Loss Reduction Allocation to Distributed Generation Units in Distribution Systems

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***Abstract*-- This paper proposes a novel loss reduction allocation method in distribution systems in the presence of distributed generation (DG) units. The proposed method aims to procure the participation of each DG unit in the reduced amount of energy losses in distribution systems brought about by participation of all DG units in power market. The method is based on the assumption that DG units have private owners; hence, it provides a proper solution for distribution companies to have a fair incentive to specify which DG units are more beneficial to them. Two cooperative game theory approaches namely Shapley Value and τ Value methods are applied in order to provide fair and stable models for loss reduction allocation in distribution networks. Consistent and stable results qualify the equity and validity of the method.**

***Index Terms*-- Loss allocation, Distributed Generation, Shapley Value, τ -Value**

I. Introduction

Distributed Generations (DGs) have become an economic solution for electrical generation in distribution networks. Integration of DG units in distribution network provides many potential benefits to distribution companies (DISCOs). The benefits include loss reduction, reliability improvement, voltage support, improved power quality, capacity release, as well as deferment of upgrading distribution infrastructures [1].

As DISCOs have no control on placement of DG units, it is important for them to provide incentives for DG owners to place DG units in critical points of distribution network. In order to have a fair incentive, DISCOs should specify which DG units are more beneficial to them. Hence, they should consider the parameters by which DG units can be selected as the most economical solution. Among them, loss reduction is a key consideration to select the most beneficial DG units.

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Several studies have been conducted to assess losses variations in distribution networks in the presence of DG units. Reference [1] described the importance of losses variations for DG connection costs and proposed a method to compute such loss variations. However, the proposed method is only valid for small DG penetration variations. Allocation of energy losses to consumers connected to distribution networks was proposed in [2]. A comparison was then made between the allocation methods of energy loss in distribution network.

A method was proposed in [3] for optimally allocating various types of DG technologies in distribution network to minimize energy loss. In [4], the impact of DG on distribution losses was analyzed. It was shown that energy losses variation, as a function of the DG penetration, presents a U-shape trajectory. The authors of [4] have considered the overall impact of DG units on loss reduction. However, it was not specified the share of each DG unit. This brief review of the literature shows that considerable work has been performed to assess the effect of DG units in loss reduction of distribution networks.

The problem of specifying the share of each DG in the reduced losses can be regarded as a mathematical equation with equilibrium constraints. The problem is solved in this paper by using Cooperative game approaches based on Shapley Value and τ Value which provide fair and stable models. Cooperative game theory is concerned primarily with coalitions groups of players who coordinate their actions and pool their winnings [5]. Consequently, one of the problems here is how to divide the reduced losses among the DG units participate in power market.

Game theory approaches has been used in many power system studies. Some studies have proposed fair schemes for the transmission loss allocation under pool-based or bilateral contracts in electricity markets. Hrieh have implemented Shapley Value to allocate transmission losses under pool-based electricity market [6, 7]. The impact of bilateral transactions on system losses in order to allocate a corresponding loss component to each individual transaction for improving economic efficiency has been considered in other studies [8]-[11]. In [11], two cooperative game theory methods named Nucleolus-based Method and Shapley Value Method have been applied for loss allocation of bilateral transactions in transmission systems. Some researches have