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Integration of Demand and Supply Side Management strategies in Generation Expansion Planning

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ABSTRACT

Electric utilities across the globe concerned with environmental issues associated with conventional fossil fuel based plants are exploring more into the possibility of introducing Renewable Energy Sources (RES) type of plants into the system as an alternative. A realistic power system planning needs integration of both Demand Side Management (DSM) and Supply Side Management (SSM) that which involve simultaneous consideration of both quantitative and qualitative issues like plant mix, costs and reliability of power supply. In this paper, an attempt is made to study the economic and environmental influence of RES introduction into an existing peak deficit power system, in the state of Tamil Nadu (TN), India, using the Long-Range Energy Alternative Planning system (LEAP) an energy-economic model, integrating both DSM and SSM strategies. The Generation Expansion Planning (GEP) study is carried out for TN power system for the period of thirty years from 2014 to 2043. The Base System Analyses (BSA) carried out was indicative of differential impact of RES levels and Reserve Margin on the system performance. Based on the BSA, an extended three dimensional sensitivity analysis was performed to get a comprehensive picture of the impact of variations in RES and Reserve Margin planned on system performance factors such as, Total Installed Capacity (TIC), Net Present Value (NPV) of investments, reliability of the system (ENS-Energy Not Served), one hundred year global warming potential (CO_2E) and Flexibility Index (FI) for every DSM and SSM strategy planned. While TIC and NPV were more sensitive to changes in Reserve Margin (RM) than RES penetrations levels, the CO_2E and FI were more sensitive to RES penetration levels. The ENS was sensitive to both RM and RES levels. The results also indicate that simultaneous implementation of DSM and SSM strategies could result in the reduction of as much as 10% in TIC, 18% in NPV, 23% in CO_2E, 18% in ENS and 20% improvement in FI value.

1. Introduction and Literature review

Energy planning is the process of developing long-range policies for the local, national, regional and even global energy system to save the future. The main purpose of the energy planning model is to analyze the environmental and economical impact on various energy strategies. The planning of the electric sector needs to analyze the effect of Demand Side Management (DSM) and supply side management (SSM) resulting in the economical and environmental benefits and also the improvement on the reliability of the system.

1.1. Demand Side Management

The DSM has been traditionally considered as a mode of reducing peak demand so that utilities can delay building the further capacity. In fact, by reducing the overall load of an electricity network, the DSM has various beneficial effects including mitigating electrical system emergencies, reducing the number of blackouts and increasing system reliability thereby reducing dependency on expensive imports of fuel, energy prices and harmful emissions to the environment. Finally, DSM plays a major role in deferring high investments in the Generation, Transmission and Distribution networks. Thus the DSM applied to the electricity systems provides significant economical, reliability and environmental benefits [1].

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The main types of DSM activities may be classified in two categories:

- Energy reduction programmes — reducing demand through the processes that are more efficient buildings or equipment.
- Load management programmes — changing the load pattern and encouraging less demand during peak times.

The motivation behind the implementation of DSM is obviously different for different parties involved. For power generating companies, the reduction or shift of a customer's energy demand means avoiding or delaying the building of additional generating capacity, thereby, making the maximum utilization of the existing resources. For customers, DSM offers an opportunity to reduce their energy bill through efficiency and conservation measures. Another option is to reduce demand in agriculture sector is wind driven pumps. The evolution of the major achievements in water lifting devices with emphasis on the major technologies over the centuries is presented in [2]. The authors discussed the adaptation of the traditional water wheel, which is a simple construction for use with renewable energy sources, providing a sustainable solution to meeting the water needs for rural agricultural development.

1.2. Supply Side Management

The Supply Side Management (SSM) refers to the actions taken to ensure the generation, transmission and distribution of energy efficiently. The SSM enables the installed generating capacity to provide electricity at lower cost and reduces environmental emissions per unit of end-use electricity provided. The SSM also contributes to improve the reliability of a supply system [3].

The following activities are generally included in SSM.

- Supply and utilization of energy resources—includes clean coal technologies, fuel substitution and renewable energy usage.
- Power generation and energy conversion—includes operational improvements, upgrading units and cogeneration in existing plants
- Transmission and distribution of electricity— includes reduction of losses in lines by up gradation of transmission and distribution networks

The Clean Coal Technologies (CCTs) are designed to improve the efficiency of the extraction, preparation and use of coal. The improved efficiency in extracting energy from the coal delivers the same amount of electricity but with reduced gaseous emissions and solid waste. The CCTs improve the efficiency of the coal-based electricity generation with the benefits such as reduced specific fuel consumption and reduced environmental impact per unit of coal fired [4].

1.3. Literature review

The Nautilus Institute, USA has designed an analytical framework and compared the energy security characteristics of different quantitative energy paths in Northeast Asia using LEAP [5]. A brief review of the commonly used bottom-up energy models has been presented and a sustainable long-term electricity supply-demand framework has been proposed [6]. In the proposed framework, DSM is considered as one of system's scenarios on the demand side whereas the utilization of locally available renewable energy resources is taken into account on the supply side. The different scenarios such as Business As Usual (BAU), maximizes resource diversity and minimizes global warming potential, have been quantitatively analyzed for the Panama power sector [7]. The possible future paths for Lebanon's electricity have been modelled and evaluated using the LEAP software. The Renewable Energy Scenario and the Natural Gas Scenario are compared with BAU scenario. The results show that the alternative scenarios are environmentally and economically more attractive than the BAU scenario [8]. In [9] the current electricity generation as well as the future expansion plans of Nigeria power system is analyzed using LEAP. The role of renewable energy technologies in helping rural communities of Nepal to adapt to climate change is analyzed in [10]. The economic and environmental influence of the renewable energies on the existing electricity generation market of South Korea is also discussed using the LEAP for different scenarios such as BAU, installation plan of different renewable energy facilities, technological improvement and the cost of installed renewable energy plants and CO_2 reduction potential were assessed quantitatively [11]. The status and recent trends in the Japanese energy sector includes energy demand and supply by fuel and by sector and the current energy policy focusing on climate change targets, renewable energy development and deployment, liberalization of energy markets and the evolution of the Japanese nuclear power sector are also discussed in [12]. The effects of several DSM and SSM strategies on resource depletion and environmental emissions for Iranian power sector have also been analyzed in [13].

There is a little literature available for system such as TN power system (peak deficit system), which has 47% of total installed capacities from renewable powers. In order to analyze such a peak deficit power system, a LEAP model has been developed and applied to TN power system. The rest of the paper has been organized as follows. Section 2 describes the introduction about TN power sector and the potential for both the wind and solar energy. Section 3 elucidates the implementation in LEAP software. Section 4 describes the model analysis that was carried out, Chapter 5 presents results of the analysis carried out followed by discussions and chapter 6 is the final conclusion.

2. Introduction to Tamil Nadu (TN) power sector

Tamil Nadu (TN), located in South India, roughly extends between 8° 04' N latitude (Cape Comorin) to 78° 0′ E longitude. It is bounded by Andhra Pradesh and Karnataka on the North, by the Indian Ocean on the South, by the Bay of Bengal on the East, and by Kerala on the West. The capital of TN is Chennai, associating in the northeastern portion of the state. TN is the eleventh largest state in India in area and the sixth most populous state in India.

For the past five years, TN has been facing massive power deficits and huge power cut issues. Hence, the reliability on TN power system is poor since electricity generation is not able to meet the demand. This power shortage affects all the sectors leading to loss in production and loss of income. Even though the installed capacity (21,794 MW) is sufficiently higher than that of peak demand of 13,771 MW, the power shortage continues to exist. It is to be noted that, the actual available capacity will be very less, if de-rating of generators are considered. This is due to 47% of total installed capacities from renewable resources. Since it is intermittent in nature and the wind plants are idle during no wind periods, which account 33% (7206 MW) of total installed capacities. Many of the thermal plants are being operated beyond their lifetime. Central Electricity Authority of India (CEA) [14] reports 40% power cut for HT and commercial consumers, two hour load shedding for Chennai (capital city of TN) between 08.00 and 18.00 h from 18th October 2012, three hours load shedding (between 06.00 and 18.00 h) for urban and rural areas for all periods and 10% peak hour restriction to HT and commercial consumers.

The reliability of the TN power grid for the year 2012 has been analyzed in [15]. The Generation Expansion Planning for TN has been proposed with different penetration level of RES in [16]. In [17], Climate Aware Generation Planning has been discussed and the author suggested that the cost of import of hydropower from Bhutan would be cheaper than power generation cost inside the TN. This power shortage can be reduced considerably by implementing the DSM and SSM techniques.

Tamil Nadu Generation and Distribution Corporation Limited (TANGEDCO) is an electrical power generation and distribution public