

Abstract

In the last two decades power sector has been modernized through newer, better and safer technologies. There are lots of changes starting from its restructuring, application of information technology and digital communication, incorporation of renewable energy resources, smart metering etc in the power system operation. Nowadays interconnected power systems operate country wise. In such situation frequency regulation has become one of the most focused issues in power system operation. In the restructured power system, private and public power producers, distributors participate in a competitive power market. Hence it is very much needed to maintain the frequency at a set value as well as keep the economy of the power trading sustainable. To keep both regulated, availability based tariff (ABT) can provide a solution. The deviation of the actual generation of the generators from their availability i.e. their declared generation can good impact on the frequency fluctuation if the excess generation or the deficiency of generation is either incentivised or penalised depending on the grid frequency status. Such frequency linked pricing criterion has been used here in the secondary frequency control loop of the different proposed interconnected hybrid power generating system. The thermal-hydro-diesel/biomass based three area or four area power system connected through tie-lines are tested for sudden load perturbations. Instead of conventional area control error (ACE) based secondary frequency control scheme, generation control error (GCE) based secondary frequency control scheme has been adopted for six different MATLAB/Simulink models. The GCE signal has been generated following the UI price rate as imposed by electricity regulatory commission and the deviation of the actual generation from its declared value. It is also depended on the deviation of the grid frequency from the set value of the frequency. One of the case studies includes the wind generation. As its availability is intermittent, it operates only on the primary control loop not in the secondary control loop which works on the basis of availability. The penetration of the wind power is also studied in another case. Particle swarm optimization (PSO) has been used for optimizing the controller gains which has improved the transient frequency, generation deviation and the tie line power plots significantly. The settling time has reduced a lot. Lastly, incorporation of a microgrid comprising fuel cell, offshore wind turbine generators, diesel generators along with flywheel energy storage system (FESS) and battery energy storage system (BESS) in the three area interconnected system has been studied for the load perturbations. The results show that the incorporation of wind or microgrid does not hamper the frequency regulation if the controller gains are chosen appropriately. Moreover the

unscheduled interchange costs can be kept within 1780 Rs./MWhr and 0 INR/MWhr for frequency limit of 50.00 Hz to 50.03 Hz. It is observed that the application of UI based pricing in the ABT regime can be well appreciated for the interconnected power systems comprising conventional and renewable energy resources. The grid discipline in terms of the frequency regulation and the generation control can be maintained with the proposed attempt. To solve these cases, interconnected power system models have been developed in-house and simulated in MATLAB/Simulink platform. MATLAB script has been written for PSO program to optimise the PI controller gains and feed it to the Simulink model. Several iterations are required to run both the Simulink model and the MATLAB script in an interlinked manner which took some computational time.

The work done in this thesis can contribute to achieve the Sustainable Development Goals (SDGs) viz. SDG 7 and SDG 13. The frequency regulation attained here under unscheduled interchange (UI) price based secondary frequency control scheme, finally leads to control the generation and consumption of electricity. Thus, the fuel brunt can be optimized for the conventional generators catering the base load of an interconnected power system which can reduce the cost of electricity generation and in turn it can make the electrical energy affordable worldwide. Again the integration of the wind, biomass, fuel cell and the energy storage systems in the interconnected power system facilitates green power generation. Hence this research work can help to attain the sustainable, affordable electrical energy which belong to the sustainable development goal 7. Again the RE integration leads to clean power production which helps to achieve the sustainable development goal 13. SDG 13 aims to combat the climate change and take the actions to restrict its impact. Thus this thesis can add some contributions to achieve these goals for the betterment of human living and the nature.