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Faculty of Electrical Engineering

OPTIMUM DISTRIBUTED GENERATION ALLOCATION USING MODIFIED PARTICLE SWARM OPTIMIZATION

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TAHA JABBAR SAHIB

A dissertation submitted
in fulfilment of the requirements for the degree of Master of Electrical Engineering (Industrial Power)

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DECLARATION

I declare that this dissertation entitled “Optimum Distributed Generation Allocation using Modified Particle Swarm Optimization” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature : ………………………….

Name : TAHA JABBAR SAHIB.

Date : ………………………….

APPROVAL

I hereby declare that I have read this dissertation and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Electrical Engineering (Industrial Power).

Signature : ……………………..………..…………

Supervisor Name : Datuk Prof. Dr. Mohd Ruddin Bin Ab Ghani

Date : ……………………..………..…………

DEDICATION

To my beloved parents and wife

ABSTRACT

The expansion of the Distribution Generation (DG) is consistent with its increasing popularity as a sustainable part of electric power systems. DG, being small scale generation sources placed either at or near the load centre, is normally installed in the power system network. DG optimum allocation brings a number of positive impacts-voltage improvement, environmental friendliness, delay in the system upgrade, more reliable and reduced transmission and distribution network congestion, also lower network upgrading cost are the positive points of DG integration to the system. The integration of DG into distribution might be caused several issues such as voltage rise and power losses increment. In this dissertation, the voltage improvement and power losses reduction have become the main objective of this study. The impact brought on by the DG is positive or negative on the system, depending mostly on the DG location and size. The optimal allocation of DG has been considered as main problem that can be solved using Modified Particle Swarm Optimization (MPSO) method. This dissertation has the aim of developing a successful technique that can assess the consequence of distributed generation on a distribution power system and to adopt the MPSO technique to find DG units optimal placement and size with improved system reliability by mitigating the total power losses, and improving the voltage profile. This dissertation also use the Open Distribution System Simulator (OpenDSS) and MATLAB. The MPSO technique solved the optimal DG sizing and placement problem for the IEEE 13-Node, 37-Node and 123-Node Test Cases successfully. Each case is divided into three scenarios and each scenario deals with different constraints for the size and number of DG to integrate with the test case. The test cases and its scenarios have been utilized to show the effectiveness of the MPSO method to find the optimum DG allocation and demonstrate how this optimum DG allocation makes the voltage profile better and minimizes the total power losses of the test cases study.

ABSTRAK

Perkembangan penjana pengagihan (DG) adalah konsisten dengan popularitinya yang semakin meningkat sebagai satu bahagian sistem kuasa elektrik yang mapan. DG, sebagai satu sumber penjana berskala kecil ditempatkan sama ada di pusat beban atau berdekatan dengan pusat beban, biasanya dipasang dalam jaringan sistem kuasa. Penempatan optima DG memberi beberapa impak positif- voltan tinggi, mesra alam, penangguhan penaiktarafan sistem, kesesakan transmisi dan pengagihan yang lebih boleh dipercayai dan kos dikurangkan, adalah kebaikan-kebaikan integrasi DG kepada sistem. Dalam disertasi ini, penambahbaikan voltan dan pengurangan kehilangan kuasa telah menjadi satu aspek penting dalam kajian ini. Impak yang dibawa oleh DG adalah positif atau negatif ke atas sistem, bergantung kepada lokasi dan saiz DG. Disertasi ini bertujuan membangunkan satu teknik yang berjaya yang boleh menilai impak penjanaan pengagihan ke atas satu sistem kuasa pengagihan dan menggunakan teknik Modified Particle Swarm Optimaization (MPSO) untuk memastikan penempatan dan saiz unit DG yang optima dengan kebolehpercayaan sistem yang lebih baik dengan cara mengurangkan kemerosotan kuasa, dan memperbaiki profil voltan. Disertasi ini juga menggunakan Open Distribution System Simulator (OpenDSS) dan MATLAB untuk membantu menyelesaikan masalah penempatan DG yang optima. Teknik MPSO menyelesaikan isu saiz dan penempatan DG untuk IEEE 13-nod, 37-nod dan 123 nod dengan jayanya. Setiap satu kes terbahagi kepada tiga senario dan setiap senario berdepan dengan pelbagai kekangan yang berbeza untuk saiz dan nombor DG untuk digabungkan dengan kes ujian. Kes-kes ujian dan senarionya telah digunakan untuk menunjukkan keberkesanan kaedah MPSO untuk mencari penempatan DG yang optima dan menunjukkan bagaimana penempatan optima DG ini menambahbaik profil voltan dan mengurangkan kekurangan kuasa mutlak kajian kes ujian berkenaan.

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LIST OF ABREVIATIONS

DG	Distributed generation
PUHCA	Public utilities holding company act
PURPA	Public utilities regulatory policy act
DS	Distribution system
ICLES	International council on large electric systems
CHP	Combined heat and power
ACO	Ant colony optimization
AI	Artificial intelligent
GA	Genetic algorithm
OpenDSS	Open distribution system simulator
PSO	Particle swarm optimization
Pbest	Best personal position
Gbest	Best global position
OF	Objective function
X/R	Reactance divided by resistance
NR	Newton raphson
ABC	Artificial bee colony

LIST OF SYMBOLS

X_i^t	Current position of particle
X^{Pbest}	Best personal position of particle
X^{Gbest}	Best global position of particle
V_i^t	Velocity of particle *i* towards previous vector
V_i^{t+1}	Velocity of particle *i* towards next position
w	Inertia weight factor
α & β	Acceleration coefficient
C_1	Personal learning coefficient
C_2	Global learning coefficient
r_1 & r_2	Uniformly distributed random numbers
ω_1	Coefficient of total power losses violation
ω_2	Coefficient of voltage violation
ω_3	Balancing coefficient of the total number of integrated DG
ω_4	Balancing coefficient of the total integrated DG size

LIST OF PUBLICATIONS

Journal:

1. **Taha Jabbar Sahib**, Mohd Ruddin Ab Ghani, Zanariah Jano and Imad Hazim Mohamed (2017), "Optimum Allocation of Distributed Generation using PSO: IEEE Test Case Studies Evaluation", *International Journal of Applied Engineering Research (IJAER*), **(Scopus).** *(Published).*

CHAPTER 1

INTRODUCTION

1.1 Introduction

Electric power system networks are composed typically of four major sub systems: generation, transmission, distribution, and utilizations. Distribution networks link the generated power to the end user. Transmission and distribution networks share similar functionality; both transfer electric energy at different levels from one point to another; however their network topologies and characteristics are quite different. Distribution networks are well-known for their low X/R ratio and significant voltage drop that could cause substantial power losses along the feeders. Ng et al. (2000) estimated that as much as 13% of the total power generation is lost in the distribution networks. Mendes et al. (2005) show that the percentage of the distribution losses from the total electric power system real power losses is approximately about 70%. In an effort towards manifesting the seriousness of such losses, Azim and Swarup (2005) reported that 23% of the total generated power in the Republic of India is lost in the form of losses in transmission and distribution. The higher power losses in the transmission and distribution system also lead to reducing efficiency of the existing system. Figure 1.1 shows the total transmission and distribution losses (in percentage of total power output) for different countries of the world for 2012, including pilferage as giving by World bank development indicator, (2015). According to world bank development indicator (2015) annual electricity transmission and distribution losses world wide average is about 8.12% of the electricity that is transmitted. Electrical transmission and distribution losses as high as 55.39% have been reported for Haiti.This non negligible amount of losses has adirect impact on the financial results and the overall efficiency of the system.Thus the major focus of present-day research is on effectively utilizing the existing infrastructure with better planning and use of smart technologies.

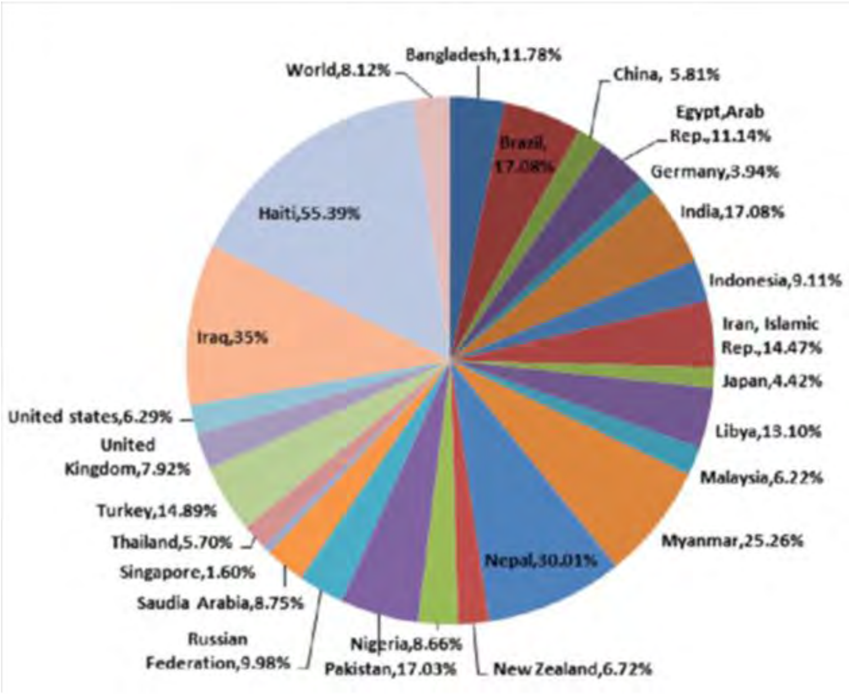

Figure 1.1: Various Countries Losses in Percentage of Output

Distribution systems usually encompass distribution feeders configured radially and exclusively fed by a utility substation. Integrating Distribution Generation (DG) within the distribution level has an overall positive impact towards reducing the losses as well as improving the network voltage profiles. Due to advances in small generation technologies, electric utilities have begun to change their electric infrastructure and have started adapting on-site, multiple, small, and dispersed DG. In order to maximize the benefits obtained by integrating DGs within the distribution system, careful attention has to be paid to their placement, as well as to the appropriate amount of power that is injected by the utilized

DGs. In other words, to achieve the best results of DG deployments, the DG should be both optimally placed and sized in the corresponding distribution network. During the first third of the twentieth century, there were no restrictions on how many utility companies could be owned by financial corporations known as utility holding companies. By 1929, 80% of US electricity was controlled by 16 holding companies, and three of those corporations controlled 36% of the nation's electricity market as reported by Masters (2004). During the Great Depression most of these utility holding companies went bankrupt. As a result, the US Congress Public Utilities Holding Company Act (PUHCA) of 1935 regulated the gas and electric industries and restricted holding companies to the ownership of a single integrated utility. PUHCA indirectly discouraged wholesale wheeling of power between different states, provinces or even countries. The Public Utilities Regulatory Policy Act (PURPA) of 1978 allowed grid interconnection and required electric utilities to buy electricity from non-utility-owned entities called Qualifying Facilities (QF) at each utility's avoided cost. The term QF refers to nonutility-owned (independent) power generators. The term 'at each utility's avoided cost' is interpreted to mean that the utility shall buy the generated electricity at a price equivalent to what it would cost the utility itself if had generated the same amount of power in its own facility or if it had purchased the power from an open electricity market, what the utility saves by not generating the same amount of power. This act heralded the dawn of the DG industry era, which paved the way to generate electricity, arguably, at a lower cost compared to that of traditional utility companies and consequently have it delivered to the end user at lower rates. The English Policy Act of 1992 (EPA) intensified competition in the wholesale electricity market by opening the transmission system for access by utilities and non-utilities electricity producers as founded by Philipson (2006).

1.2 Distribution Generation

Distributed generation (DG), also called on-site generation, dispersed generation, embedded generation (EG), decentralized generation, decentralized energy, site generation or distributed energy, generates electricity from many small energy sources. A large number of terms and definitions are used in relation to distributed generation.

ICLES has a working group that devotes efforts to DG. They defines DG as all generation units with a maximum capacity of 50 to 100 MW, usually connected to the distribution network and neither centrally planned nor dispatched as clarify by Massimo et al. (2003). Clearly, this latter part of their definition implies that DG units are beyond the control of the transmission grid operator. Thus, generation units built by the transmission grid operator as a substitute for grid expansion and that have measures implemented for dispatching is not considered to be DG according to this philosophy.

The IEEE defines DG as the generation of electricity by facilities that are sufficiently smaller than central generating plants so as to allow interconnection at nearly any point in a power system.

On the basis of the definitions surveyed, Dondi et al. (2002) has defined DG as a small source of electric power generation or storage (typically ranging from less than a kW to tens of MW) not part of a large central power system and located close to the load. Storage facilities are also included in the definition of DG, which is not conventional. Furthermore, this definition emphasizes the relatively small scale of the generation units as opposed to ICLES.

K.Purchala et al. (2006) also defined DG as relatively small generation units of 30 MW or less. These units are placed at or close consumers to meet specific needs, to support