FREQUENCY CONTROL OF A SMART MICROGRID

by

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CERTIFICATE

This is to certify that the thesis entitled "**Frequency Control of a Smart Microgrid**" being submitted by **Mr. Gaddam Mallesham** for the award of the degree of **Doctor of Philosophy** is a record of bonafide research work carried out by him in the Department of Electrical Engineering of the Indian Institute of Technology Delhi.

Mr. Gaddam Mallesham has worked under our guidance and supervision and has fulfilled the requirements for the submission of this thesis, which to our knowledge has reached the requisite standard. The results obtained here, have not been submitted to any other University or Institute for the award of any degree.

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ABSTRACT

Today's world is very much concerned to reduce greenhouse gas emissions from the conventional thermal power plants as cutting down emissions from transport and heating sector may not be realistic in the near future. To reduce pollution from electrical power sources, the world is now marching towards the usage of renewable energy sources. These sources being small in capacity are mostly connected at the distribution voltage level. This indirectly reduces transmission and distribution losses since the sources are near the load. This distribution system having small scale energy sources is called as a *microgrid* or *active distribution network*.

Microgrid operates generally in a grid connected mode. However, circumstances such as fault, voltage sag and large frequency oscillations in the main grid may force the active distribution network to be disconnected from the main grid and operate as an isolated microgrid. During this isolation period, there will be changes in output power from the controllable micro sources which are to be regulated properly to have a stable operation in regard to power balance and frequency of operation within the isolated microgrid. To bridge the gap between the load consumption and power produced by the renewable energy sources, the controllable sources: diesel generator, combine cycle gas turbine based system, fuel cell, aqua electrolyzer, battery and wind etc. are used as possible alternate solutions, if available in the microgrid.

The regulation is not linear due to the inherent time delay and ramp rate limit/generation rate constraint (GRC), therefore this leads to oscillations in the frequency. These oscillations should be damped out using proper controllers. In microgrid when all sources are in parallel to obtain a stable feedback loop, there is a

requirement of proper load sharing among the sources, hence we introduce the power-frequency (P-f) droop characteristics (R) for the power generating sources which are participating in frequency control. Similarly, each controllable source should have a proper control signal, to regulate output power proportional to the frequency deviation called frequency bias (B). The control signal for each controllable source is to be properly selected.

In modern power system the secondary control for frequency regulation is carried out with the help of supervisory control and data acquisitions (SCADAs) and remote terminal units (RTUs), being employed at the load dispatch centre and substations respectively. The scanning rate of SCADA to fetch the data from the RTUs is quite slow. Since SCADA houses the secondary controller, its influence over the dynamics of load frequency control is slow. Moreover, the data obtained at the SCADA level may not be of much use for improving the dynamic performance of the system as it does not bear any time stamping. Therefore, to overcome this, phasor measurement units (PMUs) are placed in strategic locations. This enables to use a dedicated link/internet between different entities in a microgrid for the data exchange. The microgrid central controller (MGCC) analogous to SCADA can handle both primary as well as secondary controllers. However, the decision depends on the reliability and bandwidth of the communication channels. Hence, a smart microgrid is developed for efficient resource utilization, monitoring and control of power sources based on Multi Agent System (MAS) concept with agents being connected over internet.

The tuning of proportional and integral of controller parameters (PI) for frequency regulation is addressed by gradient descent method (GD), and some evolutionary algorithms (EA): genetic algorithms (GA), bacterial foraging algorithm (BFO) and biogeography based optimization (BBO) are used. The PI controller tuned with BBO best among the above methods with minimum cost function, so BBO based tuning is used in subsequent chapters. However the PI controller tuned with the above methods may fall in local minimum which give suboptimal performance as some of the information of the microgrid is not be available.

To overcome this, Kalman state observer with linear quadratic regulators (LQR) is proposed. But the challenging issue here is tuning of weightage matrices ‘Q’ and ‘R’ simultaneously in a non linear microgrid.

The limitation of LQR method is the requirement of mathematical model of a microgrid. This is addressed by using non linearly variable gain controller reinforced learned multi layer perceptron (MLP) neural networks which resulted improved transient response of a smart microgrid.

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