OPTIMAL LOAD SHEDDING FOR MICROGRIDS WITH UNLIMITED DGs

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For my beloved wife, daughter and siblings

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ABSTRACT

Recent years, increasing trends on electrical supply demand, make us to search for the new alternative in supplying the electrical power. A study in micro grid system with embedded Distribution Generations (DGs) to the system is rapidly increasing. Micro grid system basically is design either operate in islanding mode or interconnect with the main grid system. In any condition, the system must have reliable power supply and operating at low transmission power loss. During the emergency state such as outages of power due to electrical or mechanical faults in the system, it is important for the system to shed any load in order to maintain the system stability and security. In order to reduce the transmission loss, it is very important to calculate best size of the DGs as well as to find the best positions in locating the DG itself.. Analytical Hierarchy Process (AHP) has been applied to find and calculate the load shedding priorities based on decision alternatives which have been made. The main objective of this project is to optimize the load shedding in the micro grid system with unlimited DG's by applied optimization technique Gravitational Search Algorithm (GSA). The technique is used to optimize the placement and sizing of DGs, as well as to optimal the load shedding. Several load shedding schemes have been proposed and studied in this project such as load shedding with fixed priority index, without priority index and with dynamic priority index. The proposed technique was tested on the IEEE 69 Test Bus Distribution system.

ABSTRAK

Semenjak kebelakangan ini, peningkatan kadar permintaan bekalan elektrik, memaksa kita untuk mencari alternatif baru dalam membekalkan kuasa elektrik. Kajian terhadap penggunaan sistem grid mikro dengan aplikasi Generator Pengagihan Tertanam (DG) untuk sistem ini semakin mendapat tempat dan kian meningkat. Sistem grid mikro sama ada beroperasi dalam mod bersambung atau berpisah daripada system grid utama adalah bertujuan untuk membekal atau menjana bekalan kuasa elektrik yang berkekalan dan mengurangkan kebocoran atau kehilangan bekalan semasa proses penghantaran kepada beban bekalan. Semasa keadaan kecemasan seperti gangguan kuasa disebabkan kerosakan elektrik atau mekanikal dalam sistem itu, ia adalah amat penting untuk sistem menumpahkan atau mengurangkan, apa-apa beban untuk mengekalkan kestabilan sistem dan keselamatan. Kajian terperinci dan menyeluruh bagi saiz dan lokasi DG yang sesuai amat perlu untuk mengurangkan kehilangan penghantaran dalam sistem grid mikro.Mengoptimum beban yang perlu ditumpahkan adalah amat penting untuk memastikan kestabilan dan keselamatan system.Proses Hierarki Analisis (AHP) telah diguna pakai untuk mencari dan mengira indek keutamaan bagi setiap beban.berdasarkan alternatif keputusan yang telah diambil. Objektif utama projek ini adalah untuk mengoptimumkan beban yang perlu ditumpahkan dalam sistem grid mikro dengan aplikasi DG tanpa had. Teknik yang telah digunakan adalah Algoritma Pencarian Graviti (GSA).Teknik ini digunakan untuk mengoptimumkan penempatan dan saiz beberapa DGdalam sistem grid mikro, dan juga untuk mengoptimumkan beban yang perlu ditumpahkan. Tiga teknik skim menumpahkan beban telah dikaji dan dibincangkan dalam kajian ini. Teknik yang dicadangkan telah diuji pada Sistem Ujian Bus Pengagihan IEEE 69.

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LIST OF SYMBOLS AND ABBREVIATIONS

$a_i^d(t)$	-	Acceleration
a_{ij}	-	Lower diagonal matric
a_{ji}		Upper diagonal matric
best(t)	-	fitness of all agents of the best (minimum) .
F	-	Objective Function
$F_i^d(t)$	-	Total Force acting on *ith* agent
fit_j	-	Fitness on the *jth* agent at t time
G (t)	-	Gravitational Constant
I_{ij}	-	The line current I_{ij}, measured atbus*i*
I_{ji}	-	The line current I_{ij}, measured at bus *j*
Kbest	-	The set of initial K agent with the best fitness value and the largest
$Mg_i(t)$	-	Mass of ith agent at t time
$M_i(t)$	-	Forces acting on *ith* masses
$M_j(t)$	-	Forces acting on *jth* masses
N	-	The number of buses in the system,
NO_x	-	Nitrogen Oxide
P	-	The active power
P_{di}	-	The active powers supplied to the load

$\overline{P}_{di}$	-The active load powers,
P_i	-The active power injections at bus
P_{Gi}	-The active power generations at bus *i*
$P_{load,i}$	-The load at bus-*i* with DG unit is to be modified
Q	-The reactive power
Q_i	-The reactive power injections at bus
Q_{di}	-The reactive powers supplied to the load
$\overline{Q}_{di}$	-The reactive load powers,
Q_{Gi}	-The reactive power generations at bus *i*
$rand_j$	-Random number between the intervals [0,1]
S_{ij}	-The complex powers from *i* bus
S_{ji}	-The complex powers from *j* bus
S_{Lij}	-The power loss in $i \rightarrow j$
t	-Current epoch
$v_i^d(t+1)$	-Velocityof *ith* agent at *t* time in *ith*
worst(t)-	-Fitness of all agents of the and worst (maximum).
$x_i{}^d$	-Position of the *ith* mass in dth dimension
$x_i^d(t+1)$	-The next position of *ith* agent in *dth*
α_i	-Weighting factor which are problem dependent
β_i	-Weighting factor which are problem dependent
ε	-A small constant
λ_{max}	-Maximum Eigen value
CI	-Consistency Index
CR	-Consistency Ratio

DG	-Distributed Generation
GSA	-Gravitational Search Algorithm
KCL	-Kirchhoff Current Law
LAN	-Local Area Network
MG	-Micro Grid
p.u	-Per units
RES	-Renewable Energy Resources
UTHM	-Universiti Tun Hussein Onn Malaysia

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CHAPTER 1

INTRODUCTION

1.1 Project background

Using devices with modern technologies is almost inevitable in every aspect of human life. Most activities in daily life cannot be executed smoothly in the event of power failure. This phenomenon proves that the existence and stability of electricity is important, since it has significant impact on human convenience and comfort in performing daily tasks. The industrial sector also requires electricity to produce the output that is efficient, fast and effective. Machines in this sector typically require high-powered electricity.

There is an arising concern in the issues of growth in load demand in developing and developed countries, which has significant impacts to the power system planners and operators. The growth of load demand is estimated to be in increasing trend and the trend will continue to expand in near future. A prolonged electrical power supply interruption would result in serious financial implication to the customers. However, in emergency situation, the system itself requires making load shedding decisions based on its security aspects such as voltage, current, power and frequency constrains to maintain its stability and reliability.

Nowadays, many countries are working on micro-grid system (MG) technology which is based on distributed generation (DG). The MG is a small-scale complex energy network system, embedded by many small-scale generations such as wind turbines, micro turbines, photo voltaic generation system, bio-gas generation system, electronic equipment, loads and ancillary facilities etc [1]. MG is designed to function independently as an islanded system in the non-electrified remote areas, and the MG can operate in a grid connected mode by connecting the MG to a low voltage utility grid

DG is normally defined as a small generation unit (<10 MW) installed in distribution system [2]. As today and in the future Distributed generation will be played an important role in emerging electric power system. Distributed generation technologies can be categorized as non-renewable DG and renewable energy. In distribution system, DG units are installed close to the load side, hence the energy losses in transmission lines and distribution network is reduced. In another factor, applying DG technologies in many cases provide flexibility and mobility due to their small size, short construction time compared to traditional power plants. In fact, the penetration of DG in the power system will change the structure of the grid as well as operation and planning for traditional power systems. It also will increasethe complexity of controlling, protecting and maintaining of distributed systems [1].

Comprehensive planning on installation of distributed generation is needed and requires the definition of several factors such as the best technology to be used, the number and capacity of units, the best location, the type of network connection and etc. The impact of DG in system operating characteristic, such as electric losses, voltage profile, stability and reliability needs to be appropriately evaluated [3]. Due to this characteristic constrains, the most important factor to evaluate is DG allocation and sizing. Allocation of DG at the wrong places or non-optimal places can incurred system losses, increase in cost and the worst case having an effect opposite to the desired.

Normally when there is emergency state in a distributed generation system, operators will shed most of the loads except the priority loads, as the last resorts to maintain system integrity. The nearby generator has to keep supplying the electricity to the priority loads. However this method cannot utilize the maximum capacity of the distributed generators. We may face problem in defining the nearby generation when there are multiple distributed generations.

For this purpose a study is done in order to optimize the load shedding in the micro grids with unlimited number of distributed generators (limit to 2DGs).The load shedding problem will be formulated as an optimization problemand combined with load flow studies to optimizing the DG installation places and sizing as to minimize loss. Then the results will be discussed base on the formulated problem.

1.2 Problem statement

Nowadays, the power electricity demand is growing fast and it must keep supplying the electricity even though in crisis or emergency state. One of the alternative solutions is applying micro grid system with embedded distributed generation to the current system or totally islanded from the main grid system. Increasing price of crude oil also give a challenge to power engineers to work and generates the electricity from renewable energy resources such as photovoltaic arrays, wind turbines, geothermal energy and small hydro. Applying the distributed generation might benefit to both parties either provider or user. For utility, distributed generation can help to maintain system stability, provide the spinning reserve and reduce the transmission and distribution cost [4]. On top of that, end user might have flexibility and improve quality of electricity supply. Electricity generating from the renewable resources also can reduce the emission from traditional power plants.

Energy services industry in Malaysia today is monopoly by Tenaga Nasional Berhad (TNB). It was different compared to developed countries such as United State of America, United Kingdom and in European countries where by the energy services is provided and shared by many companies. It will be acompetition between the companies involved in the energy supply, indirectly encourage the industry to develop and provide the best service to the customers. It is hope that the competition also would reduce the power generation cost. However, there will be electricity price fluctuation in new environment. In order to avoid the effect of price fluctuation and transmission and distribution cost, installing the distributed generation is better for end customers.

More distributed generation in the power systems will change the structure of the distribution system and will introduce the new problem [4]. One of the problems is the optimal load shedding. There are some researchers have studied in this matter, researcher [5]had studied on the power system in a large pump station (simulated by computer program). The studies show the load shedding scheme can maintain the power supply to important load during disturbance. In [6] they did studied for captive power plants. The main duty of load shedding is to maintain the power balance after islanding. A few more results are presented by other researchers. In [7], the respective researchers have applied and control load shedding schemes with Local Area Network (LAN). Outcomes of the study, the control the load shedding based on the priorities list. In [4], an optimal load shedding strategy for power system with multiple DGs is presented and in this paper discretization and mathematical programming has been introduced. In [3], a Genetic Algorithm is us for Distributed Generation allocation to reduce losses and improve voltage profile. In [8], a Genetic algorithm is applied to optimal placement of multi Distributed Generation in distribution system with considering DG bus available limits.

Hence a new approach is proposed to optimize the load shedding problem as to reduce load shedding cost in micro grid considering unlimited DGs units by using Gravitational Search Algorithm (GSA).

1.3 Project objective

The main objectives are:

- To find the best size and placement of DGs in micro grids in order to reduce the system loss.

- To optimize the load shedding in microgrids in order to optimizeload shedding amount to be shed.

1.4 Project scope

There are 3 scopes of this project. They are:

- This study has focus on reducing system loss due to allocation of DGs and sizing using GSA technique.
- To formulate and simulate the load shedding problem (optimize the amount of the load to be shed) based on steady state model.
- To obtain the result 2 by using GSA technique.

1.5 Organization of the thesis

The progress report is orderly into 5 chapters. The content of each chapter explained briefly below.

Chapter 1:presents the background, objective and the scope of the project. The chapter also summarizes the content of the thesis.

Chapter2: discusses about the theory of the project along with the literature review.

Chapter 3: gives a detail discussion on the design of the project and the methodology used to construct the project.

Chapter 4: present and discusses details finding and results of the project. Also do analyzed the findings data and make a brief comments about the results.

Chapter 5: give a summary about the findings of the project; make a conclusion and suggestion towards achievement of the project.

1.6 Summary

This chapter of this thesis discusses about the introduction for the whole project. Firstly, the principle and concept of the microgrids, distributed generation and load shedding are introduced. Next, the problem statement is discussed. Then, the next part is about the objectives and scopes of the project. Lastly, the thesis outline is discussed which will give an overview for the reader about the thesis.

CHAPTER 2

LITERATURE REVIEW

2.1 Micro grid (MG) system

Recently, there has been an increasing interest in the application of DG to enhance power supply reliability, especially in the event of main power failure. The recent concept is to group a cluster of loads and paralleled DG systems within a certain local area, which is referred to as a MG. The IEEE 1547.4 working group is dedicated to providing general guidelines for design and operation of such an islanded power system [9].

The MG appears as a single consumer by the national supply system. It can be quickly switched on and off from the large network. If utility company offers cheap electricity, the owner of micro grid may purchase electricity from them. However when the power offered is expensive or fails completely, the consumer can use the MG separately.

Basic MG architecture is shown in Figure 2.1. This consists of a group of radial feeders, which could be part of a distribution system or a building's electrical system. There is single point of connection to the utility called point of common coupling. Some feeders, (Feeders A-C) have sensitive loads, which require local generation. The non-critical load feeders do not have any local generation. In our example, this is Feeder D Feeders A-C can island from the grid using the static switch which can separate in less than a cycle. In this example there are four micro sources such as fuel cells, micro turbine, gas turbine and electronic storage at nodes 8, 11, 16 and 22, which control the operation using only local voltages and currents measurements.

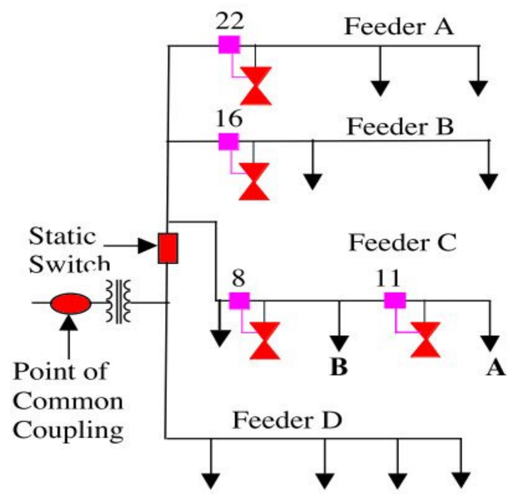

Figure 0.1: Basic micro grid architecture

When there is a problem with the utility supply the static switch will open, isolating the sensitive loads from the power grid. Feeder D loads ride through the event. It is assumed that there is sufficient generation to meet the loads demand. When the micro grid is grid-connected power from the local generation can be directed to Feeder D [10].

2.2 Distribution Generation (DG)

Distributed generation (DG) is related with the use of small generating units installed at strategic points of the electric power system or location of load center .DG can be used in isolated way, supplying the consumer's local demand, or integrated into grid supplying energy to the remainder of the electric power system. DG technologies can run on renewable energy resources, fossil fuels or waste heat. Equipment ranges in size from less than a kilowatt(kW) to tens of megawatts(MW). DG can meet all or part of a customer's power needs. If connected to a distribution or transmission system, power can be sold to the utility or third party.

DG and renewable energy resources(RES) have attracted a lot of attention worldwide. Both are considered to be important in improving the security of energy supplies by decreasing the dependency on imported fossil fuels and in reducing the emission of Green House gases (CHGs). The viability of DG and RES depends largely on regulation and stimulation measures which are a matter of political decisions.

2.2.1 Reason for DG

DG can be applied in many ways and some examples are listed below:

- It may be more economic than running a power line to remote locations.
- It provides primary power, with the utility providing backup and supplemental power.
- It can provide backup power during utility system outages, for facilities requiring uninterrupted service.
- For cogeneration, where waste heat can be used for heating, cooling or steam. Traditional uses include large industrial facilities with high steam and power demands, such as universities and hospitals.
- It can provide higher power quality for electronic equipment.
- For reactive supply and voltage control of generation by injecting and absorbing reactive power to control grid voltage.
- For network stability in using fast-response equipment to maintain a secure transmission system.
- For system black-start to start generation and restore a portion of the utility system without outside support after a system collapse.

DG can provide benefit for consumers as well as for utilities. Some example are listed below :

- Transmission costs are reduced because the generators are closer to the load and smaller plants reduce construction time and investment cost.
- Technologies such as micro turbines, fuel cells and photovoltaic can serve in several capacities including backup or emergency power, peak shaving or base load power.
- Given the uncertainties of power utility restricting and volatility of natural gas prices, power from a DG unit may be less expensive than conventional electric plant. The enhanced efficiency of combined heat and power (CHP) also contributes to cost savings.
- DG is less capital intensive and can be up and running in a fraction of the time necessary for the construction of large central generating stations.
- Certain type of DG, such as those run on renewable resources or clearer energy systems, can dramatically reduce emissions as compared with conventional centralized large power plants.
- DG is well suited to providing the ancillary services necessaryfor the stability of the electrical system.
- DG is most economical in application where it covers the base load electricity and uses utility electricity to cover peak consumption and the load during DG equipment outages, such as a standby service.
- DG may allow customers to sell excess power or ancillary services to power markets, thus increasing numbers of suppliers selling energy and increasing competition and reducing market power.
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2.2.2 DG technologies

DG technologies include engines, small wind turbines, fuel cells and photovoltaic systems. Despite their small size, DG technologies are having a stronger impact in electricity markets.

There is no single DG technology can accurately represent the full range of capabilities and applications or the scope benefits and costs associated with DG. Some of these technologies have been use form many years, especially reciprocating engines and gas turbines. Others, such as fuels cells and micro turbines, are relative new developments. Several DG technologies are now commercially available, and some are expected to be introduced or substantially improved within next few years.

i. Reciprocating engines. Diesel and gas reciprocating engines are well-established commercial DG technologies. Industrial-sized diesel engines can achieve fuel efficiencies in excess of 40% and relatively low cost per kilowatt. While nearly half of the capacity was ordered for standby use, the demand for units for continuous or peak use has also been increasing.

ii. Gas turbines. Originally developed for jet engines, gas turbines are now widely used in the power industry. Small industry gas turbines of 1-20 MW are commonly used in combined heat and power applications. They are particularly useful when higher temperature steam is required than can be produced by a reciprocating engine. The maintenance cost is slightly lower than for reciprocating engines, but so is the electrical conversion efficiency. Gas turbines can be noisy. Emissions are somewhat lower than for engines, and cost-effective NO_x emission control technology is commercially available.

iii. Micro turbines. Micro turbines extend gas turbines technology to units of small size. The technology was originally developed for transportation application, but is now finding place in power generation. One of the most striking technical characteristic of micro turbines is its extremely high rotational speed. The turbines rotates up to 120,000 r/min and the generator up to 40,000 r/min. Individual units range from 30 to 200kW but can be combined into systems of multiple units. Low combustion temperatures can assure very low NO_x emission levels. These turbines make much less noise than an engine of comparable size. Natural gas is expected to be the most common fuel but flare gas, landfill gas or biogas can also be used. The main

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