Abstract

Sizeable portion of world’s electric power generation is being contributed by non-renewable energy resources such as coal, gas, oil etc. The use of these fossil fuels results in increased emission of CO₂ and other harmful gases in the atmosphere while the residues as a result of these fuels are mainly released into water. This results in several health related issues to human and other living bodies on earth as well as raises global warming issues. It is projected that world electricity demand is expected to grow more than 2% annually. The ever increasing demand for electric power in the face of global warming and health related issues in use of fossil fuel based power generation, demand for a paradigm shift towards the use of natural renewable resources based electricity generation e.g. using wind, solar, hydro, geo-thermal and bio-gas etc. The renewable energy based generation admits distributed or hybrid kind of generation due the distributed availability or insufficient availability of a single renewable source. The integration of different types of renewable as well as conventional electric generations, to cater the requirements of local area in an isolated way or local area as well as main grid in an interconnected way has led to the concept of micro-grid.

Historically, wind generation has been exploited and is in use since generations. Modern wind energy generation is well established due to various positive factors like lesser conversion equipment, land requirements and maintenance, and due to direct coupling of wind turbine to generator shaft. Both fixed speed and variable speed wind energy conversion systems are currently being used. Over time, Doubly Fed Induction Generator (DFIG) based wind power conversion became popular and has been widely accepted in many parts of the world due to its wider range of operation i.e. almost ± 30% around synchronous speed.
The research work taken up in this thesis concerns the development of robust heuristic control technique for grid connected DFIG based wind turbine units along-with other local renewable energy resources. Here, using a mathematical model based upon the Park’s transformations in stationary and rotor reference frames, the steady state and transient response of DFIG has been studied. This mathematical model was implemented to analyze the dynamic and steady state response of DFIG connected to grid under different operating conditions. To render reduced mathematical complexity a reduced order model of DFIG has been obtained to analyze the inertial response of DFIG. Further, the dynamics of wind turbine is represented by state space model for analyzing the impact of wind speed variations on wind turbine structure for 1.5 MW wind turbine.

The ever increasing power requirements with increased reliability, demands for interconnection of large number of hybrid generating units over existing transmission infrastructure operating close to their thermal limits. Any sudden rise or fall in demand over such stressed tie line infrastructure may results in low frequency power oscillations. The problem of steady state stability circumvents around ways to mitigate these low frequency oscillations, and is more involved in modern interconnected power systems with several renewable energy resources. To damp or mitigate low frequency oscillations formulates the problem of load frequency control.

The interconnected power systems with hybrid energy resources formulate a nonlinear, distributed and overall complex dynamical system. The conventional control techniques based upon the linearized dynamics of the system may render themselves ineffective to address load frequency control (LFC) issues in such modern power systems. This demands for extension of heuristic control techniques based upon modern optimization techniques to damp low frequency oscillations. Many conventional and heuristic control techniques have been applied to address the issue of LFC in recent past.
This thesis further investigates load frequency control of large interconnected power system consisting of conventional and renewable energy sources, using hybrid heuristic approach. The conventional, fuzzy and particle swarm intelligence based conventional controllers have been investigated.

This work considers LFC problem in a power system with five areas connected to same tie-line consisting of non-conventional main power grids (Thermal–Hydro) and micro-grids (Wind-Diesel). For the considered system, the performance of the existing conventional proportional and integral (PI) controllers and fuzzy tuned PI controller is compared with particle swarm optimization (PSO) tuned PI controllers in a regulated and deregulated environment. The considered system with PSO optimized PI controller has been implemented on Matlab/Simulink platform to analyze oscillation damping under different conditions based on participation factors, load disturbances and variations in local load demands. Simulation results show that the PSO tuned PI controller results in better performance than the conventional and fuzzy tuned PI controller. Further, a hybrid heuristic technique using iterative PSO and Bacteria Foraging (BFO) steps for optimizing controller gains in multi area system incorporating DFIG has been proposed. A heuristic load frequency controller for a three area power system model using hybrid BFOA-PSO control technique has been proposed. The simulations of the considered three area power system model with existing BFOA, PSO and proposed hybrid BFOA-PSO control technique has been carried out in MATLAB-Simulink environment. The proposed hybrid BFOA-PSO based PI control design admits better control performance as compared to existing BFOA and PSO based controllers.

However, for the given complex hybrid power system setup, the task of calculating conventional PI parameters is more involved and time consuming. An Ant colony optimization (ACO) based controller has been implemented and compared with
existing multi-objective Genetic Algorithms based and Teacher Learner Based Optimization (TLBO) controllers.

The research work reported is summarized as

- Study and development of mathematical models for the DFIG based system verified with simulations in Matlab/Simulink environment.
- Study of Wind turbine structural dynamics on 1.5 MW DFIG
- Study and modeling of DFIG based Wind Turbine for Inertial response
- Development of interconnected micro-grid models for steady state stability
- Study of LFC problem using Conventional, Fuzzy and heuristically tuned existing controllers.
- Development of robust hybrid heuristic load frequency controller for developed power system models incorporating DFIG with comparison to existing ones.
- Further scope and extension to this work.