ABSTRACT

The electric power system is a sheet anchor to a nation’s economy. Its development is influenced by the increase in electricity demand, the availability of primary energy resources and the national/corporate finance. Power system planning is made up of the electricity load forecast, generation expansion planning and transmission (network for carrying electricity) expansion planning. The electrical load forecast forms the basis of power system planning and provides information on expected consumption increase, load curve profiles and load distribution. The electricity generation scheme and the electricity transmission schemes are actually dependent features within a power system. However, generation expansion planning and transmission expansion planning are generally dealt with separately in power systems.

One of the reasons for generation and transmission expansion planning exercise being carried out sequentially rather than in an integrated way may be attributed to the unbundling of vertically integrated entities into separate entities looking after the generation, transmission and distribution of electricity. Restructuring of electricity sector has been done in several countries. In some countries, the electricity industry is still vertically integrated. To promote competition and for better management, unbundling of vertical entities into generation, transmission and distribution entities is justified from investment and operation point of view. However, for planning the system expansion and its development in a coordinated way, the role of a central agency cannot be underestimated.

Generation and transmission expansion planning may not have much relevance in developed countries where there is much less growth of electricity demand and only small generation capacity is required to be added to replace the old and inefficient generating units. However, generation and transmission expansion planning is very important in developing countries having big power system, like in India. In India, the demand of electricity is projected to increase at an annual compound growth rate of 7-8%. To meet the growing
electricity demand, massive electricity generation capacity of the order of 75 GW-100 GW is planned to be added during a Five Year Plan Period. Commensurate transmission lines are also planned for evacuation of power. Further, in addition to coal being used for power generation near the coal mines, coal is also transported over long distance to the power plants located at load centres through the vast rail network. In such systems the fuel transportation and power transmission network must be optimized together.

Most of the commercial generation expansion planning models like EGEAS and WASP are single-node generation expansion planning models i.e. the generating units and loads are assumed to be located at the same node in these models, as far as generation expansion planning is concerned. These models do not consider the fuel transportation and power transmission network in the optimization. Even some of the integrated generating and transmission expansion planning models reported in literature do not consider the fuel transportation network in optimization; or they do not consider Kirchoff's second law relating power flow in transmission line to the bus (node) angles.

With increasing concern over global climate change, renewable sources for electricity generation, especially wind, is being promoted worldwide. Wind is intermittent and it cannot be predicted with complete accuracy. The level of penetration of wind power in a system depends upon the ramping capability and minimum operating limit of thermal/hydro generators in the system. With high penetration of wind power, the conventional generating units may be required to be ramp up/ramp down and start up/shut down more frequently. Hence the operational constraints like ramp up/down rates, minimum operating limit, minimum up and down time (constraints generally considered in unit commitment) of conventional generating units need to be considered in generation expansion planning while planning for high penetration of wind power. This is very important to ensure that the
planned system is feasible from operational aspects. Traditional generation expansion planning models do not consider these operational issues.

High penetration of wind in the electricity grid requires additional operating reserve, in addition to the reserve required to cater to forced outage of generating units and unpredicted increase in load. Reserves are also required to take care of periods of no electricity generation conditions from wind in certain seasons.

The present research work intends to develop an integrated generation and transmission expansion planning model considering fuel transportation and power transmission networks. Integrated generation and transmission expansion planning model with high penetration of wind power has also been developed in this thesis. With high penetration of wind power, the model used for generation expansion planning should incorporate the features of expansion planning as well as operation planning models. The unit commitment constraints are taken care of in the developed integrated generation and transmission expansion planning model with high penetration of wind power. Hence, in addition to expansion planning study, the developed model can also be used for operation planning study, like transmission constrained unit commitment study.

Reserve assessment in the system has been done using both deterministic and hybrid deterministic/probabilistic approach to bring out the difference between the two approaches. The Integrated Generation and Transmission Expansion Planning models have been developed using General Algebraic Modeling System (GAMS) software which is a modeling language and has been solved using CPLEX solver available in GAMS. The developed models have been exemplified by its application to a test system and real system.