Biomass Fuels Allocation for Energy Generation Using Genetic Algorithm

Anurak Choeichum, Narongdech Keeratipranon, and Chaiyaporn Khemapatapan

Abstract— *Biomass fuels allocation for energy generation planning (BFAP) is a difficult problem because of a variety of data and complexity, which many energy conversion technologies, many type of resources. It requires permutations of work for optimal solution which takes considerable computing time when the size of problem is large. Moreover, the results will not be effective in all aspects. This research applied a genetic algorithm (GA) for solving and optimizing the BFAP problem. A case study was conducted on a data base simulation to demonstrate the feasibility BFAP. BFAP offers simple steps and provides more allocation plans to satisfy decision-makers' requirements for minimum investment cost, maximum gas emission reduction, and maximum investment returns.*

The first step of GA is to generate an initial population randomly, including the result obtained by using fitness function, such as the energy efficiency of the energy conversion technology and the bestselling value of electricity in a day. Then, the population will go through the process of reproduction, modify crossover and mutation to create a new population for the next generation until some stopping criteria were reached.

The testing result indicates that the efficiency of the processing complex and varied factors as well with accuracy. These results suggest that BFAP can solve a variety and variability of the data. It can maximize revenue from sales of electricity. In this case, BFAP helped decision-makers optimize the electric power generation planning. Causing resource use to be worthwhile and increase stability in the production of electricity to the grid..

Keywords— **Biomass fuels, allocation, power generation, genetic algorithm.**

1. INTRODUCTION

Thailand relies heavily on imported energy. In 2011, crude oil was imported as high as 85%, and the total imported value was about 1,125 billion Baht. This situation plus the impact of climate change and environment resulting from greenhouse gas emission is the critical issue that everywhere in the world, including Thailand, pays great attention and set measures for solving it out. Among effective mechanism to tackle with this issue, alternative energy seems to be the best ways out for us to develop and promote towards a final end of green house gas reduction and paving the ways for Thailand to become a low carbon society and the world renowned showcase as the country of alternative energy consumer and developer [1-2].

In terms of alternative energy sources, Thailand is rich in agricultural products that can be yielded for energy purposes such as biomass, biogas, biodiesel, ethanol, and the by-products from processed food industry. Geographically situated in the equator, Thailand also has great potential in solar with average radiation of 18.2 MJ/m^2 /day; and in some areas with wind speed potential. Thus, these can make Thailand the best potential on alternative energy development and create opportunity to strengthen energy security in the future. The Government of Thailand has currently assigned the Ministry of Energy to set up the 10 Years Alternative Energy Development Plan (AEDP) aiming to create the framework and direction for increasing alternative energy consumption by 25% in 2021 [1].

The Biomass target set under AEDP is 3,630 MW while the existing generating capacity is 1,751.86 MW. The development includes the following strategies: Promoting the installation of Distributed-Green-Generation (DGG) to be owned, managed by energy enterprise groups and communities. Support financial incentives such as ADDER adjustment to be FIT (Feed In Tariff) and special Renewable Energy Incentives for community based DGG projects. This also includes financial support for the biomass power plant to increase its efficiency by changing low pressure boiler to higher one. Facilitating biomass development by assigning Provincial Electricity Authority (PEA) and Electricity Generating Authority of Thailand (EGAT) to expand the transmission system and distribution to go hand in hand with biomass power plant development, especially in high potential areas like in the South of the country. Creating participation in the targeted areas where biomass production system can be installed and making knowledge campaign to educate the youth on biomass management as well as biomass networking. Research

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and development on biomass pallet in terms of production, consumption and standards, in order to serve the future hub of biomass fuels. Besides, Gasifier, Gas Engine technology, and downstream industries for the purpose of domestic production capability and Biomass to-Liquid technology are also included in the research list.

The AEDP target for biomass is 8,200 ktoe while the existing combined generating capacity is 3,286 ktoe. This will be promoted through biomass pellet production and the comprehensive use of heat co-generation (Electricity and heat) or biomass co-generation.

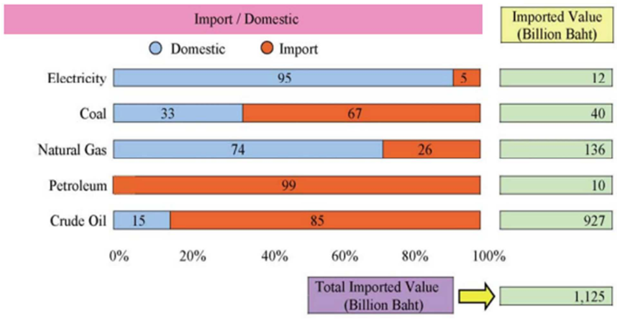

Fig.1. Thailand Energy Consumption in 2011[1].

In the year 2014, biomass is a renewable energy that has highest share of the heat production (89% the thermal energy produced from all renewable energy). Biogas accounted for 9% and the rest is thermal energy from waste and solar. The production of energy from waste and solar energy is also the need the government promotion for encouraging more utilization in services and household sector [2].

The use of biomass for energy does not increase the net amount of carbon dioxide in the atmosphere. If it is made of renewable biomass used, the new biomass will be equal to the amount of carbon dioxide emitted from the biomass combustion. In addition, the biomass conversion technology is applied into energy such as gas, liquid fuels and energy efficiency. Has been your attention and turned a widely used.

The government wants to use alternative energy; including energy from biomass has increased to 25 % under the planned development of renewable energy. Therefore, it is necessary to make efficient use of fuel from biomass in a variety of biomass power plant or factory in Thailand. To obtain information for use in planning and policy formulation, production, storage, and distribution of energy pass through the unmanaged energy efficiency. To take into account variations in many aspects, both the planting season environment of value-added raw material and fuel costs, rates trading or the cost of storage. The management plan from a lot of variation and complexity. The need for tools and methods that is highly effective. It must be designed to reflect a variety of factors existent in Thailand. This research has selected the evolutionary computation to help allocate and planning to be effective and meet the problems of today and the policy of the state [1].

The optimal energy generation planning has been frequently solved using classical optimization methods and usually considered as the maximization of an objective function representing the energy or the minimization of an objective function representing the greenhouse gas, investment cost, operation cost and generation cost [4]-[9], or optimal sizing [10]-[13]. The genetic algorithm (GA) is a metaheuristic inspired by the process of natural selection that belongs to the larger class of evolutionary algorithms. GA is commonly used to generate high-quality solutions to optimization and search problems by relying on bio-inspired operators such as mutation, crossover and selection.

This paper enables the GA to the problem of optimal multi fuels allocation for power generation [14]-[18]. This research was conducted in a simulation with three different input factors; four types of raw materials, four types of energy conversion technology, and daily electricity prices.

Table 1. The capacity target in the 2021

Type	The installed capacity target in 2021(GW-hr)	The storage installed capacity in 2021(MW)
1. Wind	1,283	1,200
2. Solar	2,484	2,000
3. Hydro	5,604	1,608
4. Biomass	14,008	3,630
5. Biogas	1,050	600
6. MSW	518	160
7. New Energy	10	3
Total	24,956	9,201

2. METHODOLOGY

Framework of BFAP

This research was conducted simulation of three different raw materials for energy conversion and the trading of electricity per day during the week. The details are as follows:

Raw materials are imported data, with the size and performance of the individual that is set to be simulated with the four raw materials were different. Each type of raw materials has different properties, such as energy efficiency, cost, and size.

The energy conversion technologies are processed with the implied value of energy efficiency and limitations of each technology available in the system. The energy conversion technologies are the four categories were different, which are combustion and gasification technology.

Daily electricity prices are traded electricity rates vary by date. In this simulator is assumed to change daily, that this system must plan to produce more on higher price days.

From all three of the above information, this research has a different set of data to be diverse and reflect the realities of raw materials such as some of the more energy efficient but there is less volume in the energy conversion process. Proportion to the volume of raw materials that are not very high with some energy conversion technology [4-7], [15-18].

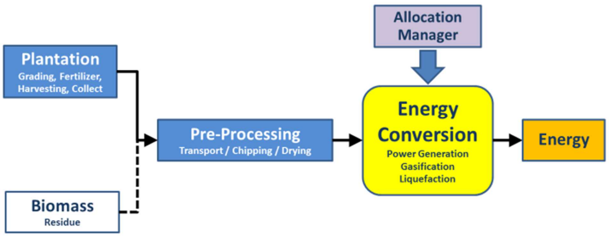

Fig.2. Energy Conversion Diagram.

Development of BFAP

As a quite promising stochastic globaloptimization method, genetic algorithms (GA), originally presented by Holland [3], are widely applied to a variety of complicated cases. GA is directed random search techniques, based on the mechanics of natural selection and genetics. This research has made preliminary structural design of the system based on the GA. Each answer is a characteristic in the form of chromosomes as shown in Fig. 3, This encoding scheme is designed to represent the candidate solution. Starting from an arbitrary number of raw materials in the stock, the GA process evolves the value in the chromosomes to have a good candidate solution.

GA is described using biological terminology which differentiates them from other evolutionary computation methods. The most important terms are as follows [6-9], [19-24]:

- Chromosome: A representation of a possible solution to an optimization problem where parameter values are encoded using either binary, real-valued or tree encoding.
- Genes: Groups of bits or real values which encode one particular element of a possible solution (Chromosome)
- Crossover: An operation in which genetic material is exchanged between two different chromosomes to generate new chromosomes.
- Mutation: An operation which randomly changes parts of a gene in a chromosome at randomly chosen places.
- Population: The set of chromosomes used to explore the optimization space. This can either be fixed or vary as optimization progresses.
- Generation: One optimization cycle of a GA.

A basic genetic algorithm works as follows [6]:

1. Generate a random initial population of n chromosomes.
2. Calculate the fitness $f(c)$ of each chromosome c in the population.
3. The following steps are repeated to obtain a new population with n offspring:
   3.1 Selection of two parent chromosomes according to the calculated fitness.
   3.2 Crossover the parents at a chosen point with a crossover probability p_c and create two offspring.
   3.3 Mutation of the offspring at every position with mutation probability p_m and addition of the mutated chromosomes to the new population.
4. Exchange the current population against the newly generated population.
5. Start back at Step 2.

A single iteration of the described steps represents one generation. The most critical parameter in a GA is the fitness function which evaluates all possible solution to the optimization problem. If fitness function performance is poor, optimization results will also be poor. Finding the appropriate fitness function for a complex optimization problem is often the most difficult task. Furthermore, algorithm performance is sensitive to the choice of generation and population size, crossover and mutation functions and chromosome encoding: hence these parameters must also be carefully chosen for optimum results [6].

3. IMPLEMENTATION OF THE PROPOSED ALGORITHM

This paper using structural design of the system based on the GA. This will determine the answer to the problem of the answer. Each answer candidate is a characteristic which is in the form of chromosomes as shown in Fig 3. The encoding is the first step and an important step [3-9], [21-28]. It is designed to represent the chromosomes of the answer. Starting from an arbitrary number of raw materials in the inventory, the data is processed substrate. This research describes the structure of chromosomes. By simulating the following information:

Framework of the Genetic Algorithm

1. Machine or energy conversion technology into the system. In the four technologies have different based on energy conversion technology with a current physical.

2. Gene or raw materials are introduced into the energy conversion process.

3. Capacity factor or restrictions on imports of raw materials each type of energy conversion technology to transform the energy of technology.

4. Energy factor or energy from raw materials limitations of each technology, as opposed to individual energy conversion technology [14], [18].

5. Real-time pricing or daily electricity price.

Each the chromosome of this case has 7 days with 112 genes, there are 4 machines or type of energy conversion technologies per day, 4 type of raw materials per each energy conversion technology. Each day the daily electricity price is different(P_g). In this research there are the capacity factors (C_f) of raw materials each type of energy conversion technologies and the energy factor (E_g) is the energy efficiency from raw materials limitations of each technology, as opposed to individual energy conversion technology.

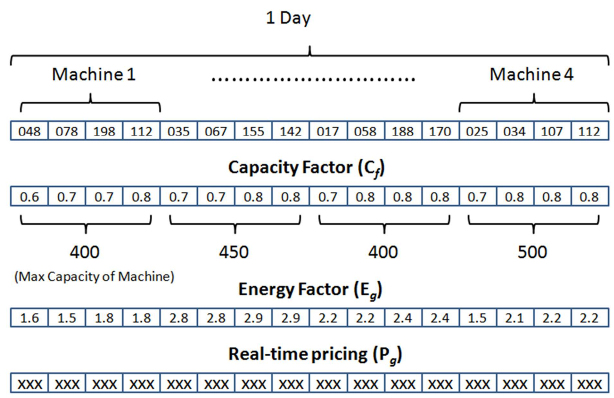

Fig.3. Conceptual illustration and components of the BFAP.

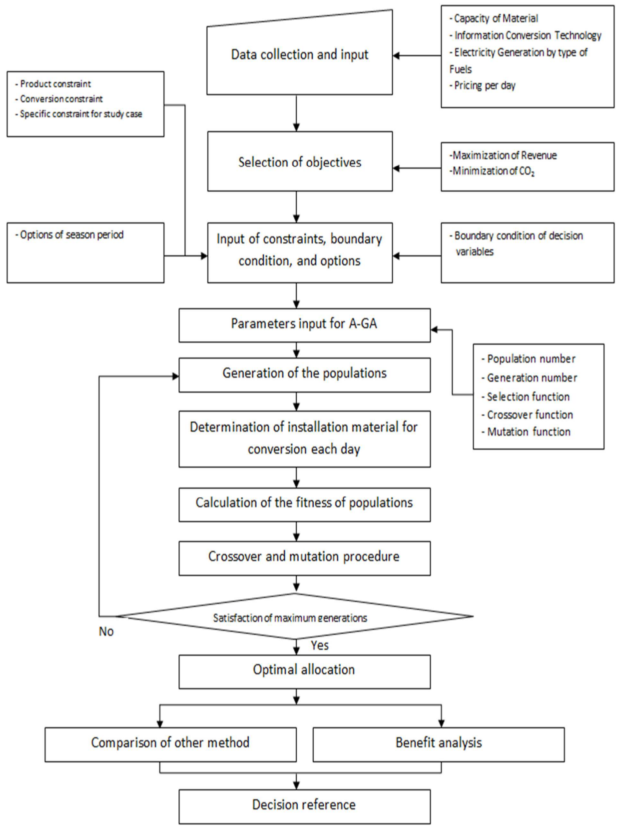

Fig.4. Flow chart of this study.

Factors to consider are the cost-efficiency of energy conversion technologies from the appropriate; costs, production processes, volatility of daily electricity price, respectively. In terms of the allocation of biomass to be more efficient, it is necessary to consider the optimum raw materials selection for with the existing technology and daily electricity price. The processing conditions and limitations on the amount of fuel efficient technology and each different, the system can be written as the following [7]:

The mathematics in the BFAP can be described by the following equations:

$$PV = P_g . E_g . \left[\frac{K_g \cdot \left(1 - K_g^{V_u}\right)}{1 - K_g} \right] \tag{1}$$

where

- PV gained from the sold electric energy.
- P_g the selling price of electric energy.
- E_g the sold and produced electric energy.
- K_g the rate of sold energy price.
- V_u the useful lifetime.

Objective function

The objective is to maximize the electric power energy output and minimize the fuels cost. In this study case, the fitness function of this implementation shown in (2).

$$\max C_k = \sum_{t=0}^{T} (PV) - \left[INV_s + L_p + M_c \right] \tag{2}$$

where

- $maxC_k$: the maximum of selling.
- INV_s : the investment cost in the production cycle.
- L_p : the electricity used in manufacturing.
- M_c : the maintenance technology.

$$f_1(x) = \max C_k \tag{3}$$

where

- $maxC_k$: the maximum of selling.
- $f_1(x)$: the Objective Optimization.

$$\mathrm{Fit}\big(f(x)\big) = \begin{cases} f_x + C_{max}, & f(x) > C_{max} \\ 0, & f(x) \geq C_{max} \end{cases} \tag{4}$$

Encoding of Chromosomes for the Problem

From the variety of variables has used genetic algorithms to solve the BFAP problem. The design chromosome to find the best result of Fig. 5, with the first position in every four is the number of each type of material in each of the four species.

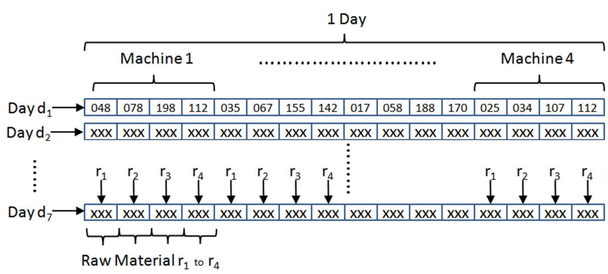

Fig.5. An example of a chromosome.

Situated in the same machine (Energy conversion technology) and another four next positions will be for each of four types of raw materials, as well as the first set but in a different type of energy conversion technology. There are four types of technology. That means that the first 16 to be composed of four types of raw materials in each of the four types of energy conversion technology, all of the above. To represent the work in one day, which will be evaluated in this research, planning is producing in one week or seven days. As a result, the total number of chromosomes is equal 112 positions (112 genes).

4. MODIFICATIONS TO GENETIC OPERATIONS FOR THE PROBLEM

4.1 Modified Crossover

After parent selection, a crossover operation is performed. The idea of crossover is that useful segments of parents should be combined to yield a child, which will lead to better energy conversion technology. This research used a classical one-point crossover operation by randomly generating a crossover and then swapping segments of the two parents to produce a child. Our crossover operation generates the crossover point by cutting the row of array.

After performing crossover to two chromosomes, the offspring will be adjusted if they are infeasible solutions. After the adjustment, the total capacity of machines will not be larger than the maximum capacity of machines [18-26].

Fig. 6 shows the crossover of each gene or raw material and Fig. 7 shows the crossover of machines.

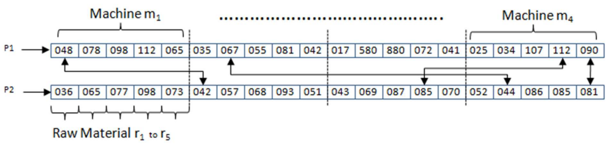

Fig.6. Crossover of each gene or raw material (Crossover V1).

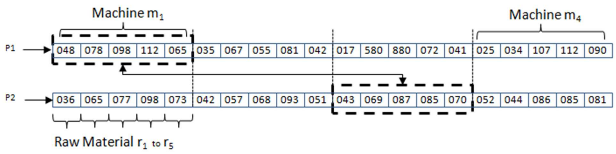

Fig.7. Crossover of machines (Crossover V2).

4.2 Modified Mutation

In the mutation operation, each gene has a probability of a mutation rate to be mutated. If a gene is to be mutated, the new value of the gene will be a random value within the range of the sum of the gene value and the rest number of capacity of machine. At one point mutation is a mutation equals another point of time to prevent exceeding the capacity of the machine or missing of raw materials available in the inventory [26-28].

Fig. 8 is a random mutation at position 6, the number is random mutations by 32 is negative or reduce the amount of raw materials into a machine. The system then performs a random mutation another position. The type and amount of raw materials match the first position (position 10). This is the opposite to the first position. If a change is reduced, the mutation of this second position will add more value equal to the lower of the first or it can be said that the bringing the mutations that were introduced in the first mutation in a second position to comply with the existing system.

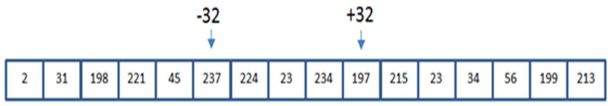

Fig.8. An example of a modified mutation.

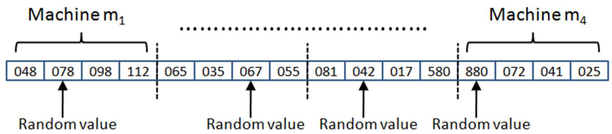

Fig.9. The multi-point mutation (Mutation V1).

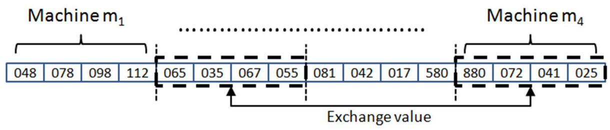

Fig.10. Mutation between machines (Mutation V2).

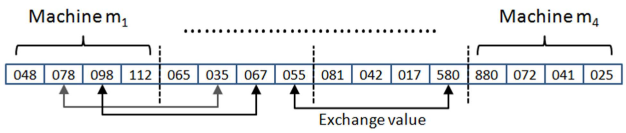

Fig.11. Mutation between each raw material (Mutation V3)

The multi-point of mutation, mutation between machines, and mutation between each raw material, as shown in Fig. 9, 10 and 11. The mutation technique of each version is an evolved characteristic and is strongly influenced by the genetics of each version. This research uses a variety of mutations to find the best result.

Table 2. Simulation Parameters in GA

GA Parameter	Type	Value
Chromosome length	Real Value	112
Population size	Rank	200-500
Number of generations	Round	1000
Crossover rate	Multi	0.7-0.8
Mutation rate	Multi	0.05-0.1
Selection strategy	Tournament	-

In Table 2 shows the parameters used in the GA for this implementation. A tournament based selection [4], [19], [24], [29] is used to form a new population form the existing ones, and the algorithm is terminated when generation criteria are met.

5. RESULTS AND DISCUSSION

The results in Fig. 12 shows the proposed method can find the best result using less processing time, about 15 seconds. In Fig. 13, shows that use of GA out performs clearly averaging about 25% and compared with greedy method [30].

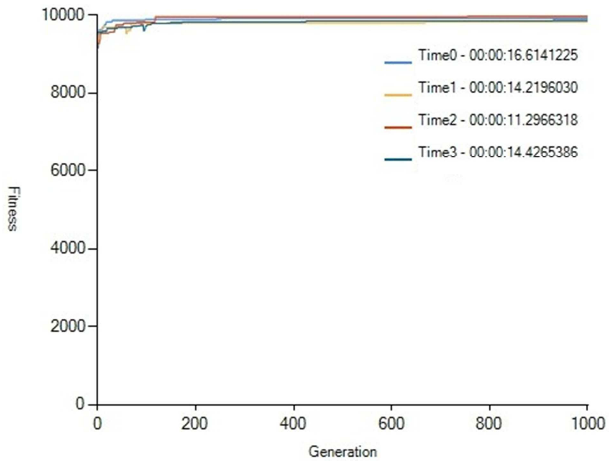

Fig.12. Improvement in the best fitness of fitness function for GA.

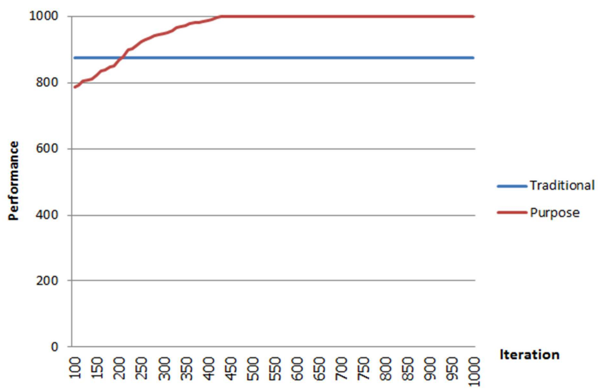

Fig.13. Comparison of performance

The results of the above simulation is the 7 days using a variety of variables such as, volatility of daily electricity price. The results from Fig. 13 can be seen that in early test results of greedy method has better performance, but after passing through the period, the GA has to adapt and develop themselves. Therefore, the answer of GA better than the greedy method, and the results of GA can go to the best result. In this case, a higher rate of mutation can lead to a quicker solution because its population try a new value more often.

The results in Fig. 14, shows the crossover V1 compared with V2. From this experiment, the crossover V1 is better.

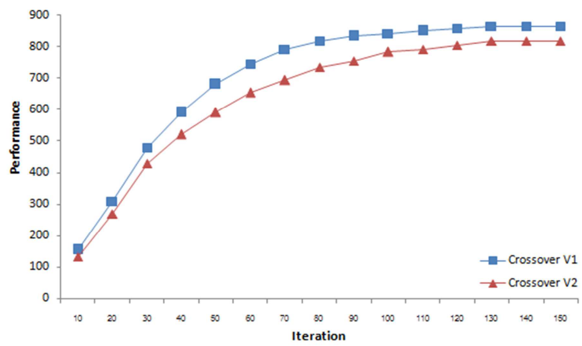

Fig.14. Comparison of each crossover technique.

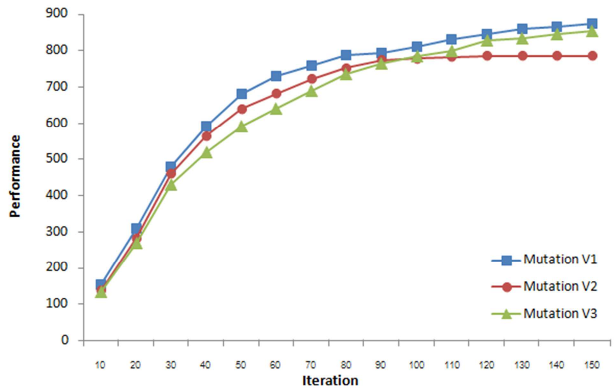

Fig.15. Comparison of each mutation technique.

The results in Fig. 15, shows each mutation technique can descript that 200 population size and the probability ratio of mutation 5%. From this experiment, the mutation V1 and is the best performance.

6. CONCLUSIONS

This paper was conducted using genetic algorithm to allocate biomass for energy generation planning. This research can improve allocation of biomass efficiently to analyze a wide variety of biomass to energy conversion technologies to maximize the produce electricity value. It can also adjust the parameters to modify the plan is long-term (Real-time Pricing) or calculate the FIT.

The results of this research are consistent with an efficient industrial sector. In response the government power development plan of the country. It can add stability to the electric grid. To reduce the cost of fuel or fuel supply in the country as well. The BFAP can help optimize energy conversion, allocation plan, power system and help to satisfy decision-makers' requirements for mini-mum investment cost and maximum investment returns.

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