On Improvement of Frequency Stability of Power System with Grid Following Converters

A thesis submitted

in partial fulfillment for the award of the degree of

Doctor of Philosophy

by

Rachakonda Shri Rama Akshay

SC18D028

Department of Avionics

Indian Institute of Space Science and Technology

Thiruvananthapuram, India

December 2023

Abstract

The fundamental advantage of electrical energy over other forms of energy is its ability to transmit and distribute over a large system instantly. The demand for electrical energy varies dynamically in the vast system. The ever-changing demand leads to an imbalance between generation and demand. The system frequency deviates from its nominal operating point with the imbalance between power demand and generation. The ancillary service that maintains the equilibrium between the load demand and power generation is known as Load Frequency Control (LFC). The power plants with high ramp rate such as the gas turbine power plants and the hydro power plants have been assigned for LFC, while, the low ramp rate power plants have shared base loads and do not participate in LFC. With development of semiconductor based power switches, power converters have been used to interface energy sources such as Solar PV, Battery Energy Storage System, Super Magnetic Energy Storage, etc. to the grid. In an interconnected system, the control areas are linked through tie lines. LFC of a control area has to adjust the generation of its own control area and neighbouring control areas while maintaining the generation of each power plant at optimal economic value. Automatic Generation Control (AGC) accomplishes these objectives through minimizing the Area Control Error.

This thesis aims to investigate AGC in a conventional regulated power system and a deregulated power system with the integration of Solar PV, Battery Energy Storage System (BESS), Super magnetic Energy Storage (SMES) and Static Synchronous Compensator (STATCOM). The linear time invariant models of Solar PV, BESS, SMES and STATCOM have been implemented in a two area power system for improving transient stability of the system. The average switching models of the active and reactive power devices have been presented to highlight the output current and power dynamics of the devices. A non linear model of the power system is considered with 10 % p.u. MW/s Generation Rate Constraint (GRC). With the availability of the active and reactive power compensation devices, the study extends to the optimal location and sizing of the devices which has not been attempted so far. The major area of interest for LFC is the application of the recently developed algorithm and its performance comparison. The area controller gains have been optimized using

Genetic Algorithm (GA) to show improvement in the frequency and tie line power profile with the addition of the STATCOM, SMES, BESS and solar PV.
The improved line loadings and Bus voltages by optimal sizing and location of active and reactive power devices have been reported for IEEE sample systems i.e. IEEE 9-Bus and IEEE 57-Bus systems. The objective of optimal sizing of the active and the reactive power compensating devices is to maintain the line overloadings and the Bus voltages within the nominal range during line outages and provide power security.