% and 50% increase of the unit cost of power generation from thermal power plants. But if the unit cost is increased to 175% and 200%, there is a change identified that the contribution of coal based plants is replaced with nuclear-based plants. Till 150% increase of unit cost, coal based plants accounts for nearly 4% (15,800 GWh) of the total power generation. The usage of coal would be continued for another few-year, since the cost of power generation by coal-based thermal power plants is currently cheaper.

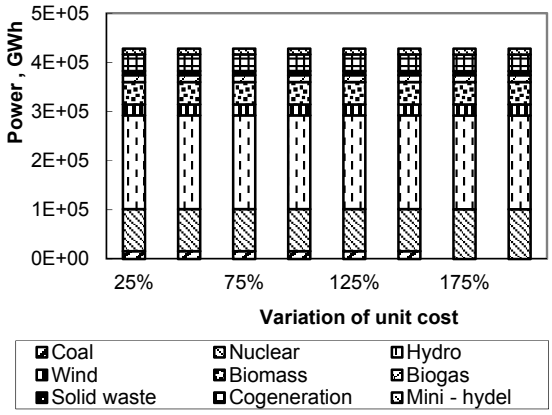

Figure-2. Variation of cost of coal power generation on energy mix.

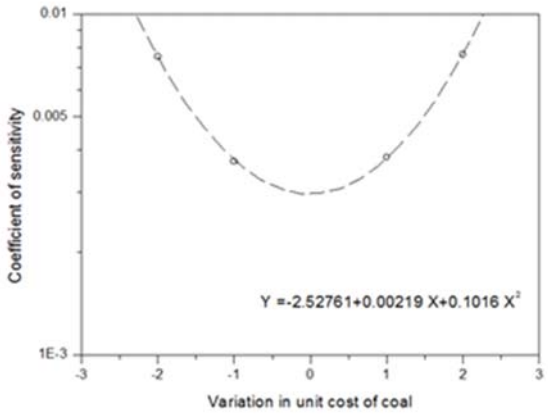

Figure-3. Sensitivity analysis.

SENSITIVITY ANALYSIS

Sensitivity analysis has been conducted to validate the OEAM energy planning model. The cost inputs are increased or decreased in the model and the sensitivity of the model is estimated. Figure 3 indicates the results of the sensitivity analysis. When the unit cost of coal is increased and decreased by 1%, the coefficient of sensitivity is determined as 0.0038 and 0.0037 respectively. When it is increased and decreased by 2%, the coefficient of sensitivity is determined as 0.0076 and 0.0075 respectively. It is confirmed that the model is more sensitive with regard to variation in the cost factor.

CONCLUSIONS

The OEAM linear programming model has been formulated for the electricity requirements for the year 2020. The model is developed with the objective of minimizing the cost of power generation subject to the constraints of demand, potential, efficiency, emission and carbon tax. The fuzzy constraints are used in the model since they do not have exact values. The extents of energy sources mix for the power generation would be 4 % from the coal based plants, 20 % from the nuclear power plants, 44 % from the hydro-electric power plants, 5 % from the wind turbines, 11 % from the biomass gasification, 3 % from the biogas plants, 2 % from the solid waste power generation, 8 % from the cogeneration plants and 3 % from the mini hydel power plants, respectively. A scenario is proposed based on the cost of coal based electricity generation. Sensitivity analysis has been performed to validate the energy planning model and determined that the model is very sensitive. Hence, this model can be used for the future energy planning for any developing countries.

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