Preface

The rapid depletion of fossil fuels lead to the development of distributed energy resources based power plants which requires reconfiguration of the existing distribution and transmission models used by the energy industry. In this concern, microgrids emerged as a solution to this problem by interconnecting such Distributed Energy Resources (DERs) harnessing renewable energy resources in urban or remote locations providing power to off-grid networks. These systems also turned out to be efficient in terms of economic benefits and environmental concerns. Thus, the small signal analysis of these microgrid systems is crucial to evaluating the stability under nominal operating conditions. With numerous DERs being connected in a microgrid, the computational burden in small signal stability analysis increases exponentially. Model Order Reduction (MOR) is a theoretical analysis of complex systems that helps in simplification of system dynamics while preserving the significant characteristics, so as to decrease the system computational burden and memory requirements. In the present work, the main objective is to approximate a complex higher order AC microgrid and DC microgrid system by a simpler lower order model that achieves the required trade-off between accuracy and simplicity. Swarm intelligence based optimization algorithms such as Particle Swarm Optimization (PSO), Bacteria Forging Optimization, Ant colony optimization, Artificial Bee colony, etc. are increasingly being used for this purpose due to their motivation from self-adaptive and synchronised natural systems.

The work reported in this thesis, deals with the small signal modelling of both AC microgrid and DC microgrid system and its subsequent order reduction. A complete higher order state space model of the microgrid systems have been obtained from the mathematical formulations of the individual distributed energy sources, interfacing circuitry and associated control schemes. The order of these complex AC microgrid systems is then reduced by minimizing the pre-defined error function by PSO and ABC optimization techniques. The reduced order modelling of DC microgrid has been obtained by timescale separation based on discrimination of fast and slow states. The configuration that has been considered consists of the fuel cell which has an inherent sluggish response than that of other components, such as PV and battery, which has faster response forms an important basis for timescale separation. Further, the state associated with high nonlinearity that does exist in a fuel cell is retained intact while the rest of the electrical components has been reduced by robust optimization through mixed H_2/H_∞ norm error function by optimization algorithms. Further, the eigenvalue sensitivity analysis of the original and reduced order models reveal the nature of the responses with reference to the different eigenvalues and the major states of the original system whose impact remains in the reduced order model. The stability of the original and reduced order models is also a major concern which has been addressed in this thesis work through state space stability approach.

An optimal control scheme for the Interlinking Converter (IC) in hybrid microgrid structures has been achieved by the proper regulation of its gate switching functions through appropriate optimal feedback controller design. Proportional-Integral-Derivative (PID), Fractional Order Proportional-Integral-Derivative (FOPID) and H_∞ loop shaping controllers have been designed for the two-fold control objective of simultaneous improvement in system robustness and reduced tracking error using parameter tuning via Particle Swarm Optimization (PSO) and Artificial Bee Colony (ABC) optimization algorithms. This robust control strategy mitigates the errors that occur due to system uncertainties caused by the intermittent nature of renewable energy resources and variations in operating conditions.