REACTIVE POWER PLANNING USING EVOLUTIONARY PROGRAMMING FOR IEEE 26-BUS

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ENDORSEMENT

“I hereby declare that I have read through this report entitle “Reactive Power Planning using Evolutionary Programming for IEEE 26-bus” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)”

Signature : ....

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Date : 20 June 2016

DECLARATION

I declare that this report entitle "Reactive Power Planning using Evolutionary Programming for IEEE 26-bus" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

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Date : 20 June 2016

To my beloved mother and father

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ABSTRACT

Reactive Power Planning (RPP) is become a vital issue for power system planning and operation in order to avoid voltage instability event which lead to severe blackout incident. The relationship between reactive power reserve and Voltage Stability Margin (VSM) also been studied which found that variation caused changes in network operation For that reason, most researches intended to enhance voltage stability condition by sustaining the reactive power across power networks. In consequence, this study introduced Evolutionary Programming (EP) technique as a simulation tool in optimizing RPP, on standard IEEE 26 bus system using MATLAB programming. The Maximum Loading Point (MLP) selected as the individual objective function to be optimized with varying on their identified control variables while total system loss minimization is observed during the implementation. From findings, the EP is capable to improve the MLP as well less total loss as referred to results obtained without RPP optimization. Upon completion, this technique also provided the better voltage profile to avoid the unsecured operation condition during any load changes.

ABSTRAK

Perancangan Kuasa Reaktif (RPP) merupakan isu penting bagi perancangan sistem kuasa dan operasi untuk mengelakkan peristiwa ketidakstabilan voltan yang boleh membawa kepada gangguan bekalan elektrik yang teruk. Hubungan diantara rizab kuasa reaktif dan Margin Kestabilan Voltan (VSM) juga telah dikaji dan didapati akan menyebabkan perubahan dalam operasi rangkaian. Oleh sebab itu, banyak kajian telah dijalankan untuk meningkatkan kestabilan voltan dengan mengekalkan kuasa reaktif pada seluruh rangkaian kuasa. Sehubungan dengan itu, kajian ini memperkenalkan teknik Pengaturcaraan Evolusi (EP) sebagai alat simulasi dalam mengoptimumkan RPP, pada sistem bas IEEE 26 dengan menggunakan pengaturcaraan MATLAB. Titik Bebanan Maksimum (MLP) dipilih sebagai fungsi objektif tunggal yang akan dioptimumkan dengan mengunakan pelbagai pembolehubah kawalan sementara memerhati jumlah kehilangan kuasa yang minima semasa pelaksanaan. Berdasarkan penemuan, EP mampu meningkatkan MLP serta mengurangkan jumlah kerugian yang bertentangan dengan keputusan tanpa pengoptimuman RPP. Selain itu, teknik ini juga memberi profil voltan yang lebih baik untuk mengelakkan keadaan operasi yang bahaya pada sebarang perubahan beban.

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LIST OF ABBREVIATIONS

AC	-	Alternating Current
BFO	-	Bacterial Foraging Optimization
CPF	-	Continuation Power Flow
DE	-	Differential Evaluation
EAs	-	Evolutionary Algorithms
EP	-	Evolutionary Programming
ES	-	Evolutionary Strategies
FACTS	-	Flexible AC Transmission System
GA	-	Genetic Algorithm
GP	-	Genetic Programming
IEEE	-	Institute of Electrical and Electronics Engineers
IP	-	Interior Point
LP	-	Linear Programming
MCGA	-	Mixed Coding of Genetic Algorithm
MINLP	-	Mixed Integer Nonlinear Programming
MLP	-	Maximum Loading Point
NLP	-	Nonlinear Programming
P	-	Active Power

PoC	-	Point of Collapse
PSO	-	Particle Swarm Optimization
Q	-	Reactive Power
Q_{gs}	-	Reactive Power Dispatch
Q_{inj}	-	Compensating Capacitor Placement
RGA	-	Real Coded Genetic Algorithm
RPP	-	Reactive Power Planning
SA	-	Simulated Annealing
SM	-	Stability Margin
TS	-	Tabu Search
VAR	-	Volt-Ampere Reactive
X_{mer}	-	Transformer tap change setting

CHAPTER 1

INTRODUCTION

1.1 Motivation

Most distribution system deals with complicated load behavior as involves with numerous types of end consumers. Reactive power is an essential tool to establish and maintain an AC fluctuating magnetic flux. In almost every section of the system (generation, transmission, distribution and the loads) reactive power is either generated or consumed. The reactive power in the circuit is contributed by the inductive or capacitive reactance. Reactive power is important to control voltage level and subsequently prevent electrical equipment from damage [26] [27] [28]. Reactive power shortage can cause blackout or breakdown event in a system due to the generator and transmission line failure [9].

Reactive Power Planning (RPP) is a nonlinear multi-constraint for large scale uncertainties. There has been huge effect on RPP issue for the security and economy power system [1] [12]. For that reason, researchers in [13] claimed that RPP require the minimization of two objective functions simultaneously. The optimization of RPP problem is completed with continuous and discrete control variable such as generator bus voltages, setting of on-load tap changer of transformers and reactive power output of the compensating devices placed on different bus bars [7].

There are two main categories in solving the optimization problems in RPP which are classified as Conventional method and Heuristic method [1]. Conventional methods are based on successive linearization which uses the first and second differentiations of objective function and its constraint equations as the search directions, it is suitable for the optimization problems with only one minimum of deterministic quadratic objective function but sometimes result in divergence [1]. Examples of conventional methods are Linear Programming (LP), Nonlinear Programming (NLP), and Mixed Integer Nonlinear Programming (MINLP) [21]. The Heuristic method is used to overcome Conventional method drawbacks by solving potential for large scale system through their less searching time process [5]. This method comprises of Simulated Annealing (SA), Evolutionary Algorithms (EAs), Differential Evaluation (DE) and Tabu Search (TS) [21] [4]. EA is a process of natural selection and genetics which are used as search algorithms. EA, such as Evolutionary Programming (EP), Real Coded Genetic Algorithm (RGA), Evolutionary Strategies (ES), and Genetic Programming (GP) have been widely used as search and optimization tools in RPP to solve local minimum problems and uncertainties [1].

Several types of EA methods are used to solve the RPP problems over the world since 1960 [9]. The studies involved with control variables such as transformer tap setting T, generator bus voltages Vg and Volt-Ampere Reactive (VAR) source installments Qc [1]. In order to obtain the best solution for RPP objective function identified as the maximum loadability with minimum losses observation during the implementation. The IEEE 26 bus system will be tested in this RPP study utilizing by EP method during any possibility on load increment in the power network.

1.2 Problem Statement

Mainly, power system network is developed from generating, transmission, and distribution system and deals with the high voltage from 400kV – 11kV with real equipment and components that are extremely dangerous and costly. Moreover, in 1992 a part of Malaysia reported blackout for 48 hours, which affected on both the economics and the consumer part [29]. This may due to the lack amount of real and reactive power demand and low voltage condition that led the entire system to collapse. At the same time, transmission losses also increase due to the low voltage even at peak demand. The flow of reactive power in the transmission lines depend upon the active power loss, voltage profile and voltage security in a power system thus VAR compensation is found as the most significant operational and functional control [7]

Nowadays, power system network becomes more complex and stressed due to the growth in electric consumption. The expansion electricity demand is served continuously by the generation, transmission and reactive power resources. Thus the daily and seasonal load variations reactive resource consumption also changes continually. At that point, RPP is a nonlinear optimization problem for a bulky power system with a lot of uncertainties which must also considered all the constraint condition and the optimization of some control variables such as, transformer tap setting T, generator bus voltages Vg and Volt-Ampere Reactive (VAR) source placement Qc [1]. In addition, an increment of load demands will reason to insufficient voltage in the system which may lead to voltage collapse and increases thermal effect on transmission line in the system [1]. Thus, RPP plays an important role in order to maintain voltage stability in large scale power system.

The RPP problems are usually solved by using either classical methods or modern heuristic methods. The advantages of classical methods are fast solutions, strong enforcement of binding constraints and convenience of inexpensive efficient packages [21]. However, these tools problems are the disposal of discrete variables and multi-extremum searching. Moreover, ideal optimizations are difficult to achieve due to obstacle such as dimensionality and large mathematical error problems [3]. In addition, Nonlinear Programming (NLP) which is one of the classic methods undergoes slow convergence and can only find one local optimum [21]. Meanwhile, the heuristic methods provided better global searching ability in optimization problems [3]. Even though most algorithm faces problems like local extremum and slow speed in order to accomplish and obtain desired results, but an EP was chosen as an approach mechanism due to its small number of disadvantages as compared to the others classical method [3]. Moreover, a better result could be achieved using this heuristic method [3].

1.3 Objective

1. To develop Evolutionary Programming technique to solve Reactive Power Planning problems with an objective function for maximum loadability or Maximum Loading Point (MLP) on IEEE 26 bus system.

2. To develop Evolutionary Programming technique to solve Reactive Power Planning problems to observe the minimum losses on IEEE 26 bus system produced by the MLP.

1.4 Scope

The scope of this project involved the following:

1. Development of Evolutionary Programming technique to solve Reactive Power Planning problems in power system. All control variables which are reactive power dispatch, Q_{gs}, compensating capacitor placement, Q_{inj}, and transformer tap changing, X_{mer} were considered individually and grouping in order to obtain the maximum loadability or MLP as single objective function. The implementation will be accomplished on standard IEEE 26 bus system using MATLAB software.
2. Development of Evolutionary Programming technique to solve Reactive Power Planning problems in power system. All control variables were considered individually and grouping in order to obtain the minimum losses as the observation value during MLP. The implementation will be accomplished on standard IEEE 26 bus system using MATLAB software.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter will discuss the review of previous researches that is related with this project. The information from the finding is then will be used as guidance and to meet the goal of this research successfully. The related research works will be described by the following subtopic in this chapter 2.

2.1 Reactive Power Planning

The large or insufficient amount of real and reactive power demand and low voltage condition due to different end users act as a factor for the whole system to shut-down. In consequence, reactive power optimization is a constraint, large-scale and nonlinear combinatorial optimization problem in power system network. It is a method to regulate reactive power with a given system parameters and the loads to obtain one or more system optimization objectives through some control variables [2] [3]. In addition, Reactive Power Planning (RPP) is needed to minimize real power loss and to minimize voltage deviation. Thus, the transformer tap setting, generator bus voltage and VAR source replacement are the control variables which necessary to be optimizing in reactive power solution [1].

2.1.1 Load Margin

Voltage stability margin is identified as the amount of additional load in specific pattern of load increase that would cause voltage instability. Failure of components such as generator, transformer, and transmission line usually reduces the voltage stability margin. In consequence, the severe contingencies may cause the voltage instabilities [32].

Furthermore, load margin analysis is defined as one of the principle measurement of voltage stability studies. During load margin evaluation, voltage breakdown point were identified by gradually increasing the load surpass its Maximum Loading Point (MLP), where eventually the system begins to become instable. Generally, the systems’ maximum loading could be determined by Direct Method (DM) and Continuation Power Flow (CPF) method [6]. These techniques involve series of power flow computation for any load increment [6]. In CPF, the MLP value is determined by using the correctorpredictor scheme [6].

Mainly, many of studies on system loadability involves in identifying appropriate techniques to improve the load margin of a system [6]. However, MLP should be kept in range to avoid voltage breakdown by using the proper control action. This analysis is important to occupy increment in system load demand and subsequently promising a secure voltage condition. Several techniques that proposed for load margin enlargement are involved with reconfiguration of distribution system, regulating the generation direction, FACTS devices installation, reactive power planning, and load shedding [6].

For a specific operating point, the tolerable amount of additional load before the incident of voltage collapse is known as the load margin. Figure 2.1 below interprets the situation in a graphical manner.

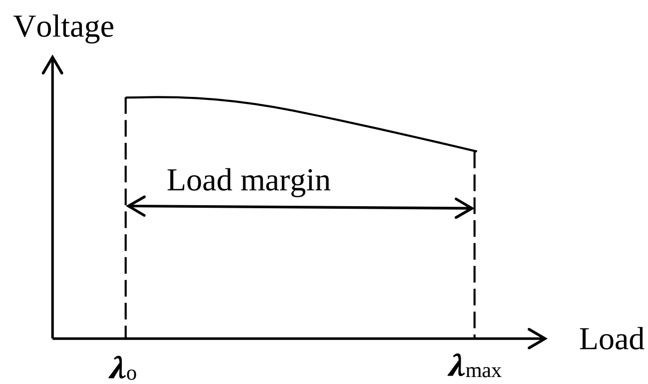

Figure 2.1: Load margin assessment, load vs. voltage

λ_o	-	The loading at base case
λ_{max}	-	The Maximum Loading Point (MLP) value

From the load margin assessment, the critical bus of a system and the maximum load it can provide could be also determined. The bus with the lowest load margin is called as the critical bus; the load margin improvement will be monitored at the critical bus. The proposed EP optimization technique with MLP maximization as the objective function have been used to implement pre and post RPP to conduct comparisons in terms of Maximum Loading Point (MLP) expansion and entire system losses [6]. Graphically, Figure 2.2 below shows the observation of Point A, A' and B.

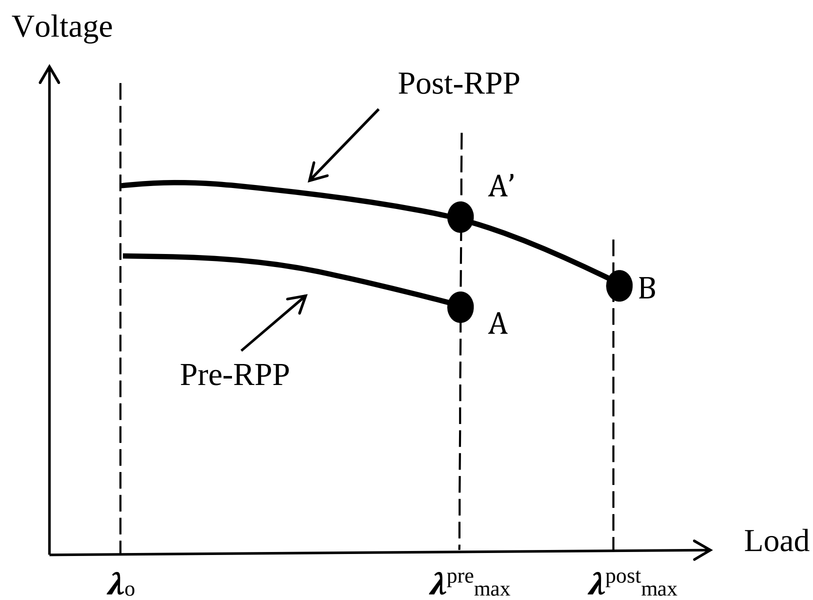

Figure 2.2: Comparison between pre and post RPP implementation.

Point A	-	MLP prior to the implementation of the RPP or Pre-RPP
Point B	-	MLP obtained as a result of RPP or Post-RPP

The researcher in [10] stated that in order to ensure the system voltage profile is acceptable for system normal and post-contingency conditions, the voltage profile criteria needed to be observed as a practical operation. However, voltage is a poor indicator of proximity to system failure condition when power system is under stressed. Subsequently, the cooperation of voltage stability becomes significant in RPP [10].

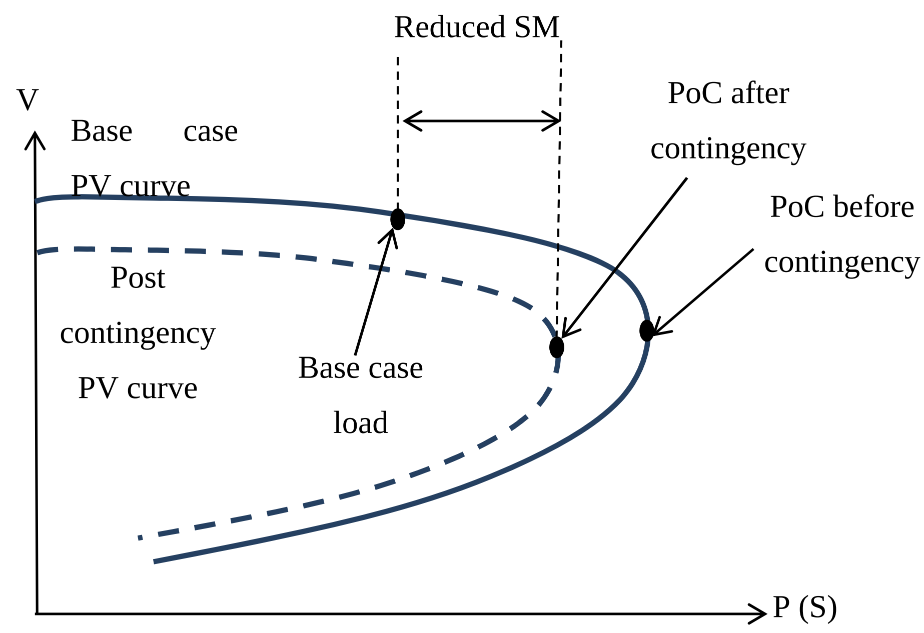

Figure 2.3: PV Curve for Base Case and Contingency

As referred to Figure 2.3, to avoid voltage instability or large scale voltage breakdown, shunt reactive power compensation is used to provide voltage support. In the Figure 2.3, voltage stability is usually identified by a P-V or S-V curve. The knee point of the curve is called the Point of Collapse (PoC), rapid voltage drop causes increment in PoC load which also known as the equilibrium point, where the respective Jacobian becomes singular. Beyond the PoC limit, power flow solution fails to converge, which express the voltage instability and can be associated with a saddle-node bifurcation point. Voltage problems in local area cause instabilities due to the reactive power shortage. Therefore, the objective to improve the static voltage stability margin (SM) defined as the displacement of saddle-node bifurcation point and base case operating point [10].

From thorough literature, several methods have been proposed for voltage stability enhancement in RPP solutions. Those methods were identified as conventional methods, heuristic methods and hybrid methods, which will be described in the following section.

2.2 Conventional Method

Conventional or classical optimization techniques is found as a tool to optimize the RPP problem such as Linear Programming (LP), Nonlinear Programming (NLP), Mixed-Integer Nonlinear Programming (MINLP), and Interior Point (IP) methods have been used in RPP throughout years [2] [21]. The techniques are based on successive linearization which applied the first and second differentiations of objective function and its constraint equations as the search directions [1].

These conventional optimization methods are suitable for quadratic objective function which has only one minimum objective function. However, the formula of RPP problem is hyper quadratic functions, such as linear and quadratic presentation which produce a lot of local minima. As a result, the conventional optimization methods always results in divergence when solving RPP problem due to its only one local minimum [1].

Nonetheless, several classical methods as an alternative approach to solve various optimal reactive power flow problems from many researchers around the world. Thus, nonlinear reactive power optimization problem is also linearized using LP based technique in [21]. The benefits of this technique are fast solution, strong binding constraints enforcement, and low cost efficient packages. Meanwhile, NLP is proposed as a solution to optimum VAR planning problem, but undergoes slow convergence and capable to find only local optimum [21] [7]. Nevertheless, MINLP decomposition method significantly reduces the number of iterations [21]. Generally, these classical method have their own disadvantages which it has limited capability to solve the non-linear and non-convex power system problems with complex constraints [7].

2.3 Heuristic Method

Since years, heuristic optimization algorithms such as genetic algorithm (GA), Particle Swarm Optimization (PSO), Differential Evolution (DE), Evolutionary Programming (EP), and Bacterial Foraging Optimization (BFO) become popular in solving RPP problems [30].

These techniques are adaptable, which solution search and optimization problems could be provided, based on the natural biological genetic processes. Evolutionary algorithms (EA) are able to solve real-world problems, based on the natural selection principle and Charles Darwin rule of ‘survival of the fittest’ [31].

The heuristic method effectively overcame the classical algorithm weaknesses. Even though, these methods may be easily trapped in a local optimum when solving complex multimodal problems and its searching performance depends on the appropriate parameter settings but they have promising global searching ability and process multi-objective optimization problems [30]. However, single algorithm preferred outcome is difficult to be gained due to the numerous weaknesses like local extremum and slow convergence speed [3].

Heuristic algorithms also have been implemented to solve multi-objective reactive power flow problems in order to improve the inaccuracy by conventional techniques. As a reason, EP algorithm is used to overcome RPP problems and reduction of real power losses [3]. Besides that, Mixed Coding of Genetic Algorithm (MCGA) was proposed to minimize the system losses and presented a better result [3]. PSO also have been a solution for RPP problems, while modified PSO method is applied for RPP problems with an improvement in voltage stability margin [3]. DE algorithm is utilized effectively for both network losses minimization and voltage security problems [3].

2.4 Hybrid Method

Hybrid intelligent approaches have been proposed since a few years ago. These methods are created by hybridization of various methods to produce various types of intelligent system architectures [31]. The integration of different algorithms is mainly to overcome their individual weaknesses, by merging attributes and strengths of different approaches [31].

Hybrid methods have been widely used for solving RPP problem such as hybrid Particle Swarm Optimization (PSO), Pseudo-Gradient Guided Particle Swarm Optimization, and Genetic Evolving Ant Direction Particle Swarm Optimization algorithm [22]. Even though, these methods offered better solution than using single methods but it suffers from