PARTICLE SWARM OPTIMIZATION (PSO) BASED APPROACH FOR MINIMIZATION POWER LOSS

MOHAMAD KHALEEQ BIN AHMAD
B071110234

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This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor's Degree in Electrical Engineering Technology (Industrial Power) (Hons.)

by

MOHAMAD KHALEEQ BIN AHMAD
B071110234
920708-13-6483

FACULTY OF ENGINEERING TECHNOLOGY
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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering Technology (Industrial Power) (Hons.). The member of the supervisory is as follow:

………………………………

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ABSTRAK

Masalah Aliran Kuasa Optimum (OPF) telah menerima banyak perhatian dalam dua dekad yang lalu yang mana penyelesaian masalah ini bertujuan untuk mengoptimumkan fungsi objektif tertentu seperti kehilangan kuasa oleh pelarasan pembolehubah kawalan kuasa dan pada masa yang sama memenuhi kehendak kekangan kesaksamaan dan ketaksamaan. Kajian ini bertujuan untuk mengoptimumkan sistem kuasa dengan mengurangkan kehilangan kuasa dalam penghantaran tenaga. Selain itu kajian ini juga bertujuan untuk melaksanakan kaedah Particle Swarm Optimization (PSO) untuk menganalisis masalah ini. Walau bagaimanapun, kaedah Newton-Raphson juga akan digunakan untuk membandingkan keberkesanan antara kedua-dua kaedah tersebut. Bagi menggambarkan masalah ini, satu rangkaian sistem 3-bas akan diuji. Kajian tersebut akan dimulakan dengan menganalisa dan mendapatkan data dengan menggunakan kaedah Newton-Raphson dan program Microsoft Excel akan digunakan bagi tujuan tersebut. Kemudian, teknik PSO akan digunakan untuk menganalisa sistem kuasa tersebut juga dengan menggunakan program Microsoft Excel. Analisis menunjukkan bahawa kaedah PSO adalah kaedah yang paling berkesan dari segi mengurangkan kehilangan kuasa. Hal ini boleh disimpulkan bahawa kaedah Artificial Intelligence (AI) seperti Particle Swarm Optimization (PSO) adalah kaedah yang paling sesuai dan berkesan untuk menganalisis masalah Aliran Kuasa Optimum (OPF) dari segi meminimumkan kehilangan kuasa.

ABSTRACT

The problem of Optimal Power Flow (OPF) has received much attention in the last two decades which this problem solution aims to optimize specific objective function such as loss power by adjustment the power control variables and at the same time satisfying the equality and inequality constraints. This research aimed to minimize the power loss and optimize the power transmission in a power system. Besides, this research also aimed to implement Particle Swarm Optimization (PSO) method to analyze this problem. However, Newton-Raphson method also will be used in order to compare the effectiveness between these two methods. To illustrate this problem, a network of 3-bus system will be tested. The study will begin by analyzing and retrieving data using the Newton-Raphson method and Microsoft Excel program will be used for that purpose. Then, PSO techniques will be used to analyze the power system which is also using the Microsoft Excel program. The analysis indicated that Particle Swarm Optimization (PSO) method was the most efficient method in terms of minimizing the power loss. This can be concluded that the Artificial Intelligence (AI) method such as Particle Swarm Optimization (PSO) is the most suitable and efficient method for analyzing the Optimal Power Flow (OPF) problem in terms of minimizing power loss.

DEDICATION

To my beloved parents, I want to thank for giving me support to complete this thesis. I was able to complete this thesis with the knowledge that I have been taught from the previous semesters especially on the power system knowledge. Once again, I would like to express my greatest gratitude to my beloved parents for all prays and continuous support from them.

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Last but not least, I would like to take this opportunity to thank all my friends who have given their support and help. Hopefully, this final year project will not be the end of my journey in seeking for more knowledge to understand the meaning of life.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

AI	-	Artificial Intelligence
NR	-	Newton-Raphson
OPF	-	Optimal Power Flow
PSO	-	Particle Swarm Optimization
ε	-	Precision index

CHAPTER 1
INTRODUCTION

This chapter will discuss the background of this project and come out the statement of problem as the base of this project that has been conducted. Besides, this chapter also emphasize on project scope and also the objectives of this project.

1.1 Background

In the last two decades, the Optimal Power Flow (OPF) problem has received much attention and the solution aims to optimize specific objective function such as power losses by adjustment the power control variables and satisfying the equality and inequality constraints at the same time. The equality constraints means by the power flow equations and for the inequality constraints, it refers to the upper and lower limits at the control and some state variables. The OPF problem can be categorized as a non-linear optimization problem. This kind of problem may face the complex situation which may require a more complex formulation, since the set of equations involved may not be linearized.

In this case, non-linear technique must be employed. The non-linear or optimization problem that will be analysed in power system is in regard to loss minimization of power. Optimization techniques have been applied to power systems in a wide range of problems. Depending on the study focused, the optimization technique employed may take into account some simplifications on the set of equations. Such simplifications may simplify the solution, leading one to employ linear techniques, whereas the results are not compromised. In particular, some market problems may be solved under this approach.

In order to analyze the problem, some of control variables will be considered such as active and reactive power. In this paper, the main tool or technique that will be employed to analyse the loss minimization of power is belong to the Artificial Intelligence (AI) algorithm. The stochastic technique called, Particle Swarm Optimization (PSO) is employed. However, one of the classical method also be used in this paper which is called Newton-Raphson (NR) method. This is because, for the analysis process will be started by Newton-Raphson method and then the PSO method will employed based on the information that has been gathered from the results after Newton-Raphson method used.

1.2 Problem statement

The Optimal Power Flow has become widely known that has received much attention in power system because it has been widely used in order to plan a power system. However, the problem of Optimal Power Flow problem always became the main subject in the power system which one of the objective function of the OPF problem is minimizing loss of power. In this paper, this specific objective function will be the problem that will be analysed in this project on how to minimize the power loss in order to optimize the power transmission in a power system. Furthermore, this problem is a non-linear optimize so it may require a more complex formulation, since the set of equations involved may not be linearized. Therefore, non-linear technique was proposed in this paper in order to analyse this problem.

1.3 Project objectives

The objectives of this project are to :

1. optimize the power transmission in a power system by minimizing the power loss.
2. implement Particle Swarm Optimization (PSO) in Optimal Power Flow (OPF) problem.
3. compare the effectiveness of Particle Swarm Optimization with Newton-Raphson method.

1.4 Project scopes

The scope of this project is limited to the following items so that the objectives stated could be achieved by focus on these items.

1. This project will focusing on optimizing the power transmission in a power system by minimizing power loss.
2. Real power and reactive power loss in the power system will be analysed in this project.
3. A model of power system will be designed and tested in this project which is a network with 3-bus system

CHAPTER 2

LITERATURE REVIEW

This chapter will discuss mainly on the theory of Particle Swarm Optimization (PSO) algorithm and also Newton-Raphson method. Besides, the comparison between classical and Artificial Intelligence (AI) method also will be discussed in this project.

2.1 Optimal Power Flow (OPF) solution methods

In the survey that has been made by K.S.Pandya, S.K.Joshi, there are two types of method that widely used to find the solution of Optimal Power Flow problem which can be categorized as a non-linear optimization problem. The methods also in the category of non-linear technique and the methods are:

a. classical method

i. Linear Programming (LP) method
ii. Quadratic Programming (QP) method
iii. Newton-Raphson (NR) method
iv. Non-linear Programming (NLP) method
v. Interior Point (IP) method

b. Artificial Intelligence (AI) method

i. Artificial Neural Network (ANN) method
ii. Genetic Algorithm (GA) method

iii. Evolutionary Programming (EP) method
iv. Ant Colony Optimization (ACO) method
v. Particle Swarm Optimization (PSO) method

2.2 Comparison between classical and Artificial Intelligence (AI) method

In classical method, they had made an excellent advancements. However, they suffer with the following disadvantages which are, in most cases, mathematical formulations have to be simplified in order to get the solutions because of the extremely limited capability to solve real-world large-scale power system problems. They are weak in handling qualitative constraints and also have poor convergence. Because of these disadvantages, classical method may get stuck at local optimum which they can find only a single optimized solution in a single simulation run. Besides, they become too slow if the number of variables are large and they are computationally expensive for the solution of a large system.

P. Smita and Prof. B.N.Vaidya (2012) have stated that the major advantage of the AI methods is that they are relatively versatile for handling various qualitative constraints. AI methods can find multiple optimal solutions in a single simulation run. So they are quite suitable in solving multi-objective optimization problems. In most cases, they can find the global optimum solution.

2.3 Newton-Raphson method

D.P. Kothari and I. J. Nagrath (1989) have stated that Newton-Raphson (NR) method also consider as a powerful method of solving non-linear algebraic equations. It works faster and is sure to converge in most cases especially on small scale problem. Furthermore, it is indeed the practical method of load flow solution of large power networks. Generally, NR method can be reviewed on the next explanation. Consider a set of n non-linear algebraic equations

$$f_i(x_1, x_2, .. x_n) = 0; \qquad i = 1,2,\ldots,n \qquad 2.1$$

Assume initial values of unknowns as $x_1^0, x_2^0, ..x_n^0$. Let $\Delta x_1^0, \Delta x_2^0, ..\Delta x_n^0$ be the corrections, which on being added to the initial guess, give the actual solution. Therefore

$$f_i\left(x_1^0 + \Delta x_1^0, x_2^0 + \Delta x_2^0, ..., x_n^0 + \Delta x_n^0\right) = 0; \qquad i = 1,2,...,n \qquad 2.2$$

After theses equations been expanded by Taylor series, it will be

$$f_i\left(x_1^0, x_2^0, ..x_n^0\right) + \left[\left(\frac{\partial f_i}{\partial x_i}\right)^0 \Delta x_1^0 + \left(\frac{\partial f_i}{\partial x_2}\right)^0 \Delta x_2^0 + ... + \left(\frac{\partial f_i}{\partial x_n}\right)^0 \Delta x_n^0\right] + \text{higher order}$$

terms = 0 2.3

where $\left(\frac{\partial f_i}{\partial x_1}\right)^0, \left(\frac{\partial f_i}{\partial x_2}\right)^0, ..., \left(\frac{\partial f_i}{\partial x_n}\right)^0$ are derivatives of f_i with respect to $x_1, x_2, ..x_n$ evaluated at $\left(x_1^0, x_2^0, ..x_n^0\right)$.

Neglecting the higher order terms, the equation can be write in matrix form

$$\begin{bmatrix} f_1^0 \\ f_2^0 \\ \vdots \\ f_n^0 \end{bmatrix} + \begin{bmatrix} \left(\frac{\partial f_1}{\partial x_1}\right)^0 & \left(\frac{\partial f_1}{\partial x_2}\right)^0 & \cdots & \left(\frac{\partial f_1}{\partial x_n}\right)^0 \\ \left(\frac{\partial f_2}{\partial x_1}\right)^0 & \left(\frac{\partial f_2}{\partial x_2}\right)^0 & \cdots & \left(\frac{\partial f_2}{\partial x_n}\right)^0 \\ \vdots & \vdots & & \vdots \\ \left(\frac{\partial f_n}{\partial x_n}\right)^0 & \left(\frac{\partial f_n}{\partial x_n}\right)^0 & \cdots & \left(\frac{\partial f_n}{\partial x_n}\right)^0 \end{bmatrix} \begin{bmatrix} \Delta x_1^0 \\ \Delta x_2^0 \\ \vdots \\ \Delta x_n^0 \end{bmatrix} \cong \begin{bmatrix} 0 \\ 0 \\ \vdots \\ 0 \end{bmatrix} \qquad 2.4$$

Or in vector form

$$f^0 + J^0 \Delta x^0 \cong 0. \qquad 2.5$$

J^0 is known as the Jacobian matrix obtained by differentiating the function vector f with respect to x and evaluating it at x^0. The equation also can be written as

$$f^0 \cong \left[-J^0\right]\Delta x^0 \qquad 2.6$$

and the approximate values of correction Δx^0 can be obtained from this equation. These being a set of linear algebraic equations can be solved efficiently by triangularization and back substitution. Update values of x are then

$$x^1 = x^0 + \Delta x^0 \qquad 2.7$$

or in general, for the $(r+1)$th iteration

$$x^{(r+1)} = x^{(r)} + \Delta x^{(r)} \quad 2.8$$

Iterations are continued till equation 2.3 (a) is satisfied to any desire accuracy, i.e.

$$\left|f_i\left(x^{(r)}\right)\right| \leq \varepsilon \text{ (a specified value);} \qquad i = 1,2,\ldots,n \quad 2.9$$

2.4 Particle Swarm Optimization

The Particle Swarm Optimization (PSO) is a population-based optimization method first proposed by James Kennedy, a social-psychologist and Russell Eberhart who was an electrical engineer and PSO technique is to find the optimal solution using a population of particles which has been stated by Esmin and Lambert-Torres (2006). Each particle represents a candidate solution to the problem. Basically, PSO was developed through simulation of bird flocking in two-dimensional space and some of the attractive features of the PSO include ease of implementation and the fact that no gradient information is required. Therefore, it can be used to solve a wide array of different optimization problems. Smita and Vaidya (2012) also have stated that Particle Swarm Optimization (PSO) is a relatively new evolutionary algorithm that may be used to find optimal (or near optimal) solutions to numerical and qualitative problems.

Smita and Vaidya (2006) also said that the PSO technique was emerged from an experiments with algorithms that modelled the flocking behaviour seen in many species of birds. James Kennedy and Russell Eberhart run the experiments through simulation and based on the simulation, birds would begin by flying around with no particular destination and spontaneously formed flocks until one of the birds flew over the roosting area. Due to the simple rules the birds used to set their directions and velocities, a bird pulling away from the flock in order to land at the roost would result in nearby birds will moving towards the roost. As these birds have discovered the roost, they would land there which pulling more birds towards it and so on until the entire flock had landed. Finding a roost is analogous to finding a solution in a field of possible solutions in a solution space. The manner in which a bird who has found the roost, leads its neighbours to move towards it, increases the chances that they will also find it.

This is known as the "socio-cognitive view of mind". The "socio-cognitive view of mind" means that a particle learns primarily from the success of its neighbours. The concept of the PSO consists of, at each time step, changing the velocity of (accelerating) each particle toward its global best and local best locations (local version of PSO). Acceleration is weighted by a random term, with separate random numbers being generated for acceleration toward global best and local best locations.

M.A.Abido (2000) have explained that there are several basic terms that will be using in the Particle Swarm Optimization technique and defined as follows:

1. Particle $x_i^{(k)}$

This particle $x_i^{(k)}$ is defined as the individual i at iteration k.

2. Swarm

Swarm may be defined as an apparently disorganized population of moving particles that tend to cluster together while each particle seems to be moving in a random direction.

3. Particle $v_i^{(k)}$

This particle $v_i^{(k)}$ is defined as the updated velocity of individual i at iteration k.

4. Inertia weight, ω

Inertia weight, ω is a control parameter, which is used to control the impact of the previous velocity on the current velocity. Hence, it influences the trade-off between the local and global exploration abilities of the particles. For the initial stages of the search process, large inertia weight to enhance the global exploration is recommended while it should be reduced at the last stages for better local exploration.

5. Individual or local best, x_i^{lbest}

When particles are moving through the search space, it compares its fitness value at the current position to the best fitness value it has ever reached at any iteration up to