UNIVERSITI TEKNIKAL MALAYSIA MELAKA

NETWORK RECONFIGURATION AND DISTRIBUTED GENERATION SIZING IN RADIAL DISTRIBUTION SYSTEM USING IMPROVED EVOLUTIONARY PARTICLE SWARM OPTIMIZATION

NUR FAZIERA BINTI NAPIS

MASTER OF SCIENCE
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NUR FAZIERA BINTI NAPIS

A thesis submitted
in fulfillment of the requirements for the degree of Master of Science
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DECLARATION

I declare that this thesis entitle "Network Reconfiguration and Distributed Generation Sizing in Radial Distribution System using Improved Evolutionary 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 candidature of any other degree.

Signature : ....

Name : ....

Date : ....

APPROVAL

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

Signature : ....

Supervisor Name : ....

Date : ....

DEDICATION

To my beloved husband, Muhammad Aqlil bin Alias,

my daughter, Nur Aqeela Aisyah,

my mother and father and my mother and father in law

for their enduring love, encouragement, motivation, and support

You are my strengths and inspirations

ABSTRACT

The present of Distributed Generation (DG) with suitable Distribution Network Reconfiguration (DNR) in the distribution system may lead to several advantages such as voltage support, power losses reduction, deferment of new transmission line and distribution structure and improved system stability. However, installation of the DG unit at non-optimal sizes with non-optimal DNR can incur higher power losses, power quality problem, voltage instability and amplification of operational cost. To overcome the power losses and voltage stability problems, an appropriate planning of DG units and DNR are considered. Thus, the first objective of this research is to develop an optimization technique named Improved Evolutionary Particle Swarm Optimization (IEPSO). The objective function is formulated to minimize the total power losses and to improve the voltage stability index. The load flow algorithm and voltage stability index calculation are integrated in the MATLAB environment to solve the optimization problem. Recently, the power system networks are being operated closer to the stability boundaries due to economic and environmental constraints. The heavier loading in the highly developed networks leads to voltage stability problems. However, the voltage stability problem of the distribution system can be improved if the loads are rescheduled efficiently with optimal DNR and DG sizing. Thus, the second objective of this research is to analyze the voltage stability index with three load demand levels; light load, nominal load, and heavy load with optimal DNR and DG sizing. The third objective of this research is to validate the performance of the proposed technique with other optimization techniques, namely Particle Swarm Optimization (PSO) and Iteration Particle Swarm Optimization (IPSO). Four case studies on 33-bus and 69-bus distribution system have been conducted to validate the effectiveness of the IEPSO. The optimization results show that, the best achievement of IEPSO technique for power losses reduction is up to 79.26%, and 58.41% improvement in the voltage stability index for three load conditions, light load, nominal load and heavy load. The proposed optimal DG sizing and DNR algorithm will provide a solution for independent power producer and power utility in terms of technical issues which beneficial for future electricity especially in integrating DG for the distribution network.

ABSTRAK

Kehadiran Penjana Teragih (PT) dengan Konfigurasi Semula Rangkaian Pengagihan (KSRP) yang sesuai di dalam sistem pengagihan boleh membawa kepada beberapa kelebihan seperti sokongan voltan, pengurangan kehilangan kuasa, penangguhan talian penghantaran baru dan struktur pengagihan dan kestabilan sistem yang lebih baik. Walau bagaimanapun, pemasangan unit PT pada saiz yang tidak optimum dengan KSRP tidak optimum boleh mengalami kerugian kuasa yang lebih tinggi, masalah kualiti kuasa, ketidakstabilan voltan dan penguatan kos operasi. Untuk mengatasi kehilangan kuasa dan masalah ketidakstabilan voltan, perancangan yang sesuai bagi unit PT dan KSRP akan dipertimbangkan. Oleh itu, objektif pertama kajian ini adalah untuk membangunkan satu teknik pengoptimuman dinamakan Evolusi Pengoptimum Kuruman Zarah Diperbaiki (EPKZD) untuk menentukan saiz optima PT dan KSRP dalam sistem pengagihan jejari. Fungsi objektif digubal adalah untuk mengurangkan jumlah kehilangan kuasa dan untuk meningkatkan indeks kestabilan voltan. Algoritma aliran beban dan voltan pengiraan indeks kestabilan disepadukan dalam persekitaran MATLAB untuk menyelesaikan masalah pengoptimuman. Baru-baru ini, rangkaian sistem kuasa beroperasi dengan lebih dekat dengan sempadan kestabilan kerana kekangan ekonomi dan alam sekitar. Muatan lebih berat di rangkaian yang maju membawa kepada masalah voltan kestabilan. Walau bagaimanapun, masalah kestabilan voltan sistem pengagihan boleh diperbaiki jika beban yang dijadualkan semula cekap dengan KSRP optima dan saiz PT optima. Oleh itu, objektif kedua kajian ini adalah untuk menganalisis indek kestabilan voltan dengan tahap permintaan tiga beban; beban ringan, beban nominal dan beban berat dengan KSRP dan saiz PT optima. Objektif ketiga kajian ini adalah untuk mengesahkan prestasi teknik yang dicadangkan dengan teknik pengoptimuman yang lain, iaitu Pengoptimum Kuruman Zarah (PKZ) dan Pengoptimum Kuruman Zarah Lelaran (PKZL). Empat kajian kes pada 33-bas dan sistem pengagihan 69-bas telah dijalankan untuk mengesahkan keberkesanan EPKZD. Keputusan pengoptimuman menunjukkan bahawa, pencapaian terbaik teknik EPKZD untuk mengurangkan kehilangan kuasa adalah sehingga 79.26%, dan peningkatan sebanyak 58.41% dalam indeks kestabilan voltan untuk tiga keadaan beban, beban ringan, beban nominal, dan beban berat. Saiz PT dan KSRP optima yang dicadangkan akan menyediakan satu penyelesaian untuk pengeluar tenaga bebas dan utiliti kuasa dari segi isu-isu teknikal yang bermanfaat untuk masa hadapan elektrik terutama dalam mengitegrasikan PT untuk rangkaian pengagihan.

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LIST OF ABBREVIATIONS

ABC	Artificial Bee Colony
ACO	Ant Colony Optimization
AIS	Artificial Immune System
APSO	Adaptive Particle Swarm Optimization
DG	Distribution Generation
DNR	Distribution Network Reconfiguration
EP	Evolutionary Programming
EPSO	Exponential Particle Swarm Optimization
ETAP	Electrical Transient and Analysis Program
FA	Firefly Algorithm
FVSI	Fast Voltage Stability Index
GA	Genetic Algorithm
HSA	Harmony Search Algorithm
IEPSO	Improved Evolutionary Particle Swarm Optimization
IPSO	Iteration Particle Swarm Optimization
LQP	Line Stability Index
LSF	Loss Sensitivity Factor
MATLAB	Matrix Laboratory
MEPSO	Modified Evolutionary Particle Swarm Optimization
MOPSO	Multiobjective Particle Swarm Optimization

PSO	Particle Swarm Optimization
RPF	Reverse Power Flow
SA	Simulated Annealing
SPSO	Simple Particle Swarm Optimization
TPL	Total Power Loss
TS	Tabu Search
VPI	Voltage Performance Index
VSI	Voltage Stability Index

LIST OF PUBLICATIONS

The following publications have been achieved by this research work

Journals:

N. F. Napis, M. F. Sulaima, R. M. A. R. A. Yusof, A. F. A. Kadir, and M. F. Baharom. 2015. A Power Distribution Network Restoration via Feeder Reconfiguration by using EPSO for Losses Reduction. Journal of Theoretical and Applied Information Technology, 79(2): 346-350.

N. F. Napis, M. F. Sulaima, A. F. A. Kadir, and M. F. Baharom. 2015. Investigation on Impact of Improved Evolutionary PSO for Modern Distribution Network Reconfiguration System. International journal of applied engineering research, 10(21): 41809-41816.

Conferences:

N. F. Napis, M. F. Sulaima, A. F. A. Kadir, C. K. Gan, W. M. Dahalan, and M. Sulaiman. 2015. A Comprehensive Study of Improved Evolutionary Particle Swarm Optimization (IEPSO) for Network Reconfiguration with DGs Sizing Concurrently. PEOCO, pp. 19-23.

CHAPTER 1

INTRODUCTION

1.1 Research Background

The classic power system model comprises about three essential components, in particular generation, transmission line and distribution network. The segments are reliant to guarantee the generated power could be transmitted from the generation to the distribution system or demand through the transmission line. In addition, the power system is designed to works with unidirectional power flow due to lack of power source except in generation component only. However, likewise the demands are anticipated with heighten in the future, one of the possible solutions could be done is to improve the entire power system performance (Al-abri, 2012). Concerning on this solution, it will require intensive planning to all the components; thus, increasing the overall cost of the power system. On the contrary, introduction of micro grid concept by Lasseter et al, (2004) offers an interesting solution to integrate small capacity of Distributed Generation (DG) in the distribution system instead of rely solely on centralized generation schemes, thereby reducing the necessary improvements made in the generation and the transmission lines.

Introduction of the DG has changed the fundamental way of the operation in the power systems, particularly the distribution networks where the status has changed from passive to active network (Master, 2002). The DG can effectively partake in the distribution system in order to give additional support to the main grid in satisfying load demands, enhancing the voltage profile, improve reliability and also power losses reduction (Barker et al, 2000; Dondi et al, 2002). The reduction of power losses is a vital undertaking to maintain the efficiency of the distribution system. There are several approaches to overcome the power losses problem such as; network reconfiguration, installing capacitors and installing DGs. However, the beneficial of these approaches can be achieved if they are carefully coordinated in the distribution system.

Chuong, (2008) suggested that voltage stability should be taken as an objective function when addressing the optimal placement of DG units. In addition, two notable studies Hedayati et al., (2008) and Alonso et al, (2009) formulated approaches that can be utilised to identify effective placements for DG units to heighten the voltage profile and voltage stability of a distribution system. The researchers Hedayati situated DG units at the busses that were sensitive to voltage collapse and the results indicated that voltage profile was enhanced while loss reduction took place.

There are several groups which have been used to solve coordination problems such as analytical, heuristic and meta-heuristic technique, where each of the groups has its own advantages and shortcomings. Among these groups, the meta-heuristic are more prominent in solving the coordination problems due to robustness and simple to implement (Paliwal et al, 2012). There are a few strategies that have been presented under the meta-heuristic groups, for example Simulated Annealing (SA) (Kerleta et al, 2014), Ant Colony Optimization (ACO) (Jamil, 2015) and Particle Swarm Optimization (PSO) (Reddy et al, 2016). Furthermore, a few researchers have additionally proposed hybridized optimization techniques by combining two optimization techniques to cancel out the discrepancies of each for achieving better solutions. Almost all of these techniques were inspired by natural life (Boussaïd et al, 2013).

1.2 Research Question

The reliability and sustainability of the power distribution system are critical issues that numerous engineers and researchers have studied and proposed various solutions for expansion its proficiency. This matter is critical with a specific end goal to satisfy load demands, which increment fundamentally year by year. Nonetheless, the advancement in improving the proficiency of the system is hindered by one main consideration that is the existence of high real power losses. Besides, the current trend of electrical energy tariff is hitting at augmentation and it is expected to escalate in the future; consequently, increasing the significance of power reduction. Therefore, numerous researchers have devoted their effort to find the conceivable answer for minimizing the power losses whilst retaining the stability and security of the system.

There are several approaches suggested by researchers to deal with the reduction of power losses and improve the voltage stability, such as determining the optimal DG (output power) and network reconfiguration. Withal, the incorrect used of these approaches might deteriorate the system's operation and appear operational and planning problems in the distribution system. The purpose of this research is to determine the answer that can harmonize the network reconfiguration with DG sizing in order to further reduce the power losses and improved voltage stability in the distribution network.

Several research questions that will be emerge while breaking down the impact of combining the approaches on the distribution system are listed below:

i. What is the impact of DG and DNR on the power losses and voltage stability?

ii. How does the performance of power system when the level of loads are varied?

iii. What is the suitable technique to determine the optimal DG sizing and DNR in order to overcome the power losses and voltage stability problem?

iv. How to verify the accuracy and efficiency of the proposed technique?

The entire question raised will be analyzed and discussed later.

1.3 Problem Statements

Transformation of distribution network toward more astute and proficient system endures with numerous challenges. A standout amongst the most difficulties confronted by the researchers is to accomplish a more economical distribution network through reduction of power loss. In addition, the essential way of the distribution network itself that has a low X/R ratio lead the distribution system have more impact on the power loss and voltage profile compared with the transmission line (Ackermann, 2001; Master, 2002). As beforehand examined, there are a few approaches that have been done to take care of the issue. Generally, these solutions are done independently, which implies a power loss reduction is accomplished either by using network reconfiguration or DGs or capacitors. Researchs in Chuong, (2008); Hedayati et al., (2008) and Gil et al, (2009) used DG approach only in solving the voltage stability problem without considering other alternative such as network reconfiguration. Therefore, a simultaneous approach is considered in this research, which is network reconfiguration and DG in solving the power losses and voltage stability problem.

Nowadays, there are various types of modern optimization techniques, such as Firefly Algorithm (FA) (Yang, 2009), Ant Colony Optimization (ACO) (Jamil, 2015), Artificial Immune System (AIS) (Alonso et al, 2015), Harmony Search Algorithm (HSA) (Z. Li et al., 2016) and Artificial Bee Colony (ABC) (Chaweewat et al, 2016). All of them can be regarded as meta-heuristic optimization methods, due to the randomization involved in their respective initial steps. Despite the usage of randomized values, the mutation process and other steps in