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IMPROVEMENT OF RADIAL DISTRIBUTION NETWORK WITH DISTRIBUTED GENERATION (DG) BY USING IMPROVED GENETIC ALGORITHM (IGA)

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A report submitted in partial fulfillment of the requirement for the degree of Bachelor of Electrical Engineering (Power Industry)

Faculty of Electrical Engineering

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STUDENT DECLARATION

I declare that this report entitle “Improvement of Radial Distribution Network with Distributed Generation (DG) by Using Improved Genetic Algorithm (IGA)” is the result of my own project except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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To my beloved mother and father

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ABSTRACT

The distribution systems deliver power to the customers from a set of distribution substations and these are normally configured radially for effective co-ordination of the protective systems. The distribution system contains two types of switches which are sectionalizing switches (normally closed) and tie switches (normally opened). The functions of these two switches are for protection and configuration management in the system. Power losses in electrical power network are mainly come from the distribution system due to the increment in load demand. The growth of load demand has led to poor performances and efficiency of the distribution system. Therefore, distribution network reconfiguration (DNR) is introduced to solve the problem of power losses in distribution system. Distribution network reconfiguration (DNR) is a technique that resolves the group of tie-switches in the network that perform as the best route of optimal solution for power losses. Furthermore, the implementation of Distribution Generation (DG) in distribution system also helps to cater the power losses and fulfill the customers' demand. Improved genetic algorithm (IGA) is proposed and tested on IEEE 33 and IEEE 69 bus system to ensure the validity and efficiency of the algorithm. There are two tested cases that are DNR without DG and DNR with DG. The results from the distribution network reconfiguration by using Improved Genetic Algorithm (IGA) help to reduce the total power losses and achieve faster computational time. Besides that, the presence of distribution generator (DG) makes the distribution system performs better than before DG installation. From the results, the performance of the crossover IGA is better than of the other approach that is GA.

Keywords: *Distribution Network Reconfiguration (DNR), Genetic Algorithm (GA), Improved Genetic Algorithm (IGA), Distributed Generator (DG)*

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ABSTRAK

Sistem pengagihan berfungsi mengagihkan kuasa elektrik kepada pelanggan-pelanggan dari satu set pencawang pengagihan dan ini biasanya di konfigurasi secara jejari untuk penyelarasan sistem perlindungan yang berkesan. Sistem pengagihan mengandungi dua jenis suis yang iaitu suis 'sectionalizing' (biasanya ditutup) dan suis 'tie' (biasanya dibuka). Fungsi kedua-dua suis untuk perlindungan dan pengurusan konfigurasi dalam sistem. Kehilangan kuasa elektrik dalam rangkaian kuasa elektrik berpunca dari sistem pengagihan disebabkan oleh peningkatan dalam permintaan beban. Peningkatan permintaan beban telah membawa kepada prestasi buruk dan kecekapan sistem pengagihan. Oleh itu, konfigurasi semula rangkaian pengedaran (DNR) diperkenalkan untuk menyelesaikan masalah kehilangan kuasa dalam sistem pengagihan. Konfigurasi semula rangkaian pengedaran (DNR) adalah teknik yang memutuskan kumpulan tie-suis dalam rangkaian yang melaksanakan sebagai jalan terbaik penyelesaian optimum untuk kehilangan kuasa. Tambahan pula, pelaksanaan Generation Distribution (DG) dalam sistem pengagihan juga membantu untuk menampung kehilangan kuasa dan memenuhi permintaan pelanggan. Penambahbaikan algoritma genetik (IGA) dicadangkan dan diuji pada IEEE 33 dan IEEE sistem 69 bas untuk memastikan kesahihan dan kecekapan algoritma. Terdapat dua kes diuji yang DNR tanpa DG dan DNR dengan DG. Hasil daripada pengagihan rangkaian konfigurasi semula dengan menggunakan 'Improved Genetic Algorithm' IGA) membantu mengurangkan jumlah kehilangan kuasa. Selain itu, penggunaan 'Generation Distribution' (DG) membuat sistem pengagihan lebih baik daripada sebelum pemasangan DG. Daripada keputusan, prestasi IGA adalah lebih baik daripada GA.

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Malaysia suffers from a total blackout after 35 years from the independent day which is in 1992 due to the lightning that strikes onto the transmission facility and leads failure to both transmission and distribution system. In 1996, the power system network tripped and caused blackout once again and consequently affected to Kuala Lumpur, Selangor, Putrajaya, Johor, Melaka and Negeri Sembilan for several hours. A power failure caused 5 hours of blackout in 2003 that affected southern parts of Peninsular Malaysia such as Malacca, Johor, Selangor, Negeri Sembilan and Kuala Lumpur [1]. Afterwards, the faults occurred at the main cable transmission line grid that caused blackout in northern peninsular including Perak, Penang, Kedah and Perlis in year 2005. These blackout occurrences from technical failure, bad weather, human failure and equipment fault. Fault can be considered by any inrush electric current that exists in electric power system caused from equipment failure. The blackout in the power system can cause power system equipment damage, heavy economic losses, and limit the communication between peoples or also known as consumers. A reliable and secure distribution system is needed to avoid any fault occurrence and also to make sure that the customers always get enough electric power supply without any disturbance.

Distribution network is known as connection between the transmission network and consumers. Out of totally generated electrical power, 13% of power is accounted for distribution losses [2].In order to reduce the power system cost, the losses that appear at distribution stage must be reduced. Distribution network reconfiguration is an important strategy in order to keep check on the problems arising due to the radial structure of the distribution system. The occurrence fault in the power system will enforce the system

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restoration to recover customer satisfactions. The system is attempted to restore network by isolating the affected area and give supply back to unaffected area. This is a response of the system due to blackout or fault. The power losses might be increase due to any blackout or fault in the distribution system. To reduce the distribution power losses, distribution network reconfiguration (DNR) need to be very effective. DNR is the method of changing the topological structure of the distribution network. The process in DNR is by closing the open or close status of sectionalizing and tie-switches for loss reduction. Other than DNR, distributed generator (DG) is another option to minimize the power losses in the distribution system.

DG is known as small scale generator which place near to the consumer's area. The effectiveness of DG implementation depends on the consistency of transmitting power with appropriate location and exact size of the DG. In [3], to find the best route and the most suitable size of DG, the distribution network can be reconfigured based on several ways of developing heuristic algorithms such as Tabu Search (TS), Simulating Anealing (SA), Genetic Algorithm (GA) and Improved Genetic Algorithm (IGA). Conventional GA is a calculation adjustment system that used research-based approaches direct binary coding. The principle used in GA is the evolution via natural selection, employing a population of individuals that undergo selection in the presence of operator such as mutation and crossover [4].

However, GA may take long time to evaluate the individuals due to the large population number required. Therefore, IGA is introduced in this paper to overcome the disadvantage of GA. The IGA consists of the same main idea as the GA but some improvement is done either at selection, crossover or mutation. In this project, the improvement is done at the crossover part. The results obtained are compared with the results of GA. IGA shows that the results are more accurate and the power losses are reduced.

1.2 Problem Statement

According to [6], successful arrangement of distribution network is compulsory to encounter the present rising domestic, industrial and commercial load day by day. The increment of load demand in the distribution system cause technical losses such as energy

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dissipated in the conductors, equipment used for transmission line, transformer, sub transmission line and distribution line and magnetic losses in transformers. The DNR method is the effective way that create new topology of network which able to reduce the power losses to optimum level. Other than that, the consideration of DG at the network is able to reduce power losses while DNR process takes place.

1.3 Objectives

The objectives below need to be successfully achieved in order to meet all requirement of minimizing the power losses of distribution network system.

1. To develop Improved Genetic Algorithm (IGA) for IEEE 33 and IEEE 69 buses test system of distribution network configuration in determining the best combination set of switches by using MATLAB vr2015b for load restoration via DNR.
2. To compare the reduction of power losses between the load restoration via DNR and without DNR.
3. To analyze the performance between IEEE 33 and IEEE 69 buses system via DNR with DG and DNR without DG using the improved genetic algorithm (IGA) and compare with genetic algorithm (GA).

1.4 Scope

For IEEE 33 and IEEE 69 buses system with base voltage of 132kV, the method of distribution network reconfiguration (DNR) is implemented in both networks. In this particular method, there are certain algorithms in finding the resolution of DNR such as Simulated Annealing (SA), Particle Swarm Optimization (PSO), Tabu Search (SA) and Genetic Algorithm (GA). Eventually, this DNR study only aim on using Improved Genetic Algorithm (IGA). Besides that, the DG sizing of both networks will be defined using the GA and IGA method with varies in DG position. MATLAB vr2015b is used to implement the improved genetic algorithm (IGA). Finally, the performance of system when including DG and without DG is compared in term of power losses.

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1.5 Expected project outcome

At the end of this project, the load restoration distribution IEEE 33 and IEEE 69 buses are expected to be able reduces power losses via network reconfiguration (DNR). This system uses the method of improved genetic algorithm (IGA) to reconfigure the radial configuration system.

1.6 Significance of project

With the reconfiguration of the distribution network of IEEE 33 and IEEE 69 buses test system of distribution network configuration, a better optimization of power delivering and improving the minimizing of power losses is provided. Improved genetic algorithm (IGA) is used as an evolutionary search engine to accomplish the objective of the reconfiguration.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Based on the problem statement, objective and scope in the Chapter 1, a study on the theory and basic principle is done in order to fully understand the project. The theory on distribution network system (DNS), distribution network reconfiguration (DNR), genetic algorithm (GA) and improved genetic algorithm (IGA) are explained in this sub-chapter.

2.2 Distribution Network System

Distribution Network System (DNS) hold a very significant position in the power system since it is the main point of link between bulk power and consumers. The main function of the DNS is to provide or deliver the power to the consumers. Thus, distribution network system can be divided into three components: distribution substation, distribution primary and secondary. At the substation level, the voltage is reduced and the power is distributed in a smaller amount to the customers. Furthermore, the protection devices such as switchgear, fuse, relay and circuit breaker also were placed in the substation level. The primary distribution system includes feeders coming out from the substation and supplying power to several secondary distribution systems.

2.2.1 Radial distribution system

Radial distribution system is the most common system used because of the simplest and least expensive system to be built. In this system, the power in primary feeder is

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supplied from distribution substation to the load areas through the sub-feeders and branch circuit [5]. A radial system has only one power source for a group of customers. Radial feeders are characterized by having only one path for the power to flow from the source (distribution substation) to each customer. According to [6], radial system has its own advantages and disadvantages. The advantages of radial system are its simplicity and low cost, the amount of switching equipment required is small and protective relaying is simple. The major disadvantage of radial system is its lack of security of supply. It is not the most reliable system, because a fault or short circuit in a main feeder may result in a power outage to all the users served by the system. A schematic example of a radial distribution system is shown in Figure 2.1.

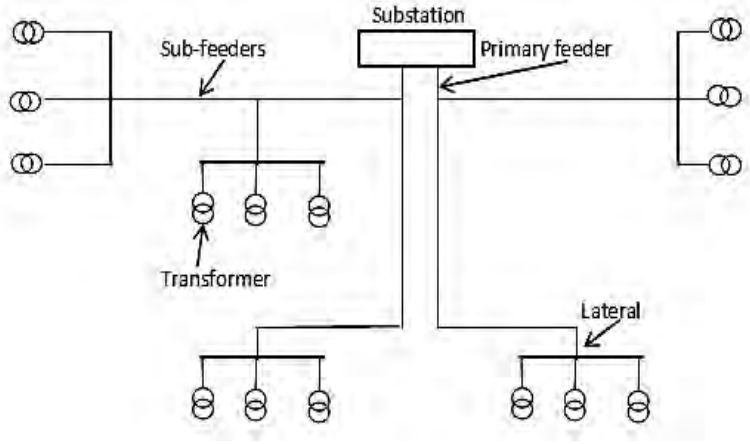

Figure 2.1: Radial distribution system [5]

2.2.2 Ring main system

The loop (or ring) distribution system is one that starts at a distribution substation, runs through or around an area serving one or more distribution transformers or load Centre, and returns to the same substation [5]. The advantages of main ring system are less voltage fluctuations at consumer's terminal and the system is very reliable because of the feeder always interconnected with each other. In case faults were happen at any section of feeder, the continuity of supply is maintained.

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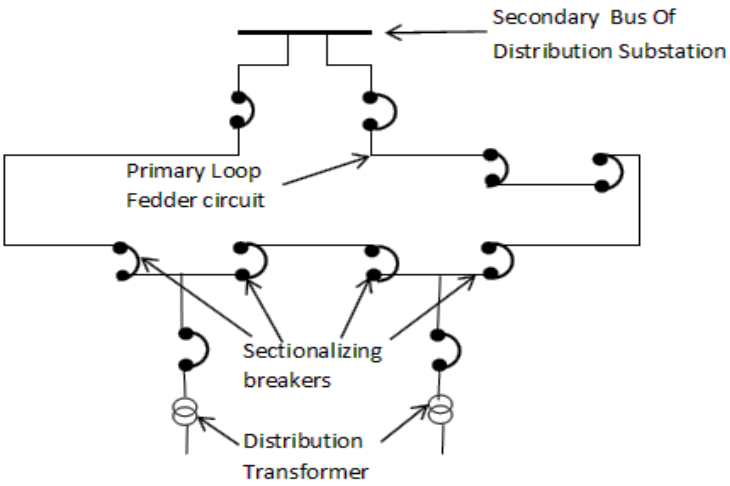

Figure 2.2: Ring main system [5]

2.2.3 Interconnected system

Interconnected system provides the reliability to the distribution system. The system is supplied from two or more distribution substations. Power can flow from any substation to any distribution transformer or load in the network system. The system is adapted to the additional and expansion of network due to many feeders connected.

For this reason, interconnected system is commonly used at high load density which town and residential area [6]. The energized feeder by two or more generating station or substation, it is well known as interconnected system.

2.3 Distribution network reconfiguration (DNR)

Network reconfiguration in distribution networks is recognized by changing the status of sectionalizing switches and is usually done for loss reduction. As there are multiple constraints in the distribution networks reconfiguration, it belongs to a complex combinatorial optimization problem. In network reconfiguration for loss reduction, the solution is required to search radial configurations for the network. Besides that, distribution network reconfiguration (DNR) also provide the solution for load balancing, service restoration and improve the quality and reliability of power supply. According to [7], one of the major problems in the reconfiguration criteria is the representation of the

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configuration which means the network must be operated in a radial manner. Otherwise, the entire system will lose one of the operating constraints.

Distribution network reconfiguration (DNR) is an important technique for solving optimization network problem. Advanced researches have been carried out in the reconfiguration strategies to come out with new formulated method. Artificial intelligence algorithms are implemented in distribution network reconfiguration (DNR) to optimize the system. Artificial intelligence algorithms are arrangement computer science and formulated mathematical technique such as genetic programming, heuristics, pattern recognition, inference and data analytic. There are examples of the artificial intelligence algorithm such as Particle Swarm Optimization, Simulated Annealing and Genetic Algorithm [8, 9].

Particle Swamp Optimization (PSO) is one of the heuristic methods used by researchers to solve many problems related to power systems. The basic idea of the PSO is based on the social behavior (foraging) of organisms such as fish (schooling) and bird (flocking). The birds or fish will move to the food in certain speed or position [8]. PSO is capable of solving large-scale problems arose in network reconfiguration as compared to the existing methods such as Artificial Bee Colony (ABC).

Simulated Annealing (SA) is well suited for solving combinatorial optimization problems because simulated annealing can prevent from local minima. Annealing process is the process of heating the solid in the hot liquid by increasing the liquid until the solid is melted with the liquid then the temperature is decreased slowly [9]. However, the use of simulated annealing is also responsible for an excessive computation time requirement.

Genetic algorithm (GA) which has becomes very popular for network optimization. In [10], GA combines solution evaluation with randomized, structured exchanges of information between solutions to obtain optimality. Genetic algorithms are considered to be robust methods because restrictions on solution space are not made during the process. The benefit of GA is the ability to access the historical information structure from the previous solution in order to develop the better future solution.

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2.4 Distribution Generation

A power generation system is an industrial facility for the generation of electricity. It is a process of producing electric power that used other sources of main energy. Thus, power plant is located near the power source such as fuel sources for fuel power plant or dam for hydropower plant. Furthermore, power plant eventually located further from the customer due to environmental concern. A long distant of power transmission from generation system to distribution system has contributed to power losses. As stated in [10, 11], the main advantages of distribution generation are:

1. Reduced line losses
2. Voltage profile improvement
3. Reduced emissions of pollutants
4. Increased overall energy efficiency
5. Enhanced system reliability and security
6. Improved power quality and relieved transmission and distribution congestion
7. Reduced operation and maintenance costs of some DG technologies
8. Enhanced productivity
9. Reduced health care costs due to improved environment and
10. Reduced fuel costs due to increased overall efficiency

Distributed generation (DG) is an alternative electricity supply instead of the traditional centralized power supply. The power generated by distributed generation (DG) is sufficiently smaller than centralized power supply at any point in power system. The purpose is to cater back the power losses and at the same time fulfill the consumers' demand.

2.5 Genetic Algorithm (GA)

One of the methods that able to produced global optimal solution is genetic algorithm (GA). Genetic algorithm uses the principle of natural evolution and population genetics to search and attain at a high quality near global solution. A set of chromosomes known as initial solutions is used in GA. The group of chromosomes is named a population. The quality of a child produced is judged by the fitness function, which is derived from the objective function and is used in successive genetic operation. During

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each generation procedure, a new set of child with improved performance is generated using three GA operators which are selection, crossover and mutation.

Genetic algorithm (GA) first defines the chromosomes according to fitness function before going through selection process. The next stage of genetic algorithm (GA) would be crossover. Crossover is the process of selecting a random position in the parent's strings and exchanges the characters either left or right of this point with each other. This random position is called the crossover point. The last stage is the mutation process. Mutation is the process of random alteration of a child position by changing "0" to "1" or vice versa, with a small probability. This condition is repeated until it finds the best improvement of solutions.

2.6 Improved Genetic Algorithm (IGA)

Improved Genetic Algorithm (IGA) is the upgrade of the conventional genetic algorithm (GA) that can generate a better set of solution with faster computational time. Genetic algorithm (GA) is generally influenced by its operators. Therefore, a good improvement of genetic algorithm (IGA) can be found by varying selected stage either at selection, crossover or mutation operator [13].

A group of chromosome is ranked based on fitness size. In [14], chromosomes with the high fitness value have possibility to be selected as the parents. The fitness value represents the total power losses produced by individuals. Parents with highest fitness are selected in selection process. In this selection process, the improvement of genetic algorithm can be improved by arranging the chromosomes into a group from the best fitness to the least fitness. As for crossover process, a uniform crossover and multipoint crossover is the example of the types of crossover operator that can be used instead of the single point crossover in conventional genetic algorithm (GA). The child produced when some segment in both parents is exchange before proceed to the mutation process. Mutation takes place after the crossover is performed. The new offspring create by crossover is randomly changes based on the mathematical. For example, a few randomly chosen bits can be switch such as bits 1 to 0 or 0 to 1.

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The radial topology of the network is maintained to alter the valid solution when using improved genetic algorithm (IGA). So, every stages of genetic operator process need to take a proper measurement to perform the radiality of the network.

2.7 Review of previous related research

Nowadays, metaheuristic techniques are used in the reconfiguration of the distribution network. The examples of the techniques are Artificial Bee Colony (ABC), Genetic Algorithm (GA) and Improved Genetic Algorithm (IGA) [15, 16, 17]. These techniques are applied to obtain the lowest power losses in a distribution system.

The distribution network reconfiguration is recognized by changing the status of sectionalizing switches to minimize power losses due to a few system constraints. The constraints are the network radiality voltage limits and feeder capability limits. The metaheuristic methods can be applied to solve the problem due to its complexity. One of the methods is artificial bee colony (ABC). Artificial bee colony (ABC) is proposed as a new population based metaheuristics approach inspired by intelligent foraging behavior of honeybee swarm. There are three groups of bees in the colony of artificial bees which is employed bees, onlookers and scouts as stated in [15]. Artificial bee colony (ABC) has its own advantage in obtaining the lowest power losses in distribution system. Artificial bee colony (ABC) does not require external parameter as genetic algorithm (GA). The external parameters are known as crossover rate and mutation rate. However, artificial bee colony (ABC) has slower convergence characteristic compare to genetic algorithm (GA) as discussed in [16].

Genetic algorithm (GA) is proposed to overcome the problem of artificial bee colony (ABC). Genetic algorithm (GA) allowed the reduction of the search space and making the application of the algorithm possible for large distribution system. GA is an effective parameter search techniques that considered when conventional techniques have not achieved the desired speed, accuracy or efficiency. However, there is a disadvantage of genetic algorithm. The performance of GA is mainly influenced by its operators. Thus, a good improvement of genetic algorithm (GA) can be found by altering the operators in genetic algorithm (GA). An improvement of genetic algorithm (IGA) is applied at the selection operator as stated in [17] where the processes of selection random population take place first before the re-ranked processes for second selection. Other than selection

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operator, there are another two operators in genetic algorithm (GA) that can be the altering which is crossover and mutation operator. There are many types of crossover operator such as single point crossover, double point crossover and uniform crossover [18]. Double point and uniform crossover is the improvement from the single point crossover used in conventional genetic algorithm (GA). The results of the improved genetic algorithm (IGA) show a better reduction in power losses compared to genetic algorithm (GA).

Another way of solving the optimization problem is the presence of distributed generation (DG) in distribution system. Optimum distributed generation (DG) placement and sizing is one of the present topics in restructured power system. Most of the authors have come out on with own optimum placement based on the power losses reduction concept. To simultaneously reconfigure and identify the optimal locations for installation of distributed generation (DG) units in a distribution network, a metaheuristic Harmony Search Algorithm (HSA) is used [19]. Sensitivity analysis is used in order to determine optimal locations for installation of distribution generation (DG) units. Different scenarios of distributed generation (DG) placement and reconfiguration of network are recognized to study the performance of the proposed method.

Besides Harmony Search Algorithm (HS), another method which is partial swarm optimization (PSO) is also introduced. In [20], partial swarm optimization (PSO) is able to achieve an optimum configuration in network distribution and at the same time produces the optimal size of distributed generation (DG) and reduce power loss.

2.8 Summary of previous related research

Recently, a variety of optimization algorithms are developed to solved the network optimization problem such as power flow analysis and distribution network reconfiguration. Among the algorithms presently used are Particle Swarm Optimization (PSO), Artificial Bee Colony (ABC), Harmony Search algorithm (HSA), Genetic Algorithm (GA) and Improved Genetic Algorithm (IGA). The solution obtained from each algorithms contrast from one application to another. The review of previous research proved that the heuristic search algorithm used in distribution network reconfiguration (DNR) is very beneficial in order to improve the reliability and reduce the power losses. Distributed generation (DG) also gives a good impact to the power losses in the distribution system.

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