THE ECONOMICAL WITH LESS POLLUTION LOAD DISPATCHUSING AN EVOLUTIONARY PROGRAMMING OPTIMIZATION APPROACH

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DECLARATION

I declare that this thesis entitled “The Economical with Less Pollution Load Dispatch via an Evolutionary Programming Optimization Approach” is the result of my own research except ascited in the references. The thesis has not been accepted for any degree and is not concurrentlysubmitted in candidature for any other degree.

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Date : 5/7/2021

APPROVAL

I hereby declare that I have checked this report entitled "The Economical with Less Pollution Load Dispatch via An Evolutionary Programming Optimization Approach" and in my opinion, this thesis it compiles the partial fulfilment for awarding the award of Bachelor of Electrical Engineering with Honours.

Signature : ....

Supervisor name : Dr Elia Erwani Binti Hassan

Date : 5/7/2021

DEDICATIONS

To my beloved mother and
mother

Mohamed Noh Bin Mohamad

Salmi Binti Md.Din

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Alhamdulillah praise to Allah, I would like to thanks to Allah S.W.T, The Almighty, a place where I pray and pledge, who has given me a strength and ability to execute the project in time. The numerous trials and tribulations I have faced in preparing this project. But I am making this a very important lesson and experience for me. At this opportunity, I would like to take this opportunity to express my special thanksto my project supervisor, Dr Elia Erwani Binti Hassan for give me an encouragement, guidance, advice, and motivation during complete my project. Without the guidance and persistent help, this project would not be same as presented here. A million thanks also to my beloved parents who always give me a support, prayers, and encouragement. A thanks also to all my colleagues who do not fail to give me endless support to finish this project. Lastly, I hope report of this project will give a benefit to others researcher in the future.

ABSTARCT

Nowadays, economic load dispatch (ELD) become critical issue in our power system. ELD turns to more challenging when the generating unit need to be operated into power system generation to satisfy the load demand while minimizing overall cost of generator. For that reason, the evolutionary programming (EP) is introduced to overcome the ELD problem at the same time satisfy for system constraints. There are three objective functions of ELD which are minimize the total generation cost, minimize emission and minimize total losses with limitation of operational units for standard IEEE 26 bus system and IEEE 57 bus system. The EP is executed using 10,20 and 30 populations to minimize all three mentioned objective functions. All generators named as Pg2, Pg3, Pg4, Pg5, and Pg26 for 26 bus system while the generator for 57 bus system is known as Pg2, Pg3, Pg6, Pg8, Pg9, and Pg12 will be optimized to achieve the objective function. There are four major steps involves in EP which are initialization, mutation, combination, and selection phase. From the result obtained, the EP was able to minimize an objective function for 26 bus and 57 bus system.

ABSTRAK

Pada masa ini, penghantaran beban ekonomi (ELD) menjadi isu kritikal dalam sistem kuasa kita. ELD berubah menjadi lebih mencabar apabila unit penjana perlu dikendalikan menjadi penjanaan sistem kuasa untuk memenuhi permintaan beban sambil meminimumkan kos keseluruhan penjana. Atas sebab itu, pengaturcaraan evolusi (EP) diperkenalkan untuk mengatasi masalah ELD sekaligus memuaskan untuk kekangan sistem. Terdapat tiga fungsi objektif ELD iaitu meminimumkan jumlah kos penjanaan, meminimumkan pelepasan dan meminimumkan jumlah kerugian dengan pembatasan unit operasi untuk sistem bas IEEE 26 standard dan sistem bas IEEE 57. EP dijalankan menggunakan 10,20 dan 30 populasi untuk meminimumkan ketiga-tiga fungsi objektif yang disebutkan. Semua penjana yang dinamakan sebagai Pg2, Pg3, Pg4, Pg5, dan Pg26 untuk sistem bas 26 sementara penjana untuk sistem bas 57 dikenali sebagai Pg2, Pg3, Pg6, Pg8, Pg9, dan Pg12 akan dioptimumkan untuk mencapai fungsi objektif. Terdapat empat langkah utama yang melibatkan EP iaitu inisialisasi, mutasi, kombinasi, dan fasa pemilihan. Dari hasil yang diperoleh, EP dapat meminimumkan fungsi objektif untuk sistem bas 26 dan 57 bas.

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LIST OF SYMBOLS AND ABBREVIATIONS

CO	-	Carbon
CO2	-	Carbon Dioxide
NOx	-	Nitrogen Oxide
SOx	-	Sulphur Oxide
ELD	-	Economic Load Dispatch
EP	-	Evolutionary Programming
EA	-	Evolutionary Algorithm
OPF	-	Optimal Power Flow
UTeM	-	Universiti Teknikal Malaysia Melaka

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Recently, economic load dispatch (ELD) become critical aspect in our power system. ELD turns to more challenging when the generating unit need to be introduced into power system to satisfy the load demand while minimizing overall cost of generator. Today, ELD solution need cheapest possible price the minimum level of a pollution. Based on appendices A, Global Database's Malaysia, in August 2020 a Malaysia's Electricity's Malaysia Consumption data was reported at 12,380.475 kWh Mn compare in July 2020 which is only 12,339.904 kWh. Therefore, it is important for electric utilities in reducing carbon (CO), carbon dioxide (CO2), and nitrogen oxide NOx [1]. Hence, the power system needs to operate economically to make sure the system operates at the minimum cost.

The total fuel cost is entirely different since the power plants are situated at various from the center of the load. The purpose of ELD is to configure generating unit's outputs to satisfy the load demand at the minimum cost [2]. ELD important in term to minimize the total generation cost with limitation of operational parameters and at the same time the constraints are also satisfied [3]. The ELD also known as a non-convex optimization problem. This is because linear discontinuous features, including the loading effect of the valve stage, prohibited operating zones and multi type fuel, exist [4].

There are two constraints need to be satisfied which are equality constraint and inequality constraint [1]. In 1970s, it was pointed those economic strategies are developed to minimize the emission and minimize the production cost subject to emission constraints to satisfy the load demand at minimum running cost subject to process operational constraints which is equality and inequality [4].

Mainly, total demand must be equivalent among of generating units. This economy dispatch has been solved before by others researcher via others optimization method such as newton method, linear programming, non-linear programming [5].

These three techniques are poor for solving the optimization problem with a non-convex, non- continuous and linear solution space [5]. These three method are not effective when thedispatch problem when the dispatch problem become more complex [6].

A new optimization to solve this complex optimization problems are discovered from year to year. One of the techniques that use to solve this problem of ELD is by using EP. EP is known as an evolution process that found in nature such as an initialization, mutation,and selection. The evolutionary programming is one of four major evolutionary algorithms which are genetic programming, differential programming, and evolutionary strategy. A simulation task are performed by using 26 bus system for 6 generator test system and 57 bus system for 7 generator test system respectively using MATLAB programming.

1.1 Objectives

- To minimize total generation cost with the limitation of operational constraints for standard IEEE 26 bus system and IEEE 57 bus system for 10,20 and 30 populations using MATLAB programming.

- To minimize less emission polluted of each generator with limitation of operational constraints for standard IEEE 26 bus system and IEEE 57 bus system for 10,20 and 30 populations using MATLAB programming.

- To determine power losses with the limitation of operational constraintsfor standard IEEE 26 bus system and IEEE 57 bus system for 10,20 and30 populations using MATLAB programming

1.2 Problem Statement

The ELD become to complexity from day to on a daily basic requirement. Most society does not concern about how to use energy efficiently in daily lives. Thus, ELD is crucial aspect of total electricity demand by considering operating efficiency of production. Fuel costs and lost transmission are the factors affecting power generation at the minimum cost. Thus,in operating power each unit for generator must minimize the total operational cost andtotal emission polluted are dispensed as well for minimum losses. The foremost efficientgenerator does not give a guarantee the cost could be a minimum because it could alsobe in a district where the fuel is higher. The transmission is considered higher when the power system is far away from load. Based on researcher before, it shows that theinstalled capacity in Malaysia increased 8.5 per cent to 33,023 MW in 2016 comparedto 30,439 MW in 2015[7]. Hence, the power each unit for generator need to be optimized while minimize the total operational cost and total emission polluted.

1.3 Motivation

Economy dispatch is important thing in power system. This ELD plays a very significant role in power economic aspect. For the reliable and efficient running of such alarge, it required careful research of the interconnected power system and the way of economically running. Therefore, in the electrical power grid, ELD managed to operate power systems economically with an efficient simulation tools [8]. The ELD ensures that the generator's actual and reactive capacity varies under certain limits and meets the demand for lower fuel costs. The constraints need to be satisfied when to achieve the objective function. The ELD helps to produce the electricity at the lowest cost and reduces the impact on environmental pollution.

1.4 Scope of Works

The economy dispatch is important to our power system. The power system needs to operate at high degree of economy systemto ensure the system operates at the minimum cost in order to achieve a cheapest price with the minimum levels of a pollution, the total cost generation, and the less emission polluted, and the power losses need to be determined. Thus, the scope of this projects is the implentation of EP using MATLAB programming is executed for total generation on IEEE 26 bus system and IEEE 57 bus system. The implentation of EP using MATLAB programming in the total emission on IEEE 26 bus system and IEEE 57 bus system minimisation for 10,20 and 30 populations. All the three objective function needs to determine as well constraints need to be satisfied.

1.5 Report Outline

The report of this project contains of five main chapter. The first chapter of this report are the introduction which is covers researched background, objectives, problem statement, motivation, scope of works and a report outline. Secondly, the reports will cover on research done by the previous researchers for the related results. Thirdly, the chapters are about methodology to solve the objective function of ELD using EP. The following part was the result discussion of EP. Finally, the chapter five is to conclude the finding of the research.

CHAPTER 2

LITERATURE REVIEW

2.1 Energy Consumption in Malaysia

Energy sector in Malaysia is based on non-renewable fuel [9]. For example, the most popular one is fossil fuel and natural gas. They are constant growth for the electricity supply in industry due to the advances in technology that have fully geared the industry to the world that now does not work under conventional supply theory follows demand [11]. Economic development also related to the energy consumption due to the increasing of economic development when the energy consumed in Malaysia are higher [10]. In Malaysia, a carbon emission is targeted to be reduced until 40% by government of Malaysia [11].

A fundamental question is whether the goals of increased economic growth and enhanced environmental sustainability (lower emission) are mutually exclusive. The type of fossil fuel use for the electricity are sulfur oxide (Sox), nitrogen oxide (NOx) and carbon dioxide (CO2). This fossil fuel is releasing several contaminants inour atmospheric. The one of major obstacles for electric utilities are reducing the atmospheric pollution [12]. The power sector is the one of the types of major sources of energy consumption and CO2 emissions. For greenhouse cases, the CO2 emissions are responsible for more than 60% of greenhouse effect [11]. This effect can cause a global climate change. Hence, the limiting of CO2 emissions become an important concern for securing renewable resources and minimizing the effect of climate.

A power system with such an appropriate power capacity of 100MW, the CO2 reduction will be achieved at 1% reduction in fuel consumption due to the adopting appropriate operational of optimization and the maintenance [13]. Hence, the research of administrative of optimization is essential for the generation of power in power system which is produce the pollutant gases.

2.2 Economic load dispatch

Economic load dispatch (ELD) is an important optimization task in operation of power system [14]. This ELD is crucial for allocating the generation units to the appropriate combination of generation levels. Therefore, the demand mechanism process can be provided entirely and most economically [15]. Today, ELD problem is including the reduction of NOx and SO2 of emission which is added as an objective function of ELD [16]. There is three objective function to overcome the problem of ELD in power system. The three objective function is minimizing the total generation cost, minimize the total emission and minimize the total system loss while satisfying constraints.

2.2.1 Total generation minimum cost

The most objective in ELD is the minimization of the total generation cost of fuel consumed for produce the electric power. The cost of output depends on the amount of fuel consumed by the generating unit to produce sufficient power to satisfy the load demand [17]. This total generating cost are assumed to be a function and known by quadratic curves of second order [1]. This objective can be expressed by the equation of [18]

$$C_{Total} = \sum_{i=1}^{Ng} Ci\ (Pgi) \quad \text{dollar per hour (\$/ h)} \tag{2-1}$$

$$Ci\ (Pgi) = ai + biPgi + CiPgi^2$$

Where:

C_{Total}= sum function for each generating unit Ng

$C_i P_{gi}$= cost of generation in terms of unit i

P_{gi}= power generated in terms of unit i

a_i, b_i, c_i = cost of coefficient in terms of unit i

2.2.2 Total Emission Minimization

The total of emission is reduced by minimizing the three major pollutants which is NOx, Sox, and CO2 [19]. The objective can be expressed as an equation below [18]

$$E_{Total} = \sum_{i=1}^{Ng} (\gamma_i P_{gi}^{2} + \beta_i P_i + \alpha_i) * (10^{-2}) + \varepsilon_i \exp(\lambda_i P_{gi}) \qquad (2\text{-}2)$$

Where:

E_{Total} = Total function for each generating emission unit Ng

α_i, β_i, λ_i, ε, = Emission coefficient in unit i

P_{gi} = power generated in terms of unit i

2.2.3 Total system loss minimization

The last objective function of ELD is the generation cost is minimizing the total system losses [19]. The objective can be expressed as an equation below [18]

$$T_{loss} = \sum_{i=1}^{N_g} P_{gi} - P_{load} \qquad (2\text{-}3)$$

Where:

T_{loss}= Total of system losses in demand

P_{gi} = Power generated in terms of unit i

P_{load}= Total of load in system demand

2.3 Operational Constraint

The constraint needs to satisfy to ensure the total generation cost in under the limitations [1]. There are two types of constraint which are equality constraint and inequality constraint [1]. Equality constrains mainly focus on power flow balance and inequality constraint are focusing on upper and lower limits of system [20].

2.3.1 Equality Constraint

Equality constraint is necessary for generation deliver the load demand and losses in transmission lines when minimize the objective function of economic load dispatch. The equation is expressed as a [18]:

$$\sum_{i=1}^{Ng} P\text{gi} = P_{load} + T_{loss} \qquad (2\text{-}4)$$

where:

$P_{load=}$ Total of load in system demand

$T_{loss=}$ Total of losses in system demand

2.3.2 Inequality Constraint

Inequality constraint is the limit in power system to ensure system security. Itcan be expressed as a in [18];

$$P_{min} \leq P_{gi} \leq P_{max} \qquad (2\text{-}5)$$

where:

P_{min} = the minimum real power of generation in terms of i

P_{max} = the maximum real power of generation in terms of i

P_{gi} = Power generated in terms of unit i

2.4 IEEE Bus System Network

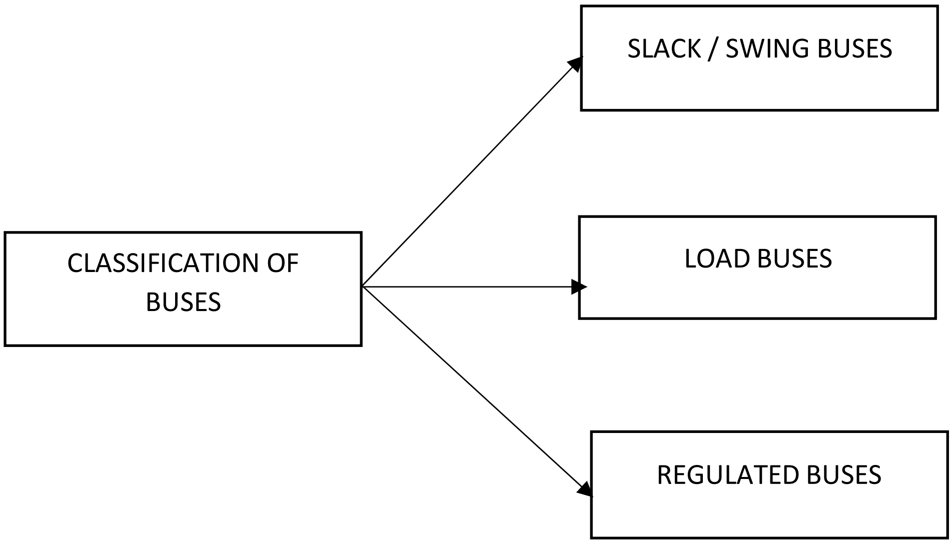

Figure 2.1: Classification of buses

In this simulation, the standard bus use to overcome the economic load dispatch are by using IEEE 26 bus system and IEEE 57 bus network. Basically, there is three types of buses in powerflow analysis which are slack buses, load buses and regulated buses. The purpose of thepower flow study is to measure for a given load, generation, and network the voltages.The slack or swing bus is referred to as a reference bus where the magnitude and the phase angle are defined [21]. The generation bus used for 26 bus system are known as a Pg2, Pg3, Pg4, Pg5, and Pg26 while generation buses used for 57 bus system known as a Pg2, Pg3, Pg6, Pg8, Pg9, and Pg12. The load buses are bus that the real and activepower are determined [21]. The load buses also known as a PQ buses [22]. It is knownas a constraint which is equality constraint. The regulated bus is also known as a voltage regulated buses. The balance of the generator buses is named controlled, or PV buses This voltage regulated bus are connected to the generator. It also known as an inequality constraint.

2.5 Optimal Power Flow

The other name for power system problem also called as an optimal power flow (OPF) [23]. In this era, the power system operation become a major issue. This is related to the scarcity of energy supplies, increased power generation, and increase demand for electricity [23]. The OPF is one of issues that faces in engineering fields to organize the large-scale power systems in an efficient way [24]. The objective of OPF are to find total generation cost, total cost of system operation and necessity for reactive power [25]. Therefore, to meet the environmental regulations, the emissions control also become the one of the crucial aspects in objective of ELD [12]. There is two main task that involved in OPF which is economic dispatch and unit commitment. This ELD assigns a process load demands for various generators in order to minimize the power generation cost [23]. OPF can be expressed by equation below [26],

$$\min f(x,u) \tag{2-6}$$

Subject to:

$$g(x,u) = 0 \tag{2-7}$$

$$h(x,u) \leq 0 \tag{2-8}$$

Where:

u = the vector of control variables which include generator active powerx = vectors of dependent variables (load buses and reactive power)

$f\ (x,u)$ = the objective

$h(x,u)$ = inequality constraints on dependent variables and independent variable

$g(x,u)$ = nodal power

2.6 Evolutionary Programming

Evolutionary programming (EP) was introduced in year 1960's by Lawrence J. Lawrence. Fogel use finite states machine as a predictor and evolved them [27]. EPis one of the types of Evolutionary Algorithm (EA). EA was known as an optimization method analogous to the natural selection process in genetics. Technically, this approach meets the requirement for the optimum complete solution with probability one [28]. EP is aimed to determine the ELD problem for minimize fuel cost unit. The objective of EP is not only solving ELD problem, which is minimize the total cost generation, it also acquires the solution of minimum global such as transmission losses not within sensible execution time [29]. Based on research before,the EP is defined as a method that generates the initial parent vectors distributed uniformly in intervals within constraint to obtain global optimum solution over the optimal solution [29]. Based on inherent versatility in the fitness function and simplicity in coding, EP technique can generate the solution with the minimum number of generations [30]. The process in EP are initialization, mutation, selection, and convergence.

CHAPTER 3

METHODOLOGY

3.1 Overview

In this chapter is the discussion about method that be used to solve the objective inELD. The EP as a tool for ELD solution involved with initialization, mutation, selection, and convergence process.

3.2 Evolutionary Programming Technique

In solving the ELD objective function, the method of evolutionary programming (EP) using 26 bus system and 57 bus system are implemented suggested. EP are suggesting for the evolution of finite – state machines to solve the problem of ELD [14]. EP is the method that generating the initial parent vectors within the limits and gain the optimum solution over a several generations [30]. EP are the solution that formed by a population of optimization problem over a few of generation. Using the mutation operator, a new population is generated from an existing mutation. A new population are obtained fromthe existing population by using mutation operator. Overall process of this method are initialization, mutation, and selection. These stages are used to determine the best fitness solution.

3.3 Optimization Techniques

Figure 3.1 shows the process methodology of ELD. This process can be categorized into four stages which is project detail, project approach, activities, and result. To solve the three objectives, the EP method are used on standard IEEE26 bus and IEEE 57 bus system by applying with different population which is 10, 20, and 30 populations. The EP method is used to aim the minimum cost generation, minimize total emission, and minimize the total losses.

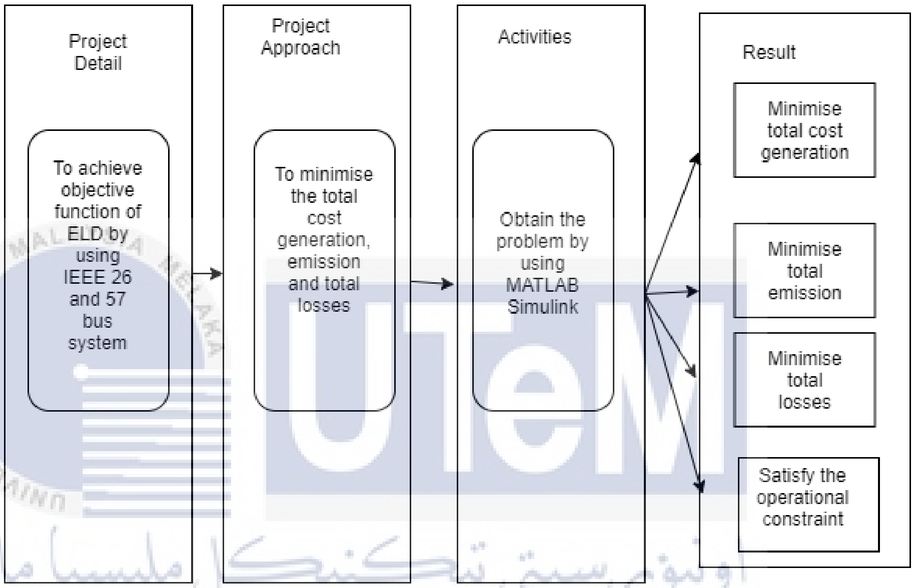

Figure 3.1: Process of EP method

3.4 Flowchart of EP

The following flowchart shows in figure 3.2 are the process on how to achieve the objective function by using EP technique. The constraints are needed to be satisfied during the total cost generation and the total emission minimization.

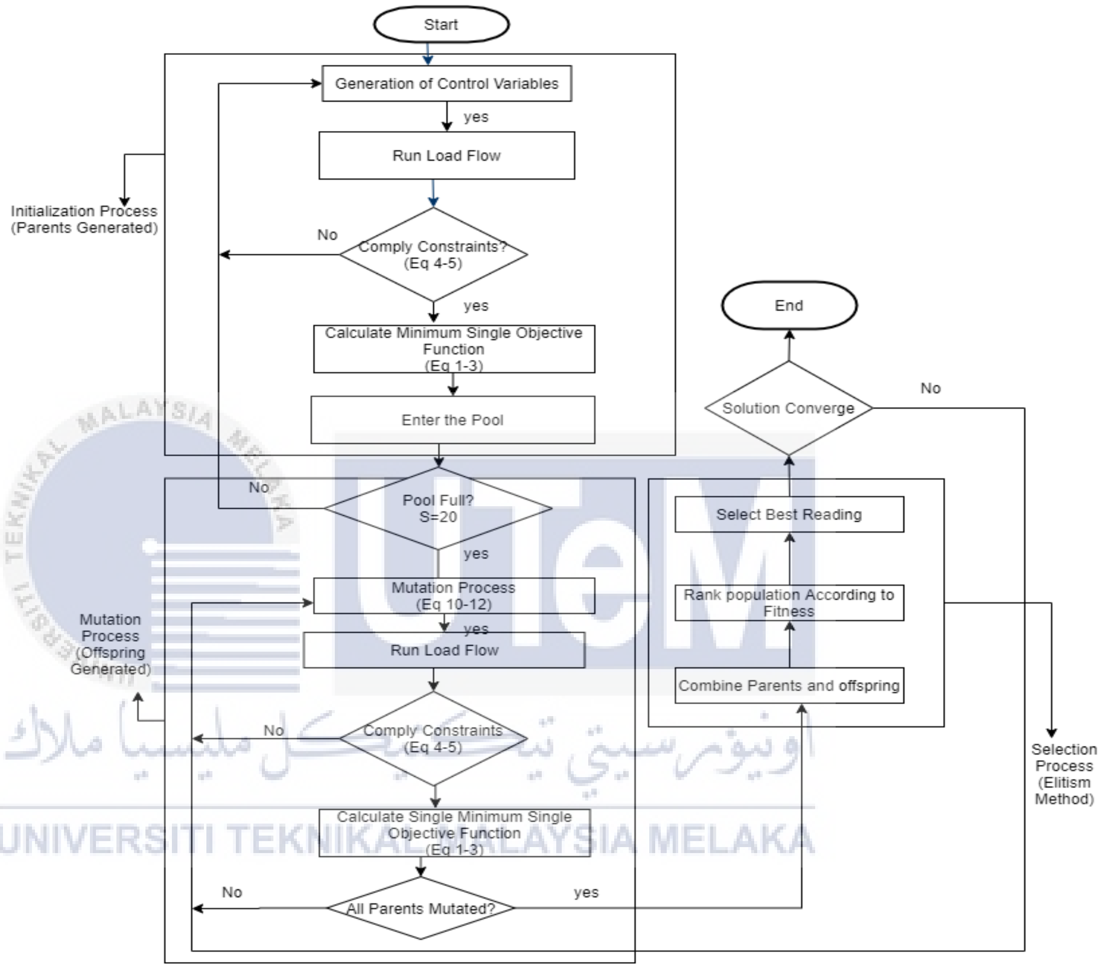

Figure 3.2: Flowchart of EP

Step 1: The random number for each variable for Real Power Output (Pg) was generated and the rand function are uniformly distributed in range interval (0-1)

Step 2: Substitute the control variables generated in Step 1 with their corresponding bus data and use the Newton-Raphson method to execute the load flow. To ensure safe working region, the load flow solution must be within the constraints.

Step 3: The fitness for all the objective function were calculated and the other objective function were observed with value generated in Step 1.

Step 4: The results save in program memory.

Step 5: Run the load flow algorithm and compute the new fitness value for the selected objective function, as well as compared the value generated in Step 1. Step 1 until step 1 need to repeat until the maximum population is set to 10, 20, and 30 populations for 20 loops.

Step 6: The population(parents) was mutated, and new generation was produced which is known as offspring.

Step 7: The new offspring and parents was combined.

Step 8: Since the objective function is to find the minimum solutions, the best 20 populations was rank and select for the best 20 populations with the minimum fitness value.

Step 9: The result for best 20 population was saved.

Step 10: The convergence test was applied. If the program not satisfied, repeat the step 5 to 10.

3.5 Steps in Evolutionary Programming

Several steps involved in the EP simulation process for ELD solution which as follows:

Step 1: Initialization

Initialization process is also known as a parent generated [29]. It is generating the initial population using a random number generation. Random numbers are represented by actual power output (Pg), which is Pg2, Pg3, Pg4, Pg5, Pg6, Pg8, Pg9, Pg12, and Pg26 as the variables to be optimized to establish the minimum generating cost, less emission, and least system loss.[18]. The number of populations are set to 10,20, and 30 with constraints need be satisfied. Based on previous research, the minimum voltage must within limit. The limit is between 0.95(pu) to 1.05(pu) for26 bus system and 0.9(pu) to 1.1(pu) for 57 bus system when the system is operated. [18].

Step 2: Mutation

Second step is known as a mutation process. This process is transforming the initial populations (parents) to offspring (children). This can be expressed by equation below [18]

$$\eta'_{i,j} = \eta'_{i,j} \exp(\tau' N(0,1) + \tau\eta'_{i,j}(0,1)) \tag{3-1}$$

$$L'_{i,j} = L_{i,j} + \eta'_{i,j}(N_j(0,1)) \tag{3-2}$$

$$L'_{0i,j} = L_{oi,j} + \eta'_{i,j}(N_j(0,1)) \tag{3-3}$$

Where:

$$\tau = \sqrt{\frac{1}{2n}}$$

$$\tau' = \frac{1}{\sqrt{2n}}$$

L_{oi} and L_i, $\eta_{i,j}$ and $\eta'_{i,j}$ = the i^{th} components with

respective vectors N (0,1) = normally distribution

one dimensional random with mean 0

and 1

$N_j(0,1)$ = new random number for each value of j

Step 3: Selection process

Process of selection is the combination of parents and offspring. This process is to aim which child and parent from mutation process will survive in next generation [31].

Step 4: Convergence process

Convergence process or also known as a stopping rule is the process of stopping the optimization process. The three process which is initialization, mutation and selection will be repeated if the criterion of convergence is not achieving the optimal solution. The difference between minimum and maximum output for the convergence criterion are established to be less than 0.001[18].

CHAPTER 4

DISCUSSION AND RESULT

4.1 Introduction

This chapter discusses the outcomes of EP solution to solve ELDissues. The goal of the ELD problem is to reduce the total cost generation, total emission and total losses while maintaining operational constraints in check. This EPtechnique solves the problem by comparing the IEEE 26 bus and 57 bus system. Pg1.Pg2, Pg3, Pg4, Pg5, and Pg26 are the six generating units for the 26 bus system, whilePg1, Pg2, Pg3, Pg6, Pg8, Pg9, and Pg12 are the seven generating units for the 57 bus system. The 10, 20 and 30 populations were examined to make a comparison for both buses.The cost and emission coefficient utilisas in Equation 1 and Equation 2 throughout theMATLAB simulation procedure are shown in Tables 1 and 2 below.

4.2 Parameter for standard IEEE 26 bus system

The parameter of 26 bus system is refereed from reference book by Hadi Saadat [21]. A limitation for each variable also shown in table below.

Table 4.1: Parameter coefficient for 26 bus system [21]

Standard coefficient 26 bus system										
Generator	Pmin ,Mva	Pmax ,Mva	Cost Coefficient			Emission Coefficient				
			a_i	b_i	c_i	α_i	β_i	γ_i	ε_i	λ_i
1	100	500	240	7.0	0.0070	4.091	-5.543	6.490	2.0e-4	3.857
2	50	200	200	10.0	0.0095	2.543	-6.047	5.638	5.0e-4	3.333
3	80	300	220	8.5	0.0090	4.258	-5.094	4.638	1.0e-6	8.000
4	50	150	200	11.0	0.0090	5.326	-3.550	3.380	2.0e-3	2.000
5	50	200	220	10.5	0.0080	4.258	-5.094	4.586	1.0e-6	8.000
26	50	120	190	12.0	0.0075	6.131	-5.555	5.151	1.0e-5	6.667

Table 4.2: Total demand for 26 bus system

Total Demand (MW)
1263

4.3 Parameter for standard IEEE 57 bus system

Table below shows the parameter of 57 bus system [32]. The coefficient of costand emission also shown in table below.

Table 4.3: Parameter standard coefficient for 57 bus system[32]

Standard coefficient 57 bus system										
Generator	Pmin ,Mva	Pmax ,Mva	Cost Coefficient			Emission Coefficient				
			a_i	b_i	c_i	α_i	β_i	γ_i	ε_i	λ_i
1	50	576	115	2.00	0.0055	4.091	-5.543	6.490	2.0e-4	3.857
2	10	100	40	3.50	0.0060	2.543	-6.047	5.638	5.0e-4	3.333
3	20	140	122	3.15	0.0050	4.258	-5.094	4.638	1.0e-6	8.000
6	10	100	125	3.05	0.0050	5.326	-3.550	3.380	2.0e-3	2.000
8	40	550	120	2.75	0.0070	4.258	-5.094	4.586	1.0e-6	8.000
9	10	100	70	3.45	0.0070	6.131	-5.555	5.151	1.0e-5	6.667
12	30	410	150	1.89	0.0050	4.258	-5.094	4.586	1.0e-6	8.000

Table 4.4: Total demand for 57 bus system

Total Demand (MW)
1250.8

4.4 Result for 26 bus system and 57 bus system

The objective of ELD is to optimize the total cost generation, emission, and total losses while the limitations are satisfying. The simulation was set for 20 loops for every population. The population was set by ten, twenty and thirty populations. This section also shows the result obtained by 26 bus system and 57 bus system respectively. Optimal generating unit for 10 population are calculated based in Equation (1), (2), and (3).

4.4.1 Total generation cost for 26 bus system

Generator of Pg2, Pg3, Pg4, Pg5, and Pg26 was set randomly between the generator limitations in simulation MATLAB in order to minimize the total generation cost while total emission and total loss was observed. The result for each population was shown below.The optimal generating unit for more saving population shown in table 4.5.

Table 4.5: Result total generation cost for 26 bus system

No of population	Total Generation Cost($/h) (fitness)	Total Emission (ton/h) (observed)	Total System Loss (MW) (observed)	Completion times (seconds)
10	15317.32	21727.78	13.19465	9.987583
20	15488.63	21382.38	13.44966	13.39298
30	15490.4	18570.88	13.05145	16.64123

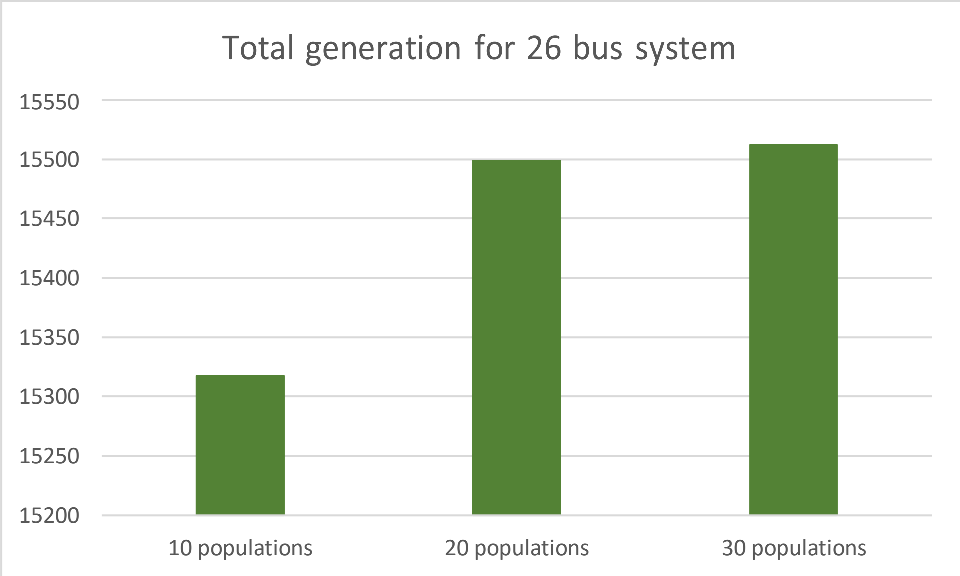

Figure 4.1: Graph total generation cost for 26 bus

The simulation is conducted through three populations which are 10, 20, and 30 populations, respectively. The minimize total cost generation is from 10 population which is 15317.32 dollar/h. Thus, it shown that the 10 populations have more saving than 20 and 30 populations. The higher cost generation is 15490.4 dollar/h by 30 population which means that 30 population need higher generation cost compared with other 10 and 20 populations.

Table 4.6: Optimal generating unit of 26 bus system for total cost generation of 10population

Pg1(MW)	472.9849	**Cost1($/h)**	5116.897	**Emission1(ton/h)**	14542.42
Pg2(MW)	188	**Cost2($/h)**	2212.278	**Emission2(ton/h)**	2038.735
Pg3(MW)	274	**Cost3($/h)**	3224.684	**Emission3(ton/h)**	3434.504
Pg4(MW)	126	**Cost4($/h)**	1728.884	**Emission4(ton/h)**	561.7547
Pg5(MW)	99	**Cost5($/h)**	1337.908	**Emission5(ton/h)**	446.4366
Pg26(MW)	117	**Cost26($/h)**	1696.668	**Emission26(ton/h)**	703.9382
$\sum Pg$	1276.98	**Total cost ($/h)**	15317.32	**Total Emission (ton/h)**	21727.78
Total loss (MW)	13.98489	**Power Demand**	1263	**Voltage min (pu)**	0.966834
				Voltage max (pu)	1.05

Table 4.6 above shows the optimal generating for 10 populations of total cost generation. The table shows the power of each generator which led to minimum total cost of standard IEEE 26 bus system. The total demand for 26 bus system is satisfied which is 1263 MW using Equation 3. Hence, when the total of generator is subtracted from total loss, the total demand can be achieved. The minimum voltage and maximum voltage also satisfied.

4.4.2 Total generation cost for 57 bus system

IEEE 57 bus system was another IEEE standard system to minimize the total generation cost as well. Table 4.7 presented the fitness of generation cost while the emission and losses were observed.

Table 4.7: Result total cost generation for 57 bus system

No of population	Total Generation Cost($/h) (fitness)	Total Emission (ton/h) (observed)	Total System Loss (MW) (observed)	Completion times
10	6535.398	20733.64	21.01684	6.543336
20	6577.93	18697.13	21.84395	6.869046
30	6721.529	21562.14	23.75601	6.995604

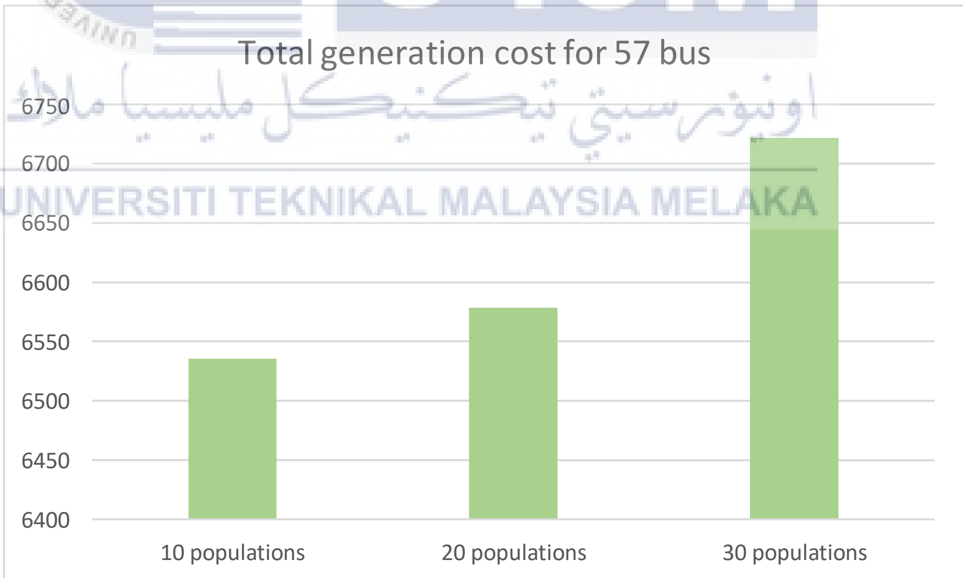

Figure 4.2: Graph total generation cost for 57 bus

From the simulation result, the table 4.7 above shows the 10 populations produced lower cost generation which is 6535.398 dollar/h compared to other population. The overall emission and loss are observing at the same time. Besides that, 10 population has the fastest completion times among others population.

Table 4.8: Optimal generating unit of 57 bus system for total generation cost of 10population

Pg1(MW)	238.8003	**Cost1($/h)**	906.2413	**Emission1(ton/h)**	3712.756
Pg2(MW)	86	**Cost2($/h)**	385.376	**Emission2(ton/h)**	438.0613
Pg3(MW)	66	**Cost3($/h)**	351.68	**Emission3(ton/h)**	158.0868
Pg6(MW)	28	**Cost6($/h)**	214.32	**Emission6(ton/h)**	197.7555
Pg8(MW)	493	**Cost8($/h)**	3177.093	**Emission8(ton/h)**	11130.93
Pg9(MW)	28	**Cost9($/h)**	172.088	**Emission9(ton/h)**	40.14756
Pg12(MW)	332	**Cost12($/h)**	1328.6	**Emission12(ton/h)**	5055.899
$\sum Pg$	1271.80	**Total cost ($/h)**	6535.398	**Total Emission (ton/h)**	20733.64
Total loss (MW)	21.01684	**Power Demand (MW)**	1250.8	**Voltage min (pu)**	0.9
				Voltage max (pu)	1.1

Table 4.8 above shows the real power generator which is contributed to minimize the total cost generation. The total generator for IEEE 57 bus system of 10 population was 1271.80 MW. The estimation of each generator can be acceptable since the power demand are satisfied. The minimum voltage and maximum voltage is in limit of 0.9(pu) to 1.1 (pu).

4.4.3 Total emission for 26 bus system

The second of objective function was to minimize total emission with the limitation constraints. The fitness of emission was presented in table below while generation cost and system loss were observed.

Table 4.9: Result total emission for 26 bus system

No of population	Total Generation Cost($/h) (observe)	Total Emission (ton/h) (fitness)	Total System Loss (MW) (observe)	Completion times (seconds)
10	15498.98	20213.67	13.54158	17.09708
20	15478.27	20886.76	13.51544	19.86534
30	15504.55	21601.74	13.20995	18.57312

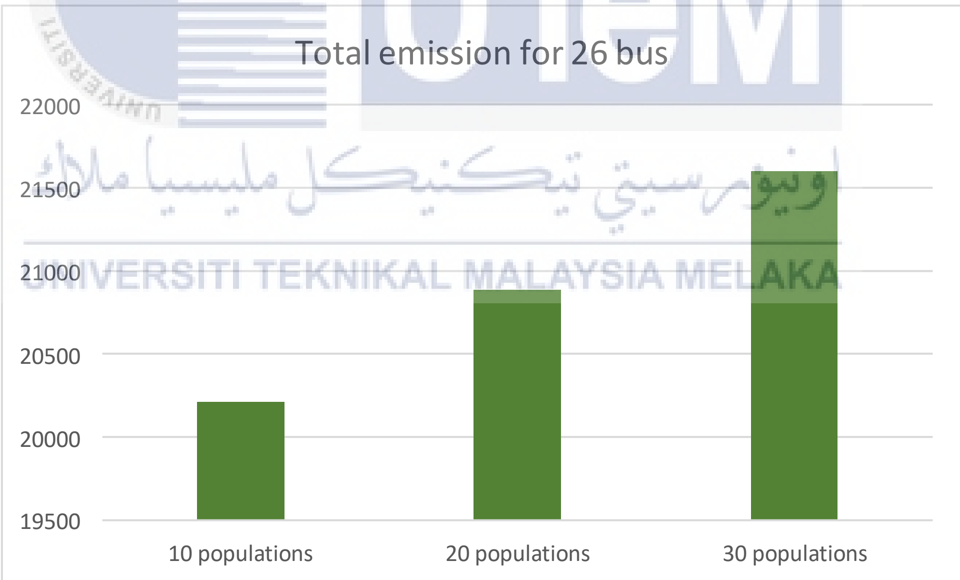

Figure 4.3: Total emission 26 bus

Figure 4.3 shows the least value of total emission by IEEE 26 bus system was at 20213.67 ton/h with the total generation cost at 15498.98 dollar/h. The higher pollutedto the environment is by 30 population with 21601.74 ton/h with the completion timearound 18.57312 seconds.

Table 4.10: Optimal generating unit through 26 bus system for total emission for 10population

Pg1(MW)	441.5416	**Cost($/h)**	4695.504	**Emission1(ton/h)**	12674.61
Pg2(MW)	190	**Cost2($/h)**	2442.95	**Emission2(ton/h)**	2081.848
Pg3(MW)	277	**Cost3($/h)**	3265.061	**Emission3(ton/h)**	3510.217
Pg4(MW)	141	**Cost4($/h)**	1929.929	**Emission4(ton/h)**	695.1055
Pg5(MW)	112	**Cost5($/h)**	1496.352	**Emission5(ton/h)**	571.8261
Pg26(MW)	115	**Cost26($/h)**	1669.188	**Emission26(ton/h)**	680.0588
$\sum Pg$	1276.542	**Total cost ($/h)**	15498.98	**Total Emission (ton/h)**	20213.67
Total loss (MW)	13.54158	**Power Demand (MW)**	1263	**Voltage min (pu)**	0.966834
				Voltage max (pu)	1.05

From the table 4.10, it shows that total emission dispersed by Pg2, Pg3, Pg4, Pg5 and Pg26 was 15498.98 ton/h while the power demand, minimum voltage and maximum voltageare satisfied. The total loss also satisfied according to Equation 3. The total generation costand total loss were observed at 15498.98 dollar/h and 20213.67 ton/h.

4.4.4 Total emission for 57 bus system

For the IEEE 57 bus system the total emission of minimization was shown in table 4.11 above while thegeneration cost and losses were observed.

Table 4.11: Result of total emission for 57 bus system

No of population	Total generation cost ($/h) (observe)	Total Emission (ton/h) (fitness)	Total System Loss (MW) (observe)	Completion times (seconds)
10	6387.722	19500.19	19.57633	6.330848
20	6631.312	20532.72	22.57489	6.595749
30	6546.207	23283.29	22.81557	10.40971

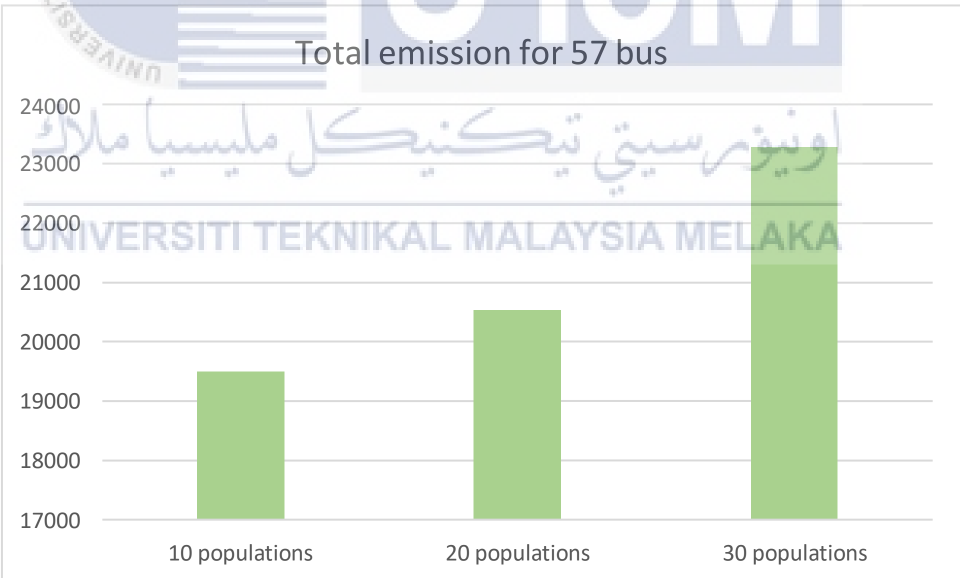

Figure 3.4: Total emission for 57 bus

The total emission for IEEE 57 bus system showed that 10 population recorded the most cleanest environment with 19500.19 ton/h. The completion times also the faster among others population while30 population has higher emission with 23283.29 ton/h.

Table 4.12: Optimal generating unit through 57 bus system for total emission for 10population

Pg1(MW)	250.358	**Cost1($/h)**	960.4512	**Emission1(ton/h)**	4080.24
Pg2(MW)	51	**Cost2($/h)**	234.106	**Emission2(ton/h)**	159.1526
Pg3(MW)	61	**Cost3($/h)**	332.755	**Emission3(ton/h)**	168.7899
Pg6(MW)	36	**Cost6($/h)**	241.28	**Emission6(ton/h)**	49.7494
Pg8(MW)	469	**Cost8($/h)**	2949.477	**Emission8(ton/h)**	10072.86
Pg9(MW)	87	**Cost9($/h)**	423.133	**Emission9(ton/h)**	389.0159
Pg12(MW)	316	**Cost12($/h)**	1246.52	**Emission12(ton/h)**	4580.375
$\sum Pg$	1270.358	**Total cost ($/h)**	6387.722	**Total Emission (ton/h)**	19500.19
Total loss (MW)	19.57633	**Power Demand (MW)**	1250.8	**Voltage min (pu)**	0.947617
				Voltage max (pu)	1.065252

Table 4.12 recorded all generating unit of Pg2, Pg3, Pg6, Pg9, Pg12 were optimized by using IEEE 57 bus system. The 10 population was selected since it has lower emission compared to other population. The minimum rate of total emission was 6387.722 ton/h with total losses 19.57633 MW. The highest emission polluted to the environment is using Pg8. The minimum voltage and maximum voltage is still under limitation between 0.9 (pu) to 1.1 (pu).

4.4.5 Total losses for 26 bus system

The final objective function was to minimize the total system losses. There are 10, 20 and 30 population were applied identified which population result to less the losses.

Table 4.13: Result total losses for 26 bus system

No of population	Total generation cost ($/h) (observe)	Total Emission (ton/h) (fitness)	Total System Loss (MW) (observe)	Completion times (seconds)
10	15512.08	20405.41055	13.65635	14.384
20	15543.07	21412.63	13.96598	39.87592
30	15561.28	21369.65	13.97225	40.00122

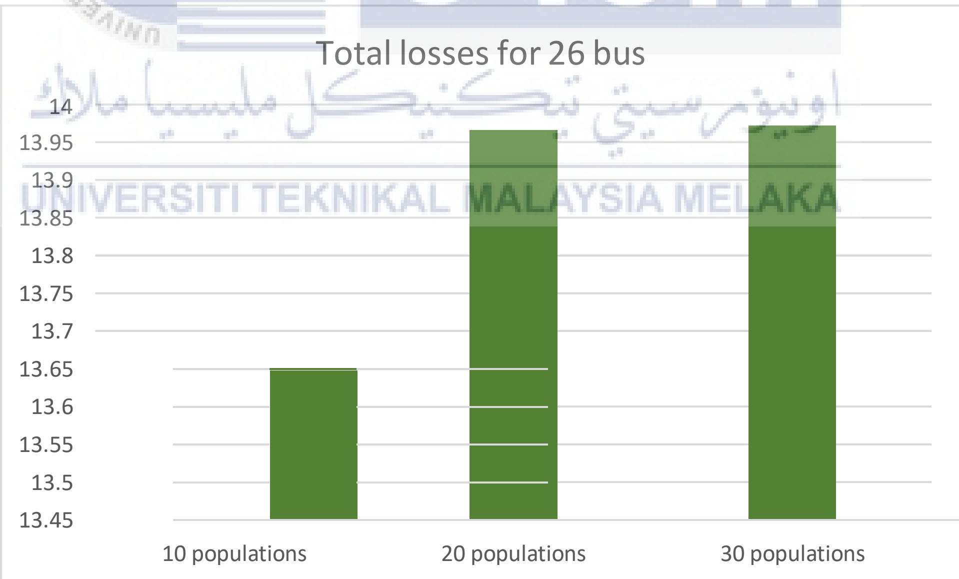

Figure 4.4: Total losses for 26 bus system

The figure 4.4 shows the outcome of total losses for 26 bus system. The table were recorded to highlight the best result of which population has the excellent in saving the losses. The 10 population has the lowest total loss with 13.65635 MW while 30 population has higher total loss with 13.97225 MW.

Table 4.14: Optimal generating unit through 26 bus system for total losses

Pg1(MW)	445.6564	**Cost1($/h)**	4749.862	**Emission1(ton/h)**	12911.74338
Pg2(MW)	193	**Cost2($/h)**	2483.866	**Emission2(ton/h)**	2147.362754
Pg3(MW)	274	**Cost3($/h)**	3224.684	**Emission3(ton/h)**	3434.503805
Pg4(MW)	144	**Cost4($/h)**	1970.624	**Emission4(ton/h)**	724.4954114
Pg5(MW)	103	**Cost5($/h)**	1386.372	**Emission5(ton/h)**	483.3669918
Pg26(MW)	117	**Cost26($/h)**	1696.668	**Emission26(ton/h)**	703.9382114
$\sum Pg$	1276.656	**Total cost ($/h)**	15512.08	**Total Emission (ton/h)**	20405.41055
Total loss (MW)	13.65635	**Power Demand (MW)**	1263	**Voltage min (pu)**	0.968737
				Voltage max (pu)	1.05

for 10population

The generating unit Pg2, Pg3, Pg4, Pg5, and Pg26 are optimized using EP method to minimize the total losses at 13.65635 MW. The total cost is 15512.08 dollar/h with the total emission 20405.41 ton/h. From table 4.14 above also proved that sumof power generator subtracted with power demand by load equal to the total losses of system.

4.4.6 Total losses for 57 bus system

The total losses objective function for 57 bus system is displayed in table 4.15 below. The simulation process involved with 10,20 and 30 population of EP generation.

Table 4.15: Result of total losses for 57 bus system

No of population	Total generation cost ($/h) (observe)	Total Emission (ton/h) (fitness)	Total SystemLoss (MW) (observe)	Completion times (seconds)
10	6651.698	21578.04	22.30796	6.201533 seconds.
20	6092.993	18912.81	31.2732	6.307255
30	6485.405	23091.36	31.61004	10.96949

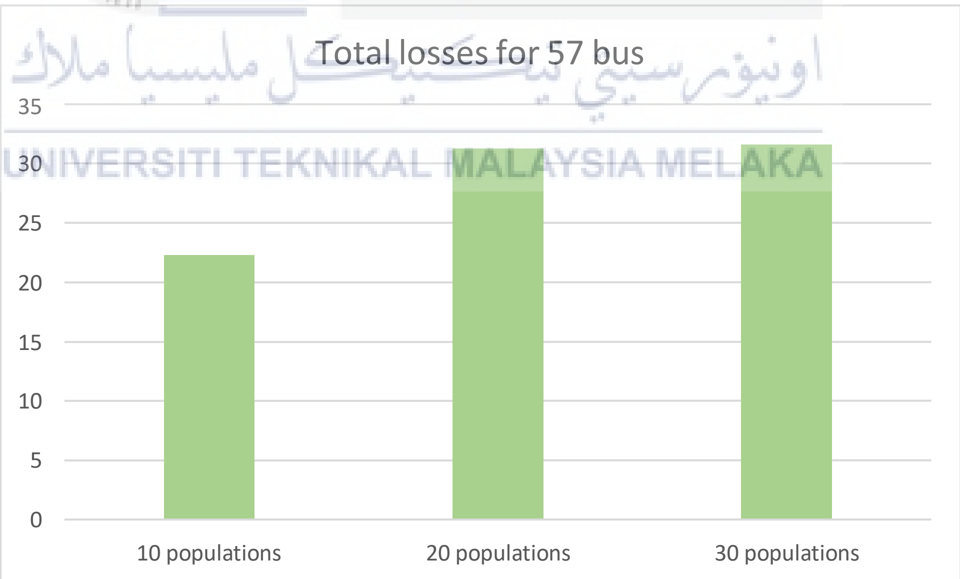

Figure 4.5: Total losses for 57 bus

From three population above that applied in 57 bus system, 10 population has the smallest total system loss with 22.30976 MW with total generation cost 6651.698 dollar/h and total emission of 21578.04 ton/h. The highest losses won by 30 population with 31.61004 seconds.

Table 4.16: Optimal generating unit through 57 bus system for total losses for 10population

Pg1(MW)	253.108	**Cost1($/h)**	18074.62	**Emission1(ton/h)**	4170.232
Pg2(MW)	62	**Cost2($/h)**	20877.78	**Emission2(ton/h)**	231.9253
Pg3(MW)	48	**Cost3($/h)**	12147.81	**Emission3(ton/h)**	104.2107
Pg6(MW)	60	**Cost6($/h)**	25091.79	**Emission6(ton/h)**	131.5522
Pg8(MW)	515	**Cost8($/h)**	13682.82	**Emission8(ton/h)**	12147.24
Pg9(MW)	12	**Cost9($/h)**	16584.72	**Emission9(ton/h)**	7.351213
Pg12(MW)	323	**Cost12($/h)**	17049.65	**Emission12(ton/h)**	4785.528
$\sum Pg$	1273.108	**Total cost ($/h)**	123509.2	**Total Emission (ton/h)**	21578.04
Total loss (MW)	22.30796	**Power Demand (MW)**	1250.8	**Voltage min (pu)**	0.945858
				Voltage max (pu)	1.062637

As referred to the table 4.16 above, 10 population has the lowest total system loss, which is 22.30796 MW when Pg2,Pg3, Pg4, Pg5, and Pg26 were at optimal values as shown in table respectively. The total generator is supplied power demand too. The voltage minimum and maximum under limitation of 0.9(pu) and 1.1(pu) at each bus in system. From here, it shows that the IEEE 57 bus system gives a good result to maintain the voltage stability.

4.5 Comparison between 26 bus system and 57 bus system

The first objective function is to minimize the total generation cost. While the total emission and system loss are monitored, the objective function targeted. To justify the optimum optimization between IEEE 26 bus system and IEEE 57 bus system, the overall generation cost, emission, and system loss was compared. The 10 population is selected since it has the lowest value among them. Table 4.5.1 below shows the achievement of 26 bus system and 57 bus system, respectively.

4.5.1 Total generation cost for 26 bus system and 57 bus system

Table 4.17: Total generation cost between 26 bus system and 57 bus system

Bus system	Total generation cost ($/h) (fitness)	Total Emission (ton/h) (observed)	Total System Loss (MW) (observed)	Completion times (seconds)
26	15317.32	21727.78	13.19465	9.987583
57	6535.398	20733.64	21.01684	6.543336

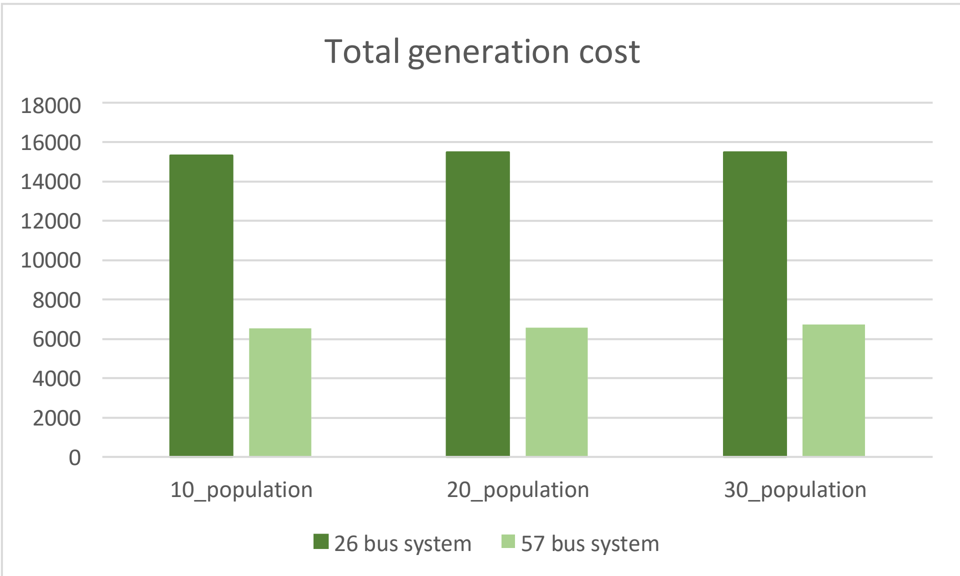

Figure 4.7: Graph comparison total generation cost between 26 bus system and 57bus system

Table 4.17 above shows lowest total generation cost obtained by IEEE 26 bus system and 57 bus system. The total generation cost obtained by 57 bus system has lowest generation cost with 6535.398 dollar/h compared to 26 bus system with 15317.32 dollar/h. From the table, we can see 57 bus system can save 8781.922 dollar/h. If the plant operates 8760 hours in a year, 57 bus system can save 76.93 million dollar/h. The plant can save more cost for 57 bus system are used. The completion times of 57 bus system faster with 6.54336 seconds. As well 57 bus system clean in pollution to environment.

4.5.2 Total emission for 26 bus system and 57 bus system

Second of objective function is minimize the total emission polluted by 26 bus system and 57 bus system. The best possible outcome for total emission is tabulated as in table 4.18 below.

Table 4.18: Total emission for 26 bus system and 57 bus system

Bus system	Total generation cost ($/h) (observe)	Total Emission (ton/h) (fitness)	Total System Loss (MW) (observe)	Completion times (seconds)
26	15498.98	20213.67	13.54158	17.09708
57	6387.722	19500.19	19.57633	6.330848

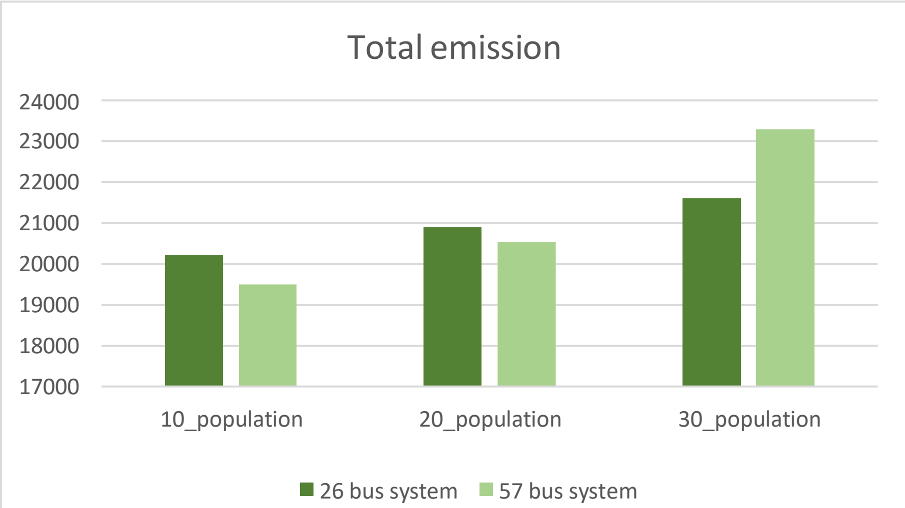

Figure 4.8: Graph comparison total emission between 26 bus system and 57 bussystem

The graph as in figure 4.8 above expressed the best result of minimizing the total emission using 26 bus system and 57 bus system while the total generation cost and total losses are observed. 57 bus system has less emission polluted to the environment that recorded at 19500.19 ton/h compared to 26 bus system with 20213.67 ton/h. The advantages of 57 bus system less pollution environment.

4.5.3 Total losses for 26 bus system and 57 bus system

The third objective function is minimizing the total system losses while determined the total cost generation and emission. Table below shows the best result of total losses between 26 bus system and 57 bus system for 10 population using EP.

Table 4.19: Comparison total losses between 26 bus system and 57 bus system

Bus system	Total generation cost ($/h) (observe)	Total Emission (ton/h) (fitness)	Total System Loss (MW) (observe)	Completion times (seconds)
26	93101.52	126374.3	13.51421	14.384
57	6651.698	21578.04	22.30796	6.201533

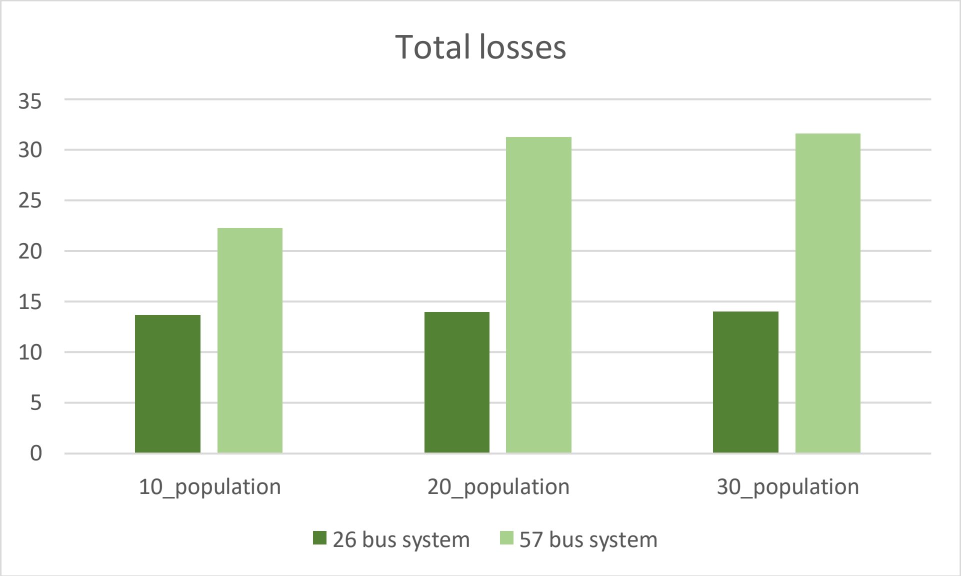

Figure4.9: Comparison total losses between 26 bus system and 57 bus system

The graph of figure 4.9 demonstrate that 26 bus system has lowest value losses at 13.51421 MW compared to 57 bus system. It shows that, the 26 bus system can minimize losses with 8.794 MW. Therefore, 26 bus system can save about77033.25 MW losses in a year while the total generation cost and total emission are 93101.52 dollar/h and 126374.3 ton/h respectively. However, 57 bus system method faster in completing the task as compared to 26 bus system.

4.6 Summary

Chapter 4 discussed about the result and analysis on the ELD using EP optimization approach using 10, 20, and 30 population. The method is using IEEE 26 bus system and IEEE 57 bus system. The overall of minimization task on the total generation cost, total emission and total losses were presented in tables. The IEEE 57 bus system shown a minimum generation cost and emission value as compared with the IEEE26 bus system.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The thesis represented solving ELD problem using EP optimization method. The number of generations in power systems has increased due to demand or load. This increasing is caused by power plants located at different places form the center of load. The other factors that caused increment in cost are the pollution and environmental which is become more serious when industry is growth. There are three objective functions need to be solved which are to minimize total generation cost, total emission, and total losses minimization. The number of populations are set for 10, 20 and 30 in EP simulation method. The best population for 26 bus system and 57 bus system performed by number of EP system shown more saving generation on cost compared to 26 bus system with 6535.398 dollar/h while the IEEE 57 bus system produce less emission with 19500.19 ton/h compared to IEEE 26 bus system which produces an emission about 20213.67 ton/h. However, the IEEE 57 bus system produces higher losses with 22.30796 MW. The efficient generator does not guarantee the minimum emission. From the result, 57 bus system more efficient to be used in order to minimize the generation cost and emission. The less the value of objective function, the more saving to environment and pollutant.From result obtained, it can be proved the EP is suitable tool to be applied for both IEEE 26 bus system and 57 bus system in order to solve the ELD problem by using 10 number of populations.

5.2 Future Works

The total demand or load plays an important role in determine the increasing number generation for each bus. The increment cost of generation cost is from the fuel cost, cost of labor, and maintenance of power plant. Besides, environmental pollution contributes to global warming and ozone layer depletion. As a result, today environment is necessary to generate power at the lowest possible cost while minimizing into the pollutant. The efficient and reliable management of such a huge-interconnected power system necessitated throughout study and a cost- effective operating strategy. Hence, in future works, the EP can be tested on the greater the bus system to minimize the generation cost and emission. The cost for greater bus system is seen be higher than smaller bus system, however it is more efficient to be used.

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APPENDICES

APPENDIX A GLOBAL DATABASE'S MALAYSIA

Last	Previous	Min	Max	Unit	Frequency	Range
▲ 12,380.475 Aug 2020	▲ 12,339.904 Jul 2020	1,385.300 Feb 1989	12,943.806 Apr 2019	kWh mn	Monthly	Jan 1989 - Aug 2020 Updated on 30 Oct 2020