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A Three Phase Power Flow Algorithm for Distribution Network Incorporating the Impact of Distributed Generation Models

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Abstract

The significant penetration of Distributed Generation(DG) systems in electrical power industry is mainly driven by the ever increasing demand for electrical power and growing environmental concerns. Power Flow Studies play a vital role in planning the future expansion of power system as well as for deciding the optimum operation of the existing power system. The ill conditioned nature of distribution system as well as unbalanced nature of DG sources demand unbalanced power flow studies for analysing the DG integrated distribution system. For the power flow studies, DGs can be modelled as either PQ or PV nodes based on the type and interconnection method to the grid. The paper presents an unbalanced power flow algorithm based on the current summation method for the distribution system with the DGs modelled either as PQ or PV node. Handling of PV nodes is done with the help of the sensitivity impedance matrix. The proposed algorithm is validated with IEEE 13 bus distribution feeder

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1. Introduction

The substantial growth of distributed generation in the deregulated power market is driven by various technical, commercial, economic as well as environmental factors which surround electric power industry[1]. These may include reduction in power loss and on-peak operating costs, improvement in voltage profile and load factors, elimination of system upgrades and thereby improving the system integrity, reliability and efficiency etc [2].

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Distributed generation (or DG) generally refers to small-scale (typically 1 kW 50 MW) electric power generators that produce electricity at a site close to customers or that are tied to an electric distribution system[3]. There are a number of challenges to the increased penetration of DG into the distribution network which can be categorised as technical, and commercial and regulatory challenges[4], . Voltage rise effect, Power quality issues, stability and Protection are the various aspects of technical challenges. The second category deals with the cost of implementation and connection of DG and the corresponding market mechanism in determining the overall cost of electricity. There is an absence of clear cut policy and regulatory framework for integration of DG which also pose challenge to the power industry. Strategic placement of the DER units is very essential for maximising the benefits and limiting the challenges by the addition of DER units into the distribution networks[5]. The DG placement has critical impacts on the operation of the distribution network[6]. Unless placed properly, DG may increase network operating cost instead of improving the network performance in terms of reduction in losses, improvement in voltage profile, power quality and reliability of the power system. Efficient analysis of the planned system on the steady state behaviour is a prerequisite before implementing a new integral power system[7].

Power Flow Analysis is an important and basic tool for any power system which is used at the planning, design as well as the operational stages. It helps to determine the steady state behavior of the power system. Distribution networks are characterized by highly radial topological structure which is different from the highly meshed structure of the transmission networks. This makes distribution systems as ill conditioned power system. They also possess some features, which rules out the application of conventional well established power flow algorithm for distribution networks[8]. They are

- High R/X ratio
- Multi phase, unbalanced operation
- Radial or weakly meshed networks
- Unbalanced distributed load
- Distributed generation

Efficient Distribution power flow helps in realizing various applications in distribution automation and distribution management like VAR planning, switching, state estimation etc. The solution technique used for distribution power flow can be classified as current summation methods, power summation methods and admittance summation methods. Instead of real and reactive power, current summation method uses Voltage and current and hence found to be more convenient. There are many literature available for conducting load flow for balanced radial distribution system. The forward and backward sweep method is the basic algorithm which handles power flow for radial distribution feeders. An efficient algorithm based on modified ladder iterative technique using forward and backward sweeps was proposed in [9]. R Berg [10] developed an efficient algorithm which suits both for balanced as well as unbalanced distribution feeders. Quadratic equation was used in forward and backward sweep in [11] which works only for balanced distribution feeders. Power summation method was used instead of current summation in order to develop a load flow algorithm for balanced three phase radial network using unique node, branch and lateral numbering scheme in [12] . The incorporation of DG also alters the power flow of the system which necessitates unbalanced power flow for the distribution system .While addressing the impacts of DG penetration, the most important issue to be addressed is the impacts on the steady state operation. Changes in voltage profile, active and reactive losses and congestion levels in system branches resulting from the load flow solution form the evaluation criteria for the steady state operation impacts. Therefore load flow becomes very important in analysing the impacts of the DG on the overall system. An efficient power flow algorithm should be able to produce the above mentioned system parameters accurately as possible which in turn helps to analyse the impacts of DG correctly.

The objective of this paper is to analyse the system parameters in terms of of voltage profile, active and reactive losses in a system with DG sources by load flow computation. This provides a preassigned and necessary task for utility before providing license to the consumers for connecting DG to the distribution grid. This is as well important from the consumer point of view since significant unbalance in the system results in malfunctioning of the equipment. Hence an efficient and general power flow algorithm suitable for a DG integrated system is very needed for ensuring better steady state operation of the power system. The paper is organized as follows. Section II gives an introduction to the type and characteristics of various DG units and their modeling aspects. Section III provides a brief review of the relevant literature for the three phase power flow analysis. Section IV describes the proposed