THESIS – EE185401

MINIMIZING OF THE LOSSES AND THE COST OF STANDALONE PHOTOVOLTAIC GENERATION SYSTEM (PVGS) WITH CONSIDERATION OF SOLAR RADIATION PROBABILITY USING FIREFLY ALGORITHM, (A CASE STUDY OF TOMIA ISLAND, WAKATOBI, SOUTH-EAST SULAWESI,INDONESIA)

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MASTER PROGRAM
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ELECTRICAL ENGINEERING DEPARTMENT
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STATEMENT OF THE AUTHENTICITY OF THESIS

I hereby declare that the entire contents of my thesis with the title "MNIMIZING OF THE LOSSES AND THE COST OF STANDALONE PHOTOVOLTAIC GENERATION SYSTEM (PVGS) WITH CONSIDERATION OF SOLAR RADIATION PROBABILITY USING FIREFLY ALGORITHM, (A CASE STUDY OF TOMIA ISLAND, WAKATOBI, SOUTH-EAST SULAWESI, INDONESIA" are truly the results of independent intellectual work, completed without the use of materials that are not permitted and are not the work of another party that I acknowledge as own work.

All references cited or referred to have been written in full in the bibliography. If it turns out this statement is not true, I am willing to accept sanctions in accordance with applicable regulations.

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MOHAMED ELSAYED SHIYBAHELHAMD ABDELWARETH
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ABSTRAK

Sumber energi terbarukan adalah sumber energi yang tepat untuk memenuhi peningkatan konsumsi energi. Kenaikan tingkat CO_2 membuat para peneliti mencari penggunaan sumber daya energi terbarukan, dan peneliti menambahkan sumber energi terbarukan ini sebagai pelengkap sumber energi berbasis fosil tradisional untuk menciptakan Sistem Energi Terbarukan Hibrida.

Penelitian ini menyajikan studi kasus nyata di Pulau Tomia, Sulawesi Tenggara, Indonesia. Tujuannya adalah untuk mengurangi waktu pengoperasian generator diesel dengan menginjeksikan suplai pada sistem Photovoltaic (PV) dengan baterai ke jaringan, dan mengoptimalkan sistem ini dengan menggunakan salah satu metode optimalisasi yang dapat meminimalkan biaya operasi dan pemeliharaan, mengurangi kerugian dalam jaring radial menggunakan konfigurasi ulang pengumpan (feeder) serta metode alokasi generator diesel memenuhi beban, selain menggunakan metode Liu dan Jordan untuk menghitung radiasi matahari setiap jam. Algoritma Firefly adalah salah satu metode optimsasi yang merupakan salah satu metode kecerdasan buatan dan dapat digunakan untuk mengoptimalkan sistem. Selain menghitung emisi CO_2 dari generator diesel juga mempelajari efek penambahan Photovoltaic Generation System (PVGS).

Pada akhirnya, menghasilkan studi menggunakan turbin angin sebagai pengganti generator diesel di Pulau Tomia untuk mempelajari efek dalam pengoperasian sistem, output daya di setiap lokasi dan biaya, untuk membuat sistem pembangkit ramah lingkungan di Pulau ini.

Kata kunci: (emisi CO2, Sistem Photovoltaic, metode optimisasi, meminimalkan kerugian dalam jaring, jaring Radial, algoritma Firefly, , turbin angin)

MINIMIZING OF THE LOSSES AND THE COST OF STANDALONE PHOTOVOLTAIC GENERATION SYSTEM (PVGS) WITH CONSIDERATION OF SOLAR RADIATION PROBABILITY USING FIREFLY ALGORITHM, (A CASE STUDY OF TOMIA ISLAND, WAKATOBI, SOUTH-EAST SULAWESI, INDONESIA)

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ABSTRACT

Renewable energy resources are the appropriate alternatives for traditional resources to meet the increasing energy consumption. Increasing of the CO_2 level made researchers searching for integration of using renewable energy resources, researchers add these renewable energy sources to be an addition to the traditional fossil-based resources create Hybrid Renewable Energy Systems.

This research presents a real case study in Tomia Island, South-East of Sulawesi, Indonesia. The purpose is to decrease the running time of the Diesel Generator (DG) by injecting Photovoltaic (PV) system with batteries to the network, and optimize this system by using one of the optimization methods which can minimize the operation and maintenance costs, decreasing the losses in a radial network using feeder reconfiguration or DG allocation method to satisfy the load, we use Liu and Jordan method to calculate the hourly solar radiation. Firefly Algorithm (FA) is one of the optimization methods which is one of the Artificial Intelligence (AI) methods and can be used to optimize the system. In addition to calculate the CO_2 emissions from the DG and study the effect of adding the Photovoltaic Generation System (PVGS).

In the end, making a study of using wind turbine instead of DG in Tomia island to study its effect in the operation of the system, output power at each location and the cost, to make a clean generation system in this Island.

Key words: (Photovoltaic systems, optimization methods, minimizing the losses in the network, Radial network, FA, CO_2 emissions, Wind turbines)

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PREFACE

Alhamdulillah, I finished my thesis for my master degree. This basis for this research originally stemmed from my passion for developing better methods of electricity generation with minimum cost and high efficiency and best performance. As the world moves further into the renewable energy as a main source of power generation, the demand vast amounts of electricity and the world's aspirations for clean energy there will be a greater need to more focused on energy production with high efficiency and lowest cost. This drove me to make my study in renewable energy and make a study of replacing the DG in my case study with wind turbine to encourage the using of renewable energy instead of fossil fuel.

In truth, I could not have achieved my current level of success without a strong support group. First of all, my parents, who supported me with love and understanding. Secondly, my supervisors, my laboratory members in Power System Operation and Control (PSOC) and my classmate friends, each of whom has provided patient advice and guidance throughout the research process. Thank you all for your unwavering support.

Surabaya, 12 Juli 2019
Author

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LIST OF APPREVIATIONS

CO_2 : Carbon Dioxide
H_2O : Water
RE : Renewable Energy
PV : Photovoltaic
DG : Distribution Generator
FA : Firefly Algorithm
PWM : Pulse Width Modulation
PLN : Perusahan Listrik Negara
MPPT : Maximum Power Point Tracker
AI : Artificial Intelligent
ANN : Artificial Neural network
GA : Genetic Algorithm
PSO : Particle Swarm Optimization
G_0 : Extraterrestrial irradiance over a horizontal surface
K_T : Clearness index
B_H : Direct radiation
D_H : Diffuse radiation
G_{til} : hourly global irradiance
SOC : State of Charge
PLTS : Pembangkit listrik Tenaga Surya
PLTD : Pembangkit listrik Tenaga Diesel
PVGS : Photovoltaic Generation System
k_1 : Anisotropy index
NPC : Net Price Cost
IC : Investment Cost
OMC : Operation and Maintenance Cost
Ŋ : Efficiency
α_{PV} : PV initial cost ($/m2)
α_{inv} : Inverter initial cost ($/m2)

α_{dg} : DG initial cost (\$/m2)

α_{batt} : Battery initial cost (\$/m2)

B : Escalation rate

r : Interest rate

δ : Inflation rate

C_f : Cost of fuel consumption

F_p : Fuel price

Fc_{dg} : DG fuel

N_{run} : Number of working hours of DG (h)

RC : Replacement Cost (\$)

P_N^D : Nominal Power

FBSM : Forward-Backward Sweep Method

CHAPTER 1

INTRODUCTION

1.1 Background

Day by day using of electricity appear to be one of the most important inventios in our world. All countries trying to make Energy available to all human but it can be accessed to more than 5 billion people around the world, Electricity becomes the essential thing in our daily life which we cannot live without. Which it intervenes to the whole technologies and everything in our life, it used in homes, industrial and many other uses. In the past, generating electricity was not a problem because of the affluence of petrol, but now all fossil fuels in its way to completely exhaust from the earth, that's why many researchers working on new methods to generate energy.

Since more than 30 years ago, renewable energy resources had been used to generate electricity like solar radiation, wind speed, geothermal plants, fuel cells and many more. Besides of percentage declining of fossil fuel every day, rising of CO_2 level in the air making a real warning of the environment in the planet, so many international summits occurred to find a solution of what is called global warming. Many countries such as Germany and Netherlands and many others have a plan in the next 10 years to make more than 80 % of its energy comes from renewable energy resources [1].

We can see that there are an increasing of using renewable energy during time, many countries invest in these resources. Our world in data organization [2] made a figure to represent the percentage of using fossil fuel besides renewable energy resources in the worldwide. As we can see in from 2010 to 2017 the using of renewable energy like solar and wind are increasing continuously besides hydropower.

Wind and solar energies are renewable energy sources which have the fastest growing percentage and capacity according to our world in data statistical data as we can see also in Figure 1.1.

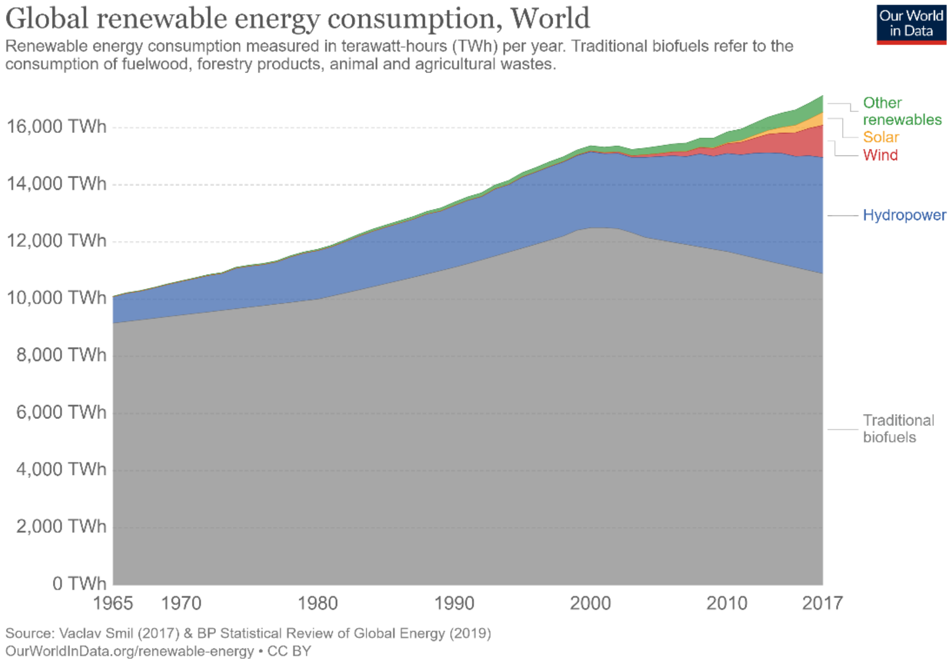

Figure 1.1.World Global Renewable Energy consumption.[3]

There are many kinds of renewable energy sources like photovoltaic, wind energy, fuel cell, etc. which now has many researches talking about them and also turning to a vital issue on the way to decrease using fossil fuel which is the main reason for the nowadays worldwide case. its effect to the climate change made the whole countries always making summits to find a solution to decrease using fossil fuel which made many countries like Germany do a plan to eliminate using the fossil fuel in 2050 [4].

Simply, solar energy is the energy which comes from radiation of the sun, there are many forms of using this energy including solar photovoltaic (PV), thermal electricity, and heating system. Due to the new achievements improvements in the PV systems, government policies supporting renewable energy development and utilization, and a solar PV system have experienced high growth in recent years [5]. and many researches nowadays searching about methods to minimizing the losses and the cost of using renewable energy sources by using traditional and modern methods.

Hybrid renewable energy systems has two kinds, grid connected and standalone systems. for grid connected, renewable energy sources connected to the country network which is linked with generators in generation stations and normally it is like a supportive source to the network on a specific area if the network does not able enough to provide energy during the 24 hours because of the heavily demanding requesting at rush hours, so renewable energy with battery banks is a good method.

Another kind is standalone hybrid system which is normally link between two or more renewable energy sources together [6], with a back-up batteries and DGs. Normally standalone system for the places which cannot connect to nearest grid network like far places in dessert, isolated islands etc. and it will be very expensive to make the connection between the network and this area, so standalone system is the best option for this case.

1.2 Information about the case study location

Our case study is an isolated island which is an area belongs to Wakatobi national park in south-east of Sulawesi, Indonesia. which listed as tentative world heritage site with a population of 94,846 inhabitants, and consists of four islands Wangi-wangi, Kaledupa, Tomia, and Binongko [7].

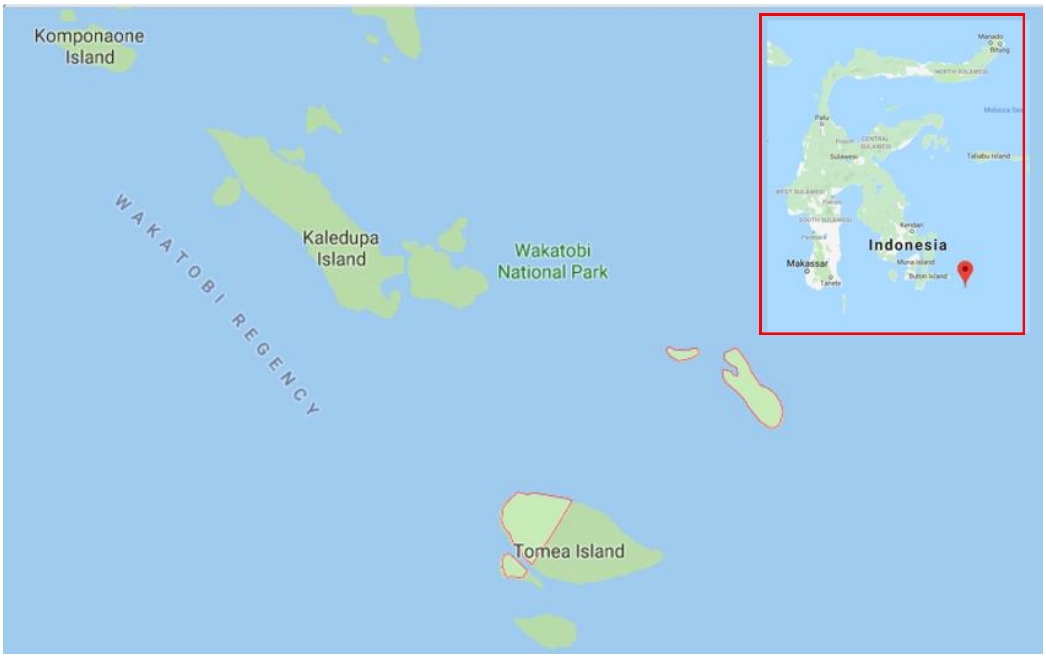

Figure 1.2 The location of Tomia island.[8]

Our case study in Tomia island, so connecting electricity from the national network to this island it is not an economic solution, so they used a DG as a main source of electricity there, and newly they add a PV system with batteries to make it provide electricity during the existence of the sun, and at night the DG will work with the batteries.

So, Tomia’s network belongs to PLN (Perusahaan Listrik Negara) company which is a big electricity distribution company in Indonesia. They used a 20 kv line for transmit the electricity and at each bus there is a transformer 20 kV/400 V to the load. There were seven small generators worked there but for some reasons they converted them to one DG working from Mitsubishi with rated power 1400kw which called by PLTD, and PLTS which is mean (solar power plant). The Photovoltaic Generation System (PVGS) added to the network in different places the first location is Kulati with an output solar power 140 kWp, the second is Dete with 112 kWp, the third is Kahaianga with 308 kWp and the last one in Lamanggau with 224 kWp.

Figure 1.3 The location of the Electricity Network in Tomia island.[9]

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Figure 1.4 PLTS Lamamgau.

Figure 1.5 PLTS Kahaianga.

Figure 1.6 PLTS Dete.

Figure 1.7 PLTS Kulati.

And the operation system in our case study in Tomia at day and night times.

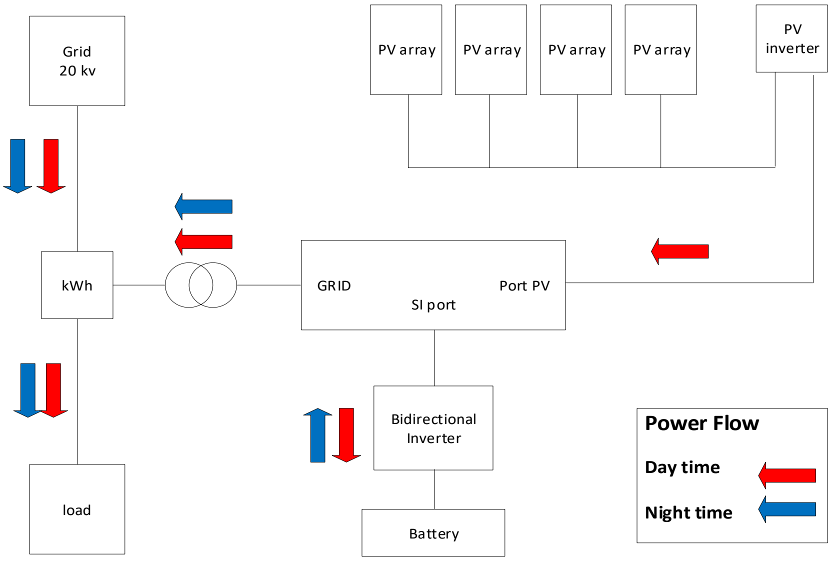

Figure 1.8 The operation system of our case study.

1.3 Problem Formulation

In this study we will use the data from this site to.

1- Minimizing the operational and maintenance costs of the system include PV, batteries and DG.

2- Searching for an optimization method which can allow us to take the maximum output power from the PV with the lowest cost from batteries and DG in the perspective of the minimum overall cost by using FA as an optimization method.

3- Calculate and minimize the losses for this radial SLD.

4- Calculate and minimize the CO_2 emission from this site and study the effect of adding PVGS.

5- Eliminate the using of the DG and instead of it use wind turbine to make this site run only by renewable energy sources with batteries.

1.4 Purpose

The aim from this study to optimize the system and implement some goals which are summarized as follow:

1- As we mentioned before that the only electricity source in Tomia island is the Mitsubishi DG, and we want to provide a 24 hours electricity includes PV system. That’s why a PV system linked to the network to decrease the burden on the DG, increase the reliability and the availability of the electricity during the whole day like what is shown in Figure 1-9.

2- Find the best way to calculate the losses of a radial network then searching for an optimization method to minimize the network losses which is suitable for this radial system.

3- Calculating the amount of CO_2 emission from the DG before using PV and after using PV. And also trying to find a new idea to more decreasing the emissions.

4- After finishing all of them, we will search for optimum sizing of wind turbine to replace the DG with respective of getting the minimum cost and best solution.

5- FA can be used as an optimization method to get the minimum losses and minimum cost.

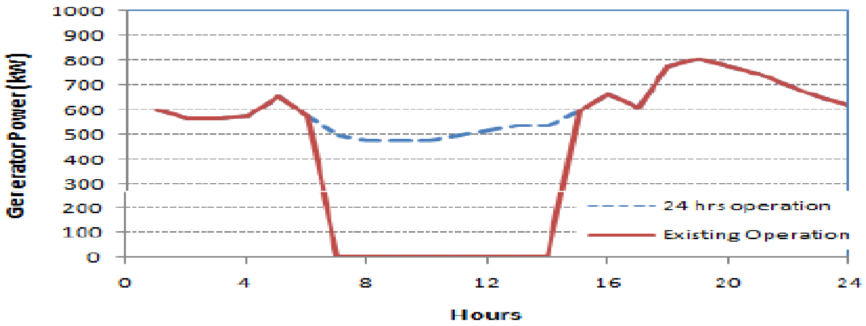

Figure 1.9 The generator output power during the whole day.

1.5 Limitation of the study

For our system we will make our calculation from the data which provided by the PLN company in Tomia' location.

1- These data are calculated for several days at different time throw the year, and to make our optimization calculations we will make an average of thee data throw a day.

2- The output power from the PV will be always consider to be at maximum power point.

1.6 Contributions

In this case study our contributions will be

1- Minimizing the losses using the suitable optimization method for this radial system.

2- Making a power management to the system with the minimum operational and maintenance costs and getting the optimum output power from battery and DG. Besides getting the maximum output power from the PV system.

3- Calculating the hourly solar radiation by using Liu and Jordan method to the provided daily solar radiation data.

4- Making the optimization to get electricity in Tomia during the 24 hours a day with the minimum cost.

5- Minimizing the CO_2 emission from the environment by controlling the working hours of the DG and decreasing its operating hours.

6- Making a study for eliminating the using of the DG and turning Tomia to a clean island with no emissions.

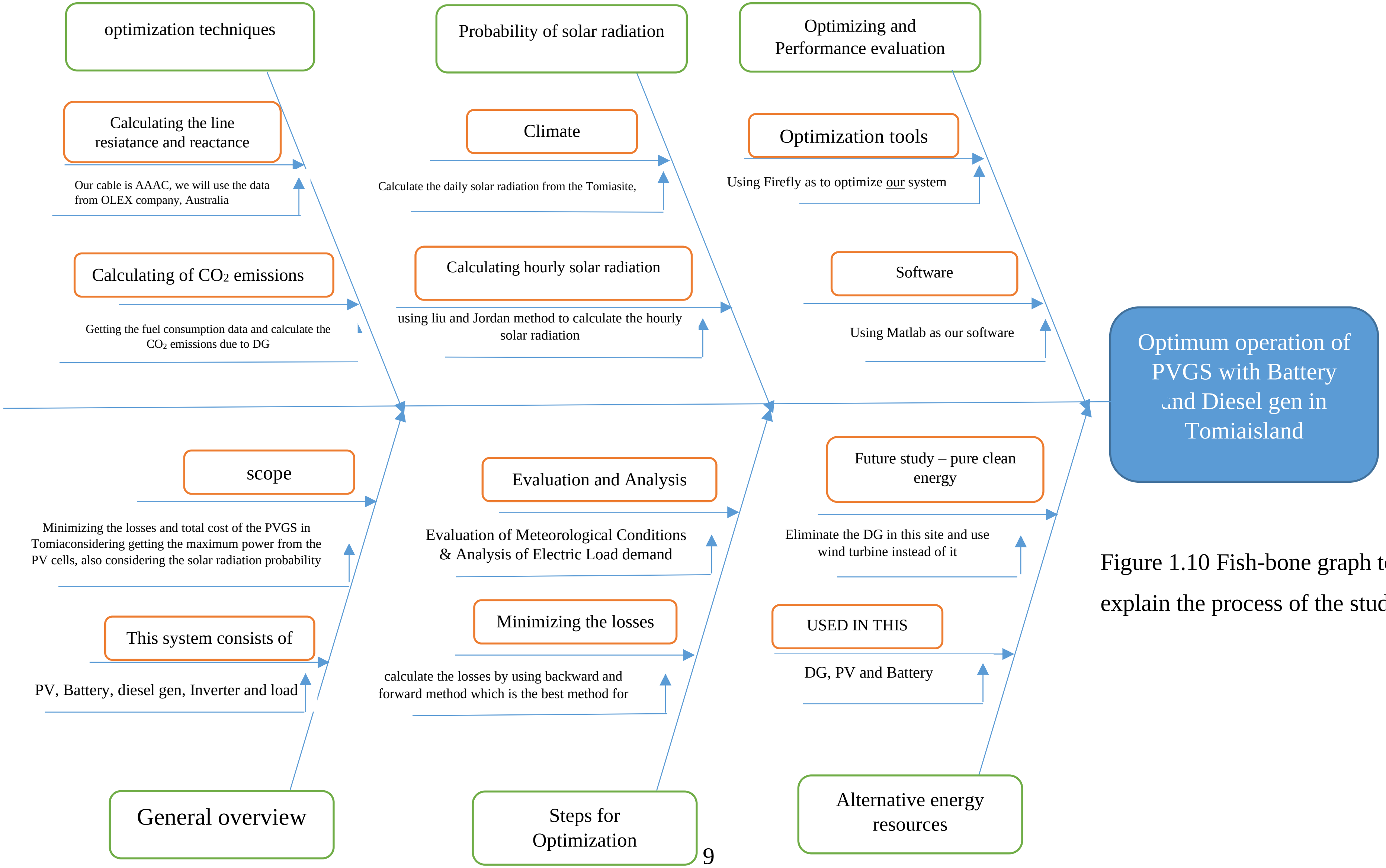

Figure 1.10 Fish-bone graph to explain the process of the study

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CHAPTER 2

LITERATURE REVIEW

There are requirements for renewable energy sources optimization [10] such as Meteorological data which takes from the location and then making analysis to it for the optimization process. Different optimization methods had been used such as dynamic programming, artificial intelligence and linear programming were implemented by researchers to optimize PV systems [11]. Generic Algorithm is one of the Artificial intelligence methods used for optimization which has the solve difficult real-problems. As an example Yang et al. [12] use GAs for a PV hybrid wind system as an optimal sizing method to optimize the hybrid PV-wind system and using batteries banks. This method is implemented to calculate the optimum system configuration that can achieve the customers required loos of power supply probability (LPSP) with a minimum Annualized Cost of System (ACS). Aeidapu Mahesh [13] using PSO for a grid connected PV, wind and battery system to minimize the total cost of the system which is the objective function while maintaining the system reliability and lees fluctuation of power injected into the grid. For the stand alone system we use batteries to save our energy for the future needs or for the time which the output power from the solar cells are not available, the output power from the PV is DC voltage then it entered the batteries which is DC voltage also, the output from batteries has to pass by a AC-DC inverter to provide the required electricity to the customers.

2.1 Related Research Studies

Abdelhamid Kaabeche and Said Diaf [14], who used FA for PV, wind and battery system to determine the system optimum configuration which can achieve the desired Load Dissatisfaction Rate (LDR) with minimum electricity cost (EC). They made 3 study stages, first study the optimization between PV with battery, secondly between PV with wind and third between PV, wind and battery, they also made 3 levels of iterations and divided them best, main and worst. Nishant Saxena and Souvik Ganguli [15] they discussed economic load dispatch and implemented it using FA optimization techniques to obtain the best optimal solution for the fuel cost of generator. Also included PV and wind energy resources in economic load dispatch problem by estimating generation of solar and wind power through probability density function including the under-estimation cost and over estimation cost of wind and solar units. Mohamed Louxaxani and Aurelian Crăciunescu [16] they used FA to extract the parameters of single diode model solar cell from experimental I-V characteristics. Akbar Maleki and Fathollah Pourfayaz [17] they evaluated the performance of different evolutionary Algorithms for optimum sizing of a PV,wind turbine and battery hybrid system to continuously satisfy the load demand with the Total Minimum Annual Cost (TAC). For this aim, all the components are modeled and an objective function is defined based on the TAC. They applied many kinds of optimization techniques like Particle Swarm Optimization (PSO), Tabu Search (TS) and Simulated Annealing (SA), and four recently invented metaheuristic Algorithms, namely, Improved Particle Swarm Optimization (IPSO), Improved Harmony Search (IHS), Improved Harmony Search-Based Simulated Annealing (IHSBSA), and Artificial Bee Swarm Optimization (ABSO), are applied to the system and the results are compared in terms of the TAC. K.R. Devabalaji and A. Mohamed Imran [18] their objective function is to minimize the total power loss of the system while satisfying all the constraints. The Loss Sensitivity Factor (LSF) has implemented to pre-identify the optimal location of the capacitor by using Bat Algorithm to search the optimal size of the capacitor banks. He testes on IEEE 34-bus distribution system. Ketfi Nadhir and Djabali Chabane [19] they used the FA for optimal placement and sixing of DG in radial distribution system to minimize the total real power losses and to improve the voltage profile, he used IEEE 33-bus distribution as a test system to show the effectiveness of the FA. J. A. Michline Rupa and S. Ganesh [20] they proposes a backward/forward sweep method to analyze the power flow in radial distribution systems. Which is one of the most effective methods for the load-flow analysis of the radial distribution system. By using this method, power losses for each bus branch and voltage magnitudes for each bus node are determined, and they used IEEE 33-bus radial distribution system to test the system.

2.1.1 Analytical Methods

There are many different analytical methods used for DG placement studies like what mentioned in [21-23]. These methods based on “Exact Loss Formula”, “Rule of thumb (2/3 rule)” and other analytical approaches. Discussion about the advantages and limitations will be discussed below:

2.1.1.1 Methods based on “Exact Loss Formula”

“Exact Loss Formula” can be used to obtain the total loss in a system. Detailed description and derivation of this formula are given in [24]. The objective of the methods based is to minimize the active power losses of a distribution system at a fixed load condition. One of the best advantages of these methods is that they are computationally fast and very efficient. However, these methods have some limitations. As what mentioned in [25] To obtain the optimum size and location of DG using ‘Exact Loss Formula’ can be applied only if DG delivers real power [21] and has not considered multiple DG allocation. [21, 25] discussing the improvement of this method. Here, which authors modified the method in [25] To make an allocation of four different types of DG. This method is computationally very efficient but cannot allocate multiple DG units.

2.1.1.2 Methods based on “Rule of thumb (2/3 rule)”

In [22], the “Rule of Thumb” method used to allocated the DG. according to this method, the DG size is equal to 2/3 of the kVAR of the load and it is located at 2/3 of the distance from a radial feeder [22]. In this method, loads had been assumed to be uniformly distributed, the limitation of this method is cannot be applied to any meshed network or system which has different load distributions [26]. A survey into this approach is explained in [24].

2.1.2 Other Analytical Approaches

This for the analytical approaches for DG placement in radial and meshed distribution systems, considering both time-invariant and time-varying loads is to minimise power losses. One significant advantage of this analysis it does not require any iteration, So, there is no convergence problem. However, it does not address DG sizing issues [21].

The next table is a comparison of different analytical methods and their objective functions.

Table 2-1 Comparison of different analytical methods

Literature	Objective	Load Condition	Test System
Acharya et al [25]	Loss minimization	Fixed load level	30 bus, 33 bus, 69 bus balanced test system
Hung et al [21]	Loss minimization	Fixed load level	16 bus, 33 bus, 69 bus balanced test system
Wang and Nehrir	To minimize average power loss and to maintain voltage	Time-varying load	IEEE 6 bus, IEEE 30 bus balanced transmission/sub-transmission system
Willis [22]	Loss minimization	Uniformly distributed load	Radial test feeder balanced transmission/sub transmission system
Hung et al [23]	Loss minimization	Fixed load level	16 bus, 33 bus, 69 bus balanced test system
Ugranli and Karatepe [24]	Loss minimization	Fixed load level	9 bus, 14 bus, IEEE 30 bus balanced test system

2.1.2.1 Methods based on Meta-heuristics

Many researches of DG allocation has been done based on a GA, fuzzy logic, PSO, and some other artificial intelligence based methods [27-38]. To defer the grid update cost, in [32] a GA method has been used for DG siting and sizing. This cost minimization technique concludes that considerable savings can be achieved by appropriate selection of DG sites. GA based Algorithm is also used in [30, 34, 35]. In all of these research works, the peak load is considered and renewable energy-based DG is misplaced. The installation of solar and wind type DG which represent one of renewable energy-based DG is very dependent on the location at which the energy resources (i.e., wind flow and solar irradiance) are available.

In [38], a value-based analysis is proposed based on GA. The uncertainty of load growth is considered during the analysis. The proposed strategy explore the optimal DG size and location which is considered a way to mproved the system reliability and make the cost reduced.

In [28], a GA and fuzzy based method is proposed In this research to allocate DG effectively, to maximize loading margin and Distribution Company's (DISCO) profit an Algorithm has been developed for DG allocation. Voltage constraints and feeder power flow constraints are also considered on the optimization procedure. This Algorithm also can be used to find optimal DG capacity considering a certain load level. GA and decision theory have been used for DG planning in [29]. to make the analysis more realistic, Uncertainties due to renewable energy resources are considered in [31]. And multi-objective optimization is performed to provide the planner with ideas regarding the best possible alternatives.

PSO has been used for DG allocation research as an another method in [33, 36, 37]. An Improved Initialized Social Structure (IISS)-based PSO, in which different DG technologies are considered in the analysis, which used for DG placement in a microgrid in [37]. An adaptive-weight PSO is used in [36] in which multiple DGs are placed in a radial network. in [33] Another method for determining the capacity of multiple DGs considering different load models is proposed, so they used a multi-objective index-based method to optimize the real and reactive power losses, Mega Volt Amber (MVA) capacity, voltage profile and short-circuit level, and different types of loads (i.e., industrial, residential, commercial and mixed) are considered. In [27] and [39] Other population-based search techniques used such as the Artificial Bee Colony (ABC) and ant colony Algorithms respectively. In [27], as the ABC Algorithm needs only two parameters to be tuned, compared with those of other metaheuristic methods, the analysis is very efficient and effective, and loss minimization of the system under peak load conditions is the objective, subject to other inequality constraints such as the voltage stability limit. Based on the reliability index, the ant colony Algorithm determines the DG locations in [39] the System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) are widely used for reliability evaluation, and the maximization of system reliability is the main objective of the research proposed in [39] Differences among different studies in the literature based on meta-heuristic methods are discussed in Table 2-2

Table 2-2 Comparison of different meta-heuristic methods

Literature	Basic Objective	Load Condition	Test system
Celli and Pilo [50]	Total cost minimization	3% load growth annually	148 node MV balanced network
Jalili et al [55]	Reduction of power loss with the improvement of voltage profile	Fixed load level	33 bus balanced test system
Mithulananthan et al [45]	Real power loss minimization	Fixed load level	30 bus balanced test system
Celli et al [48]	Minimization of total cost	3% load growth annually	142 node balanced network
Teng et al [57]	Benefit maximization and cost minimization		
Akorede et al [46]	Loading margin and profit maximization	Three different load level	6 bus and 30 bus balanced test system
Carpinelli et al [54]	Minimization of the cost from energy loss while maintaining voltage profile and power quality	Fixed load level	18 busbars balanced three phase networks
Celli et al [47]	Minimizing network upgrading cost	Time-varying load	60 node balanced network
Prommee and Ongsakul [52]	Power loss minimization	Fixed load level	69 bus balanced test system
Prommee and Ongsakul [51]	Power loss minimization		33 bus and 69 bus balanced test system
El-Zonkoly [53]	Network efficiency enhancement and stability augmentation	Fixed load level	38 bus and 30 bus balanced test system
Abu-Mouti and El-Hawary [49]	real power loss minimization	Fixed load level	33 bus and 69 bus balanced test system
Wang and Singh [56]	Reliability enhancement	Fixed load level	69 bus and 394 bus balanced test system

2.2 Basic theory

In this part the theoretical of each component in this study will be discussed. The working procedures and mathematical equation for modeling steps including PV system component, DG, batteries and diagnostic monitoring.

2.2.1 Photovoltaic System

2.2.1.1 Calculation of solar radiation, generated PV power and its cost.

Solar irradiance is the main object to calculate the output power from the PV cell. Which represents the electricity that can be taken from the solar radiation by using the chemical formulation in the solar cell.

Normally there are a specific equipment to calculate the solar radiation at any area, or it can be calculated mathematically using an equation which can give the nearest value of the irradiance. The hardest thing in calculating the solar radiation is the long time which required to calculate it, so we have to calculate it every day at different time For the calculation of solar irradiance on tilted surface, it is necessary to know extraterrestrial irradiance over a horizontal surface, in addition to determining the direct and diffuse component of the irradiance on a horizontal surface, and the direct, diffuse and reflected components on a tilted surface.

2.2.1.2 Extraterrestrial irradiance over the horizontal surface and clearness index.

From the reference [40] a mathematical equation given which can be used to calculate the extra-terrestrial irradiance over a horizontal surface G_0

$$G_0 = G_{SC} * \left[1 + 0.33\cos\left(\frac{360.d_n}{365}\right)\right][\cos\emptyset\cos\delta\sin\omega + \sin\emptyset\sin\delta] \qquad (1)$$

Where G_{SC} is the solar constant (1367 W/m2); dn is the day number counted from the beginning of the year, $\emptyset$ is the geographic latitude (^{o}), δ is the solar declination (^{o}) , and ω is the true solar time.

Angle of true solar time and solar declination are calculated from the equations:

$$\omega = (hour - 12hour).\left(\frac{15^{o}}{hour}\right) \qquad (2)$$

$$\delta = 23.45 * \sin\left(360.\frac{284+d_n}{365}\right) \qquad (3)$$

Instantaneous power generated in a photovoltaic system is given by

$$P_{pv}(t) = \eta_g * N_m * A_m * G_{til}(t) \tag{4}$$

Where G_{til} is hourly global solar irradiance on tilted surface, A_m is stands for the PV panel area (m^2), η_g is PV panels efficiency.

2.2.2 Inverter

There are many kinds of inverters used for the standalone systems. We will discuss some of the characteristics of some commercial power converter topologies for central, string, multi-string and ac-module PV inverter[41].

The string inverter has two common topologies which are full-bridge and H-bridge inverter. The H-bridge with the low-frequency transformer side features a simple power circuit which enables a larger range of input voltages. This converter can be controlled with three-level carrier based Pulse Width Modulation (PWM) techniques. And due to the isolation, the common mode voltages cannot generate a leakage current. the bypass switching state (zero voltage level) prevents a reactive current flow between the filter inductor and the dc-link capacitor. The H-bridge with high frequency isolated DC-DC stage is composed of a mosfet full-bridge inverter a high frequency transformer and a diode full-bridge rectifier. This approach reduces greatly size of the converter improving power density compared to low frequency transformer-based topologies. Then we will take about the Three-Level Neutral Point Clamped Inverter (3L-NPC) which also has several modified and enhanced versions for PV string inverters [42]. The advantage of the 3L-NPC over the H-bridge is that it provides a three-level output without a switched common mode voltage since the neutral of the grid is grounded to the same potential as the midpoint of the dc-link. This enables transformer-less operation without the problem of the leakage currents and modulation methods that do not use the potential of the converter. The full-bridge of two 3L-NPC legs was introduced by ABB company, resulting in the 5L-HNPC inverter. The T-type or three-level transistor clamped string inverter was introduced by Conergy. The converter can clamp the phase of the grid directly to the neutral to generate zero voltage level using a bidirectional power switch. For the same reason as the 3L-NPC it can operate transformer-less. the main difference it does not require the two additional diodes of the 3L-NPC. The bidirectional switches block each half of the voltage blocked by the phase-leg switches.

The multi-string topologies is exclusively a two-stage system composed by more than one dc-dc stage, and this is the main difference between multi-string and string configuration. All inverter topologies which have been mentioned in the previous section could be used in a multi-string configuration. Like with string inverters, the same combinations of isolated and transformer-less configurations. With or without symmetric grid filter apply. One of the first multi-string inverters introduced in practice was the half-bridge inverter with boost converters in the DC-DC stage. Other topologies that have followed include the H-bridge, the H5, the three-phase Two-Level Voltage Source Inverter (2L-VSI), the 3L-NPC and the three-phase Three-Level T-type converter (3L-T). the most common DC-DC stages used for multi-string configurations are the boost converter and the high-frequency isolated dc-dc switch mode converter based on an H-bridge, high-frequency transformer and diode rectifier.

Central Inverter configurations are mainly used to interface large PV systems to the grid. The common inverter topology found in practice is the Two-Level Voltage Source Inverter (2L-VSI), composed of the three half-bridge phase legs connected to a single dc-link. The inverter operated below 1000 v at the dc-side (typically between 500 v and 800 v), limited by the PV modules insulation, which prevents larger strings. Grid-connected is done through a low frequency to evaluate voltage already within the collector of the power plant to reduce losses. More recently, the three-phase 3L-NPC and the three phase 3L-T converter have been also used for this configuration.

A commercial AC-module topology is the interleaved flyback converter, developed by Enphase Energy, currently commercialized by siemens, the flyback converter performs MPPT, voltage elevation and provides galvanic isolation, while the H-bridge inverter controls the DC-link voltage (output voltage of the flyback). Another commercial ac-module integrated converter includes a resonant H-bridge stage with high-frequency isolation transformer and diode bridge rectifier as

DC-DC converter instead of the flyback, the H-bridge DC-DC stage has better power conversion properties compared to the flyback.

2.2.3 Transformer

Is a very important component in the Electricity system, which it can allow transferring the electricity from generation stations to the customers by stepping up and down the voltage to decrease the losses during the transmission process and also increase the potential until reach the customers. It’s main operating function is based on the electromagnetic induction between the primary and secondary side of the transformer.

2.2.4 Optimizer

Optimizer is a DC-DC converter coconnected to each module. Optimizer can increase the power output of the entire system by using one of the maximum power point tracking methods. This tool is very important in power system.

2.2.5 Utility meter

This is the measurments tools to know how much power will be delivered to the customers and how much power will be taken by the hybrid system to the network. And also to make the bills to the customers according to thier consumes. Then it will calcuate the consuming of each meter and make the electrisity distribution companies make the bill.

2.2.6 Mounting System

The type of a mounting system of a PV system depends on a site and area available for installation. To maximize the use of the project area according to site conditions, different configurations of mounting system such as ground mount, pole mount and roof mount with and without roof penetration can be installed.

2.2.7 Wind turbine

Wind turbines is the machine which convert the wind speed to electricity by converting the kinetic energy in the wind to power. the upwind velocity of the undisturbed wind is v, the velocity of the wind through the plane of the rotor blades is vb, and the downwind velocity is vd as shown in Figure 2.1. The mass flow rate of air within the stream tube is everywhere the same, call it $\dot{m}$. The power extracted by the blades Pb is equal to the difference in kinetic energy between the upwind and downwind air flows:

$$P_b = \frac{1}{2}\dot{m}(v^2 - v_d^2) \tag{5}$$

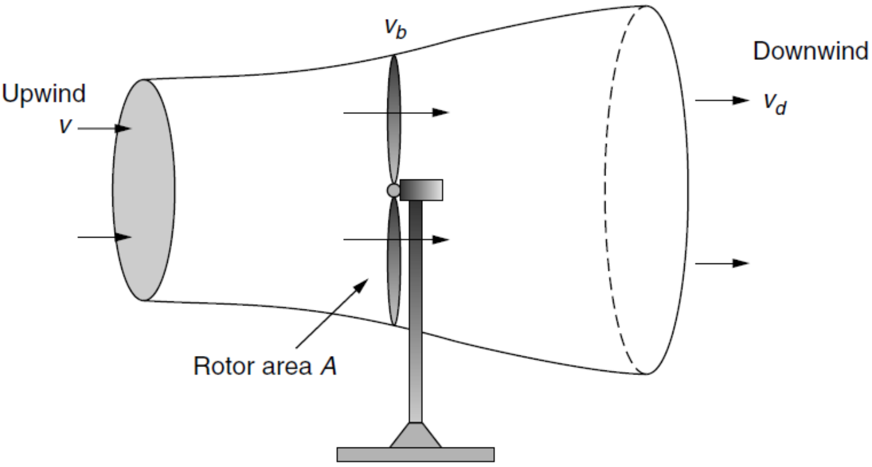

Figure 2.1 Approaching wind slows and expands as a portion of its kinetic energy is extracted by the wind turbine. Forming the tube shown.

The easiest spot to determine mass flow rate $\dot{}$ m is at the plane of the rotor where we know the cross-sectional area is just the swept area of the rotor A. The mass flow rate is thus

$$\dot{m} = \rho A v_b \tag{6}$$

If we now make the assumption that the velocity of the wind through the plane of the rotor is just the average of the upwind and downwind speeds (Betz's derivation actually does not depend on this assumption), then we can write

$$P_b = \frac{1}{2}\rho A\left(\frac{v+v_d}{2}\right)(v^2 - v_d^2) \tag{7}$$

To help keep the algebra simple, let us define the ratio of downstream to upstream windspeed to be λ:

$$\lambda = \left(\frac{v_d}{v}\right) \tag{8}$$

$$P_b = \frac{1}{2}\rho A\left(\frac{v+v_d}{2}\right)(v^2 - v_d^2) = \frac{1}{2}\rho A v^3 .\left[\frac{1}{2}(1+\lambda)(1+\lambda^2)\right] \tag{9}$$

This equation shows us that the power extracted from the wind is equal to the upstream power in the wind multiplied by the quantity in brackets. The quantity in the brackets is therefore the fraction of the wind's power that is extracted by he blades; that is, it is the efficiency of the rotor, usually designated as Cp.

$$Rotor\ efficiency = C_p = \frac{1}{2}(1+\lambda)(1+\lambda^2) \qquad (10)$$

So our fundamental relationship for the power delivered by the rotor becomes [43]

$$P_b = \frac{1}{2}\rho A v^3 . C_p \qquad (11)$$

2.2.8 CO_2 emissions

Conventionally, electric power is supplied by a diesel power generating system in an isolated island which is not connected to the power grid. In recent years, for the purpose of reducing CO_2 emissions, the introduction of photovoltaic/wind power generation into this kind of region has been positively advanced.

When a photovoltaic/wind power generating system is introduced, fuel consumption is generally reduced ac-companying the operation of the DG. However, although the photovoltaic/wind power generating facilities will not consume fossil energy during their operation, fossil energy will be consumed during equipment manufacture. In particular, the photovoltaic power generating equipment consumes more fossil energy during manufacturing than other system equipment.

For that reason, the effect of introduction of a photo-voltaic/wind power generating system must be evaluated over the life cycle, including the effects during manufacture of system equipment and during operation of the system.

There are many ways to calculate the total CO_2 emissions, input energy, and total cost throughout the life cycle of the photovoltaic/wind/diesel power generating system. The CO_2 emissions during equipment manufacture are calculated using the. process analysis method. and. inter- industry method. The CO_2 emissions during system operation are calculated using dynamic programming such that the fuel consumption will reach a minimum, assuming that the hourly series data of the electric load, insolation intensity, wind velocity, and air temperature are known during one year.[44]

2.2.8.1 Calculation method of CO_2 Emissions

The total emissions of CO_2 emitted in the life cycle of the system can be classified into those accompanying fossil energy consumption during system equipment manufacturer (facility energy) and those accompanying fossil energy consumption during system operation (operation energy). In this research, the CO_2 emissions during equipment manufacture and those during operation are calculated separately, and their sum is taken as the total CO_2 emissions.

The CO_2 emissions during system equipment manufacturing are calculated for each equipment by the process analysis method or the interindustry method. The calculated value is divided by the lifetime of each equipment and the emission per year is determined [44].

The CO_2 emissions during equipment manufacture are subdivided into: 1- emission accompanying energy consumption during the manufacture of the materials used, 2- emissions accompanying energy consumption during assembly in the factory, and 3- emissions accompanying energy consumption during transportation (distribution) of materials and system equipment. For calculating the CO_2 emissions which are emitted during material manufacturing and equipment assembly, the process analysis method and interindustry method have been proposed.

In the process analysis method, the materials used in the system equipment and their quantities, the energy consumption rates of materials, and the CO_2 emission rate must be known. In addition, there is a problem that it cannot handle all processes. In the interindustry method, direct and indirect exchanges are estimated for physical quantities such as energy or environmental loads, from the exchanges among the respective branches of industry in monetary terms.

2.3 Solar Radiation and Solar data sources

Solar radiation that reaches the earth surface is called extraterrestrial solar radiation (above the atmosphere). In the meanwhile, the attenuated solar radiation within the atmosphere is called global solar radiation. Global solar radiation incident on a horizontal surface has three components, namely, direct (beam), diffuse solar radiation and Reflected Radiation.

2.4 Firefly optimization Algorithm

Swarm Intelligence (SI) belongs to an Artificial Intelligence disciplne (AI) that became incresingly popular over the last decade. It is inspired from the collective behavior of social swarms of ants, termities, bees and worms, folks of birds and schools of fish, Although these swarms consist of relatively unsophisticated individulals, they exhibit they exhibit coordinated behavior that directs the swarms to their desired goals. This usually results in the self-organizing behavior of the whole system, and collective intelligence or swarm intelligence is in essence the self-organization of such multi-agent systems, based on simple interaction rules

Swarm Intelligence refers to a research field that is concerned with a collective behavior within self-organised and decentralized systems. This term wa probably first used in the sense of cellylar robotoc systems consisting of simple agents that organize themselves through neighborhood interactions, the cotrol of robots, and routing and load balancing in new-generation mobile telecommunication networks, demanding robustness and flexibilibty.

Firefly is one of the recent swarm intelligence methods developed by yang [45] in 2008 and is a kind of stochastic, nature-inspired, meta-heuristic algorithm that can be applied for solving the hardest optimization problems (also NP-hard problems). This algorithm belongs to stochastic algorithms. This means that it uses a kind of randomization by searching for a set of solutions. It is inspired by the flashing lights of fireflies in nature. Heuristic means ’to find’ or ’to discover solutions by trail and error’. In fact, there is no guarantee that the optimal solution will be found in a reasonable amount of time. Finally, meta-heuristic means ‘higher level’. In the FA, the ‘lower level’ (heuristic) concentrates on the generation of new solutions within a search space and thus, selects the best solution for survival. On the other hand, randomization enables the search process to avoid the solution being trapped into local optima. The local search improves a candidate solution until improvements are detected.[46]

Note that FA is population-based. The population-based algorithms have the following advantages when compared with single-point search algorithms.

The FA is inspired by the flashing behavior of fireflies, use the following three idealized rules: (i) All fireflies are attracted to each other regardless to its gender because its unisex; (ii) The strength of the attractiveness of a Firefly is proportion to its brightness, thus for any two flashing fireflies, the less brighter one will move towards the brighter one and the more brightness means the less distance between two fireflies. If there is no brighter one than a particular Firefly, it will move randomly; (iii) the brightness of a Firefly is determined by the value of the objective function. Figure 2-2 shown the flow chart of the FA.

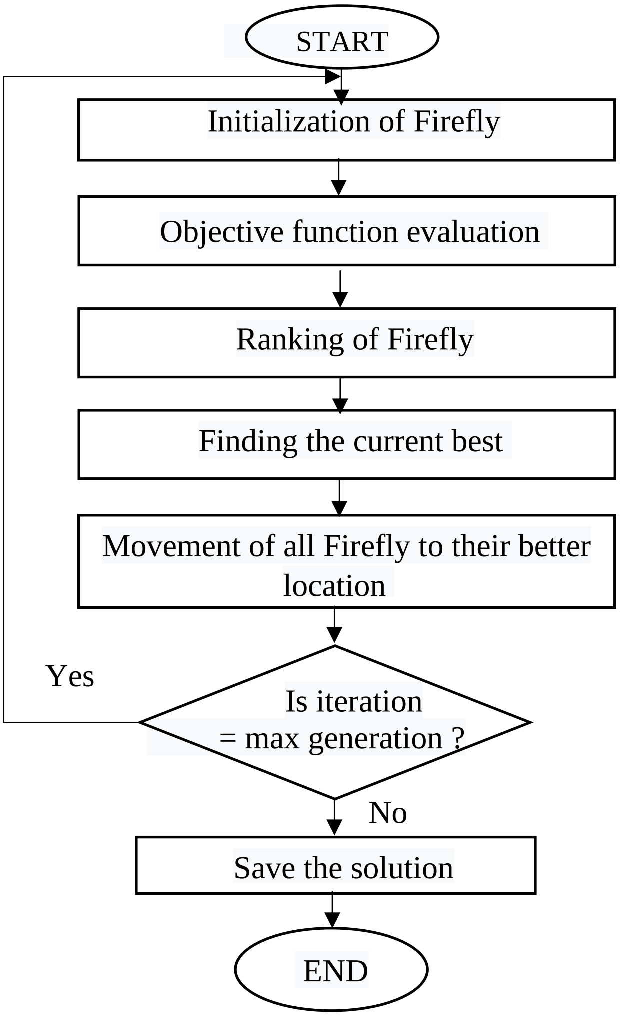

Figure 2.2 The FA.

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CHAPTER 3

RESEARCH METHODOLOGY

This chapter explains the broad philosophical underpinning for the chosen research methods, including qualitative or quantitave methods, or a mizture of both. Also explains the academic basis for all the choices research methods, which is linked back to the litreature to explain the reason of using certain methods with a clear justification ao all the choices that will be made. This section will be accompained by the flowchart of research steps or other figures required to clarify the thesis research method.

3.1 Description of the process

In this section we will explain every step in our process and also the tools which we will use. Nowadays a great variety of different PV installations is available on the market including on-grid and off-grid systems with or without battery as a storage system; hybrid systems as combination of a PV system and another energy source (e.g. wind and hydropower) are progressively getting more attention. Figure 3.1 shows the Types of Solar Photovoltaic System (SPVS) configurations:

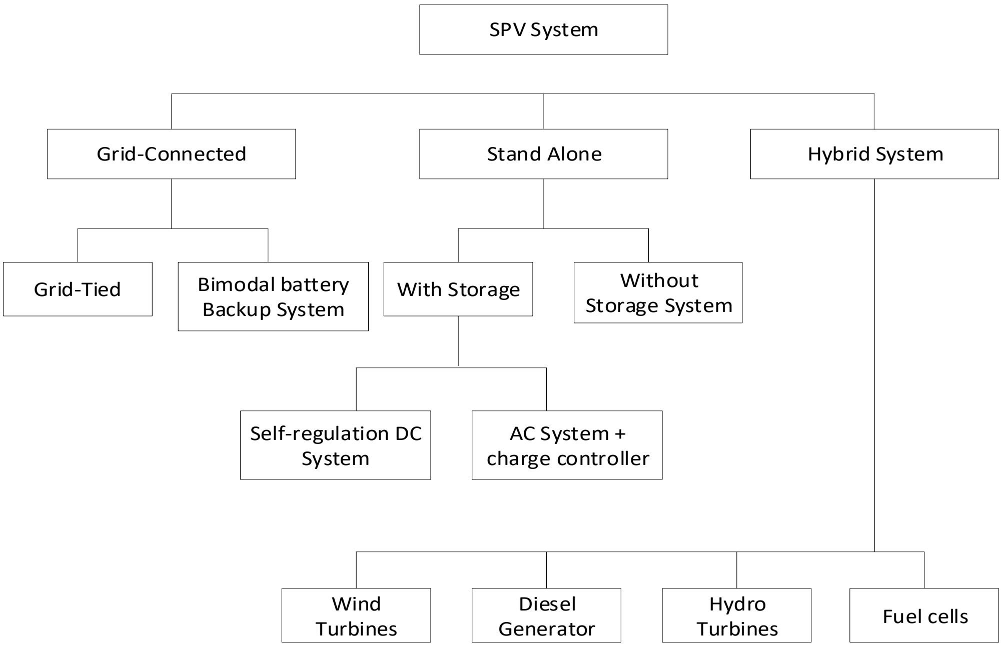

Figure 3.1 PV System Configurations.

3.1.1 Solar radiation

We can calculate the instantaneous power generator in a photovoltaic system by this equation.

$$P_{pv}(t) = \eta_g * N_m * A_m * G_{til}(t) \tag{12}$$

G_{til} is the hourly global solar irradiance on titled surface, so to calculate this hourly data we have to calculate it every hour from the location. We can use one of the estimation calculation methods to caculate it. There are many methods like Model Collares Pereira and Rabel, Model Biag et al., Model Jain and Model Liu and Jordan.

In our study we will use Model Liu and Jordan [47]

3.1.1.1 Model liu and Jordan to calcluate the hourly solar radiation

This method is one of the statistical methods to calculate hourly solar radiation for horizontal surfaces. We use this method if we can not get the hourly measured radiaition from the location, so the input in this calsulation will be the daily solar radiation and the output will be the hourly solar radiation.

So first we will calculate the normalized parameters K_T

$$K_T = \frac{H}{H_0} \tag{13}$$

Where H_0 is extra-terrestrial daily insulation received on a horizontal service, is computed from the following equation:

$$H_0 = \frac{24}{\pi} I_{on} * (cosL * cos\delta * cos\omega_s + \omega_s * \sin L * \sin\delta) \tag{14}$$

Where ω_s is the sunset hour angle .

$$\cos\omega_s = -\tan L * \tan\delta \tag{15}$$

The value of *r* is the ratio of the average intensity of diffuse radiation to the dial diffuse radiation equal to

$$r = \frac{\pi}{24} * \frac{\cos L * \cos\delta * \cos\omega + \sin L * \sin\delta}{\cos L * \cos\delta * \sin\omega_s + \omega_s * \sin L * \sin\delta} \tag{16}$$

Since the earth rotates 15°/h, the hour angle can be converted to time of sunrise or sunset using:

$$Sunrise\ (geometric) = 12{:}00 - \frac{\omega_{SR}}{15^{0}\ /\ h} \tag{17}$$

$where\ \omega_{SR}$ is the hour angle of sunrise. Then the correction factor will be [48].

$$Q = \frac{3.467}{\cos L * \cos\delta * \sin\omega_{SR}} \tag{19}$$

Then when the sunset hour angle ω_S equation will substitute into the r equation the results will be

$$r = \frac{\pi}{24} * \frac{\cos\omega - \cos\omega_S}{\sin\omega_S - \omega_S\ cos\omega_S} \tag{20}$$

1.1.2 Data and calculations

In this section we will discuss and collect the data then managing according to the methods mentioned in the methodology. So, we will discuss the PV output power, battery ratings and inverter ratings, the load data according to the single line diagram provide by PLN (Perusahaan Listrik Negara) company, solar radiation values which collected from the location with respect to the probability of the radiation, calculating the resistance R and the reactance X using the cable catalogue from Olex (Olex Australia Pty Ltd) cable company, Australia. Also, the methods which can be used to minimize the losses.

3.1.2.1 PV output, Battery KWh and Inverter data

The data which shown in Table 3.1 are the PV output power of the four PVGS in Tomia island, it distributed in four locations Kulati, Dete, Kahianaga and Lamanggau. Also, these data provided the rated battery energy and the rated inverter which is a brand called Sunny Island Inverter from System, Mess and Anlagentechnik (SMA) company, Germany.

Table 3-1 PLTS data at each location

	Location	PV o/p power	Battery kWh @48 v	Sunny island inverter
1	Kulati	140 kWp	800 kWh	144 kVA
2	Dete	112 kWp	600 kWh	72 kVA
3	Kahianga & Wawotimu	308 kWp	1600 kWh	54 kVA
4	Lamanggau	224 kWp	1200 kWh	108 kVA

3.1.2.2 Load data

In our system we have a radial network consist of 21 bus, each bus deliver electricity to the load which all of them are residential loads in Tomia island, Single Line Diagram is shown in Figure 3.2

We got the load data from the location site, the data is collected throw one year, so we will make an average of these data throw a one day and we will use this average in our optimization process.

The data is measuring solar resources data such as solar radiation throw a specific time which is the main input. Hourly or daily radiation and weather data are preferable. If getting these measured data not provided so the satellite-based data or estimated data can also be used.

Then we have to know the load profile and it will be more reliable if it is a yearly data, it is really difficult if we will analyse real load demand with all minute fluctuations. So hourly or daily averages of load demand is generally used for design optimization purpose as is shown in Table 3.2.

Then we have to make our system configuration according to our needs and according to the situation in the location like in the day hours the solar radiation is in its peak, so we will get almost the electricity from the solar cell. And at night hours we will take the electricity from the batteries and DG. Then the modelling of the system will take its position in the process, these models are used to identify and solve the problems using various computing systems. and these models must include all necessary variables which affect energy conversion.

Finally, the optimization results must be accurate enough to avoid excess or leakage of the power generation from the PV system. Many Algorithms used to solve optimization problems using many softwares, one of these softwares is Matlab software.

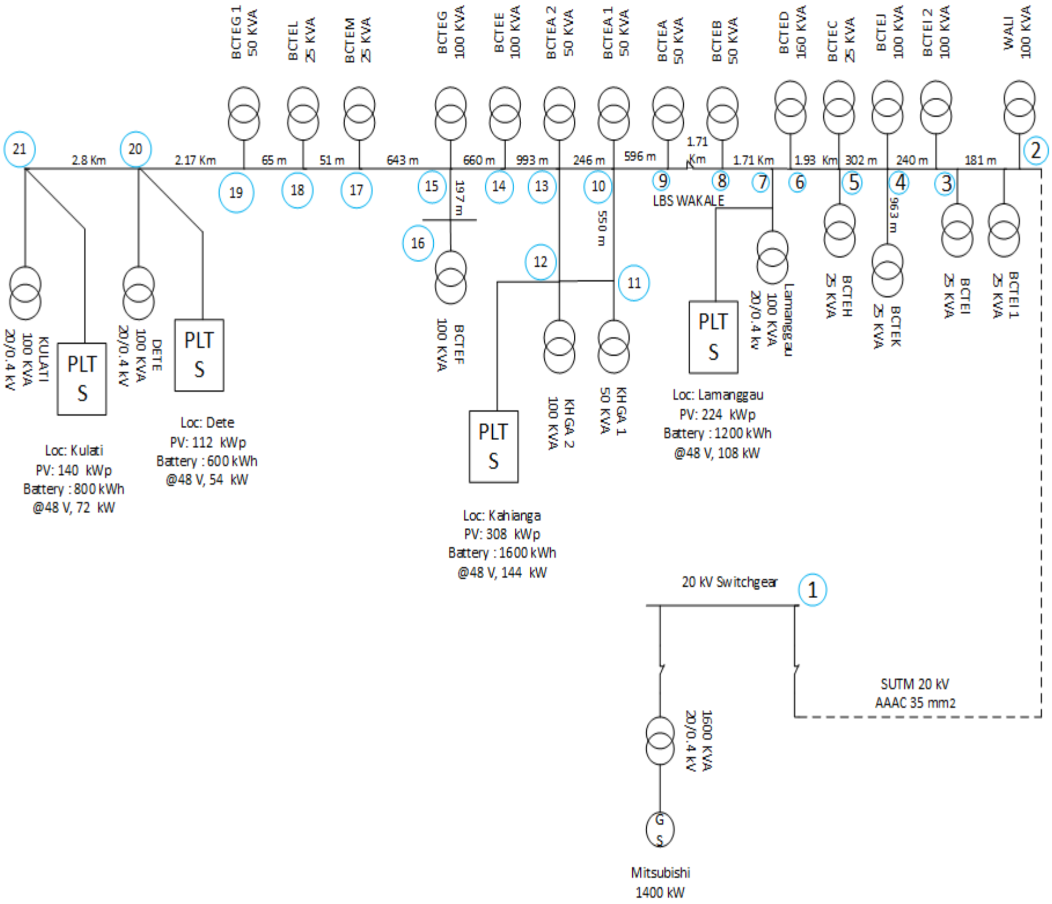

Figure 3.2 Single Line Diagram of the case study in Tomia island.

Table 3-2 The hourly distributed load at each bus after using the PVSG.

		Tr. Rating		hours																										
bus	type	main	adding	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	total load at each bus	P (active power)	Q (reactive power)
1	generator	1600																												
2	load	100	25	55.69	53.58	52.31	51.52	54.42	59.06	47.26	38.22	38.22	42.04	42.04	42.04	42.04	38.22	38.22	54.17	55.48	55.32	55.32	71.78	53.53	66.03	62.23	59.06	1227.92	1227.92	479.199
3	load	100	25	55.69	53.58	52.31	51.52	54.42	59.06	47.26	38.22	38.22	42.04	42.04	42.04	42.04	38.22	38.22	54.17	55.48	55.32	55.32	71.78	53.53	66.03	62.23	59.06	1227.92	1227.92	479.199
4	load	100	25	55.69	53.58	52.31	51.52	54.42	59.06	47.26	38.22	38.22	42.04	42.04	42.04	42.04	38.22	38.22	54.17	55.48	55.32	55.32	71.78	53.53	66.03	62.23	59.06	1227.92	1227.92	479.199
5	load	25	25	22.27	21.43	20.92	20.60	21.77	23.62	18.90	15.29	15.29	16.81	16.81	16.81	16.81	15.29	15.29	21.66	22.19	22.12	22.12	28.71	21.41	26.41	24.89	23.62	491.171	491.171	191.679
6	load	160		71.28	68.58	66.96	65.94	69.66	75.60	60.49	48.92	48.92	53.82	53.82	53.82	53.82	48.92	48.92	69.34	71.01	70.81	70.81	91.88	68.52	84.51	79.65	75.60	1571.748	1571.74	613.375
7	PV	100		44.55	42.86	41.85	41.21	43.54	47.25	37.80	30.58	30.58	33.63	33.63	33.63	33.63	30.58	30.58	43.33	44.38	44.25	44.25	57.42	42.82	52.82	49.78	47.25	982.342	982.342	383.359
8	load	50		22.27	21.43	20.92	20.60	21.77	23.62	18.90	15.29	15.29	16.81	16.81	16.81	16.81	15.29	15.29	21.66	22.19	22.12	22.12	28.71	21.41	26.41	24.89	23.62	491.171	491.171	191.679
9	load	50		22.27	21.43	20.92	20.60	21.77	23.62	18.90	15.29	15.29	16.81	16.81	16.81	16.81	15.29	15.29	21.66	22.19	22.12	22.12	28.71	21.41	26.41	24.89	23.62	491.171	491.171	191.679
10	load	50		22.27	21.43	20.92	20.60	21.77	23.62	18.90	15.29	15.29	16.81	16.81	16.81	16.81	15.29	15.29	21.66	22.19	22.12	22.12	28.71	21.41	26.41	24.89	23.62	491.171	491.171	191.679
11	load	50		22.27	21.43	20.92	20.60	21.77	23.62	18.90	15.29	15.29	16.81	16.81	16.81	16.81	15.29	15.29	21.66	22.19	22.12	22.12	28.71	21.41	26.41	24.89	23.62	491.171	491.171	191.679
12	PV	100		44.55	42.86	41.85	41.21	43.54	47.25	37.80	30.58	30.58	33.63	33.63	33.63	33.63	30.58	30.58	43.33	44.38	44.25	44.25	57.42	42.82	52.82	49.78	47.25	982.342	982.342	383.359
13	load	50		22.27	21.43	20.92	20.60	21.77	23.62	18.90	15.29	15.29	16.81	16.81	16.81	16.81	15.29	15.29	21.66	22.19	22.12	22.12	28.71	21.41	26.41	24.89	23.62	491.171	491.171	191.679
14	load	100		44.55	42.86	41.85	41.21	43.54	47.25	37.80	30.58	30.58	33.63	33.63	33.63	33.63	30.58	30.58	43.33	44.38	44.25	44.25	57.42	42.82	52.82	49.78	47.25	982.342	982.342	383.359
15	load	100		44.55	42.86	41.85	41.21	43.54	47.25	37.80	30.58	30.58	33.63	33.63	33.63	33.63	30.58	30.58	43.33	44.38	44.25	44.25	57.42	42.82	52.82	49.78	47.25	982.342	982.342	383.359
16	load	100		44.55	42.86	41.85	41.21	43.54	47.25	37.80	30.58	30.58	33.63	33.63	33.63	33.63	30.58	30.58	43.33	44.38	44.25	44.25	57.42	42.82	52.82	49.78	47.25	982.342	982.342	383.359
17	load	25		11.13	10.71	10.46	10.30	10.88	11.81	9.45	7.645	7.645	8.409	8.409	8.409	8.409	7.645	7.645	10.83	11.09	11.06	11.06	14.35	10.70	13.20	12.44	11.81	245.585	245.585	95.8399
18	load	25		11.13	10.71	10.46	10.30	10.88	11.81	9.452	7.645	7.645	8.409	8.409	8.409	8.409	7.645	7.645	10.83	11.09	11.06	11.06	14.35	10.70	13.20	12.44	11.81	245.585	245.585	95.8399
19	load	50		22.27	21.43	20.92	20.60	21.77	23.62	18.90	15.29	15.29	16.81	16.81	16.81	16.81	15.29	15.29	21.66	22.19	22.12	22.12	28.71	21.41	26.41	24.89	23.62	491.171	491.171	191.679
20	PV	100		44.55	42.86	41.85	41.21	43.54	47.25	37.80	30.58	30.58	33.63	33.63	33.63	33.63	30.58	30.58	43.33	44.38	44.25	44.25	57.42	42.82	52.82	49.78	47.25	982.342	982.342	383.359
21	PV	100		44.55	42.86	41.85	41.21	43.54	47.25	37.80	30.58	30.58	33.63	33.63	33.63	33.63	30.58	30.58	43.33	44.38	44.25	44.25	57.42	42.82	52.82	49.78	47.25	982.342	982.342	383.359
total																														
T.r ratings		1535	100																									16061.3		
		1635		728.461406	700.8772	684.3167	673.9152	711.9292	772.6061	618.181	500	500	550	550	550	550	500	500	708.5776	725.6966	723.6248	918.878	938.925	900.232	863.681	814.007	772.63	16456.53		

3.1.2.3 Calculating the losses of the system

According to what mentioned in the previous section, it's clear that two important questions should be answered during the planning to reduce the loss and improve the system efficiency. These two questions are

1- What is the optimum size of the DG?
2- What is the best location of the DG which can give the minimum losses?

To calculate the system losses, we will use a backward-forward sweep method to analyze the power flow, our system is a radial distribution system. The distribution system has a radial structure and high R/X ratios. So, the Newton-Raphson and fast decoupled methods are failed with distribution system.

The proposed method presents a load flow study using backward/forward sweep method. Which is one of the most effective methods for the load-flow analysis of the radial distribution system by using this method, power losses for each bus branch and voltage magnitudes for each bus node are determined. A radial network leaves the station and passes through the network area with no normal connection to any other supply. The Forward-Backward Sweep Method (FBSM) is easy to program and runs quickly. The method is designed to solve the differential algebraic system generated by the maximum principle that characterizes the solution.

The Power flows in a distribution system are computed by the following set of simplified recursive equations derived from the single-line diagram. The power flow analysis can be used to obtain the voltage magnitude, power losses. The objective function is to find the power flow [20].

$$P_{k+1} = P_k - P_{loss,k} - P_{lk+1} \tag{21}$$

$$Q_{k+1} = Q_k - Q_{loss,k} - Q_{lk+1} \tag{22}$$

where P_k real power flowing out of bus, Q_k reactive power flowing out of bus, P_{lk+1} real load power at bus k+1, Q_{lk+1} reactive load power at bus k+1. The power loss in the line section connecting buses k and k+1 may be computed as

$$P_{loss}(k, k+1) = R_k \frac{P_k^2+Q_k^2}{V_k^2} \qquad) \tag{23}$$

$$Q_{loss}(k, k+1) = X_k \frac{P_k^2+Q_k^2}{V_k^2} \tag{24}$$

Where $P_{loss}(k, k+1)$ real power loss in the line section connecting buses k and k+1, $Q_{loss}(k, k+1)$ reactive power loss in the line section connecting buses k and k+1. The total power loss of the feeder, $P_{T,loss}$ may then be determined by summing up the losses of all line sections of the feeder, which is given as

$$P_{T,loss}(k, k+1) = \sum_{K=1}^{N} P_{LOSS}(k, k+1) \tag{25}$$

$$Q_{T,loss}(k, k+1) = \sum_{K=1}^{N} Q_{LOSS}(k, k+1) \tag{26}$$

Where $P_{T,loss}(k, k+1)$ total real power loss in the line section, $Q_{T,loss}(k, k+1)$ total reactive power loss in the line section.

3.1.2.3.1 Backward Sweep

The backward sweep is basically a current or power flow solution with possible voltage updates. It starting from the branches in the last layer and moving towards the branches connected to the root node. The updated effective power flows in each branch are obtained in the backward propagation computation by considering the node voltages of previous iteration.

It means the voltage values obtained in the forward path are held constant during the backward propagation and updated power flows in each branch are transmitted backward along the feeder using backward path. This indicates that the backward propagation starts at the extreme end node and proceeds towards source node.

It is well known that there exist three main variants of the forward-backward sweep method that differ from each other based on the type of electric quantities that at each iteration, starting from the terminal nodes and going up to the source node (backward sweep), are calculated.

1- The current summation method, in which the branch currents are evaluated.
2- The power summation method, in which the power flows in the branches are evaluated.
3- The admittance summation method, in which, node by node, the driving point admittances are evaluated. In other terms, the three variants of the B/F method simulate the loads within each iteration, with a constant current, a constant power and a constant admittance model.

3.1.2.3.2 Forward Sweep

The forward sweep is basically a voltage drop calculation with possible current or power flow updates. Nodal voltages are updated in a forward sweep starting from branches in the first layer toward those in the last.

The purpose of the forward propagation is to calculate the voltages at each node starting from the feeder source node. The feeder substation voltage is set at its actual value. During the forward propagation the effective power in each branch is held constant to the value obtained in backward walk.

3.1.2.4 Minimizing the losses methods

There are any methods to minimize the losses for radial networks like feeder reconfiguration, capacitor placement, high voltage distribution system, conductor grading, DG allocation, and also many researchers worked on this topic [49]. We will follow the most three commonly used methods 1) Capacitor placement, 2) Feeder reconfiguration, 3) and DG allocation for loss minimization [50].

3.1.2.4.1 Capacitor placement

The application of capacitors to electric power systems can be used for: the control of power flow, stability improvement, voltage profile management, power factor correction, and power and energy loss reduction. The capacitor is a source of reactive power as by reducing the inductive reactance portion of the line loading, it can reduce the reactive losses which can be done by the addition of shunt capacitors [51].

The main challenges in this technique are: selection of an appropriate number of capacitor units, allocation of capacitors, and sizing of capacitors to achieve a required result i.e., a) loss reduction, b) voltage regulation, and c) power flow control.

3.1.2.4.2 Feeder Reconfiguration

Distribution systems consist of groups of interconnected radial circuits. The configuration may be varied via switching operations to transfer loads among the feeders. Two types of switches are used in primary distribution systems. They are normally closed switches (sectionalizing switches) or normally open switches (tie switches).

Both types are designed for protection and configuration management. Network reconfiguration is the process of changing the topology of distribution systems by altering the open/closed status of these switches. Reconfiguration is applied for: service restoration under faulty conditions, load balancing to a) relieve overload on networks and b) improve voltage profile 3) planning outages for maintenance and 4) loss minimization.

3.1.2.4.3 DG allocation

Recently the penetration of DG's into distribution systems has been increasing rapidly in many parts of the world. Integration of DG into an existing utility can result in several benefits such as: reduced environmental impacts, increased overall energy efficiency, relieved transmission and distribution congestion, voltage support, exploitation of the renewable resources, such as wind, solar, hydro, biomass, geothermal and ocean energy and line loss reduction [26].

Distributed generators are very much beneficial in reducing the losses effectively compared to other methods of loss reduction. The main reasons for continuous growth in the penetration of DG in power network are: constraints on building new transmission and distribution lines, technological advances in small generators, power electronics and energy storage devices for transient backup and increasing public desire to promote “green” technologies based on renewable-energy sources.

3.1.2.5 Calculation resistance and the reactance of the lines between the busses

Our data is providing us the distances between the buses by kilo meter (km) which we can use it to calculate the values of resistance R and reactance X of each bus, the cable which already used in the site is an aluminum cable, one of the most important benefit to use aluminum cable instead of using cupper cable is because the aluminum cable is more cheaper and more flexible, so it can sustain the hard turning during the installation rather than the cupper one which it can broke with tough turns .

The Aluminum cable used there called All Aluminum Alloy Conductor (AAAC), so we will use the data from an industrial catalogue to calculate R & X. we will use the cable catalogue of Olex Australia Pty Ltd company which is an Australian cable company. The cross section of the AAAC cable is 35 mm^2, from the catalogue the only cable near this cross section is called Chlorine with a cross section 34.4 mm^2. Form the catalogue, the value of AC resistance = 1.05 ohm/km and Inductive resistance = 0.295 ohm/km.

From Tomia data we can know the distances by km, as it mentioned in the Single Line Diagram (SLD), to calculate it we will multiply the distance with the values of ohm/Km to know the resistance and reactance. The calculation is shown in Table 3.2. Table 3.2 divided explains the method of calculating the Resistance (R) and the Reactance (X) for the radial network in Tomia.

First of all, we have to know the distance between each two buses, the distance between each two busses is provided from Tomia location. The distance between each two buses are not far, these distances are between some few meters like the distance between bus 17 and 18, the distance between both of them is 51 meters. Some distances are also big like the distance between bus 20 and 21 which is 2.8 km.

Table 3-3 Values of R and X of by using OLEX company catalogue

from bus	to bus	distance (km)	R (ohm)	X (ohm)
1	2	1	1.05	0.295
2	3	0.181	0.19005	0.053395
3	4	0.24	0.252	0.0708
4	5	0.302	0.3171	0.08909
5	6	1.93	2.0265	0.56935
6	7	0.5	0.525	0.1475
7	8	1.2	1.26	0.354
8	9	1.71	1.7955	0.50445
9	10	0.596	0.6258	0.17582
10	11	0.55	0.5775	0.16225
11	12	3.42	3.591	1.0089
10	13	0.246	0.2583	0.07257
13	14	0.993	1.04265	0.292935
14	15	0.66	0.693	0.1947
15	16	0.197	0.20685	0.058115
15	17	0.643	0.67515	0.189685
17	18	0.051	0.05355	0.015045
18	19	0.065	0.06825	0.019175
19	20	2.17	2.2785	0.64015
20	21	2.8	2.94	0.826

3.1.3 DG (fuel consumption and cost)

A DG is normal diesel engine coupled to an electrical generator. DGs are usually designed in such a way that they always operate close to their power rating to achieve high efficiency; this condition can be used later as an operation constraint.

With this operation strategy as well as operation constraint, the DG is expected to run at high load factors, which will result a decrease of the fuel consumption, of the Carbone footprint and increase of the DG lifespan [52]. The FC (fuel cost) is calculated for a day is given by the quadratic non-linear function below:

$$FC(fuel\ cost) = C_f \sum_{j=1}^{N} \left(aP_{DG(j)}^2 + bP_{DG(j)} + C \right) \tag{27}$$

where:

N = the number of sampling intervals within the operation range or period of the system;

a,b, c = the fuel cost coefficients;

j = the jth sampling interval;

$P_{DG(j)}$ = the output power from the DG at jth sampling interval;

C_f = the price of 1 L of fuel.

3.1.4 Battery and its cost

Because of the random behaviour of PV panels, the battery bank capacity constantly changes correspondingly in the system. In such system, state of charge (SOC) of the battery is acquired as follows:

When the generating power from the PV panels is greater than the power demand from the load, the battery bank is in charging state. The charge quantity of the battery bank at time (t) can be obtained by [17].

$$E_{Batt}(t) = E_{Batt}(t-1) \times (1-\delta)\ \left[(E_{PV}(t) + E_{WT}) - \frac{E_{load}(t)}{\eta_{inv}}\right] \eta_{Batt} \tag{28}$$

Where $E_{Batt}(t)$ and $E_{Batt}(t\text{-}1)$ are the charge quantities of battery bank at time t and $t\text{-}1$, δ is the hourly self-charge rate. η_{INV} the inverter efficiency, E_{load} is the load demand, η_{Batt} efficiency of the battery charging. These variables are mentioned in the equation above.

In other case, when the total power generating from the PV is less than the power demand from the load, the battery bank is in the discharging state. If we assume the discharging efficiency of the battery is 1, Therefore, the charge quantity of the battery bank at time (t) can be obtained by.

$$E_{Batt}(t) = E_{Batt}(t-1) \times (1-\delta) - \left[(E_{PV}(t) + E_{WT}) - \frac{E_{load}(t)}{\eta_{inv}}\right] \tag{29}$$

For the batteries, the value of Net Present Cost (*NPC*) is calculated by the battery investment cost (IC_{batt}), operation and maintenance cost (OMC_{batt}) and replacement cost (RC_{batt}) as follows

$$NPC_{batt} = IC_{batt} + OMC_{batt,npv} + RC_{batt,npv} \tag{30}$$

Where

$$IC_{batt} = \alpha_{batt} \times N_{batt} \tag{31}$$

And the replacement cost is representing as follow

$$RC_{batt,npv} = RC_{batt} \times P_{batt} \times \sum_{\iota} \left(\frac{1+\delta}{1+r}\right)^{\iota} \tag{32}$$

3.1.5 CO_2 emissions calculations from the DG

The parameter considered in this paper to measure the pollutant emission is the kg of CO_2. It represents the large percentage of the emission of fuel combustion. Further, CO_2 represents the main cause of the greenhouse effect. So, we evaluate the amount of the CO_2 produced by the use of DG in the hybrid PV/wind/ diesel/battery system during one year of operation [53].

The fuel consumption of the DG depends on the output power. It can be given by

$$Cons = B * P_{NG} + A * P_{OG} \tag{33}$$

Where P_{NG} (kW) is the nominal power of DGs, and P_{OG} is the output power from DGs A=0.246 L/kWh and B=0.08145 L/kWh are the coefficient of the consumption curve. The factor considered, in this work, to assess the emission of CO_2 was 3.15 $kgCO_2/L$.

If we want to calculate the CO_2 emissions from the diesel, 1 liter of diesel weighs 835 grams. Diesel consist for 86,2% of carbon, or 720 grams of carbon per liter diesel. In order to combust this carbon to CO_2, 1920 grams of oxygen is needed. The sum is then 720 + 1920 = 2640 grams of CO_2/liter diesel. An average consumption of 5 liters/100 km then corresponds to 5l x 2640 / 100 (per km) = 132 g CO_2/km.

The Cons Equation is employed when the DG is running. When the DG is not running, the fuel consumption rate is zero. At running hours, the fuel consumption price is calculated by the fuel price (f_p) as follows:

$$C_f(t) = f_p * fC_d(t) \tag{34}$$

The annual fuel cost of the DG can be obtained by:

$$FC_{dg} = \sum_{t=1}^{8760} C_f(t) \tag{35}$$

3.2 Firefly Algorithm (FA)

Again, Overview of FA: FA is a heuristic optimization Algorithm based on the flashing characteristics of fireflies. The main functions of the flashes are to attract the mating partners as well as to attract the potential prey. FA is illustrated based on three rules where, firstly, all fireflies are of the same sex and thus the attraction between fireflies is independent regardless of their sex. Secondly, the attraction is proportional to the brightness of the fireflies and it decreases when the distance between the fireflies increases. In other words, the brighter fireflies will attract the less bright ones. The fireflies will move randomly if all of them have the same brightness. Thirdly, the brightness of the fireflies is decided by the landscape of the objective function. Two main parts in FA are the variation of light intensity and the attractiveness between the fireflies. The attractiveness of the fireflies is affected by the light intensity (brightness) which then is related to the objective function. The attractiveness β(r) of a Firefly can be defined as

$$\beta(r) = \beta_0 e^{-\gamma r^2} \tag{36}$$

Where β_0 is the attractiveness at r=0 , γ the light absorption coefficient, and r is the Cartesian distance between two fireflies as in the following expression

$$r_{ij} = \|x_i - x_j\| = \sqrt{\sum_{k=1}^{d} \left(x_{i,k} = k_{j,k}\right)^2} \tag{37}$$

Where i and j represent two different fireflies at xi and xj while xi,is the kth component of the spatial coordinate xi of ith Firefly. Meanwhile, the movement of the Firefly i which is attracted by the brighter Firefly j is defined in

$$x_i = x_i + \beta_o e^{-\gamma r^2}\left(x_j - x_i\right) + \alpha\epsilon_i \tag{38}$$

Where ϵ_i is a random number drawn from Gaussian distribution the movements of fireflies consist of three terms: the current position of ith Firefly, attraction to another more attractive Firefly, and a random walk that consists of a randomization parameter α and the random generated number from interval [0-1]. When β_0=0 the movement depends on the random walk only. On the other hand, the parameter γ has a crucial impact on the convergence speed. Typically, the value of γ varies from 0.1 to 10. There are three parameters control the FA which is α, β and γ.

3.3 Operation strategy

Our operation strategy will start to calculate the losses at normal case using Forward-Backward sweep method and to calculate them we have to calculate the resistance and the reactance of all cables in the system by knowing the distance between each two buses.

Before we define the objective function, we have to define the limits in the system like the minimum and the maximum power of the DG, Solar cells and the batteries. These limits show the edges which the sources cannot exceed it or work below this value. So, if the power will exceed these values the system will work as a fault or error.

The operation will start by defining the objective function and the constraints of our optimization system, these constraints are the limits in our system besides the values of the cost of the DG, PV and the batteries, then we will enter them to the FA, the output of the Firefly will give us the optimum output values according to our FA parameters. The flow chart at Figure 3.3

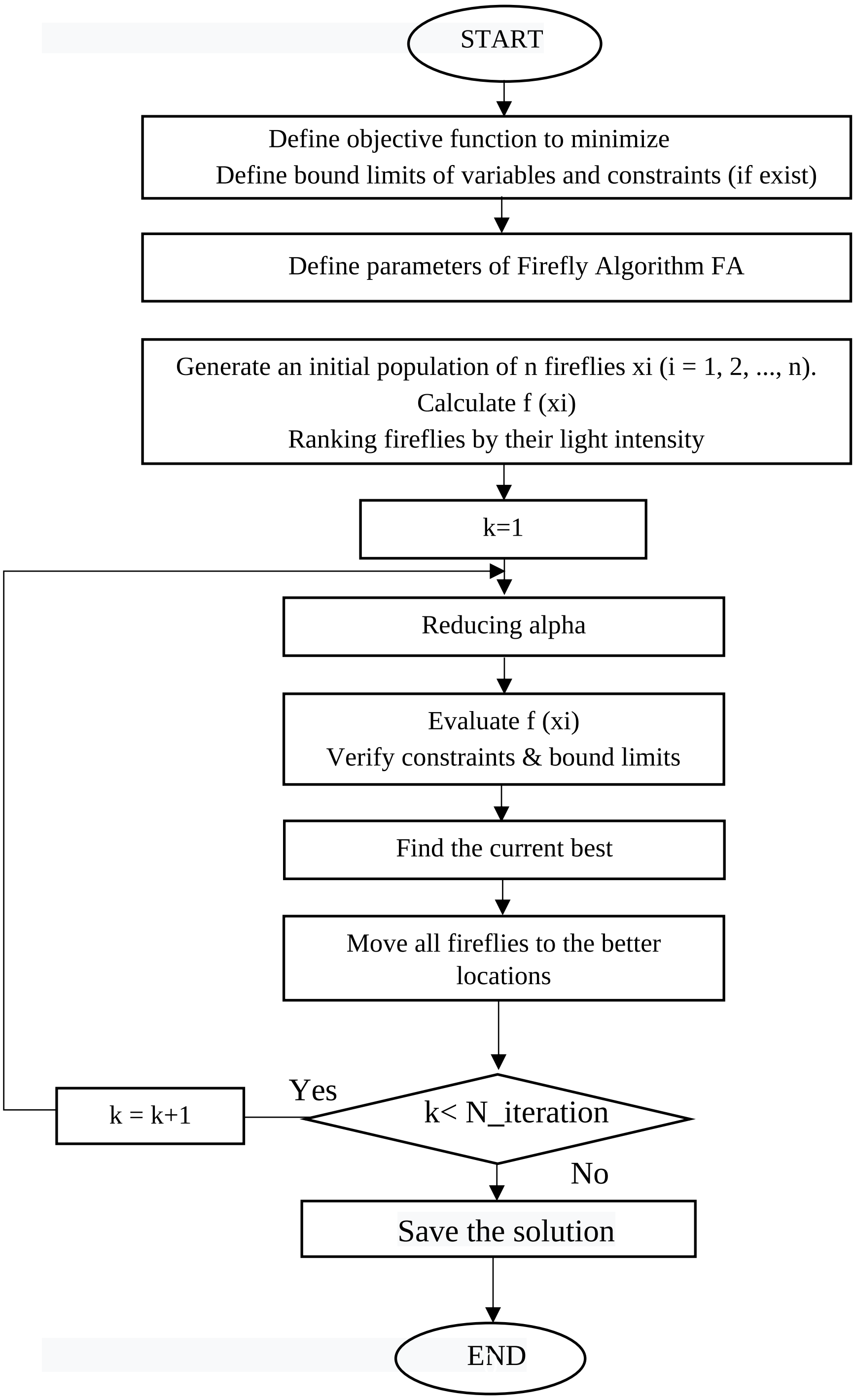

Figure 3.3 Flow chart of FA for our PVGS system.

3.4 System optimization

In this study, our optimization problem is to find the minimum cost of electricity generation by the system to satisfy the required demand load. Moreover, we are going to find the optimum tilt angle of the PV panel to collect the maximum solar radiation which allow the PV panel to generate the maximum power.

Optimal sizing of a grid-connected PV, DG and batteries power generation system is conducted using FA (FA). For this aim, a multi objective function is defined based on the minimization of the system costs and minimizing of the losses, subject to technical constraints.

Optimization problem is defined as:

$$\min F(x) = GC \qquad (39)$$

$$\max F(y) = GP \qquad (40)$$

Where GC is the Generation Cost, GP: Generated Power.

To achieve the minimum cost of generation we need to find the minimum number of PV panels, battery and minimum power generated by the DG as well as the maximize the generating power from the PV panel system by finding the optimum slop and azimuth of the system. By doing these conditions, the system will be optimized besides considering the operation constraints. The problem constraints can be expressed as follows:

The generator normally working from 3 pm to 6 am to satisfy a load of 10,505 kWh/day. PLTD which is mean in English (Diesel Power plant). The generation level is maintained at 30%-40% of its rated power and must be running for 24 hours.

$$P_{dg} = 30\%\, P_{full\ load}$$

And PV array which comes from PLTS which is mean (solar power plant) has to generate maximum power set by MPPT of grid-inverter, and the highest and lowest insolation data from the PV are

1- Maximum of 6.28 kWh/m2/day
2- Minimum of 4.26 kWh/m2/day.

$$P_{pv} = P_{full\ load}$$

The generator at any time is generated power should be limited to its rated power as the following

$$0 \le P_{dg}(t) \le P_{dgn}$$

For the batteries the state of charge should be limited in order to keep the batteries in good condition as follow

$$SOC_{min} \le SOC \le SOC_{max}$$

Which means the batteries should not discharge below the SOC_{min} and charging over the SOC_{max}.

3.5 Matlab Software in the optimization process

All the parameters and data and its equations which need for this study will calculate using Matlab software, also the FA will build using this software. The result from Matlab will be the solution of the design.

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CHAPTER 4

RESULTS AND DISCUSSION

In this section we will present our results after using the methods mentioned in chapter 3 the research methodology, so we will mention all the steps to reach our aim for decreasing the losses and the cost in our case study in Tomia island, Southeast Sulawesi, Indonesia.

4.1 Calculate the hourly solar radiation

To calculate the hourly solar radiation we will use Liu and Jordan statistical method by using the dialy solar radiation data as our input data. From the equations mentioned in chapter 3, these equations will be used in our calculations.

So, we chosed different four days in different four months, then enter the dialy solar irradiance to calculate the hourly solar radiation at each day. After this we will take the average of these days, then we will enter this average as our mean value of the dialy solar radiation throw the year, our four days are 05/01/2018, 14/04//2018, 2008/2018 and 24/11/2018. The dialy solar radiations at each day are 3.133, 4.278, 3.776 and 2.121 (W/m^2) respectively.

Then Figure 4-1 represents the hourly solar radiation for the average of the four days which represent the mean of these four days.

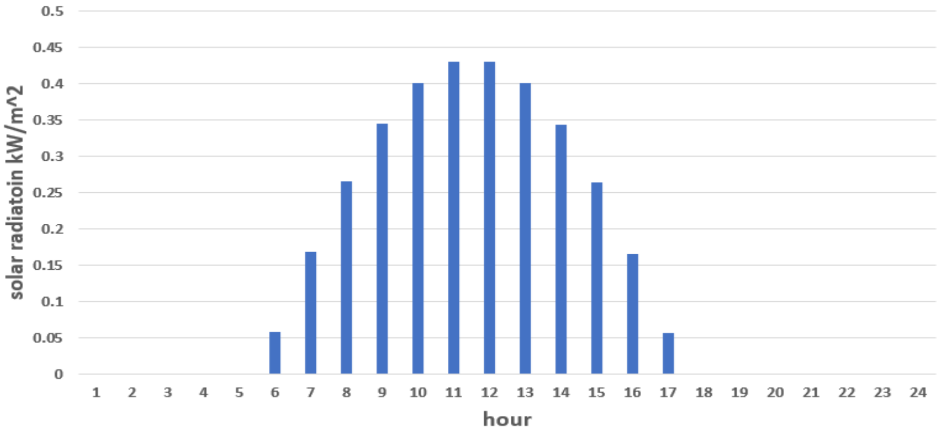


Figure 4.1 The solar radiation in Tomia location.

Table 4-1 shows the hourly solar radiations for the mentioned four days after using Liu and Jordan method.

Table 4-1 The hourly solar radiations using Liu and jordan method.

	05-01-18	14-04-18	20-08-18	24-11-18	the mean kW/m2	the mean W/m2
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0.0622091	0.0649889	0.048677	0.061279	0.059288624	59.28862389
7	0.1579788	0.21073865	0.179175	0.125061	0.168238382	168.2383824
8	0.2443561	0.3413249	0.296498	0.181181	0.265840114	265.8401141
9	0.3154546	0.44784841	0.392651	0.225816	0.345442422	345.4424223
10	0.3664291	0.52304977	0.46108	0.255923	0.401620541	401.6205413
11	0.3938056	0.56180415	0.497124	0.269451	0.430546025	430.546025
12	0.3957186	0.56147049	0.498324	0.265477	0.43024765	430.2476496
13	0.3720377	0.52207154	0.464601	0.244273	0.400745749	400.7457488
14	0.3243767	0.44629226	0.398251	0.207284	0.344050828	344.0508284
15	0.2559836	0.33929689	0.303796	0.15703	0.264026554	264.0265536
16	0.1715193	0.20837698	0.187674	0.096936	0.166126446	166.1264464
17	0.0767398	0.06245451	0.057797	0.031097	0.057022237	57.02223744
18	0	0	0	0	0	0
19	0	0	0	0	0	0
20	0	0	0	0	0	0
21	0	0	0	0	0	0
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0

4.2 Power Flow calculating

As we mentioned FBSM is the best power low method to be used for calculating the losses in radial distribution network better than Newton-Raphson method because its simplicity to program and quickly running.

Table 4-2 describes the distributed active and reactive power at each bus besides the values of the existing transformers at each bus.

Table 4-2 The active and reactive power values throw all buses.

bus	type	main	Adding	the main of the total load per hour		the main of the total load per hour	
				P active power (kW)	Q reactive power (kW)	P (p.u)	Q (p.u)
1	gen	1600		51.16367227	19.96664749	0.051163672	0.019966647
2	load	100	25	51.16367227	19.96664749	0.051163672	0.019966647
3	load	100	25	51.16367227	19.96664749	0.051163672	0.019966647
4	load	100	25	20.46546891	7.986658995	0.020465469	0.007986659
5	load	25	25	65.48950051	25.55730878	0.065489501	0.025557309
6	load	160		40.93093782	15.97331799	0.040930938	0.015973318
7	PV	100		20.46546891	7.986658995	0.020465469	0.007986659
8	load	50		20.46546891	7.986658995	0.020465469	0.007986659
9	load	50		20.46546891	7.986658995	0.020465469	0.007986659
10	load	50		20.46546891	7.986658995	0.020465469	0.007986659
11	load	50		40.93093782	15.97331799	0.040930938	0.015973318
12	PV	100		20.46546891	7.986658995	0.020465469	0.007986659
13	load	50		40.93093782	15.97331799	0.040930938	0.015973318
14	load	100		40.93093782	15.97331799	0.040930938	0.015973318
15	load	100		40.93093782	15.97331799	0.040930938	0.015973318
16	load	100		10.23273445	3.993329497	0.010232734	0.003993329
17	load	25		10.23273445	3.993329497	0.010232734	0.003993329
18	load	25		20.46546891	7.986658995	0.020465469	0.007986659
19	load	50		40.93093782	15.97331799	0.040930938	0.015973318
20	PV	100		40.93093782	15.97331799	0.040930938	0.015973318
21	PV	100		51.16367227	19.96664749	0.051163672	0.019966647
total							
T.r ratings		1535	100				

To find the power at each hour we will use this equation,

$$P_{TrN} = KVA_{RN} * \frac{P_{demand}}{sum\ (kVA_{Tr})}$$

Which KVA_{RN} is the VA at the bus at a specific hour, $sum\ (kVA_{Tr})$ is the sum for the whole buses, P_{TrN} is the distributed power at each hour for each bus. Our system consists of 21 bus, all of them connected to a 20kV radial network. The total load is 938.925 kW at its peak time. The network voltage is 20 kV. The looses of this system are 27.1 kW at normal case if we make bus 1 as our slack bus like the exsiting case.

Our system is a medium voltage system, so the best method to minimize the losses is by adding another generator to a bus, and to know the best bus which we can inject this generator, we will use the FA which will chose the best bus with the minimum losses.

Table 4-3 The values of the extra DG at each bus and the overall losses using FA.

add the generator at bus	the value of DG x(1) (kW)	losses after adding another generator (kW)
2	107	47.9733
3	474	40.3944
4	406	40.1763
5	377	39.2764
6	150	41.0236
7	157	39.4434
8	134	39.383
9	104	39.8492
10	284	24.6647
11	342	21.6301
12	330	25.6531
13	246	26.9538
14	161	32.5892
15	267	22.9981
16	267	23.0969
17	111	36.621
18	284	21.1204
19	247	23.8812
20	246	23.6068
21	210	27.3805

Table 4-3 respresnts the values of additional generator, we made our slack bus is bus 1, and we add additional generator at each bus by changing the variable x(1) in the Algorithm.

After obtaining the Firefly variables and parameters, we find that the minimun loses because of adding another generator are in busses 18, 11 and 15 with loses equal to 21.1204 kW, 21.6301 kW and 22.9981 kW repectively. And the best bus is bus 18.

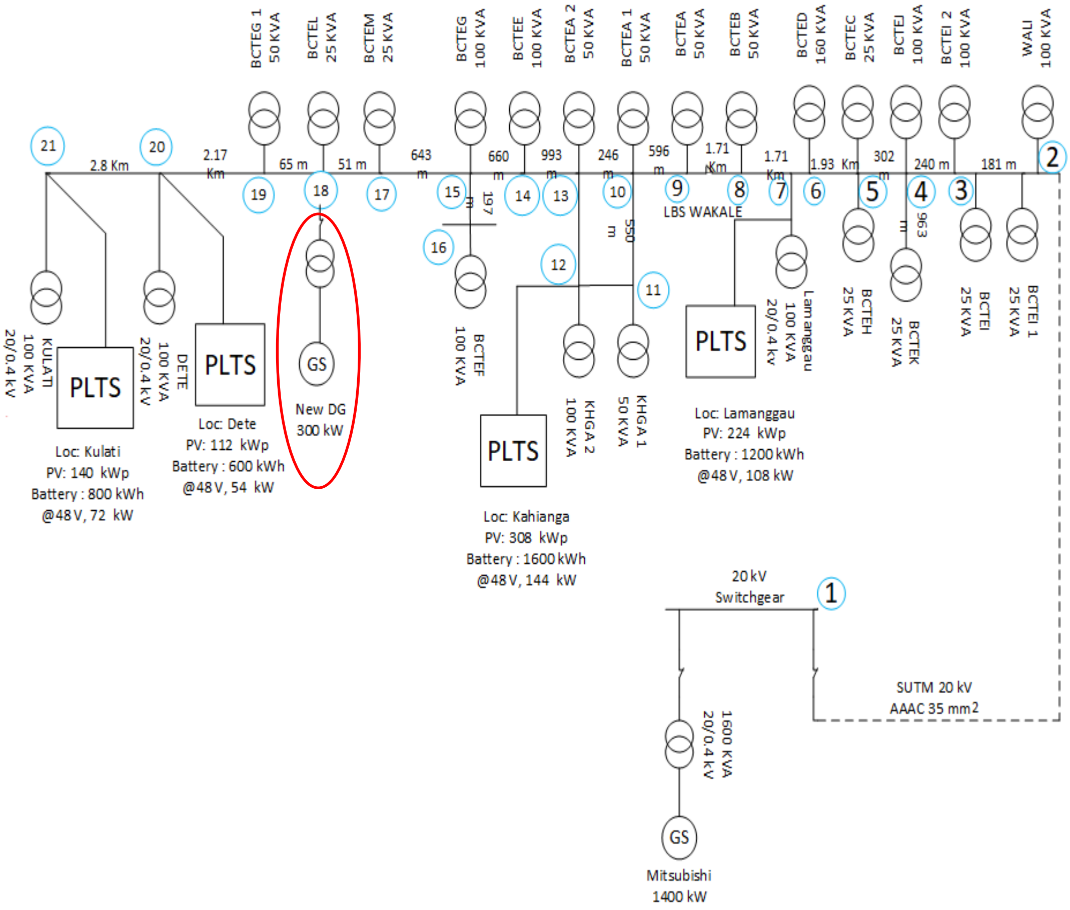


Figure 4.2 The Single Line Diagram after adding the new DG in bus 18 which can minimize the losses.

By adding this new DG, the losses will be decreased from 27.1 kW to 21.12 kW and this method as we mentioned before is the best method to be used for the radial system especially for the medium voltage networks. Some papers called this method as Losses Reduction Sensitivity Factor (LRSF) which descriped minimizing the overall losses by injecting an additional DG in the system.

Besides minimizing the losses, adding an additional DG also can minimize the overall cost of the system. This can be obtained by chosing the optimum operation of the system by calculating the output power from each source, in my system we have DG, PV and batteries, by using the FA the cost can be minimized by injecting new DG.

Table 4-4 The values of the overall looses after changing the locating of the excisting DG using FA.

add the generator at bus	looses for changing the location of the exsiting generator (kw)
2	47.3215
3	52.2531
4	52.2531
5	53.5205
6	50.1302
7	40.0335
8	57.1941
9	57.1941
10	57.1941
11	57.1941
12	58.2283
13	57.1941
14	54.1725
15	54.1725
16	54.1725
17	45.4479
18	59.1090
19	57.4343
20	42.0719
21	56.6606

To describe the values of the losses if we will change the place of the slack bus, as we mentioned before the slack bus in this system at normal case is in bus 1.so we changed the place of this slack bus to the other buses and calculate the overall losses. After using FA in the normal case, we found that the losses will be higher than the exsiting case which is the slack bus is bus 1, so the best operation for this location is to not change the location of DG.

Figure 4-3 shows the above two cases which are adding another generator to the system or changing the place of the slcak bus. Which we can notice that the losses is obviously decreased after adding another DG in the system besides the existing generator.

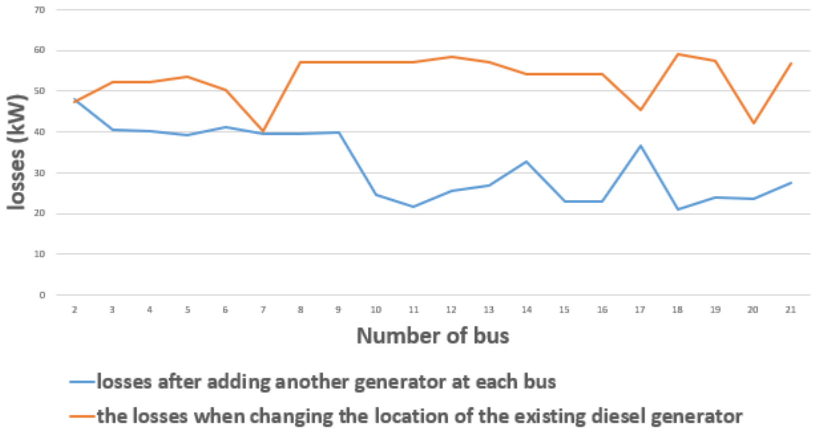


Figure 4.3 The losses at two cases 1- adding another generator to the system
2- changing the place of the slcak bus.

The next case, we add some additional loads to make a fedder reconfiguration which is a method by transfering the loads among the feeders, and this method is suitable for the low voltage side. So chosed ramdomly 4 buses bus 2, 7, 17 and 20 with additional loads equal to 200 kW, 200kW, 100kW and 100 kW respectively. Figure 4-4 explains it.

Then we will enter all of these data to the FA which it will make it's iteration and chose the minimum losses at each time we change the location of the slack bus.

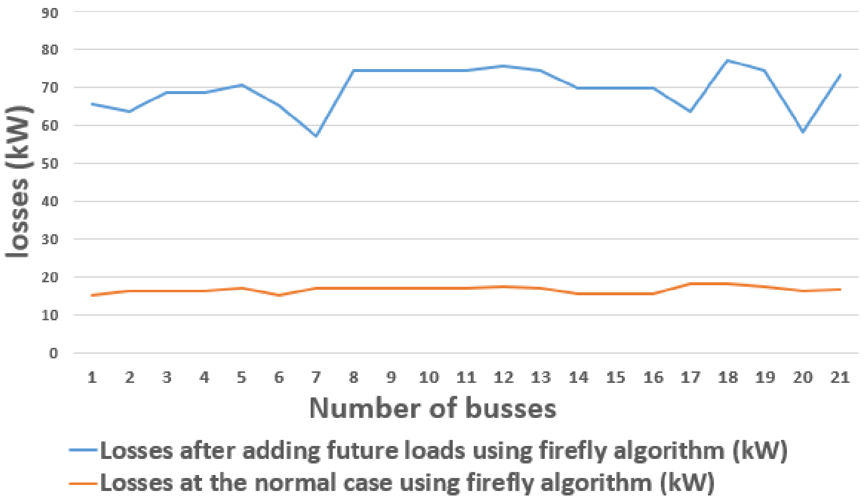


Figure 4.4 The losses at two cases 1- adding future load 2- normal case by using FA.

Table 4-5 The values of the extra DG at each bus and the overall looses after changing the locating of the excisting diesel genreator using FA.

the slack bus	losses (normal case kW)	losses (kw) after adding the additional loads
bus 1	15.2017	50.3113
bus 2	16.3348	47.3215
bus 3	16.3348	52.2531
bus 4	16.3348	52.2531
bus 5	17.0152	53.5205
bus 6	15.2592	50.1302
bus 7	17.1234	40.0335
bus 8	17.2215	57.1941
bus 9	17.2215	57.1941
bus 10	17.2215	57.1941
bus 11	17.2215	57.1941
bus 12	17.6137	58.2283
bus 13	17.2215	57.1941
bus 14	15.6782	54.1725
bus 15	15.6782	54.1725
bus 16	15.6782	54.1725
bus 17	18.1726	45.4479
bus 18	18.1726	59.109
bus 19	17.3126	57.4343
bus 20	16.3804	42.0719
bus 21	16.5798	56.6606

Table 4-5 represents the losses at two cases, the first one is at the normal case to calculate the losses using FA, the second one is the losses after adding additional loads at the buses wich mentioned above, and the figure above explains these two values.

As we can see, after adding additional loads, the lowest losses will be at buses 7, 20 and 17 with overall loses equals to 40.0335, 42.071 and 45.4479 respectively. We noticed that we add 200 kW as a future load at buses 2 and 7 but the lowest loss in bus 7 which it can be the best bus to allocate the DG in the Future.

FBSM also used to calculate the losses between each two buses, this mrthod is the normal case without using FA. The next Table 4-6 will represent the values.

Table 4-6 losses using Backward-Forward sweep method between each two buses.

	losses at normal case using backward forward method	
the slack bus	losses (p.u)	losses *100 (kW)
bus 1	0.5341	53.41
bus 2	0.0728	7.28
bus 3	0.0707	7.07
bus 4	0.0633	6.33
bus 5	0.3498	34.98
bus 6	0.0616	6.16
bus 7	0.1129	11.29
bus 8	0.1406	14.06
bus 9	0.0432	4.32
bus 10	0.0014	0.14
bus 11	0.0003	0.03
bus 12	0.1404	14.04
bus 13	0.0343	3.43
bus 14	0.0156	1.56
bus 15	0.0002	0.02
bus 16	0.0053	0.53
bus 17	0.0004	0.04
bus 18	0.0004	0.04
bus 19	0.0078	0.78
bus 20	0.0025	0.25

The next figure which is Figure 4-5 represents the looses at normal case after using FBSM.

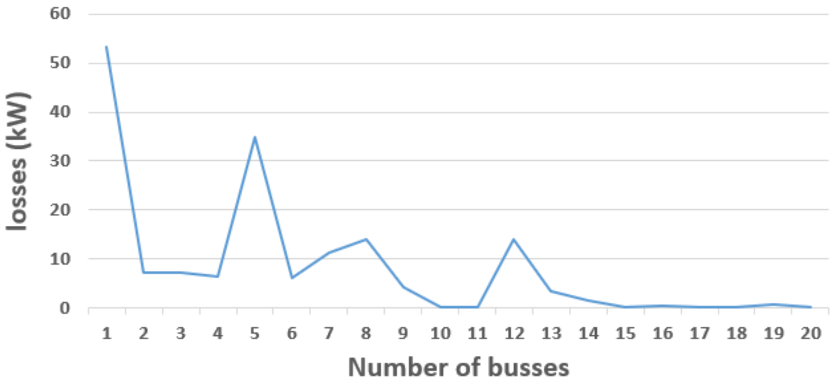


Figure 4.5 The losses using FBSM between each two buses at normal case.

4.2.1 Minimizing the Cost

To minimize the cost of the system , we will add an additional DG which our optimization method calculated it. As what mentioned in table 4-3, the best location to add an affitional DG is bus 18 because this can give us the minimum losses of the system. The value of this DG is 284 kW, so we will add a DG with a capacity equals to 300 kW in our calculations to calculate the overall cost of the system. Table 4-7 explaines the values of cost before and after adding the DG.

Table 4-7 Cost after and before adding additional DG.

	cost before add DG	cost after adding new DG (300 kW)		cost before add DG	cost after adding new DG (300 kW)
0	429.17316	103.282	12	3586.221643	3436.678
1	398.239388	56.313	13	3381.771024	3030.414
2	401.648662	61.506	14	2846.045061	2584.024
3	409.406635	73.242	15	2042.464019	1694.495
4	474.745696	172.353	16	1080.079078	750.637
5	956.822964	572.138	17	581.352487	334.032
6	1846.371873	1616.423	18	606.287146	371.876
7	2700.851188	2209.9047	19	579.634009	331.447
8	3227.119596	2879.628	20	555.555516	294.906
9	3467.66	3146.564	21	514.303841	232.341
10	3512.121022	3470.26	22	476.460126	174.95
11	3566.450125	3470.985	23	448.095183	131.92

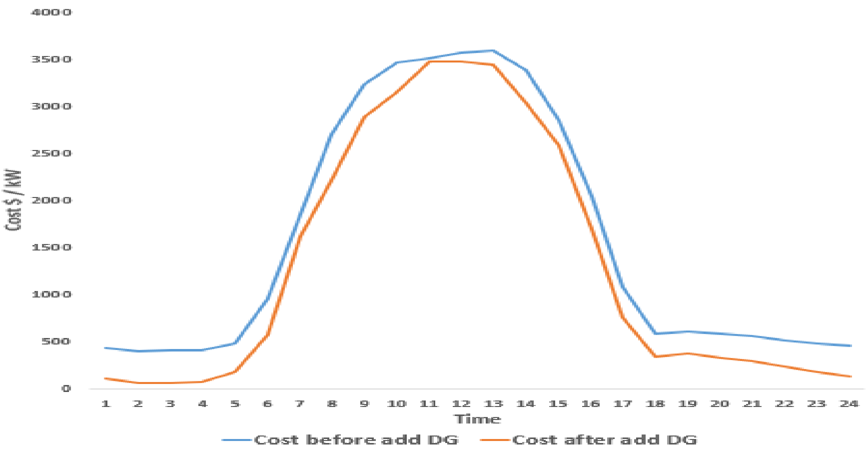


Figure 4.6 The cost before and after adding additional DG.

Figure 4-6 shows the effect of adding another DG in bus 18 on the overall. cost of the system, this additional DG minimizes the cost of the system besides minimizing the losses which is already mentioned above.

4.2.2 Cost Calculations

To minimize the Cost, we will use FA to calculate it, our input data will be the hourly solar radiation by using Liu and Jordan method because the solar radiation formula requiring the hourly solar radiation data.

In our constraints, in the normal case (DG, PV and batteries) we make the solar cells give its maximum output power because it is a free power which we can exploit and also to decrease the burden on the generator.

So our constraints are :

inequality constraints
g(1)=x(1)-(0.3*1400);

equality constraints
geq(1)=(0.3*x(1))+x(2)+x(3)-load(i);
geq(2)= x(2)-PV_out(i);

Figure 4-7 represents the cost of the DG with PV and batteries using FA considering only the initial cost without the operation and maintenance costs.

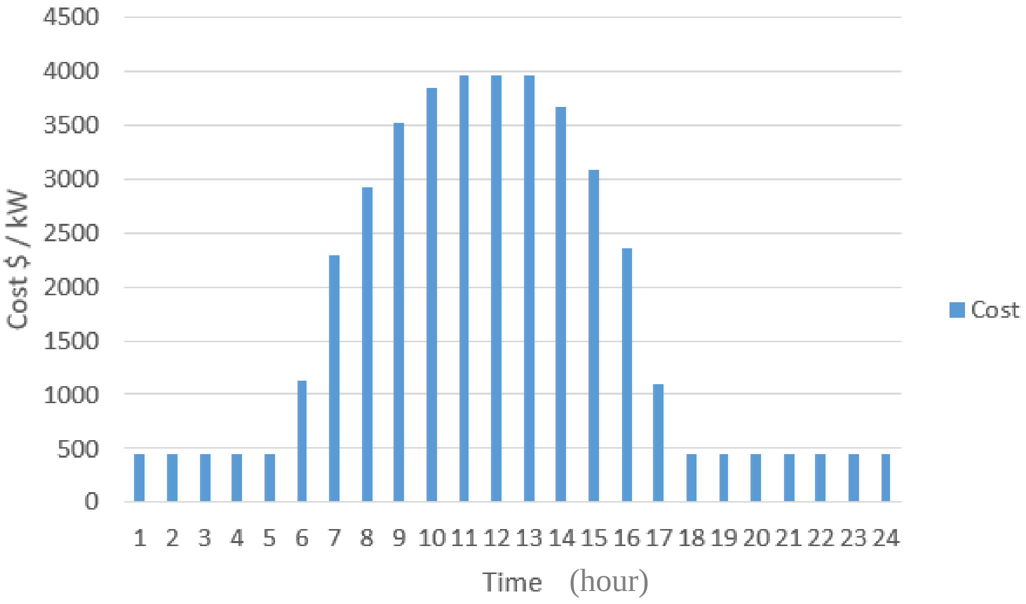


Figure 4.7 The cost of the DG with PV and batteries considering only the initial cost without the operation and maintenance costs using FA.

We can find that the huge difference between the initical cost of the PV and the DG. The time from 06:00 untill 17:00 is the operatiing time of the PV.

And Table 4-8 shows the values of the initial cost without the operation and maintenance costs.

Table 4-8 The cost during 24 hours working of the DG with PV and batteries considering only the initial cost without the operation and maintenance using FA.

hour	Cost $ / kW
1	429.17316
2	398.239388
3	401.648662
4	409.406635
5	474.745696
6	956.822964
7	1846.371873
8	2700.851188
9	3227.119596
10	3467.66
11	3512.121022
12	3566.450125
13	3586.221643
14	3381.771024
15	2846.045061
16	2042.464019
17	1080.079078
18	581.352487
19	606.287146
20	579.634009
21	555.555516
22	514.303841
23	476.460126
24	448.095183

We can see that the initial cost of the PV is more higher than the DG initial cost, the PV initial cost equal to 5600 $/kW, so the price of the PV cells in our case study equals to $= 5600\ (\frac{\$}{kW}) * 784(kWp) =\ 4.390.400\ \$$.

On the other hand the initial cost for the DG equals to 260 $/kW [54] .but in the long term the fuel cost of the DG is more higher than the maintenace cost of the PV with batteries. Normally Mitusubishi DG use 315 litter/hour of fuel (Mitsubishi DG data sheet_ model MGS1200BMG) with a cost equals to 1.4 $/L (Diesel Fuel price) [52], so for one years operation the DG will consume around $= 315 * 24 * 30 * 12 * 1.4 = 3.810.240$ $ which is more than 3.8 million dolars only for the fuel price of one year operation of DG. Which is a very big number comparable with maintenace cost of the PV.

The price of the DG 1.4 MW normally equal to 364.000 $, so the total cost of the DG including the initial, maintenance and operational cost equal to $= 3.810.240 + 364.000 = 4.174.240$ $, the difference can be shown in Figue 4-8 wich explain the dimishing of the difference between the PV, Batteries and DG when we add the fuel consumbtion cost for one year in our calculation using FA.

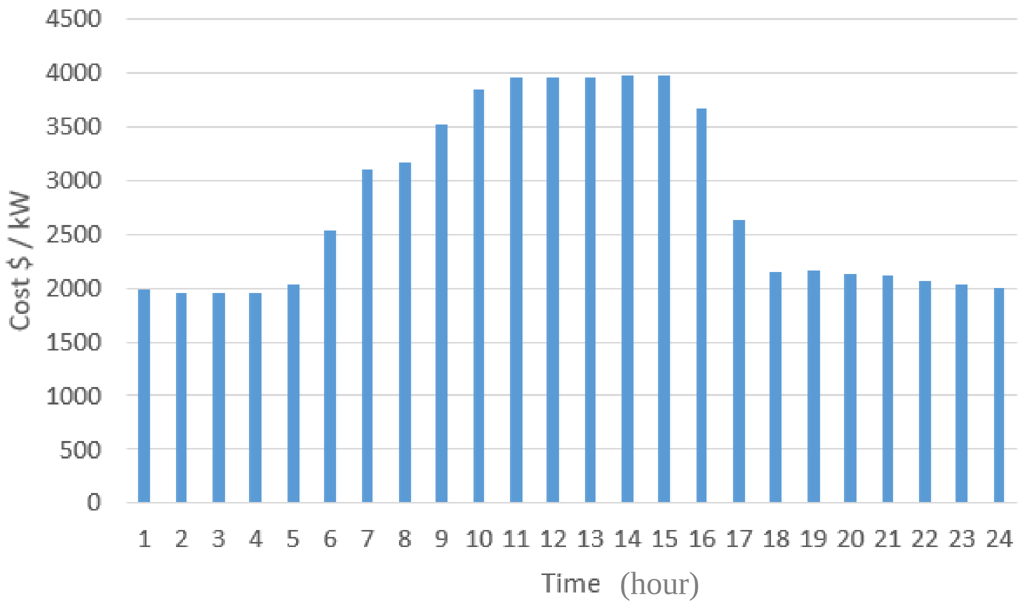


Figure 4.8 Represents the cost of the DG with PV and batteries using FA after one year operation.

If the DG will work for five years, the fuel price of the DG will increase, it will equal to $= 315 * 24 * 30 * 12 * 5 = 19.051.200$ $. The DG will consume fuel with a price equals to 19.05 million dollars in 5 years opertion which is a very very huge number comparable to the maintenance and the operation cost of the PV with batteries in the same 5 years. Figure 4-9 shows that the maintenance and the operation cost after 5 years of the DG during its working hours which is normaly at night will be more higher that the maintenece and the operation cost of the PV during its working hours which is normaly at day time from 00:07 untill 15:00 and it will be decreased during the peak irradiance hours.

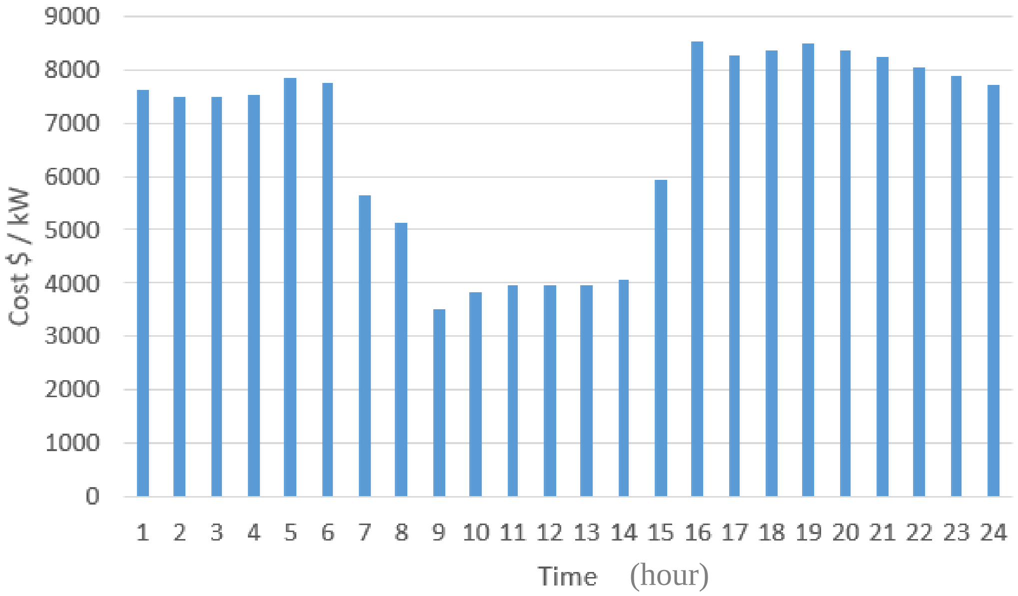
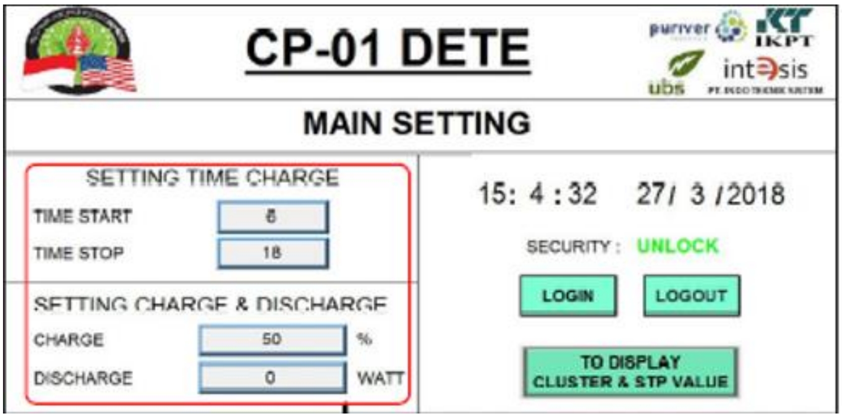


Figure 40.9 Represents the cost of the DG with PV and Batteries using FA after 5 years operation.

4.3 The Optimum output power from PV, DG and Batteries Using FA

In our system, DG, PV and batteries are working all with each other to provide the electricity to the load. At the beginning the load was covered only by the DG, then the PV and batteries joined the system to provide electricity for the load. And the operation of the system was designed to make the charge time of batteries start from 6 am until 6 pm (18:00) with a 50 % charging time. Figure 4-10 Explains it for the battery setting in the location of Dete .

So we will try to find the optimum operation hours of these batteries in all location which can give us the best performance with the minimum cost. In this study, we will use FA to make this optimization process and trying to decrease the charging time of these batteries with the highest performance.


CP-01 DETE

MAIN SETTING

SETTING TIME CHARGE

TIME START 6

TIME STOP 18

SETTING CHARGE & DISCHARGE

CHARGE 50 %

DISCHARGE 0 WATT

15: 4 : 32 27/ 3 /2018

SECURITY : UNLOCK

Figure 4.10 The Setting time charge and setting charge and discharge percentage of Dete site.

In this research, we used FA to choose the optimum operation scenario of the hybrid DG, PV and batteries which can give us the minimum cost with the best output power percentages from all sources to cover the load. Figure 4-9 explains the output power from the PV, DG and batteries to give us the optimum operation with minimum cost.

For our constraints, PV constraints are limited with the PV inverter rating in Table 4-9. DG cannot work below 30% of its full load power. And battery limits are the inverter limits which is 378 kVA, we will estimate the P.F equal to 1.the DOD equal to 0.10 of the rated value.

Table 04-9 The ratings of the inverters, PV and batteries at each location

Location	PV Grid-Connected			Bidirectional Inv & Battery	
	PV (kWp)	Grid Inverter (kVA)	Est. Energy Yeild (kWh)	Battery Inverter (kVA)	Battery Cap (kWh) @ 48V
Kahaianga	309	275	926	144	1612
Kulati	140	125	421	72	806
Dete	112	100	337	54	605
Lamanggau	224	200	673	108	1209
sum	785	700	2356	378	4232

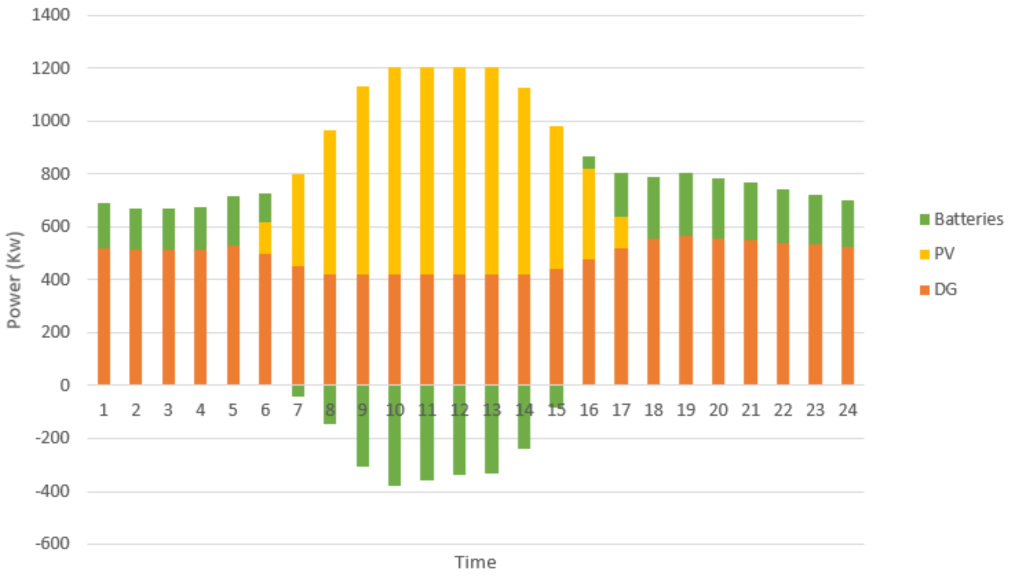


Figure 4.11 The optimum output power from PV, DG and batteries using FA.

In Figure 4-11, we can see the PV power will be at its maximum during the day time because of the MPPT control system used there, it will be at its peak radiation from 8 am until 3 pm. At this time the DG will working with its minimum capacity and the batteries will be in charging mode which we can see the power is negative value in Figure 4-11. So best charging time which can give us the optimum operation of the system with the minimum cost will be from 7 am until 3 pm, and the best time to make the DG works with 30% of its capacity is from 8 am until 3 pm instead of the existing DG when it was turning off, and this explained before in Figure 1-9. Table 4-9 shows a comparison of the operation system time in Tomia before and the optimum operation system after using FA.

Table 4-10 Comparison of the operation system between the existing operating system and the optimum operating system after using the FA.

	The Existing operating system	The Optimum operating system after using FA
DG	Off time 00:07 to 14:00	Working with 30% of its F.L. capacity 00:08 to 15:00
Charging time of Batteries	00:06 to 18:00	00:07 to 15:00

From the results in Table 4-10 we can make these changing from switching off the DG to work with 30% of its full load capacity at a specific time and control battery charging time, these changing will lead us to the optimum operating time with the minimum cost which can cover the load perfectly.

The optimum operating system power values using the FA iteration method for the PV, DG and the batteries is explained in Table 4-11.

Table 4-11 The values of the optimum power from batteries, DG and PV after using FA.

Time	Battery (kW)	DG (kW)	PV (kW)
00:01	168.270561	520.956752	0
00:02	155.825475	513.479388	0
00:03	157.196906	514.319343	0
00:04	160.318116	516.188066	0
00:05	186.605096	531.965716	0
00:06	105.662298	497.050305	121.948889
00:07	-41.4725810	452.902112	345.898874
00:08	-147.452601	421.112125	545.376821
00:09	-308.305288	420.000000	710.30601
00:10	-378.000000	420.000000	784.000000
00:11	-359.999586	420.000000	784.000000
00:12	-338.003998	420.000000	784.000000
00:13	-329.999335	420.000000	784.000000
00:14	-239.632189	420.000000	707.632595
00:15	-83.7421480	440.224887	543.114700
00:16	47.4271420	479.592885	341.580279
00:17	165.586295	519.342500	117.424647
00:18	229.494842	557.701013	0
00:19	239.526497	563.719134	0
00:20	228.803539	557.279483	0
00:21	219.116325	551.469011	0
00:22	202.520049	541.512289	0
00:23	187.294834	532.380268	0
00:00	175.883272	525.519262	0

Explains the optimum output power from the DG, PV and the batteries by calculating the power generated form the 4 PLTS PV farms and calculating the charging and the discharging power of the batteries using the FA. Figure 4-12 explains it.

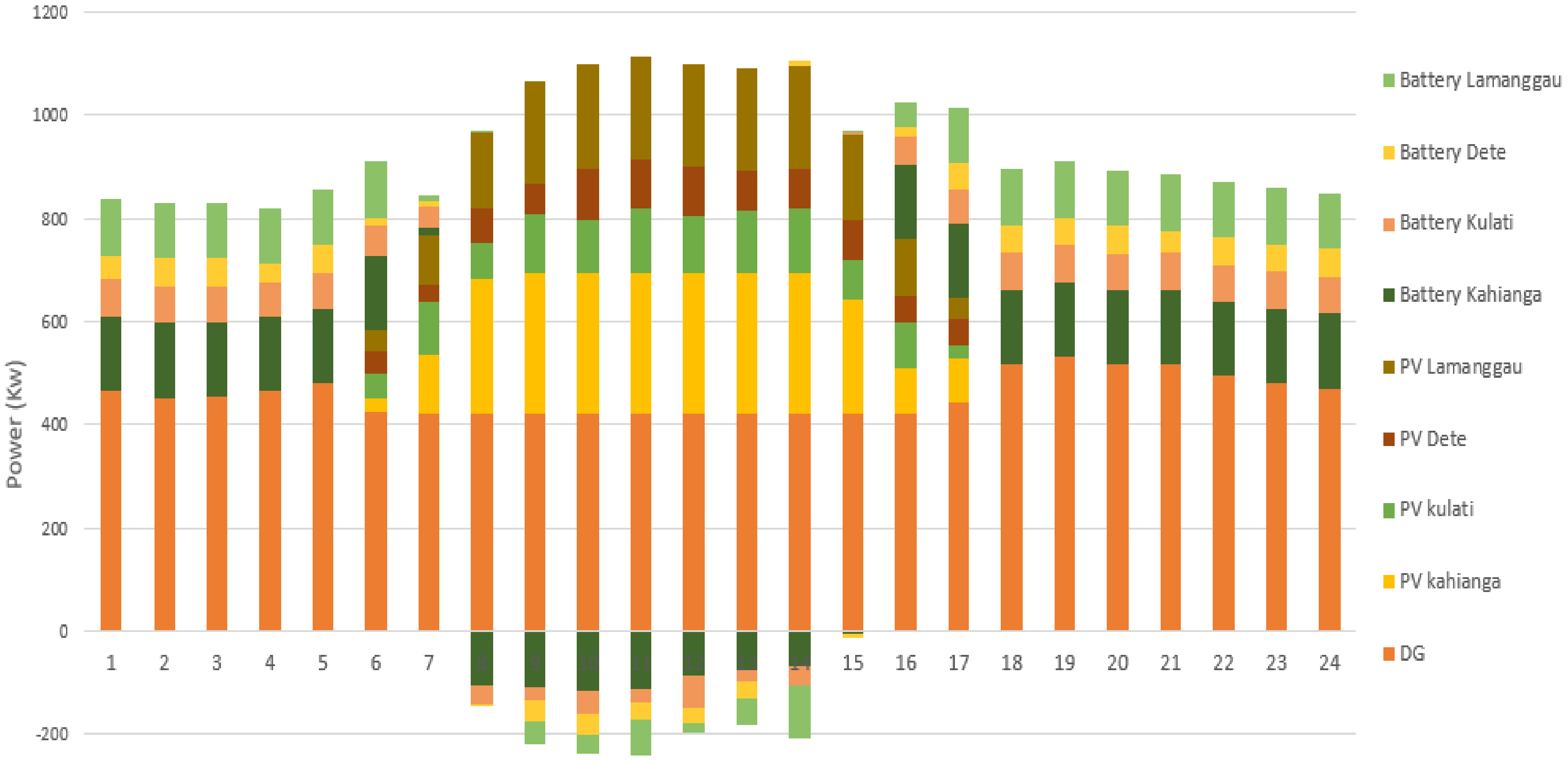


Figure 4.12 The optimum output power from DG, the four PV locations (Kahianga, Kulati, Dete, Lamanggau) with the batteries at the four locations using FA.

4.4 CO_2 Emissions Calculation

To calculate the CO_2 Emissions, we can use many methods, one of them is the manual one and already mentioned in chapter 3 by using this equation

$$Cons = B * P_{NG} + A * P_{OG}$$

So the $Cons = 0.08145 * 1400 + 0.246 * (0.85 * 1400)$

$$= 114.03 + 292.74 = 406.77\ L/h$$

Normally DGs work from 80% to 85 % of its rated power. That’s why we multiply the rated power by 0.85 to give us the output power at full load operation. And 1 litter of CO_2 = 2640 grams of CO_2 = 2.64 kg CO_2 as what mentioned in chapter 3.

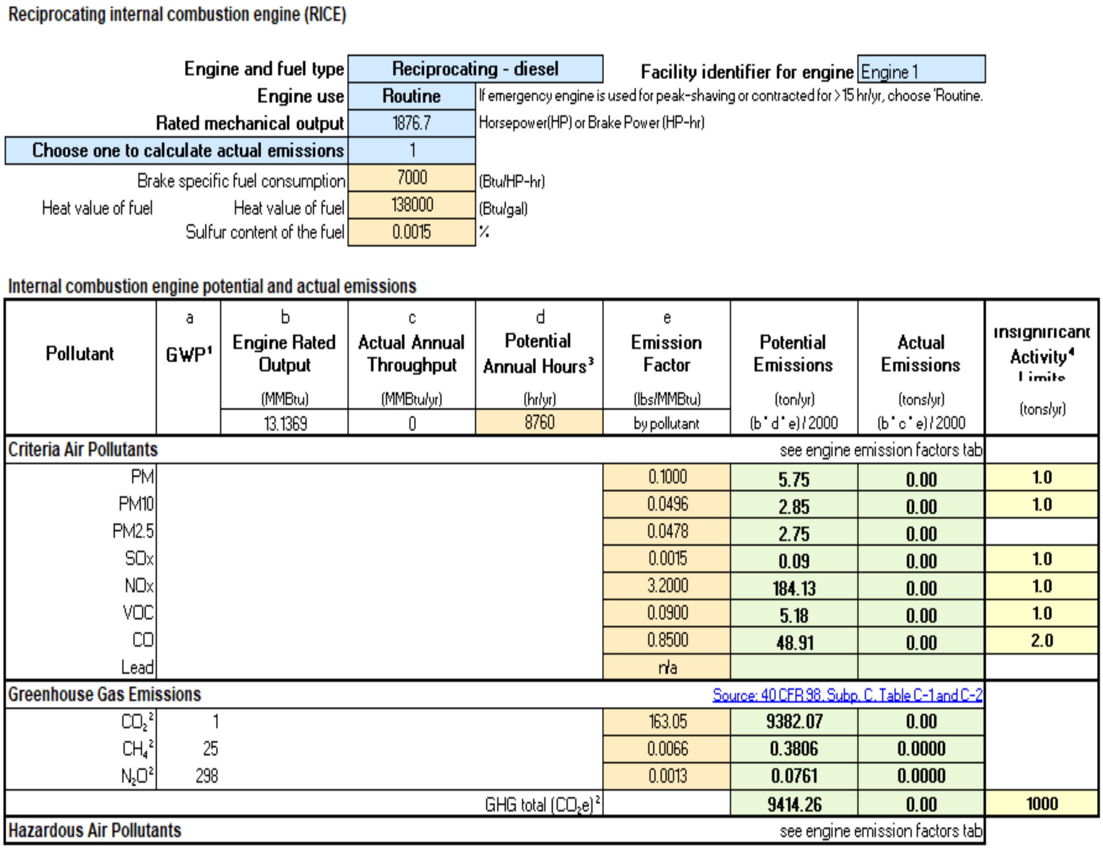
So $Cons = 406.77\ L/h = 406.77 * 2.46\ kg/h = 1000.65\ kg/h$

To calculate it per year

$$Cons = 1000.65 * \frac{8760}{1000} = 8756.73\ ton/year$$

Another method can be used to calculate the CO_2 emissions by using Minnesota Pollution Control Agency, which is a method to calculate the all pollution from Internal combustion engines like DGs. It can calculate CO_2, CH_4, N_2O and many other pollutants. Like in Figure 4-11. As we can see the CO_2 emissions using Minnesota Pollution Control Agency table will equal to 9382.07 ton/year which is almost the same by using the formula mentioned before.

We can eliminate the using of the DG by making the location in Tomia almost free generating CO_2 emissions. As we know in calculating the CO_2 emission, there are CO_2 emissions produced during the manufacturing process, so we have to consider these emissions in our calculations



Reciprocating internal combustion engine (RICE)

Engine and fuel type	**Reciprocating - diesel**	**Facility identifier for engine** Engine 1
Engine use	**Routine**	If emergency engine is used for peak-shaving or contracted for > 15 hr/yr, choose 'Routine.
Rated mechanical output	1876.7	Horsepower(HP) or Brake Power (HP-hr)
Choose one to calculate actual emissions	1	
Brake specific fuel consumption	7000	(Btu/HP-hr)
Heat value of fuel Heat value of fuel	138000	(Btu/gal)
Sulfur content of the fuel	0.0015	%

Internal combustion engine potential and actual emissions

Pollutant	a GWP^1	b Engine Rated Output	c Actual Annual Throughput	d Potential Annual Hours^3	e Emission Factor	Potential Emissions	Actual Emissions	Insignificant Activity^4 Limits
		(MMBtu)	(MMBtu/yr)	(hr/yr)	(lbs/MMBtu)	(ton/yr)	(tons/yr)	(tons/yr)
		13.1369	0	8760	by pollutant	(b * d * e) / 2000	(b * c * e) / 2000	
Criteria Air Pollutants						see engine emission factors tab		
PM					0.1000	**5.75**	**0.00**	**1.0**
PM10					0.0496	**2.85**	**0.00**	**1.0**
PM2.5					0.0478	**2.75**	**0.00**	
SOx					0.0015	**0.09**	**0.00**	**1.0**
NOx					3.2000	**184.13**	**0.00**	**1.0**
VOC					0.0900	**5.18**	**0.00**	**1.0**
CO					0.8500	**48.91**	**0.00**	**2.0**
Lead					n/a			
Greenhouse Gas Emissions						Source: 40 CFR 98, Subp. C, Table C-1 and C-2		
CO_2^2	1				163.05	**9382.07**	**0.00**	
CH_4^2	25				0.0066	**0.3806**	**0.0000**	
N_2O^2	298				0.0013	**0.0761**	**0.0000**	
				GHG total (CO_2e)^2		**9414.26**	**0.00**	**1000**
Hazardous Air Pollutants						see engine emission factors tab		

Figure 4.13 CO_2 emission using Minnesota Pollution Control Agency method.

The CO_2 emissions during equipment manufacture are subdivided into: [44]

1- emissions accompanying energy consumption during the manufacture of the materials used,

2- emissions accompanying energy consumption during assembly in the factory, and

3- emissions accompanying energy consumption during transportation (distribution) of materials and system equipment.

Table 4-13 is the energy consumption of CO_2 emissions during the equipment manufacturing, so these values are the CO_2 emissions values which will be produced from the manufacturing machines in the process of manufacturing PV, wind generator, battery and DG.

Table 4-12 CO_2 emissions during the manufacturing process of PV, wind generator, battery and DG.

System equipment	Facility energy	CO2 emissions
Photovoltaic modules	0.721MWh/kW×y	0.267t-CO2/kW×y
Wind generator	0.215MWh/kW×y	0.069t-CO2/kW×y
Battery	0.207MWh/kWh×y	0.062t-CO2/kWh×y
DG	0.235MWh/kW×y	0.066t-CO2/kW×y

In our case study, we have four photovoltaic farms with a total PV o/p peak power equal to 784 kWp, the CO_2 emission due to the Photovoltaic modules manufacturing process equal to = 0.267*784 = 209.328 ton/year.[44]

4.4.1 The overall CO_2 emissions for our case study

So, the overall CO_2 emission in our case study which is the sum of CO_2 from DG and the Photovoltaic modules manufacturing process = 8756.73 + 209.328 = 8966.056 ton/year.

4.4.2 The CO_2 emissions for PV and Wind case study without DG

For the case which we will eliminate he using of the DG and only use PV with wind to cover the whole load in Tomia island, the CO_2 emission for the manufacturing process of the wind turbine as it mentioned in the table above equal to.

CO_2 of the wind turbine = 0.069 * 1400 = 96.6 ton/year

So, the overall CO_2 from the PV and wind turbine equal to = *96.6 + 209.328 = 305.928 ton / year*

4-5 Using Wind turbine instead of DG

When we use wind turbine instead of the DG in our system, the reason for this is to reduce the CO_2 emission level as what mentioned in 4.4.1 and 4.4.2, we noticed the big difference in the two cases which the CO_2 emission will decrease from 8966.056 ton/year in the case of using DG to 305.928 ton/year in the case of wind turbine. For the type which we have to use, the DG in this system is 1.4 MW (Mega Watt) so we have to find a suitable size of wind turbine which can generate the same amount of electricity in the system. We will choose General Electric wind turbine model with a 1.5 MW onshore (General Electric GE 1.5sle) with a diameter of 77 m/s, swept area equal to 4657 m^2, 3 blades, type is spur/planetary, manufacturer (Winergy-Eickhoff-Bosch), with a generator double fed asynchronous generator with 1500 rpm and 50 Hz.

The power flow calculations will not have the big change from the DG case because the wind turbine will generate the same amount of the active and reactive powers with the same load like in the DG case. But the change will be in the maintenance and operation cost of the system with the presence of the wind turbine.

The cost of General Electric GE 1.5sle onshore wind turbine model as in the market at the range of 2.5 to 3.5 million dollars, we will estimate it equal to 3 million dollars. The location of Tomia is in the ocean, so the wind speed there is faster than Wakatpoi, as an example the wind speed in Wakatopi is 2 or 3 m/s, the wind speed in Tomia at the same time is 7or 10 m/s. to calculate the wind speed we used the online speed data from https://www.ventusky.com/ and we choose several days randomly at different months, then we calculated the mean for only 24 hours operation. Figure 4-12 shows the mean wind speed values at Tomia island.

As we can see in Figure 4-14 the fluctuation of the wind speed will make difference of the power form the system, it is not a stable system and the wind there changes continuously. Because of the fluctuation of the wind speed, Figure 4-15 explains the effect of this fluctuation of the system power using FA, we can find some times the generated power from the wind turbine be high at a specific time and after one hour the power will decrease. This make a change in the situation of the batteries from charging and discharging in different time and randomly. But generally, as what mentioned before the wind speed in Tomia is high and enough for generating electricity to cover the load demand at any time.

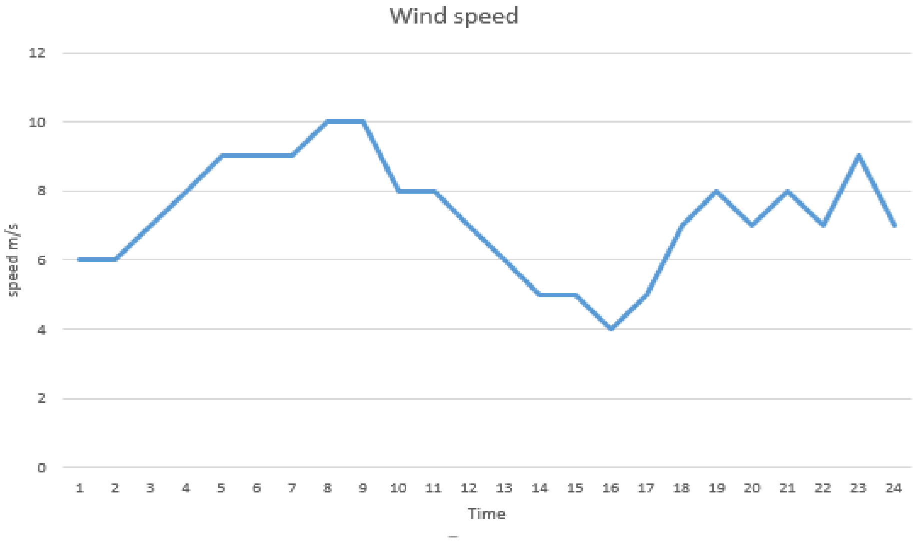


Figure 4.14 The mean wind speed values of different days at different months at Tomia island.

In our case, the cost of PV is higher than the cost of the wind turbine as what explained before, but both of maintenance and operating costs for both of them are small comparable to the Fuel cost in the case of using DG. In the long-term

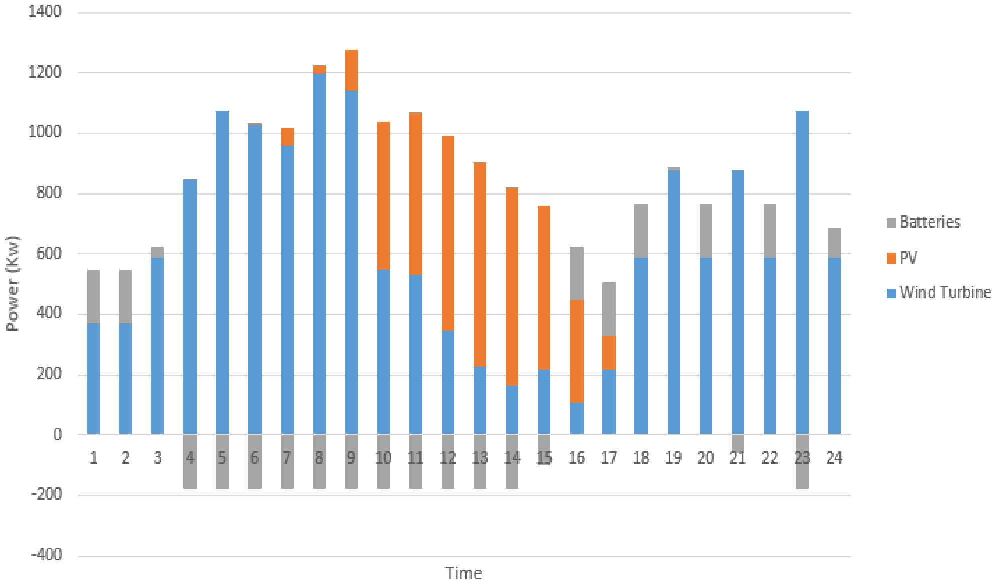


Figure 4.15 The power management of wind turbine, PV and batteries in Tomia island using FA.

The new renewable energy system which includes wind turbine and PV with batteries are cheaper than the case of using DG and PV with batteries like what explained before in Figure 4-7. Figure 4-16 explains the cost of the case of using wind turbine, PV and batteries with respect to the initial, maintenance and operating costs.

The cost of this hybrid system using wind turbine instead of the DG will not change too much in the future because the maintenance and the operation cost for wind turbine and for PV with batteries are not that big which can change the values in the Figure 4-11. So, this figure will still at this shape during the operation in the long-term using wind turbine.

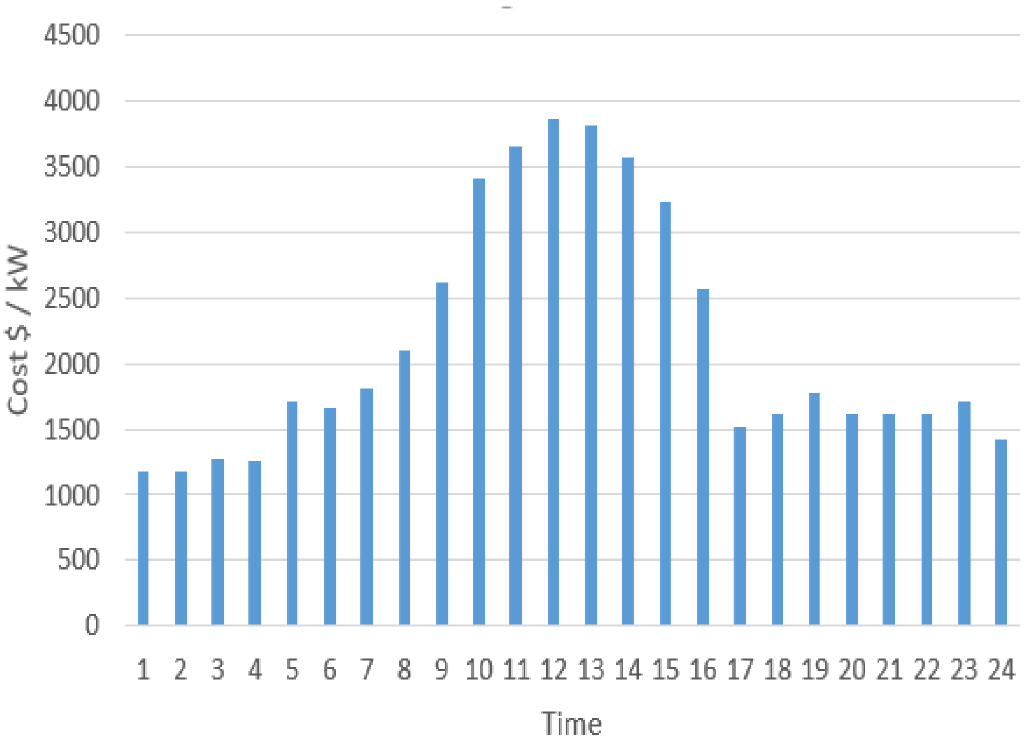


Figure 4.16 The cost of the initial, maintenance and operating costs of wind turbine, PV and batteries in Tomia island using FA.

Figure 4-17 explains the optimum output power from the DG, PV and the batteries by calculating the power generated form the 4 PLTS PV farms and calculating the charging and the discharging power of the batteries using the FA.

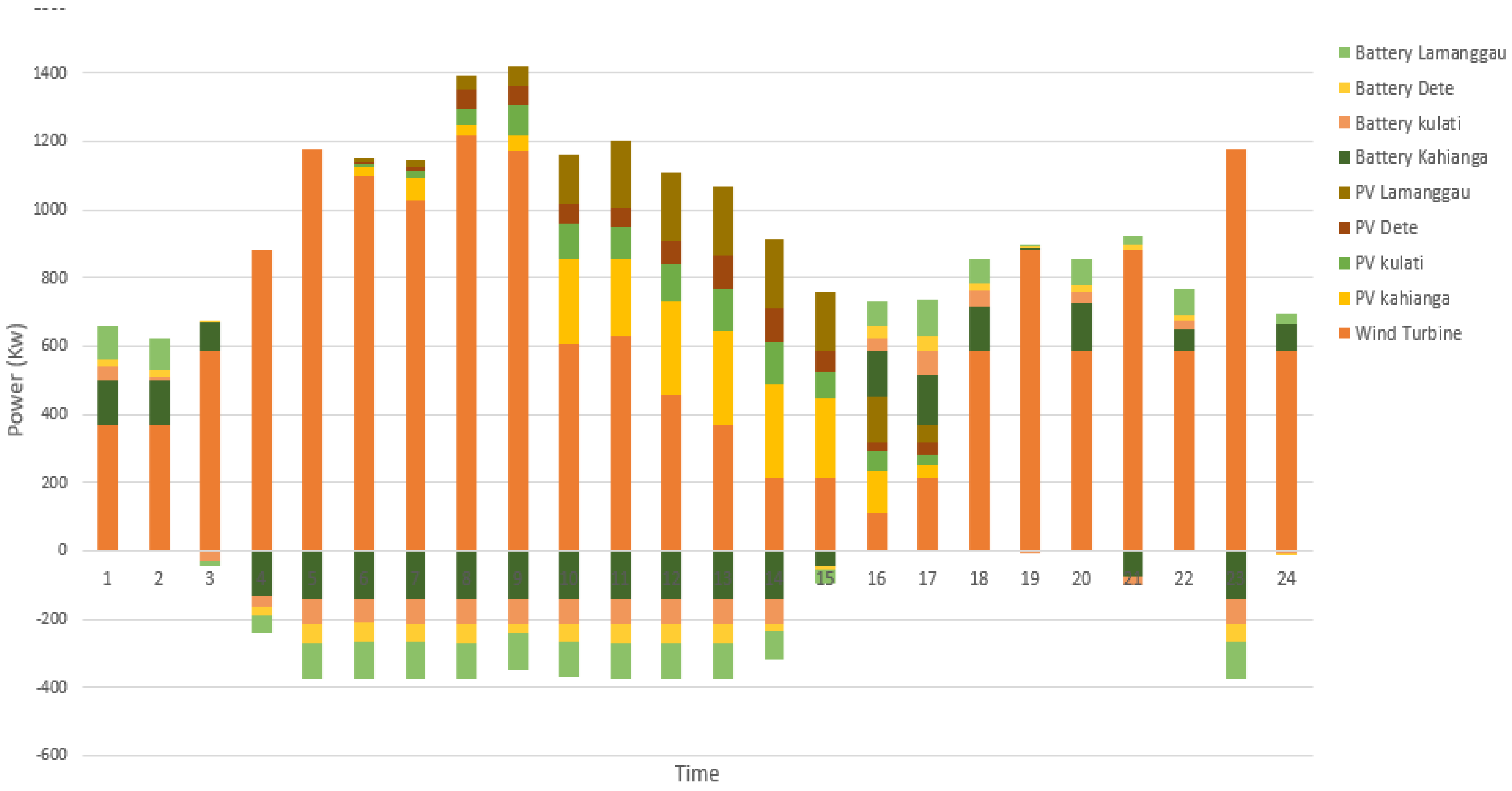
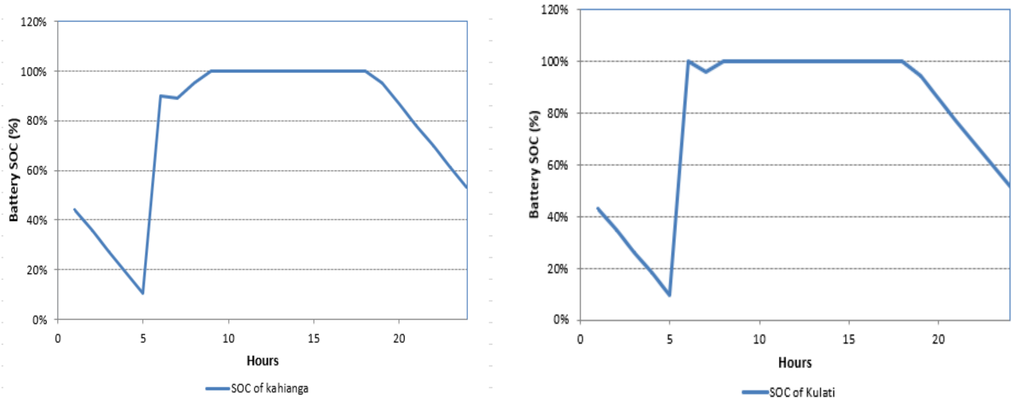
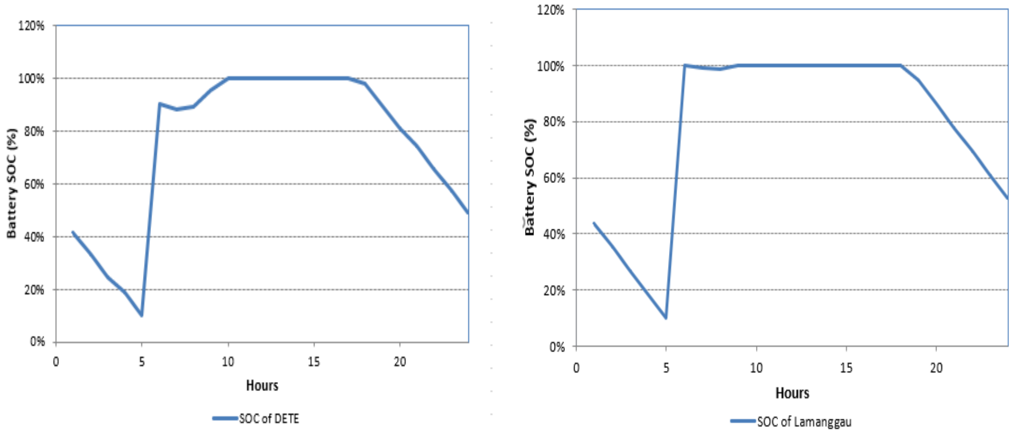


Figure 4.17 The optimum output power from wind turbine, the four PV locations (Kahianga, Kulati, Dete, Lamanggau) with the batteries at the four locations using FA.

The state of charge is different for PLTS battery system, in the case of DG, PV with batteries, the depth of charege of the batteries has to not be lower than 10% of its capacity. Figure 4-18 explaines the SOC curves for the four batteries locations at the four PV farms in Kahianga, Kulati, Dete and Lamanggau.



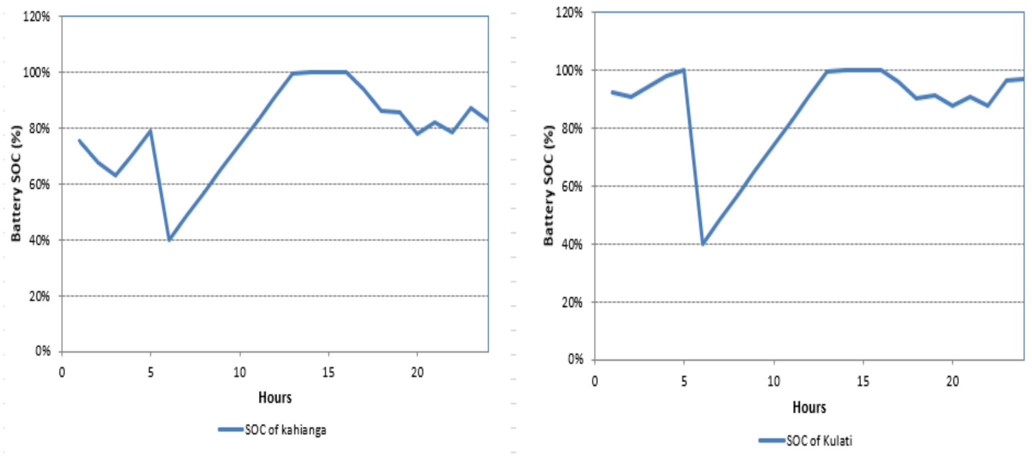
SOC of Kahianga SOC of Kulati



SOC of Dete SOC of Lamanggau

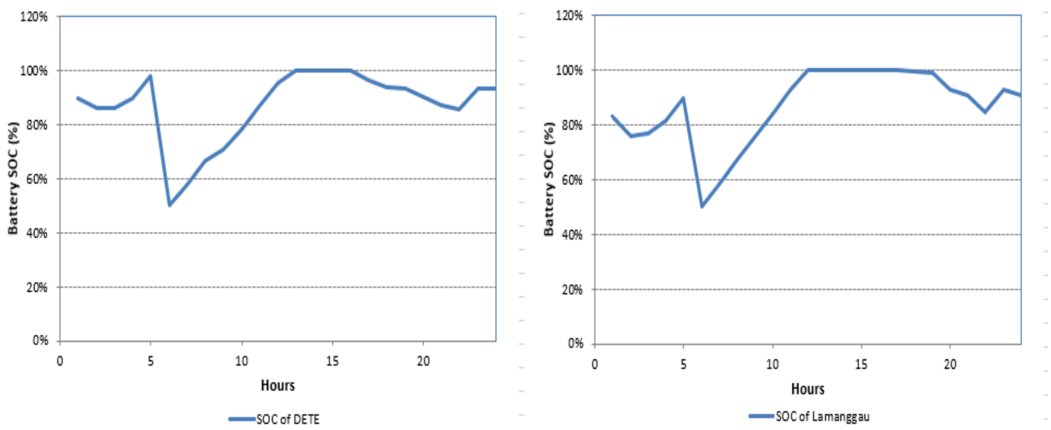
Figure 4.18 The SOC of the four batteries at the four PLTS locations in the case of DG, PV with batteries.

These batteries in these four places have to be minimally energized at the intial time of charging which is 06:00 am with a 90% for Kahianga, 100% for Kulati, 100% for Dete and 100% for Lamanggau.



SOC of Kahianga

SOC of Kulati



SOC of Dete

SOC of Lamanggau

Figure 4.19 The SOC of the four batteries at the four PLTS locations in the case of wind turbine, PV with batteries.

Figure 4-19 is the SOC of the four battery systems at the four PLTS locations, but in this case is the case of using wind turbine instead of DG as the source of generation. At the initial operation of the batteies, these batteries have to has minimum amount of energy then it will charge and discharge according to theamount of the generation and the load at each our. Out initial charging time is 00:06 am, the minimum energy percentagies at the initila charging time are 40% for Kahianga, 40% for Kulati, 50% for Dete and 50% for Lamanggau.

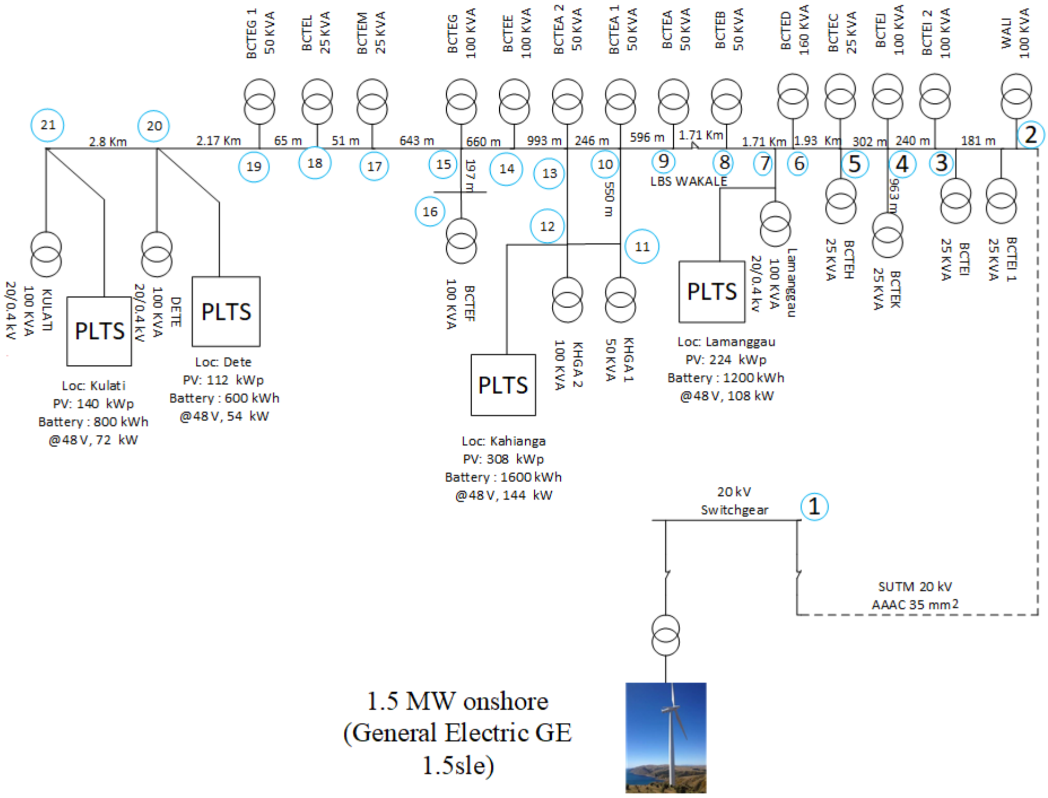


Figure 4.20 The Single Line Diagram of the future system in Tomia after adding wind turbine instead of DG.

Figure 4.20 shows the new Single Line Diagram of tomia system if we will use a wind turbine instead of DG, so we will put the wind turbine in bus 1 instead of the exsiting DG.

CHAPTER 5

CONCLUCIONS AND FUTURE WORKS

5.1 Conclusion

In this research we used FA to find the optimum operating scenario of DG, PV and batteries in Tomia island case study. Besides minimizing the losses and the cost of the same case study. To calculate the hourly solar irradiance, we used Liu and Jordan statistical method in our calculations, also used Backward-Forward Sweep method to calculate the losses then enter it with the FA to find the minimum losses. In addition calculate the CO_2 emissions in the system with DG and without using DG, we made a study to replace the DG in the location with a wind turbine to decrease the level of CO_2 emissions and the other emissions in Wakatopi is a national park and famous with its purity and contains one of the richest marine biodiversity on earth. In DG case we follow the requirements constraints like making the DG only cover 30% of the total load and many other constraints explained in the optimization procedures.

5.2 Recommendations

After making this research, the recommendation for the best optimize operating system list as follow.

a. For the best operating scenario of DG, PV with batteries system we have to change the turn off time of the DG from (00:07-14:00) to make the DG run with 30% of its full load power from (00:08-15:00) which can give us the minimum operating cost, also for the charging time of the batteries from (06:00-18:00) to (07:00-15:00).

b. To add another generator in the system to minimize the overall losses in the system, the best bus to add it is bus 18 and the size of the DG not less than 284 kW.

c. After using the Firefly, if we will change the location of the DG in our case from bus 1 the losses will increase more the existing situation, so we recommend to not change the location of the existing DG.

d. We recommend to use wind turbine instead of DG in this location because the availability of the wind speed which is between 4 m/s until 10 m/s at normal conditions, and decreasing of the cost in the long run which the fuel cost of the DG for only 5 years is more than 19 million dollars. Which is a very big number comparable of the initial, maintenance and operational costs of the wind turbine in the system.
e. In the case of using wind turbine instead of DG, the initial energy of the batteries at the 4 PLTS farms have to be 40% for Kahianga, 40% for Kulati, 50% for Dete and 50% for Lamanggau from its capacities.

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APPENDIX 1

%---------------- Line Data --------------			
Branch		Branch Impedence	
bus	bus	r	x
1	2	1.05	0.295
2	3	0.19005	0.053395
3	4	0.252	0.0708
4	5	0.3171	0.08909
5	6	2.0265	0.56935
6	7	0.525	0.1475
7	8	1.26	0.354
8	9	1.7955	0.50445
9	10	0.6258	0.17582
10	11	0.5775	0.16225
11	12	3.591	1.0089
12	13	0.2583	0.07257
13	14	1.04265	0.292935
14	15	0.693	0.1947
15	16	0.20685	0.058115
16	17	0.67515	0.189685
17	18	0.05355	0.015045
18	19	0.06825	0.019175
19	20	2.2785	0.64015
20	21	2.94	0.826

APPENDIX 2

bus	the main of the total load per hour		the main of the total load per hour	
	P (active power) (kW)	Q (reactive power) (kW)	P (p.u)	Q (p.u)
1	51.16367227	19.96664749	0.051163672	0.019966647
2	51.16367227	19.96664749	0.051163672	0.019966647
3	51.16367227	19.96664749	0.051163672	0.019966647
4	20.46546891	7.986658995	0.020465469	0.007986659
5	65.48950051	25.55730878	0.065489501	0.025557309
6	40.93093782	15.97331799	0.040930938	0.015973318
7	20.46546891	7.986658995	0.020465469	0.007986659
8	20.46546891	7.986658995	0.020465469	0.007986659
9	20.46546891	7.986658995	0.020465469	0.007986659
10	20.46546891	7.986658995	0.020465469	0.007986659
11	40.93093782	15.97331799	0.040930938	0.015973318
12	20.46546891	7.986658995	0.020465469	0.007986659
13	40.93093782	15.97331799	0.040930938	0.015973318
14	40.93093782	15.97331799	0.040930938	0.015973318
15	40.93093782	15.97331799	0.040930938	0.015973318
16	10.23273445	3.993329497	0.010232734	0.003993329
17	10.23273445	3.993329497	0.010232734	0.003993329
18	20.46546891	7.986658995	0.020465469	0.007986659
19	40.93093782	15.97331799	0.040930938	0.015973318
20	40.93093782	15.97331799	0.040930938	0.015973318
21	51.16367227	19.96664749	0.051163672	0.019966647

APPENDIX 3

The MATLAB results of DG, PV with Batteries for the total Generated Power						
time	DG	PV	Battery	Cost	load	Generated power
0	520.956752	0	168.27	429.1736	661.10000	689.22
1	513.479388	0	155.82	398.239	621.500000	669.303
2	514.319343	0	157.19	401.648	625.900000	671.51
3	516.188066	0	160.31	409.406	635.800000	676.50
4	531.965716	0	186.60	474.745	719.400000	718.57
5	497.050305	121.94	105.66	956.82	633.600000	724.66
6	452.902112	345.89	-41.47	1846.371	550.000000	757.32
7	421.112125	545.37	-147.45	2700.851	528.000000	819.03
8	420	710.3	-308.30	3227.119	528.000000	822.00
9	420	784	-378	3467.66	528.000000	826
10	420	784	-359.99	3512.121	550.000000	844.00
11	420	784	-338.00	3566.45	572.000000	865.99
12	420	784	-329.99	3586.221	580.000000	874.00
13	420	707.63	-239.63	3381.77	594.000000	888.00
14	440.224887	543.1	-83.74	2846.04	658.900000	899.59
15	479.592885	341.58	47.427	2042.46	731.500000	868.60
16	519.3425	117.42	165.58	1080.07	770.000000	802.35
17	557.701013	0	229.49	581.352	855.800000	787.196
18	563.719134	0	239.527	606.286	887.700000	803.24
19	557.279483	0	228.80	579.63	853.600000	786.08
20	551.469011	0	219.11	555.55	822.800000	770.58
21	541.512289	0	202.52	514.30	770.000000	744.03
22	532.380268	0	187.29	476.46	721.600000	719.67
23	525.519262	0	175.88	448.09	685.300000	701.40

APPENDIX 4

Power management in this case the of PV, GD with batteries with the Generated Power values for the four PV and Batteries PLTS at buses 7, 12, 20 and 21												
time		PV				Batteries				Cost	Load	Generated power
	DG	kahianga	kulati	DETE	Lamanggau	kahianga	kulati	DETE	Lamanggau			
0	466.70	0	0	0	0	144	71.99	45.46	107.99	1033.90	661.100000	836.161429
1	452.33	0	0	0	0	144	72	54	108	1051.26	621.500000	830.335305
2	453.61	0	0	0	0	144	72	54	108	1051.59	625.900000	831.612199
3	463.96	0	0	0	0	144	67.62	36.87	107.99	1001.19	635.800000	820.463654
4	479.27	0	0	0	0	144	72	54	108	1058.27	719.400000	857.278385
5	425.99	25.08	46.00	44.60	42.70	144	55.61	17.75	108	1801.43	633.600000	909.766270
6	420	113.56	104.56	31.83	95.94	17.17	37.86	13.14	9.91	2239.14	550.000000	843.994035
7	420	264.05	67.99	68.70	144.61	-104.10	-38.15	-5.54	4.43	2809.16	528.000000	821.999707
8	420	274.98	113.03	59.55	199.99	-108.59	-27.52	-40.39	-43.80	3191.43	528.000000	847.258369
9	420.04	274.99	103.48	99.59	199.94	-115.22	-46.42	-40.91	-34.34	3320.96	528.000000	861.152066
10	420	274.99	124.92	94.38	200	-114.40	-23.37	-34.89	-69.39	3399.37	550.000000	872.225027
11	420.02	275	109.68	94.63	199.99	-87.37	-61.00	-30.77	-18.41	3425.37	572.000000	901.772513
12	420.07	275	120.99	76.13	200	-75.61	-23.41	-33.01	-50.69	3421.81	580.000000	909.473724
13	420.42	274.99	123.74	77.85	200	-69.72	-34.58	9.52	-102.69	3410.45	594.000000	899.532380
14	420	220.62	79.21	75.21	168.08	-6.05	3.28	-7.66	0.22	3125.39	658.900000	952.898427
15	420.007	90.901	86.23	51.62	112.8	143.71	55.17	17.77	47.23	2673.93	731.500000	1025.49629
16	441.58	85.86	27.64	51.54	40.030	144	65.35	49.65	108	2169.76	770.000000	1013.67055
17	517.52	0	0	0	0	144	72	54	108	1068.21	855.800000	895.524908
18	531.83	0	0	0	0	144	72	54	107.99	1071.93	887.700000	909.832514
19	516.22	0	0	0	0	144	72	54	108	1067.87	853.600000	894.220561
20	516.72	0	0	0	0	144	72	43.12	107.99	1041.14	822.800000	883.850367
21	493.18	0	0	0	0	144	72	54	108	1061.88	770.000000	871.185574
22	479.87	0	0	0	0	144	72	54	108	1058.42	721.600000	857.877015
23	470.74		0	0	0	144	72	54	108	1056.05	685.300000	848.743589

APPENDIX 5

The MATLAB results of Wind Turbine, PV with Batteries for the total Generated Power						
time	Wind Turbine	PV	battery	Cost	Load	Generated power
0	370.93	0	175	1174.11	661.100	545.930
1	370.93	0	175	1174.11	621.500	545.930
2	589.02	0	36.87	1269.12	625.900	625.89
3	845.01	0	-175	1257.78	635.800	670.019
4	1073.14	0	-175	1714.03	719.400	898.144
5	1025.96	8.567	-175	1667.66	633.600	859.533
6	960.32	55.96	-175	1801.81	550.000	841.291
7	1197.37	25.49	-175	2105.27	528.000	1047.870
8	1142.41	135.42	-175	2610.98	528.000	1102.842
9	545.22	491.83	-175	3412.47	528.000	862.062
10	532.72	538.79	-175	3650.44	550.000	896.518
11	346.78	642.45	-175	3859.07	572.000	814.239
12	224.27	677.37	-175	3809.60	580.000	726.652
13	163.55	656.54	-175	3571.50	594.000	645.095
14	214.65	543.11	-98.87	3226.54	658.900	658.899
15	107.72	341.58	175	2560.55	731.500	624.305
16	214.65	117.42	175	1519.14	770.000	507.083
17	589.02	0	175	1610.29	855.800	764.023
18	879.2	0	8.45	1779.37	887.700	887.699
19	589.02	0	175	1610.29	853.600	764.023
20	879.24	0	-56.44	1619.07	822.800	822.800
21	589.02	0	175	1610.29	770.000	764.023
22	1074.24	0	-175	1716.23	721.600	899.244
23	589.02	0	96.27	1415.8	685.300	685.299

APPENDIX 6

Power management in this case the of Wind turbine, PV, with batteries with the Generated Power values for the four PV and Batteries PLTS at buses 7, 12, 20 and 21

Wind turbine	PV				Batteries				Cost	Load	Generated power
	kahianga	kulati	DETE	Lamanggau	kahianga	kulati	DETE	Lamanggau			
370.93	0	0	0	0	126.57	40.20	24.88	98.50	cost:1458.580	661.100000	661.100156
370.93	0	0	0	0	126.91	10.82	21.66	91.170	cost:1360.767	621.500000	621.499647
589.02	0	0	0	0	80.87	-30.97	1.63	-14.657	cost:1269.128	625.900000	625.898352
879.24	0	0	0	0	-132.84	-30.40	-23.76	-56.431	cost:1157.181	635.800000	635.799460
1174.72	0	0	0	0	-144	-72	-54	-108	cost:1415.794	719.400000	796.727009
1097.32	29.34	8.69	2.66	13.75	-143.99	-67.68	-53.88	-108	cost:1576.916	633.600000	778.216347
1027.36	63.71	24.66	10.00	21.373	-144	-72	-50.63	-108	cost:1800.073	550.000000	772.495427
1217.55	30.68	48.79	53.10	41.088	-143.99	-72	-53.99	-108	cost:2474.040	528.00000	1013.240227
1170.23	49.35	87.60	56.42	58.34	-143.99	-72	-27.79	-108	cost:2881.301	528.000000	1070.184013
608.98	249.04	100.52	58.38	146.384	-143.99	-72	-48.66	-108	cost:3401.825	528.000000	790.666148
625.47	232.55	91.11	54.27	196.542	-143.99	-71.99	-53.99	-107.99	cost:3534.435	550.000000	821.975870
456.95	274.99	106.13	71.75	199.994	-144	-71.99	-53.99	-107.99	cost:3636.363	572.000000	731.833238
370.93	275	122.01	98.46	199.636	-144	-71.99	-54	-107.99	cost:3700.830	580.000000	688.045444
214.65	275	124.99	97.48	199.99	-142.329	-70.85	-22.69	-80.61	cost:3553.486	594.000000	595.646656
214.65	232.55	78.10	63.27	169.17	-43.295	-3.458	-6.36	-45.75	cost:3226.542	658.900000	658.898832
109.90	126.35	55.79	26.98	132.45	137.252	34.36	34.42	73.98	cost:2824.291	731.500000	731.504480
214.65	37.03	31.99	32.41	55.11	144	71.99	42.47	108	cost:2211.271	770.000000	737.691030
589.02	0	0	0	0	128.908	46.11	17.92	73.82	cost:1836.977	855.800000	855.797055
879.24	0	0	0	0	8.639	-7.05	1.549	5.32	cost:1779.376	887.700000	887.700326
589.02	0	0	0	0	137.20	29.91	21.86	75.60	cost:1831.551	853.600000	853.600351
879.24	0	0	0	0	-75.70	-25.83	17.93	27.17	cost:1619.072	822.800000	822.799947
589.02	0	0	0	0	61.187	25.74	11.56	82.48	cost:1625.058	770.000000	769.999603
1173.98	0	0	0	0	-144	-72	-49.57	-107.9	cost:1425.242	721.600000	800.410508
573.93	0	0	0	0	-9.678	11.59	4.36	-8.82	cost:1415.851	685.300000	685.300441

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