UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Electrical Engineering

MODELING OF ELECTRICAL DISTRIBUTION NETWORKS WITH PARTICLE SWARM OPTIMIZATION TECHNIQUE FOR THE IMPROVEMENT OF VOLTAGE PROFILE AND LOSS REDUCTION

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MODELING OF ELECTRICAL DISTRIBUTION NETWORKS WITH PARTICLE SWARM OPTIMIZATION TECHNIQUE FOR THE IMPROVEMENT OF VOLTAGE PROFILE AND LOSS REDUCTION

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

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DECLARATION

I declare that this dissertation entitled "Modeling of Electrical Distribution Networks with particle swarm optimization technique for the Improvement of Voltage Profile and Reduction" is the result of my own work except as cited in the references. The dissertation has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have read this dissertation and in my opinion this report is sufficient in terms of scope and quality as a partial fulfillment of Master of Electrical Engineering (Industrial Power).

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DEDICATION

To my beloved parents, and my best friend

ABSTRACT

Modeling of power distribution networks needs accurate impedance data of overhead lines and underground cables. In unbalanced distribution networks, the mutual and self-impedances are required. The need of accurate impedance data is for evaluation electrical of distribution system planning with economic considerations. The data of series impedance is also used to investigate power flow in all segments in the distribution system. Therefore, modified Carson's equations have been utilized in this study to calculate series impedance of both overhead lines and underground cables using MATLAB program for getting more accurate results. MATLAB program has the ability to get the result of three phase, two phases, and single phase according to user's choice. The IEEE tests have been used to validate this work. Two tests, as the IEEE 34 bus test and IEEE 13 bus test are implemented. Determination of power flow was done using Open Distribution System Simulator (OpenDSS) program which is suitable for electrical distribution networks. The obtained results from OpenDSS program are used to find the optimum location and sizing of capacitors that would be installed in distribution system. The particle swarm optimization (PSO) is utilized to solve the problem of location and sizing of capacitor. Constraints of voltage profile and total demand of reactive power were considered. Installation of capacitors before and after optimization was compared based on voltage profile and reduction of power losses. The results of this work showed that the method for the calculations of the series impedance (series resistance and inductance) per unit of length is acceptable according to IEEE standard data. The method is accurate and has advantage as easy to implement which accomplished with Carson's equations. In addition, the results indicated that PSO algorithm has succeeded in finding proper placement and sizing of capacitor bank.

ABSTRAK

Pemodelan rangkaian pengagihan kuasa memerlukan data impedans yang tepat talian atas dan kabel bawah tanah. Dalam rangkaian pengagihan yang tidak seimbang, impedans bersama dan sendiri diperlukan. Keperluan data impedans tepat adalah untuk menilai perancangan sistem pengagihan elektrik dengan pertimbangan ekonomi. Data siri impedans juga digunakan untuk menyiasat aliran kuasa dalam semua segmen dalam sistem pengagihan. Oleh itu, pengubahsuaian persamaan Carson telah digunakan dalam kajian ini untuk mengira siri impedans kedua-dua talian atas dan kabel bawah tanah menggunakan program MATLAB untuk mendapatkan hasil yang lebih tepat. program MATLAB mempunyai keupayaan untuk mendapatkan hasil daripada tiga fasa, dua fasa dan satu fasa mengikut pilihan pengguna. Ujian IEEE telah digunakan untuk mengesahkan kerja-kerja ini. Dua ujian: IEEE 34 ujian bas dan IEEE 13 ujian bas dilaksanakan. Penentuan aliran kuasa itu telah dilakukan dengan menggunakan program DSS Terbuka yang sesuai untuk rangkaian pengagihan elektrik. Keputusan yang diperolehi dari program DSS terbuka telah digunakan untuk mencari lokasi yang optimum dan saiz kapasitor yang akan dipasang dalam sistem pengedaran. Pengoptimuman zarah sekumpulan (PSO) digunakan untuk menyelesaikan masalah lokasi dan saiz kapasitor. Kekangan profil voltan dan jumlah permintaan kuasa reaktif dipertimbangkan. Pemasangan kapasitor sebelum dan selepas pengoptimuman telah dibandingkan berdasarkan profil voltan dan pengurangan kehilangan kuasa. Hasil karya ini menunjukkan bahawa kaedah untuk pengiraan impedans siri (rintangan siri dan kearuhan) bagi setiap unit panjang boleh diterima mengikut IEEE data standard. Kaedah ini adalah tepat dan mempunyai kelebihan yang lebih mudah untuk dilaksanakan seperti yang dicapai dengan persamaan Carson. Di samping itu, Keputusan menunjukkan bahawa algoritma PSO telah berjaya dalam mencari penempatan yang betul dan saiz bank kapasitor.

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LIST OF ABBREVIATIONS

3-PH	-	Three-Phase
2-PH	-	Two Phase
1-PH	-	One Phase
LCT	-	Tap Changer Transformer
0-1-2	-	Symmetrical Sequence Components
0	-	Zero Sequence Component
1	-	Positive Sequence Component
2	-	Negative Sequence Component
IEEE	-	Institute of Electrical and Electronics Engineers
OpenDSS	-	Open Distribution System Simulator
PSO	-	Particle Swarm Optimization

LIST OF SYMBOLS

Z_{ii}	-	Self Impedance
Z_{ij}	-	Mutual Impedance
[A]	-	Forward Linear Transformation Matrix
$[A]^{-1}$	-	Invers Linear Transformation Matrix
$KVAR$	-	Kilo Volt Amper Recative
S_{ABC}	-	Complex Power in an Transformed System
pu	-	Per-Unit
a	-	Operator = $1\angle 120^{\circ}$
t	-	Transpose
$Q_{3\Phi}$	-	Reactive Power in Three Phase System
Z	-	Impedance
Z_s	-	Source Impedance
Z_T	-	Transformer Impedance
X	-	Reactance
X_L	-	Load Reactance
X_s	-	Source Reactance
X_T	-	Transformer Reactance
X_C	-	Cable Reactance
R	-	Resistance
R_T	-	Transformer Resistance

R_C	-	Cable Resistance
Z_{abc}	-	Series Impedance
Z_0, Z_1, Z_2	-	Zero, Positive, and Negative sequence Impedance
V	-	Volt
A	-	Amper
kV	-	Kilo Volt
kVA	-	Kilo Volt Amper
MVA	-	Mega Volt Amper
Ω	-	Ohm

CHAPTER 1

INTRODUCTION

1.1 Background

Distribution networks are considered as the final stage to deliver the electricity to consumers. The distribution system normally is beginning at the distribution substation, and served by sub-transmission feeders. The design of each substation is to supply one or more of primary feeders. Majority of the feeders for electrical networks are radial so that power flows from that substation to user meter (Ramachandran, 2011). A design of a simple distribution system and its modules is given in Figure1.1. The significant characteristic of radial distribution feeders is taking only one path of power flow from the supply to consumption. Normally, the distribution system is collected feeders from distribution substations. Majority of feeders consist of primary main feeder of three phases with separating laterals that are two phases or single phase (Lakervi, 1995).

The transmission lines for distribution system can be overhead lines or underground cables based on the possibilities and conditions depending on electrical characteristics. Voltage regulators adjust the voltage settings, to keep the voltage at all nodes within ANSI limits. Some of the primary main feeders have in-line transformers to serve large industrial consumers. To provide reactive power support to the feeder at critical nodes, single phase or three phase capacitor banks are used. The substation transformer primary usually operates at 12.47 kV and the voltage is stepped down to 4.16 kV. Smaller distribution transformers, also known as service transformers supply customers at 120/240V level. The distribution feeder supplies single phase, two phase and three phase loads categorized as smaller residential consumer in addition to large industrial consumers. The important characteristics of distribution systems are highlighted as in (Kersting, 2002).

There is always a voltage drop of distance between the substation and load end of each feeder. That voltage drop mainly depends on the loading situations of the lines of distribution. The used substation of distribution regulates the system voltage specified limits using tap changers of transformers (Load Tap Changer).The load tap changer regulates the taps on side of secondary of transformer when the load varies and regulates the voltages within specified voltages as shown in Figure 1.1 (Ramachandran, 2011).

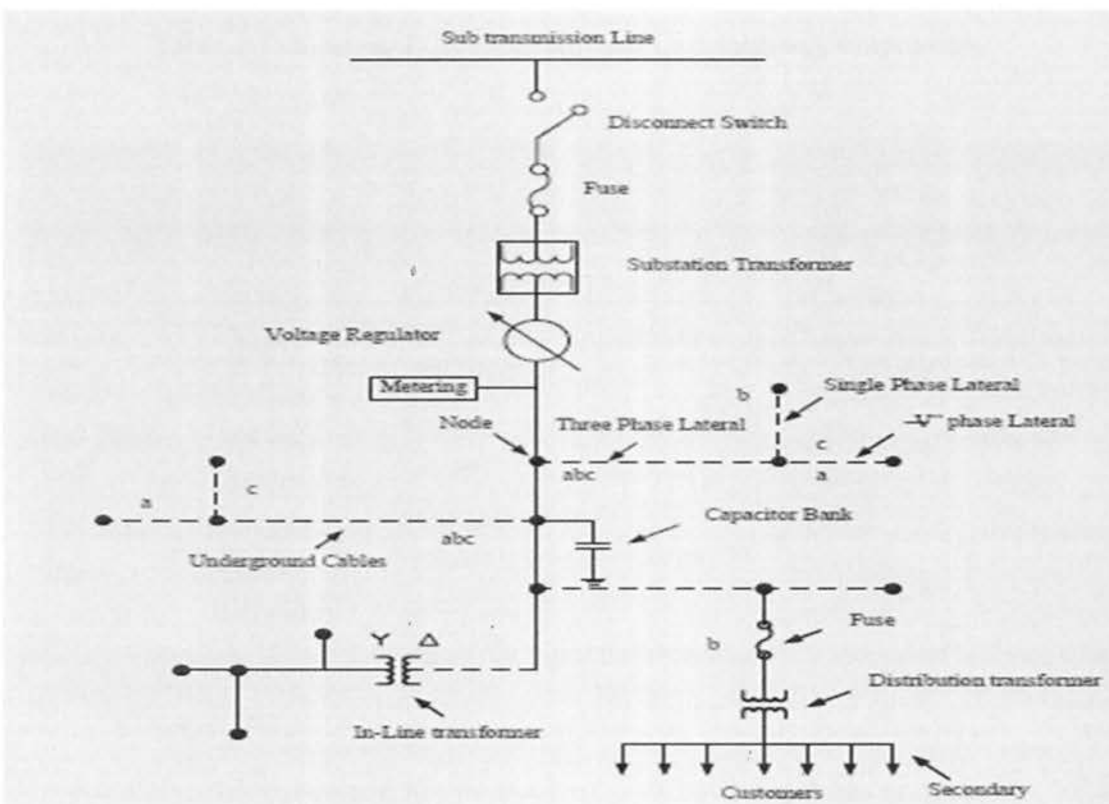

Figure 1.1: Simple Distribution System

Substation transformer is used to reduce the source voltage for distribution system level. Usually, the standard of distribution voltage levels is 34.5 kV, 23.9 kV, 14.4 kV, 13.2 kV, 12.47 kV, and 4.16 kV (Ramachandran, 2011). The electrical distribution systems are classified into primary and secondary systems. As well, the primary system includes of distribution substations and feeders. The substations will step down voltages from the sub-transmission system to 34.5 kV and 4.16 kV (Humayd, 2011). The distribution system consists of circuit breakers and simple switches for high voltage and relays that can be controlled on action of circuit breakers to achieve low voltage switching. Thus, each of equipment in a distribution feeder has electrical features that must be calculated before the power flow of the feeder. The characteristics of electrical component are showed in Table 1.1 (Kersting, 2002).

Table 1.1: Electrical Characteristics of Distribution Components

Overhead Conductors	Underground Conductors	Wire Data	Voltage Regulators	Transformers	Capacitors
• Spacing • Phasing • Distance from ground level • Wire details • Kron reduction	• Spacing • Phasing • Thickness of tape shield • Number of Concentric Neutrals • Cable details	• Geometric mean Radius (GMR) feet • Diameter (inches) • Resistance (ohms/mile) • Ampacity • Repair rate	• Potential Transformer ratios • Current transformer ratios • Compensator settings • R and X settings	• kVA rating • Voltage rating • Impedance settings (R and X) • No-load power loss	• Capacity • Phasing • Control type • ON-OFF settings • Power factor

Recently, it has become the purpose of distribution systems to generate voltages that must be stepped down to distribution system so that power generation stations will be remote to urban centers. The transmissions line is more efficient to transmit the electricity but there are some of voltage profiles levels cannot be utilized for consumers which need step-down voltages from level to another which give more benefit. The lines of power transmission is entered a substation then the voltage levels will be stepped down for another voltage levels give. Then, they will deliver to customers, and industrial as shown in Figure 1.2 (McDonald et al., 2013).

Distribution system is classically described less than 50kV, that voltages can be distributed to specified areas to connect with industrial and commercial customers. The large commercial and industrial customers are normally connected with the grid at this voltage level. Consumers are classically fed by overhead lines and underground cables. Pole mounted transformers are classically utilized in old rural areas and residential neighborhoods. Each home is connected to the pole mounted transformer. On the other hand, there are urban, rural and commercial distribution which done using underground services.

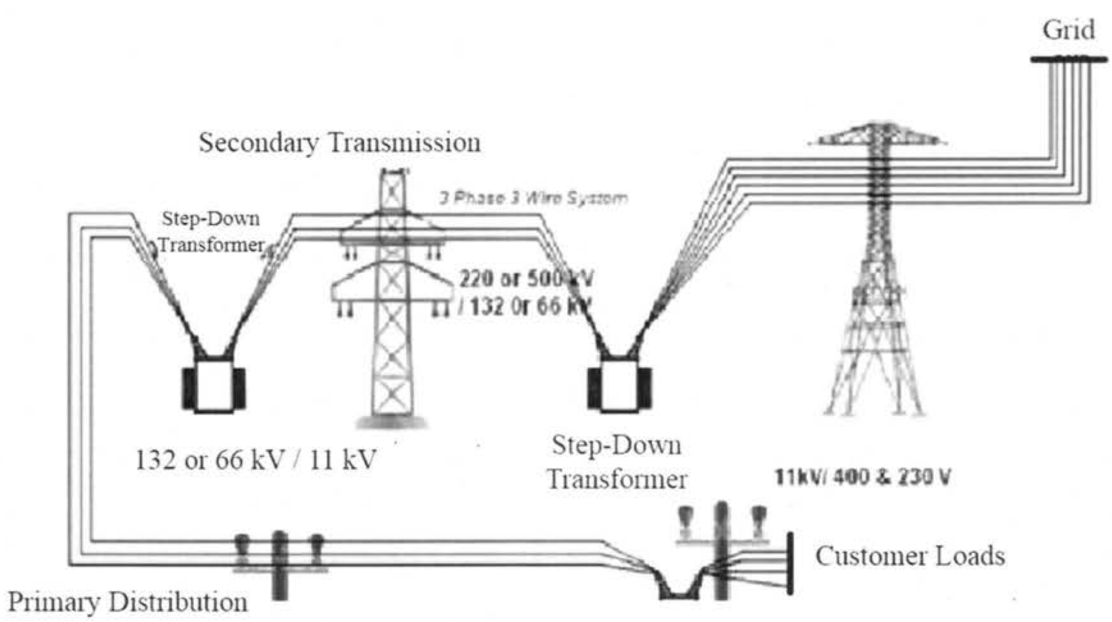

Figure 1.2: Sample of Transmission Power System

Electrical distribution networks is vital part of power system therefore, there is the need for new tools to model or analyze it as Open Distribution Simulator System program