Abstract

Distribution Power Flow analysis is one of the main features of power system studies and design. It is required for monitoring, contingency analysis, economic scheduling, planning, exchange of power between utilities, stability analysis, and expansion of Distribution Power System. Conventionally, the power flow problem is determined by numerical techniques such as Newton-Raphson (NR) and their variants Fast Decoupled Method. Such methods fail to provide the power flow solutions in some conditions, like ill-conditioned systems, distribution systems having large r/x ratio, islanded microgrids, etc. This thesis studies these aspects of Distribution Power Flow Analysis and investigates some new ideas and approaches to solve them in an effective and efficient ways.

This thesis thoroughly explores the distribution power flow problem and originates significant contributions. We investigate various numerical techniques and evolutionary algorithms in order to solve the different class of power flow problem of modern distribution systems. Using these approaches, we have been able to resolve some of the open issues regarding power flow of modern distribution systems, such as ill-conditioning, a high value of r/x ratio, issues related to islanding of distribution system. The thesis proposes 11 algorithms addressing the problem such as: (i) Ill-conditioned test systems, (ii) High r/x ratio of lines, (iii) Unbalanced test systems, (iv) Absence of slack bus in islanded microgrids, and (v) Variable system frequency in islanded microgrids.

In five algorithms, modifications is proposed in conventional power flow algorithms to overcome the above said problems. In addition, six nature-inspired optimization technique are proposed to solve power flow problems.

In grid connected distribution, systems are usually ill-conditioned and conventional algorithms poorly performs or even diverges. This thesis introduces a novel Current Injection based Newton-Raphson (CINR) power flow algorithm with new PV bus representation for improving the convergence characteristics. Moreover, an algorithm based

on fourth-order Levenberg-Marquardt algorithm with a non-monotone line search is introduced for solving power flow problem of ill-conditioned unbalanced and balanced grid-connected systems. We also propose a fourth-order Runge-Kutta algorithm in order to solve ill-conditioned grid-connected systems. The proposed approaches are validated for several ill- and well-conditioned cases. Results show that the proposed approaches have better efficiency than the conventional load flow algorithms.

In this work, a new optimization algorithm called Spherical Search (SS) is proposed to solve the bound-constrained non-linear global optimization problems. In addition, an extension of a newly proposed optimization technique, Butterfly Optimizer (BO) for constrained optimization problems (called as Butterfly Constrained Optimizer (BCO)) has been proposed to solve load flow problem. Results show that the BCO and SS perform competitively and more effectively with respect to well-known algorithms.

The existing methods of power flow problem are intricate and hard to realize due to the absence of reference bus (slack bus) in the islanded microgrids. To address this issue, an iterative power flow based technique is proposed to obtain the operating point of Droop Controlled Islanded Microgrid (DCIMG). To solve these set of equations, a nested-iterative Newton-Rapshon based algorithm is proposed. A modified version of well-known Backward/Forward Sweep (BFS) algorithm is also proposed to solve the load flow problem for droop-regulated AC microgrids operated in islanded mode. To solve this problem, a novel formulation as a constrained optimization problem is proposed. Two global optimization algorithm, Differential Evolution with Gauss-Newton based mutation (ϵDE-GN) and Matrix Adaptation Evolution Strategy (MAES), are utilized to solve this optimization problem. The performance of the proposed algorithms is compared with the Newton-trust, Interior-point and time domain methods. The proposed algorithms are employed on several test systems and results are compared with that obtained from other Jacobian-free based, Jacobian based algorithms and time-domain simulator PSCAD/EMTDC. The proposed algorithms for droop-regulated AC microgrid exhibit faster convergence, simple, accurate and easy to realize.

Effective Butterfly Optimizer with Covariance Matrix Adapted Retreat Phase (EBOwith-CMAR) is a self-adaptive Butterfly Optimizer which uses covariance matrix to generate a new solution and thus improves the local search capability of EBO. Optimal Power Flow (OPF) of grid-connected microgrids is a highly non-linear complex optimization problem.

This work utilizes EBOwithCMAR as an optimization algorithm and CINR as a power flow tool to solve the OPF of grid-connected microgrids effectively and efficiently. The proposed approach has been validated on the standard test systems for several OPF objectives. Simulation outcomes have been compared and analyzed with the recent studies.

In this thesis, an optimization approach to determine the optimal droop settings of Droop-Controlled Islanded Microgrid (DCIMG) is proposed. The objective functions are minimization of system losses in DCIMG while meeting all the power flow constraints. Therefore, this approach requires a powerful power flow tool to determine objective function values. The resultant single-objective optimization problem is solved using a powerful variant of Differential Evolution, named as ESHADE. The proposed approach is tested on a several DCIMG test system. The obtained outcomes show the superior performance of the proposed algorithm.