MINIMIZATION OF POWER LOSSES AND IMPROVE VOLTAGE PROFILE IN DISTRIBUTION NETWORK BY CONSIDERING MASSIVE SOLAR DISTRIBUTED GENERATION

AHMAD FAUZI BIN OTHMAN

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Faculty of Engineering
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DEDICACTION

This thesis in dedicated to

My lovely parents,
Othman Bin Che Hussim & Azizah Binti Omar

My inspirations,
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ABSTRACT

In developing country, electricity become the basic need of the growth industries, thus the power quality and reliability of the distribution network are very crucial. Adding with the low carbon initiatives, renewable energy or distributed generation (DGs) is a part of favourable source of generating electricity, lead the complex distribution network. Significant rises DGs in power grids will give high impact the system reliability and security in term of power losses and voltage profile. This research is focusing on an optimization capacity and location of integration of DGs in distribution systems to minimize power loss and improve voltage profile using Modified Lightning Search Algorithm (MLSA). This research has been conducted on modelled the real radial IEEE 69-bus of real radial distribution network in two conditions. Which first condition, study is done with the current load profile and second condition with the load growth by referring state load growth. Then MLSA with weight summation approach is used to identify the suitable location and size for the DGs in the design proposal stage. The optimization objectives are to reduce power losses and improve the voltage profile especially at the connection point of DGs. All power system load profile, DGs constant load and load growth pattern, the effect of integration massive solar in distribution network will be modelled using MATLAB software. The results of the simulation by using MLSA, indicated that the optimization allocation and sizes of massive solar DGs applied with current load and load changes can minimize the power losses as well as improve voltage profile. These results verify the effectiveness and successful of the proposed approach to determine the optimal location and sizing of massive solar DGs to reduce power losses and improve voltage profile.

ABSTRAK

Di negara yang pesat membangun, tenaga elektrik menjadi keperluan asas dalam membangunkan industri dan disebabkan itu kualiti dan dahayarap bekalan elektrik menjadi semakin penting dan kritikal. Dengan adanya inisiatif pengunaan Karbon yang rendah, Tenaga boleh diperbaharui menjadi tumpuan dalam menjana bekalan elektrik yang mana menjurus kepada wujudnya rangkaian lektrik yang semakin komplek. Peningkatan tenaga boleh perbaharui mendatangkan impak kepada dayaharap sistem terutamanya kepada kehilangan kuasa dan keadaan profil voltan. Tujuan kajian diadakan adalah untuk menentukan lokasi dan kapasiti yang sesuai bagi sambungan panel solar kepada rangkaian pembahagian dengan mengambikira factor sediada beban semasa dan peningkatan beban akan datang supaya kehilangan kuasa dapat dikurangkan dan profil voltan dapat ditingkatkan dengan menggunakan kaedah *"Modified Lightning Search Algoritsm (MLSA)"*. Kajian ini telah dilaksanakan ke atas 69 bus IEEE rangkaian sistem kuasa dalam dua keadaan ini iaitu keadaan beban semasa dan keadaan peningkatan beban akan datang. Pendekatan *"weight summation"* telah digunakan untuk menentukan lokasi dan saiz tenaga boleh diperbaharui pada peringkat perancangan sistem. Kaedah ini akan mengurangkan kadar kehilangan kuasa dan meningkatkan profil voltan sepanjang talian elektrik. Semua profil beban, penyambungan tenaga boleh diperbaharui kesan pemasangan solar dikaji dan dianalisa melalui MATLAB. Keputusan simulasi menunjukkan bahawa kehilangan kuasa dapat dikurangkan dan profil voltan dapat ditingkatkan dengan sambungan solar kepada rangkaian pembahagian dengan menggunakan kaedah MLSA dan keputusan yang diperolehi mengesahkan bahawa kaedah MLSA dapat mengoptimumkan pemasangan solar dalam kontek mengurangkan kehilangan kuasa dan meningkatkan profil voltan pada rangkaian pembahagian.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

DGs	-	Distributed Generations
LSA	-	Lightning Search Algorism
MLSA	-	Modified Lightning Search Algorism
PSO	-	Particle Swarm Optimization
IEEE	-	Institute of Electrical and Electronics Engineers
PV	-	Photovoltaic
WT	-	Wind Turbine
GA	-	Genetic Algorithm
IEEE	-	Institute of Electrical and Electronics Engineer
PSS	-	Power System Study
CO2	-	Carbon dioxide
IEA	-	International Energy Agency
PVDG	-	Photovoltaic Distributed Generation
WPS	-	Wind Power Station
MW	-	Megawatt
DERs	-	Distributed Energy Resources
GW	-	Gigawatt
BSS	-	Battery Storage System
LSS	-	Large Scale Solar
SEDA	-	Sustainable Energy Development Authority
TNB	-	Tenaga Nasional Berhad
HHO	-	Harris Hawks Optimization

LIST OF SYMBOLS

n_n	-	Total number of busses
R_{ij}	-	Resistance
$I_{rel,ij}$	-	Real current
X_{ij}	-	Reactance
X_{ij}	-	Reactive current
I_{ij}	-	Current branch ij
R_{ij}	-	Resistance of branch ij
P_{ef}	-	Effective active power feb by bus j
Q_{ef}	-	Effective reactive power feb by bus j
V_j	-	Voltage at bus j
V_i	-	Voltage at bus i
Z_{ij}	-	Impedance of line $i-j$
φ_{ij}	-	Angle of line $i-j$
δ_i	-	Angle of V_i
δ_j	-	Angle of V_j
P_{DGi}	-	Solar DGs power generation on bus i
OBJ	-	Multi-objective function
ω_1 and ω_2	-	Weighted coefficient
$Losses_{real}$	-	Active power losses
$V_{profile}$	-	Voltage at all busses
$V_i(t)$	-	Bus voltage in $p.u.$
V_{nom}	-	Rated voltage in the $p.u.$
n	-	Number of buses
P_{DG}	-	Size of solar DGs
g	-	Annual growth
y	-	Number of years
P_{Li}	-	Active power load at any year

Q_{Li}	-	Reactive power load at any year
$P_{Li}(0)$	-	Initial active power load at base year (y=0)
$Q_{Li}(0)$	-	Initial reactive power load at base year (y=0)

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of the problems

The objective of the global energy transition is to limit the increasing of global average temperature below 2 degrees Celsius. The existing of energy scenarios is not fully captured the implication of the Paris agreement for energy sector [1]. A conversion from type of fossil fuels to low-carbon solutions will become the essential role in term of energy-related CO2 emissions which represent of two-thirds of all greenhouse gases (GHG) [2]. Innovation of latest technologies will be used as the platform in transition the traditional energy production to usage of DGs. The rapid usage of DGs will giving benefit to the cost of generating electricity. Most utilities pursuit in produced electricity using DGs and worldwide high projection of DGs in year 2017. However, the transition agenda in transition of DGs is not going fast enough as planning by referring the constant value of CO2 energy emission form year 2014 to year 2016 and recorded only 1.4% rose in year 2017 [3–4].

In most developing country, electricity become the basic need of the growth industries, thus the power quality and reliability of the distribution network a very crucial [5]. Adding with the low carbon initiatives, renewable energy or DGs network [6]. Introduction DGs in power grids will impact the system reliability and security in term of power losses and voltage level. In previous study, there are certain problems raised need to be address.

First, most distribution network integrated with DGs, generating the power without considered optimization of allocation and sizes and this such situation may lead the issues in power quality, especially in power losses and voltage profile [7]. Secondly, existing connection and installation of DGs not stress out the mandatory technical requirement in term of generating power by optimizing power losses and voltage profile during daily operational of DGs. Previous paper discussed the allocation and size of the DGs but not consider the future growth or increasing the DGs plant at the existing or other's new location [8].

Besides that, the growth of existing and new plant of DGs need to be consider because it will impact the power losses and voltage profile at the respective area. Current and future growth are become very crucial in term to design and planning in proper way so that DGs can optimize throughout the years. However, most research are not tested and simulated the impact of integration massive solar DGs with real radial 11kV distribution network, thus the effect of appearances solar DGs not analyse and details out in term of power losses and voltage profile [9]. For better and clear understanding in performance of distribution network, the simulation and analysis need to be done with existing load profile and load growth in order to manage and mitigate the technical issue rise later at early planning stage.

The impact of connection solar DGs on voltage profile and system stability has become very important to the distribution network. The rising issues such as voltage stability and voltage profile need to be study and analysed and close monitor in order to avoid the failure of distribution network especially during peak demand or contingencies event in the power system. Integration of DGs to the distribution network can be affected to the fluctuation in voltage stability depending on the power system operational. Currently, most DGs are operating by injecting active power with unity power factor so that the voltage regulation is comply within allowable value [10-11]. Optimization of location of DGs in distribution network can mitigates network congestion as well as can improves the voltage profile in respective busses of the network. There are a lot of types of DGs used in the distribution network such as solar PV, fossil fuel power plant, wind, and others new types of DGs [12-13].

Proper design of the massive solar DGs could bring positive influence and impact to the distributed grid. The reliability and stable parameters such as voltage could be maintained, and the power loss could be control and reduced. The DGs has the following obvious advantages [14]. The most advantages of connection solar DGs is to minimize the power losses to the distribution network, Improvement in power quality, security, and reliability of the network and lastly to improved voltage profile to the allowable range in the distribution network [15].

This research focused on the optimization of allocation and sizing of the massive solar DGs and analyse the minimization of power losses and improve voltage profile of the distribution network.

1.2 Problem Statement

Solar DGs is expected drastically increase and will become very important in the future generation system. Generating energy using solar DGs giving positive and negative impact to the distribution network and will become a competitive electricity market in worldwide [16]. Connection of DGs can be at near to the generation sources or near and connected to the load by consumers. This scenario will lead to the critical technical issues rise in the distribution network. Connection of massive solar DGs with optimization of placement and size of solar DGs can minimize power losses and improve voltage profile in distribution network.

Nowadays, electricity become the basic need of the growth industries, thus the power quality and reliability of the distribution network are very crucial. Introduction massive solar DGs in power grids will impact the system reliability and security. Most distribution network integrated with massive solar DGs, generating the power without proper optimization and most solar DGs export power from the grids [17]. This situation may lead the issues in power quality, especially in power losses and voltage profile [18].

Besides that, existing integration, and installation of solar DGs did not consider load changes (current load profile and future load growth) which may lead wrong optimization in allocation and capacity of solar DGs. The element of load growth is also important especially at early design and planning stage. The proper design and plan of solar DGs connection can improve the security and reliability of the distribution network [19].

Since the optimum placement and sizing of solar DGs in distribution network system involve complex parameters, especially for large scale system, it is important to have an appropriate approach to explore the optimum placement and sizing of the solar DGs. The best optimization is used to find the minimum or best optimal value of allocation and size of solar DGs. To obtain the optimal value, the optimization of massive solar DGs will be carried out using LSA and MLSA applied with weight summation to minimize power losses and improve voltage profile in distribution network.

1.3 Research Objectives

Objectives of the research are:

i. To evaluate the existing distribution network and then integrated with massive solar DGs without optimization in order to review the impact of power losses and voltage profile to the distribution network.

ii. To optimize capacity and location of solar DGs by considering power loss reduction and voltage profile improvement. Optimization will also consider load changes by adopting LSA and MLSA in the distribution network.

iii. To utilize weight summation approach in finding the best location of solar DGs with minimize power losses and improve voltage profile. This study has been conducted on the standard IEEE 69-bus of real radial distribution network.

1.4 Research Scopes

The scopes covering in this research are:

i. This study only concentrated on power losses and voltage profile by optimal allocation and sizes of massive solar DGs in distribution network.

ii. The effect of load changes which are current load profile and load growth need to be analysed to find the best optimization of massive solar DGs in order to improve power losses and voltage profile in distribution network.

iii. The rated capacity of solar PV used in the simulation are between 0.50MW to 2.00MW that connected to 11kV distribution network.

iv. The allowable numbers of solar DGs will be tested according the typical used in distribution network in term to minimize power losses and improve volage profile in distribution network.

v. Exclude the others technical issue in the distribution network such as overloading cable, transformer in this research and focus only the optimization of massive solar DGs. Voltage constraint in all busses will be follow the Malaysian standard which is 0.95 p.u. to 1.05 p.u. (±5%).

1.5 Significant of the Research

Introduction DGs as preferable source of generation made distribution system become more complex and congested [20]. Power quality and security becoming a critical issue in generate power to consumers. The proposal of this research is about minimize power losses and improve voltage profile using LSA and MLSA with weight summation approach in IEEE 69-bus of real radial 11kV distribution network, integrated with massive solar DGs. Purpose of this projects is to secure the reliability and increase the performance of the distribution network.

Solar DGs can be used to controlling and reducing generation capacity with competitive cost of electricity [21]. Connection of solar DGs with optimization can mitigates potential of technical issues and reducing the cost of maintenance in distribution network. Rapidly increasing of solar DGs globally can eliminate the need of traditional generation and meet expected future demand in power generation [22]. Connection of massive solar DGs can lead to critical technical issues in distribution network. Optimization placement and size of solar DGs can avoid and minimize the distribution system losses and improve voltage profile in distribution network. Hence, created other advantages and benefits especially in achieving goals for greenhouse gases and reducing other environment pollution created by traditional generation sources [23].

In addition to analysing solar DGs as the alternatives sources of supply can utilise the generation capacity and develop micro and smart distribution network with multiple DGs sources support by innovative technology as the platform to serve the demand needed by the consumers [24]. For further investigation and analysis, the contribution of solar DGs, sampling of IEEE 69-bus of real radial 11kV distribution network located in Kemaman district, Terengganu has been tested with two scenarios. First scenario is modelling the 11kV distribution network without any appearances of massive solar DGs. Then integrated with massive solar DGs without and with optimization considered the current load and load growth in order to analyse the impact to the power losses and voltage profile in distribution network by using LSA and MLSA applied weight summation approach method.

1.6 Thesis Organization

The thesis is divided into 5 chapters. The synopsis of these chapters is provided below:

Chapter 2 reviews previous works by researchers throughout journal and published paper on minimizing power losses and improve voltage profile in distribution network systems. Then, the research on connection of massive solar DGs will be discussed on the standard, connection point and the technical impact to the distribution network. Power flow used in this study also will be explained. Next, the optimization method for placement and sizing the solar DGs will be analyse and discuss and significant contribution as well as effect form previous research were used as the guidance and referenced in this paper.

Meanwhile, chapter 3 focus and brief details of the research methodology enhance in this study. The research framework is then details explained, along with the flow chart. Then power losses and power losses and voltage profile will be discussed in the distribution network system. The LSA and MLSA meta heuristic techniques that will be used in the process of determining the optimal placement and sizing are also discussed in this chapter.

Chapter 4 were explained all the result gathered in this study including the optimal placement and size of the massive solar DGs connected to the IEEE 69-bus of real radial distribution network. Power system performance in term of power losses and improvement of voltage profile were presented with the clear explanation. All the results which are obtained in the simulation will be further analysed.

The final chapter presents the findings of the research. The recommendations will be further elaborated for future work as well as improving current research.

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