OPTIMAL PLACEMENT OF DISTRIBUTED GENERATION IN DISTRIBUTION NETWORKS FOR POWER LOSS MINIMIZATION AND VOLTAGE PROFILE ENHANCEMENT

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FACULTY OF ENGINEERING
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OPTIMAL PLACEMENT OF DISTRIBUTED GENERATIONIN DISTRIBUTION NETWORKS FOR POWER LOSS MINIMIZATION AND VOLTAGE PROFILE ENHANCEMENT

ABSTRACT

Distributed generations (DGs) have emerged as an alternative to meet the growing demand of electrical energy and thus contribute to sustainable development of the nation. However, DG integration into the power system, particularly renewable energy resources such as Solar Photovoltaics (PV) and Wind Turbine (WT) introduce uncertainty in its operation due to the nature of the sources themselves. Therefore, proper planning and consideration have to be done prior to actual integration to ensure continuous supply and smooth operation of the system with minimal costs in-terms of power loss. In this regard, this research project proposes an approach for optimal placement of distributed generations in terms of renewable energy resources while satisfying the operation and technical constraints of the system such as power balance, voltage profile and lines thermal limits. The proposed approach is tested on a 33-bus radial distribution network employing the Forward and Backward Sweep Method (FBS) and Particle Swarm Optimization (PSO). Multiple scenarios are considered to show the impact of optimal location of PV and WT towards overall system performance. Finally, a complete model that integrates the performance and effectiveness of the proposed method in terms of power losses which is reduced from 10% to 40% from the base case (without DGs) and voltage profiles enhanced resulted from integration of PV and WT in the optimal locations have been demonstrated and presented.

Keywords: Distributed generation, renewable energy resources, solar photovoltaic, wind turbine generating unit, Particle Swarm Optimization Algorithm, distributed forward and backward sweep method.

PENEMPATAN OPTIMUM GENERASI TERAGIH DALAM RANGKAIAN PENGEDARAN UNTUK PEMINIMUMAN KEHILANGAN KUASA DAN PENINGKATAN PROFIL VOLTAN

ABSTRAK

Pengagihan janakuasa telah muncul sebagai alternatif untuk memenuhi permintaan tenaga elektrik yang semakin meningkat dan seterusnya menyumbang kepada pembangunan mampan negara. Walau bagaimanapun, pengagihan janakuasa integrasi ke dalam sistem kuasa, terutamanya sumber tenaga asli dari sumber semulajadi seperti solar photovoltaik (PV) dan Unit penjanaan turbin oleh angin menghasilkan operasi yang tidak stabil disebabkan sifat sumber itu sendiri. Oleh itu, perancangan dan pertimbangan yang betul perlu dilakukan sebelum integrasi sebenar untuk memastikan bekalan yang berterusan dan operasi sistem yang lancar dengan kos yang minimum dari aspek kehilangan kuasa. Sehubungan itu, projek penyelidikan ini telah mencadangkan pendekatan untuk penempatan yang optimum pengagihan janakuasa dari segi sumber tenaga semulajadi dengan mengetengahkan operasi dan kekangan teknikal sistem seperti keseimbangan kuasa dan profil voltan. Pendekatan yang dicadangkan diuji pada rangkaian pengedaran jejari bas 33 yang menggunakan kedah Sapuan kedepan dan kebelakang dan Pengoptimuman Pergerakan Zarah. Pelbagai senario di ambil kira untuk menunjukkan kesan lokasi yang optimal oleh Photovoltaik dan Unit Penjanaan Turbin oleh angin ke arah prestasi sistem secara keseluruhan. Akhirnya, model lengkap yang mengintegrasikan prestasi dan keberkesanan kaedah yang dicadangkan dari segi kehilangan kuasa telah dikurangkan dari 10% to 40% dan peningkatan profil voltan yang terhasil daripada integrasi Photovoltaik dan Unit Penjanaan Turbin oleh angin di lokasi optimum telah ditunjukkan dan dibentangkan.

Keywords: Particle Swarm Optimization, kaedah sapuan ke belakang hadapan, fotovoltaik, Unit Generasi Turbin Angin

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LIST OF SYMBOLS AND ABBREVIATIONS

ABC	:	Artificial Bee Colony
AI	:	Artificial Intelligence
DERs	:	Distributed Energy Resources
DEST	:	Distributed Energy Source Types
DG	:	Distributed Generation
DGs	:	Distributed Generations
DS	:	Distributed Storage
EIDG	:	Electronically Interfaced Distributed Generation
FBS	:	Forward and Backward Sweep Method
FiT	:	Feed- In Tariff
GA	:	Genetic Algorithm
LMP	:	Locational Marginal Price
MBIPV	:	Malaysia Building Integrated Photovoltaic
MPPT	:	Maximum Power Point Tracking
OADG	:	Optimal Allocation of Distribution Generation
PQ	:	Active and Reactive Power
PSO	:	Particle Swarm Optimization Algorithm
p.u	:	per unit
PV	:	Photovoltaics
RDG	:	Renewable Distributed Generations
RDS	:	Radial Distribution Systems
RE	:	Renewable Energy
REDG	:	Renewable Energy Distributed Generations
RES	:	Renewable Energy Sources

SEDA	:	Sustainable Energy Development Authority
PV	:	Solar Photovoltaic
TNB	:	Tenaga National Berhad
VSC	:	Voltage Source Converter
WT	:	Wind Turbine
%	:	Percent

CHAPTER 1: INTRODUCTION

1.1 Overview

Electricity generated from fossil fuels have known to impose some negative impacts onto the environment in terms of greenhouse gases emission. Furthermore, fossil fuels and coals that have been traditionally used to generate electrical power has started to deplete significantly since the past decades as they are one of the non-renewable resources. On the other hand, the world's populations in general have increased substantially over the years. Increasing residential customers has greatly impacted the energy demand, made worse as these types of customers are not really aware on the amount of energy they have used in a day in which some percentage are being wasted. Moreover, as reported by the Department of Statistics in (Mokhtar; et al., 2017), the growing number of housing units completed in the country showed an increase for each year. According to recent environmental impact assessments, the number of households has increased by 32%, and the total residential square footage has increased by 41% from 2011 to 2015. Therefore, without energy conservation improvements, energy demand for domestic uses such as heating, cooling, and lighting would increase at similar rates (Mokhtar; et al., 2017).

Growing electricity demands requires more power plants for electric generations. However, power plants based on coal, oil or natural gas will further contribute to the increase in greenhouse gases emission. Thus, renewable energy sources (RES) such as sunlight, wind, rain, and geothermal have been explored as an alternative to the traditional power plant with one of the objectives to reduce greenhouse gases emission.

Utilization of renewable energies can help to reduce the depletion rate of non-renewable resources and help to preserve the natural surroundings. The most widely used of alternative energy are micro hydro, PV and WT. In addition, network powered up by renewables can be an attractive approach for rural, isolated, and remote places that have poor chances to get power supplies the main grid due to economic and technical constraints.

The growing interest in generating electricity by utilizing RES creates a new type of power system network which includes both renewable and fossil fuel power plants. The main aim of this network is to establish an energy system that is sustainable, particularly with respect to reducing greenhouse gas emissions and improving security and reliability of energy supply to all its consumers. These renewable distributed generations (RDG) are usually located near to the load centers and stability limits due to economic and environmental constraints, lead to some benefits such as system power loss; voltage profile and stability improvement and environmental friendliness which rise the issue of voltage instability and voltage collapse and made them very important terms to be understood and well-known so their negative effect can be prevented or at least minimized.

To ensure the continuity of supply, the electric power system must be stable and secure which must have voltage profile with stabilized supplied from the power grid system. Voltage stability referring to the voltage profile means maintaining steady acceptable voltage magnitudes at all buses in the system. In practice, it is defined as the ability of the system to withstand the credible incidents without suffering from any serious consequences (Taylor, 1994.). It had been regarded as one of the major sources of power system insecurity. As stated, at any point of time, a power system operating condition should be stable, meeting various operational criteria, and it should also be secure in the event of any credible contingency. To summarize, maintaining a stable and secure operation of a power system is a very important and challenging issue. Power systems are expected to become more heavily loaded in the future decade as the demand for electric power rises while economic and environmental concerns limit the construction of new transmission and generation capacity. The FBS and PSO calculation concepts has been proposed to find the optimal location of solar photovoltaic (PV) based in a microgrid. FBS has been applied to improve the power losses of radial networks considering different constraints and PSO has been applied to analyze the location of the bus in the system related to the distribution network.(Dawoud et al.)

1.2 Problem Statement

The exponential demand for energy has led to the depletion of fossil fuels such as petroleum, oil, and carbon. This, in turn, increases the greenhouse effect gases. Energy systems have incorporated small-scale and large-scale renewable sources such as solar PV, wind, biomass, and tidal energy to mitigate the problems on a global scale. The reliability of the renewable sources is a major challenge due mainly to mismatch between energy demand and supply. The increase in the demand for energy and the rethinking of power systems has led to energy being generated near the places of consumption because of power losses has been occurs in the distribution line. RDG has been used to describe the small-scale power systems, usually in sizes ranging from a few kW to a few MW(Moradi & Abedini, 2016; T. Ackennann, 2001). Power loss and voltage instability are major problems in distribution systems. However, these problems are typically mitigated by efficient network reconfiguration, including the integration of distributed generations (DGs) units in the distribution network. In this regard, the optimal placement and sizing of DGs are crucial (Haider et al., 2021). A major challenge encountered by electrical distribution companies concerns the power losses and voltage instabilities arising from their respective networks. Owing to these problems, their operating costs increase, and their profits are subsequently decreased. The utilities have a great interest in the reliability of the system, voltage regulation, and active and reactive power (PQ) problems owing to the high degree of penetration of intermittent RES into the distribution networks. That may pose a danger to the system. Therefore, distributed generation (DG) units are expected to follow strict technological and regulatory requirements to ensure the safety, stability, and efficiency of the distribution network (Singh et al., 2011).The current distribution networks face numerous challenges. A voltage profile has great importance to customers, as it is a primary requirement for quality voltage-controlled electrical equipment. DGs can provide voltage support at the end of a feeder to increase the voltage (El-Khattam, 2002). Owing to the existence of DGs, network reliability, power flow, relay safety, voltage profile, and stability may have major impacts on distribution grids. Voltage Stability is a severe problem in power systems, which steadily reach operating limits imposed by economic and environmental conditions. Whenever there is a change in load the system voltage level changes. With the drop in voltage level, the reactive power demand increases. If the reactive power demand is not met, then it leads to further decline in bus voltage resulting in the cascading effect on neighboring regions (Vanishree & V, 2014).

1.3 Aim and Objectives.

The research aims to propose an optimal location to sit distributed generation for power losses minimization. In order to achieve the aim, the following research objectives are defined:

1. To develop a model of distribution networks with distributed generation integration.
2. To determine the optimal location to connect the distributed generation units in the distribution networks.
3. To evaluate the system performance in terms of system power loss and voltage profile.

1.4 Scope and Limitation

The focus of this study is to present the 33-bus radial network connection with the excellent performance operation. Particularly this works useful for network planning engineers and future researchers to design the new operating plan. The idea is to operate the systems with excellent performance with low output power loss by delivering the required real power to the load by efficiently managing the distributed energy resources (DERs) in the systems. Since the reactive power in the system can be compensated locally, only the active power is considered in this investigation.

1.5 Thesis Outline

In this work, chapter one contains general introduction of the proposed research where a brief about electrical power system, distribution generation, and the major factors that brought about the evolution of the DG in the electrical power system where certain issue of negative impact cause by conventional power generation plant with respect to the environment, climate change on different DG technologies for an effective and reliable electricity supply that can take care of the increase in the customer demand. The main problem statement and the objective of this work has been highlighted to give an insight on the possible goal that is to be achieved at the end of this research while abiding by the scope of work as mentioned in this chapter.

Chapter two summarizes the literatures as well as the previous works that have been carried out on the similar research topic.

Chapter three presents the research methodology and approach adopted in this work. Steps and calculations employed to achieve the research objectives are described in detailed.

Chapter four presents the research findings where the main findings are highlighted and discusses thoroughly.

Chapter five concludes the research work with a few recommendations for future works in the same topic.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Electrical energy sector is facing serious challenges in sharply increasing energy demands, global warming, and depletion of fossil fuel reserves. Fossil fuels are limited, non-sustainable and causing global warming. It led researchers to work on alternate energy resources. Major developments have been seen in past few decades in solar PV, wind, tidal, biomass and geothermal energy. These sources are being integrated in system one of the most attractive ways to integrate such sources is distributed generation at distribution level. It offers to meet demand by generating clean energy on site of demand. This reduces the transmission loss and increases penetration of renewable resources. Integration of DGs defers the need to upgrade system for increasing electricity demand (Zeb et al., 2020). DG also provides economic benefits of operation besides offering a clean and sustainable energy.

2.2 Distributed Energy Resources (DERs)

A DER refers to a DG unit, a distributed storage (DS) unit or any combination of DG and DS units. In terms of prime mover (sunlight and wind) availability, DG systems are classified to two groups which are “dispatchable” and “non-dispatchable” entities. In the former case, DG guarantees the amount of power requested by the system operator provided that this value is within its power capability. Diesel gen-set plant and fuel cell are two examples brought to this end. However, in the latter case, as much as power (uncertain amount) which is available from the prime mover (such as sun and wind) can be transferred to the AC grid or stored in a storage system. DERs are divided in two groups based on their interfacing units to the AC power grid. The first group is interconnected through the conventional rotary systems such as synchronous generators and the second group is coupled through power electronic converters.

For an electronically interfaced unit, the interfacing converter provides a fast dynamic response for the system. Interfacing converter also is capable of limiting short-circuit current of the unit to less than 200% of rated current and thus extra fault current sent from the Electronically Interfaced Distributed Generation (EIDG) is practically prohibited by the voltage source converter (VSC). Against to a rotary based DG unit, an EIDG unit does not exhibit any inertia during the microgrid transients and hence has no inherent tendency to keep the frequency of microgrid stable. Interfacing converter can also minimize the dynamic interactions between the primary source of power and the distribution system (these reactions are normally severe in the case of conventional DG units) (Chowdhury & Crossley, 2009)(Chowdhury et al., 2009).

2.2.1 Utility Scale Distributed Energy Resource

A utility scale DER refers to a distributed energy power plant with a same capacity which is defined for a conventional fossil fuel power plant. For example, we can point out to a utility sized PV DG system. This type of power plant is constructed from plenty of single Solar PV cells which are mounted on a PV module or panel. Solar PV modules are usually installed in groups and each set have a separated supportive structure. Solar PV DG systems can be designed to track the sun in the sky through single or double axis tracking mechanisms (Bhatnagar & Nema, 2013; Eltawil & Zhao, 2013). In double tracking system the Solar PV radiation input is higher, but it is complex and expensive than the first type. In short, the utility scaled DG system term reflects a large commercial or industrial DG based power plant which is able to supply the three-phase loads more than 1MW (IEEE, 2000; Katiraei & Agüero, 2011(Katiraei & Romero Aguero, 2011); Photovoltaics, 2009; Sørensen et al., 2008)

2.2.2 Medium and Small Scale Distributed Energy Resource

Medium scale DER refers to an electricity generation plant which can supply electrical power for both single and three phase loads between 10kW to 1MW. The small scale DERs where their capacity of generation is less than 10kW and hence they are commonly prone to supply single-phase loads (IEEE, 2000; Katiraei & Agüero, 2011; Photovoltaics, 2009; Sørensen et al., 2008)

2.3 Non-dispatchable DERs

2.3.1 Solar Photovoltaic

By the end of 2011, total capacity of Solar PV system installed in Malaysia was about 13.5MW. 2.5MW of this amount was grid-connected PV systems. More than 60% of the grid-connected Solar PV plants in Malaysia are domestic installations and the rest is related to educational and commercial applications (PVPS, 2012)(PVPS, 2012). Although the financial support from the Malaysia Building Integrated Photovoltaic (MBIPV) project expired in 2010, the installation of grid-connected Solar PV systems grew in order to complete the outstanding financially supported projects (PVPS, 2012)(PVPS, 2012). PV policy developed significantly in 2011 in Malaysia. In this case, the government passed to approve the Renewable Energy (RE) Act 2011, the Sustainable Energy Development Authority (SEDA) Act 2011, and the associated implementation of a feed- in tariff (FiT) scheme. The opening share allocated to Solar PV was 150MW over three years (50MW for every of years 2012, 2013 and 2014), with 90% assigned for commercial sector developments and 10% for households. House owners are permitted to install up to 12kW Solar PV for each application whereas the commercial entities are permitted up to 5MW for each purpose.

The country's major national electricity utility, Tenaga National Berhad (TNB) is one of the key stakeholders in order to implement the feed-in tariff scheme (TNB adds 1% extra charge on the electricity bill for those consumers who use above 300kWh of electricity monthly) (PVPS, 2012)(PVPS, 2012). This is put down into the RE Fund and is governed by SEDA Malaysia and will be utilized to pay FiT. A feature of the Malaysian FiT scheme is the e-FiT online system that provides the users with an online FiT processing system. This system gives this facility to the public to submit their applications through internet within three hours. Three hours start counting once the quota for any commercial sector project is completed (PVPS, 2012).

2.3.2 Technical Impacts of Solar Photovoltaic Plant

The intermittency nature of Solar PV plant can affect the operation of main distribution power grid by creating steady-state and transient problems. The quantity of electricity produced from PV directly depends on intensity of sun light. Solar PV when connected to the grid have positive impact on the network. At the same time, they also can have a negative impact. The PV penetration relies on Solar PV radiation which fluctuates daily, hourly and over a shorter period (minutes and seconds).

A review by (Shah, Mithulananthan, Bansal, & Ramachandaramurthy, 2015)(Shah et al., 2015) also discussed the impact of very large scale PV when integrated with the utility and grid code requirement which would facilitate interconnection of large scale PV system with the utility grid. Since the regulation varies from one system operator to another the authors insist on developing necessary standards globally to facilitate integration of very large MW (megawatt) scale PV plant with utility grid which helps the PV equipment manufacturers and developers to reduce additional manufacturing cost.

The movement in cloud influences change in output power which also depends on size of the PV plant. The larger the size of PV plant lower the output power fluctuations. Shorter the sampling time higher the significance of the smoothing effect (Marcos, Marroyo, Lorenzo, Alvira, & Izco, 2011). In (Denholm & Margolis, 2007; Eltawil & Zhao, 2010) authors illustrate challenges faced when large scale PV installations interact with existing grid utility. Due to random fluctuations, it is difficult to prepare the scheduling of PV for electricity generation. The PV output fluctuations can be limited by using additional sources like battery, capacitors, diesel generators, fuel cell, controlling maximum power point tracking (MPPT) to control output power from PV generator or by installing dump load to divert excess power. There has been an intense research activity in the field of RES and the problems associated with it.

2.3.3 Wind Generators

Malaysia experiences two main weather seasons: southwest monsoon (May or June to September) and northeast monsoon (November to March). Data have been developed from researcher Association (2016) Wind speeds during the southwest monsoon are often below 7 m/s, but during the northeast monsoon, wind speeds could reach up to 15 m/s particularly in the east coast of Peninsular Malaysia. Moreover, during April to September, the effects from typhoons striking neighbouring countries (such as Philippines) may cause strong winds (even exceeding 10 m/s) to Sabah and Sarawak. Although Malaysia, as a whole, experiences low wind speeds, some areas in this country see strong winds during certain periods of the year. From the Malaysian Department of Meteorology, the data were from 1989 to 2008 (20 years), and in addition to them, the wind speed for Serdang, the wind speed data were from 1985 to 2007 (23 years). All wind speeds were typically measured 2 meters above the ground. From this data, Malaysia experiences stronger winds in the early and late parts of the year. According to Tenaga Nasional, in collaboration with Argentina’s renewable energy firm, Industrias Metalurgicas Pescarmona S A (IMPSA), 500 to 2000 MW worth of electricity could be generated from wind energy in Malaysia (meeting between 3.5 to 14% of the expected demand in electricity by 2020). They further reported there are areas such as the Malaysian-Thailand border which see wind speeds up to 15 m/s. It is interesting to note that wind energy suffers contrasting problems with Solar PV energy. Technology for Solar PV energy is prohibitively expensive for large scale use in Malaysia. In contrast, harnessing wind energy is much cheaper than that for Solar PV energy to set up in this country. Malaysia enjoys plenty of sunshine (as much as 3 kWh per square meter) all year round, but Malaysia sees only low wind speeds and sees high winds only at certain times of the year. (Association, 2016).

2.3.4 Technical Impacts of Wind Generation Plant

Researcher *Asian Energy Association* (Association, 2016) come with the data of the energy per square meter area of a wind turbine is determined as: 0.5 x air density (kg per cubic meter) x wind speed x wind speed x wind speed. Note that wind speed (m/s) is cubed (multiplied by itself thrice). Using the equation and taking air density as 1.3 kg per cubic meter and mean wind speed as 3 m/s give the energy per square meter area of a wind turbine as 17.55 W. The diameter (d) of a typical wind turbine is 25 m, so the circular area of a wind turbine is: 3.142 x 0.25 x d x d = 491 square meter. Hence, the total power generated from a single windmill is: 17.55 W per square meter x 491 square meter = 8,617 W. However, the efficiency of windmills is not 100% but typically only about 50%. This means the actual total power generated from a single windmill (i.e., after correcting for inefficiency) is half of 8,617 W or 4,309 W. Now let's determine the power that could be generated from a square meter of land area occupied by windmills. Windmills cannot be placed too closely to each other. Doing so would cause one windmill to slow down the wind speed for another windmill. But placing windmills too far from each other wastes land area. Typically, windmills are placed no less than five times their turbine diameter without losing power. Hence, the power that could be generated by windmills per unit land area is power per windmill (W) / land area per windmill (square meter) or 4,309 W / [(5 x 25 m) x (5 x 25 m)] = 0.28 W per square meter land area. Recall that the diameter of a typical wind turbine is 25 meter and two adjacent windmills are placed apart by five times their turbine diameter. Windmills typically require a minimum wind speed of between 3 to 5 m/s to generate electricity. Due to the problem with generate output power for the windmills may be difficult to generate wind generation in Malaysia even the construction of the wind much smaller rather than Solar PV. This work has been referring all data for wind generation from this paper (Yammani, 2012).

2.4 Optimal Placement of DG in distribution networks

Several optimization efforts had been presented in literature with a main aim of maximizing the benefits expected from connecting DGs to electrical networks, by optimizing their location with a defined specific capacity. Power loss minimization and voltage stability improvement are important areas of power systems due to existing transmission line contingency, financial loss of utility and power system blackouts. Optimal allocation (siting and sizing) of DG is one of the best ways to strengthen the efficiency of power system among capacitor placement and network reconfiguration. Power system operators and researchers put forward their efforts to solve the distribution system problem related to power loss, energy loss, voltage profile, and voltage stability based on optimal DG allocation. Furthermore, optimal DG allocation secures distribution system from unwanted events and allows the operator to run the system in islanding mode. Comprehensive study is carried out for optimum DG placement considering minimization of power or energy losses, enhancement of voltage stability, and improvement of voltage profile by Sultana et al. (2016). An attempt has been made to summarize the existing approaches and present a detailed discussion in the below:

2.4.1 Techniques for Optimal allocation of distributed generation

Various optimal techniques can solve issues related to the appropriate size and placement of DG by describing different objective functions with various technical or operational constraints that can be performed using various computational method with different DG type considerations based on various power factor consideration methods and various number of units. The author Sultana et al. (2016) introduces four step which is :

(1) *Planning objectives and constraints*

Review of the (Sultana et al., 2016) has elaborated present study only reviews research publications since the early 2000s, as summarize in the three diagrams in Figure 2.1

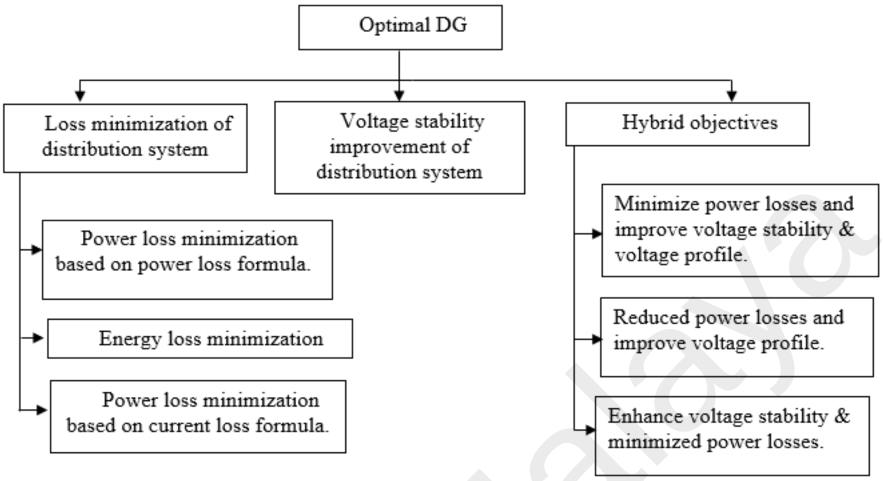


Figure 2.1: Tree diagram of considered planning objectives.

(2) *Planning variables*

Discrete location and discrete or continuous size and types of DGs are included in the category of planning variables. The main types and their characteristics are described in Table 2.1.

Table 2.1: Types and characteristics of DG(Hung & Mithulananthan, 2013)

DG Type	Description	Characteristics	Examples
1	DG is feeding only active power (PF_{DG} =Unity)	Relatively less improvement in load factor as type 3 and 2 DG	Microturbine, battery storage, PV and fuel cells
2	Providing reactive power only ($PF_{DG} = zero$)	In routine operation it is not economical to use	Capacitor & synchronous compensators
3	Injecting both active and reactive power (0<$PF_{DG} < 1)/+ve$	Highest loss compensation and load factor improvement of the power system	Synchronous generator
4	Supplying active power and drawing reactive power (0<$PF_{DG} < 1)/-ve$	Lowest cut down power losses and load ability of the system	Induction generator connected with wind turbine

(3) Nature of loads

Different authors have considered different types of loads in their research papers. Detailed load modeling is impossible because of the highly distributed and intermittent nature of the load (Ugranlı & Karatepe, 2013). During planning, three possibilities were considered by the authors example fixed load, time varying load and multi-level loads. (Sultana et al., 2016).

(4) Quantity of DG units

Authors (Sultana et al., 2016) have optimized planning variables in the presence of single or multiple DG accommodation.

2.4.2 Optimal DG planning for loss minimization of distribution system

Originally the infrastructure, protection, and control of power systems were designed without DG. Power flow is assumed to be from the grid to the substation so that heavy penetration by DG may alter the flow of power and hit the boundaries of system operation limits. Therefore, the optimal site and size of DG reflects the maximum loss reduction and improvement in voltage profile of distribution system. This task is not very simple to achieve so researchers (Sultana et al., 2016) have tried conventional, intelligent and hybrid approaches to minimize power and energy losses.

Analytical expression in DG planning for power loss minimization of distribution system based on the exact loss formula was developed by Acharya et al.(Acharya et al., 2006) to compute optimal DG rating and an efficient DG placement methodology was investigated. Load flow was carried out twice, first in the absence of DG and second in the presence of DG. However, it required calculation of bus impedance (Zbus) matrix and the bus admittance matrix (Ybus) for Optimal allocation of distribution generation (OADG) Gözel and Hocaoglu (2009) and ignored voltage constraints. Ramesh et al. performed a sensitivity analysis for OADG with a constant impedance load model so as to minimize active power loss and study bus voltages in the Indian Electricity Board TNEB 11 KV distribution feeder and IEEE 37 bus system Ramesh L (2008) .Optimum DG rating was examined through a proposed Kalman filter algorithm whereas 10 MW step size was adopted despite being less practicable. In Kansal et al. (2013), a PSO algorithm is implemented to explore the suitable placement and rating of multiple types of DGs and optimal power factor distribution generation was also found while assuming a constant power load model. The authors compared their results with ABC & GA methods-based solution found in Abu-Mouti and El-Hawary (2011); (Shukla et al., 2010), respectively for 69 bus systems. They found noticeably smaller DGs than both metaheuristic algorithms, but a slight decrease in the percentage of active power loss reduction was observed against the artificial bee colony (ABC) approach. A sensitivity analysis was applied which considered the characteristics of a constant current load model. However, downstream busses were taken possible candidate location in 69 bus long feeder. The PSO optimization technique was used to enhance the efficiency of a typical Nigerian grid in terms of voltage profile and PLR improvement. However, DG operational constraints were not mentioned explicitly.

2.4.3 Optimal DG Placement Methods

The proposed optimal placement methods of distributed generation sources are to approaches are various methods according to their objectives and loads modeling. A summary and application of each technique are considered, and the strengths and weaknesses of each method are highlighted (Abookazemi et al., 2010).

a) 2/3 Rule Method

This method often used in proper placement of shunt capacitors in distribution systems. This was presented in (Willis, 2000) to find DG optimal location on a radial feeder with uniformly distributed load. It was proposed for minimizing the losses and voltage impacts and for using in feeders with uniform loads. This approximate and useful approach has presented that the best capacitor size is 2/3 of the load which is located 2/3 of the distance out the feeder. It also can be extended to the “2/(2N+l) Rule” for N capacitors. For instance, the optimal locations for two units with approximately 2/5 capacity for each of them, might be located at 2/5 and 4/5 length of line (Willis, 2000). Based on this method, it was suggested to install DG unit with nearly 2/3 capacity of the incoming generation at approximately 2/3 of the distance. However, this is a simple and easy to use approximate technique, it cannot be applied directly to network systems or to feeders with other types of loads.

b) Optimal Power Flow

This technique is based on technical and economic aspects of load flow approaches. Different power flow methods (Ghosh et al., 2010; Harrison & Wallace, 2005; Rau & Yih-Heui, 1994) have been studied and evaluated for utilizing its potential in finding the best location to place DG. The common objectives are loss reduction, maximizing the size and voltage improvement. In an optimal power flow and based on DG participation in wholesale electricity market (deregulation), there are some more issues for finding optimal DG placement such as profit maximization, and welfare maximization. One of the proposed approaches to cover these subjects is locational marginal price (LMP) (Gautam & Nadarajah, 2007) which was based on Lagrangian multiplier along with power flow equation for each bus. In fact, the consumer payments were assumed as a product of LMP and load at each bus. Also, it was used as operational way to identify suitable DG location (Gautam & Nadarajah, 2007). This method has some advantages economically and technically like cutting the cost, reduction in loss and improving the voltage regulation. But the load types and its effects on DG placement were not studied. Moreover, this was assumed that the DG could be placed in any system buses while this assumption is not practically true.

c) Evolutionary Computational Methods

These methods cover a wide range of Artificial Intelligence (AI) techniques such as Genetic Algorithm (Mithulananthan et al., 2004), and Fuzzy Systems (Kyu-Ho et al., 2002) which have been applied in most optimization problems as well as DG optimal placement. The applications and goals of these techniques vary owing to their great potentials to optimize technical and economical DG challenges. The fundamental of these techniques are considered below. The Genetic Algorithm (GA)(Mithulananthan et al., 2004) is an optimization procedure or stochastic search based on the application of natural selection and genetics. It is a powerful search algorithm which has been solved many non-linear and large-scale problems of power systems. The GA is initialized with a population of individuals (solution-optimal location) and a binary representation of the decision variables to perform the search by using genetic operators such as selection, crossover, and mutation. The quality of an individual is assessed by its fitness, which is based on fitness function. In case of DG placement, this fitness is evaluated based on minimizing real power losses, to reduce investments and operational costs, and providing optimal size. The population is randomly created at the beginning of each search step. The fitness assessment is used to select the best solutions (individuals) from the current generation to upgrade into the next generation. The GA operators are applied for the next generation for having new and better individuals. This process is continued until the best solution (DG optimal location) in the population is found (Niknam et al., 2005).

As another technique, the fuzzy methods were generally used in power systems optimizations for fuzzy load modeling (Haghifam et al., 2008), and fuzzy economic cost (Ramirez-Rosado & Dominguez-Navarro, 2004). Also, because of its high-quality explanations, it has been applied in decision making and uncertainty concepts. In general, and in this approach, by utilizing the numerical analysis, the relationships of inputs and outputs are defined as fuzzy rules. Indeed, all objective functions such as optimal site and size of DG in this study are converted to fuzzy objective functions. The calculations of membership function related to the fuzzy optimal solution are performed individually and finally, the maximum value of the membership function can be defined as optimal solution (optimal location).

2.5 Summary

In the literature, overall review has been discussed such as type distributed energy resources, medium and small scale distributed, status of non-dispatchable DERs and optimal placement consideration in microgrid systems. The proper DG unit sizes should be placed in the optimal location to provide the maximum environmental, economic, and technical benefits. Researcher has discussed about the effect in the power grid problem was solved using numerical method and metaheuristic methods which referring to the Artificial Intelligence (AI) techniques. Mostly population-based algorithms like PSO, and evolutionary based algorithms like Genetic Algorithm (GA) and Fuzzy Systems were used. In this research has presented the recent trend of PSO for voltage profile improvement, power loss reduction and their multi-objective approach. Researchers have assumed specific planning constraints (such as bus voltage limits) and planning factors (such as DG size and DG location), each with their own prominent attributes. All the suggested approaches by the researchers in reviewed literatures will help the energy planners and utilities in improving performance of distribution system in terms of loss minimization, voltage stability and voltage profile improvement, and maximization of load ability of the system to manage the operating strategy with lowest daily operating cost.

CHAPTER 3: METHODOLOGY

3.1 Introduction

The utilities have a great interest in the reliability of the system, voltage regulation, and active and reactive power (PQ) problems owing to the high degree of penetration of intermittent RES into the distribution networks. That may pose a danger to the system. Therefore, DG units are expected to follow strict technological and regulatory requirements to ensure the safety, stability, and efficiency of the distribution network (Singh et al., 2011). The impact of DG on power losses is not only affected by DG location but also depends on the network topology as well as on DG size and type (M.F. Akorede, 2011). The placement, type and size of the DG should be optimal in order to maximize the benefits of it (Caisheng & Nehrir, 2004). For optimal placement of the DG in distribution system, evolutionary methods have been used, as they can allow continuous and discrete variable. The proposed microgrid model consists of Solar PV generator and wind system is introduced in this chapter which to optimize the power system modelled multi DGs location and size, while minimizing system real, reactive losses and to improve voltage profile and line loading by considering the bus available limit of the renewable DGs like windmills and Photovoltaic. The renewable energy DGs placement is limited to several busses with the consideration of environmental constrains.

3.2 Modelling of IEEE 33 bus system.

3.2.1 Overview

Due to the impact of power losses, power demand, voltage instability & line overloading which is reference to the voltage profile has become more seriously effect in the distribution system and has become challenging problems for engineers designing power system distribution. Unbalancing result reactive power is the major cause of voltage instability. So that the problem of enhancing the voltage profile and decreasing power losses in electrical systems is a task that must be solved in an optimal solution with improve voltage profile & stability of the existing power system. There are many researchers in presented multiple algorithm significantly, but in this work focused on three stages:

Type (1) : injects only active power for the power factor is 1.

Type (II): capable of injecting both active and reactive power to grid such as synchronous generator where the power factor is less than 1 and greater than 0.

Type (III): Produces active power by consuming reactive power (Wind turbines).

The placement of DG units in a distribution system is an optimization problem, and this is solved by minimization of system power losses, and improvement of voltage profile. This work has proposed three stages of calculation which is first, describes a FBS method-based approach for load flow analysis in radial distribution system to improve voltage stability and to minimize the transmission line losses considering cost function for entire power system planning, second, using PSO to minimization of power mismatches in the system buses to find the best location of DG, and third, calculate the

WT and PV generation using the reference data. The proposed approach will be tested on IEEE-33 bus system refer to the Figure 3.1 (Chitransh Shrivastava, 2015). The main objective of this work is to optimize the bus system which minimizing real power losses, reactive power losses which can improve voltage profile by considering the bus available limit of the RDG combination with WT and PV.

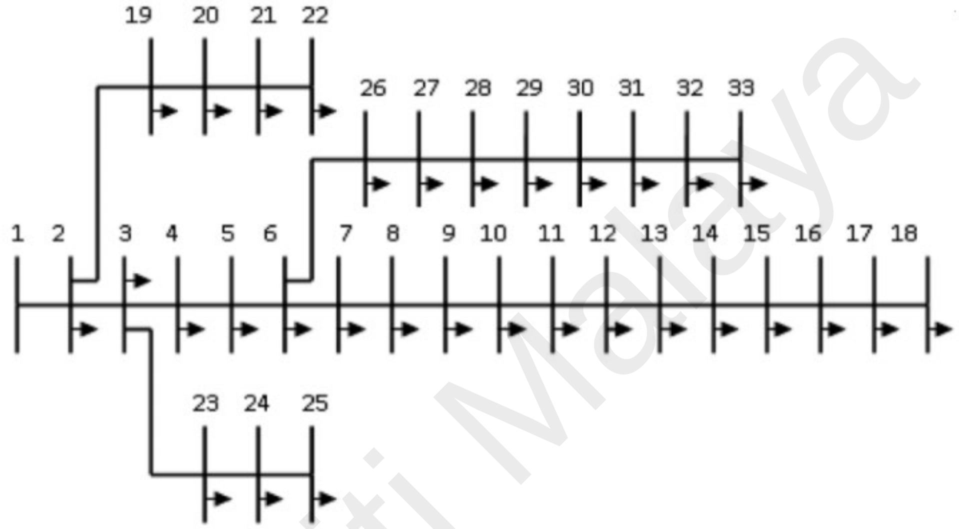


Figure 3.1: Single line diagram of 33 bus distribution test system(Kansal et al., 2013)

3.2.2 FBS method for load flow analysis

Newton Raphson and Fast Decoupled are widely used for their efficiency in transmission system analysis, but these methods are quite less effective in the analysis of distribution systems because of low line X/R ratios. The effectiveness of the FBS method in the analysis of radial distribution systems (RDS) has already been proven by comparing it to the traditional Gauss–Seidel method (Chitransh Shrivastava, 2015). This work, contribute a new approach of the load flow analysis with a method that does not require the use of any complex renumbering of nodes and branches, or any matrix calculation, flexible with network topology modification. Those proposed method is an iterative procedure based on the FBS algorithm with the only use of Kirchhoff's formulation (Ouali & Cherkaoui, 2020). The actual step for this FBS method can divide into three steps:

(1) (nodal current calculation) : the current injection at each node "i" is calculated using the following equation, where P_i is the power injection at node i and V(k) is the voltage of node i calculated from iteration k (Ouali & Cherkaoui, 2020).

$$I_i^{(k)} = conj\left(\frac{P_{n-i} + j\,(\,Q_{n-i}\,)}{V_{n=i}^{k}}\right) \quad \text{, i= 1,2,………………..,n} \qquad (3.1)$$

(2) (Backward sweep): starting from the last ordered branch, current J_i , i + 1, in branch from the node i to the node " i + 1 " is calculated using the following equation, where J_{n-r}^{k} is the current in branches emitting from node " i." (Ouali & Cherkaoui, 2020).

$$I_i^{(k)} = -conj\left(\frac{P_{n-i} + j\,(\,Q_{n-i}\,)}{V_{n=i}^{k}}\right) + \sum_r J_{n-r}^{k}\,,\,, \quad \text{r = 1,…….} \qquad (3.2)$$

(3) (Forward sweep): starting from the root bus, the node voltages are updated using the following equation (Ouali & Cherkaoui, 2020):

$$V_i^{(k)} = V_{i-1}^{(k)} - Z_i\,J_i^{(k)}\,, \quad \text{i= 2,3,……….n} \qquad (3.3)$$

Those three steps are repeated until voltage magnitudes at each node in the present iteration and the previous iteration is lower than a tolerance limit:

$$\text{Max }([V^{(k+1)}] - [V^{(k)}]) < limit \tag{3.4}$$

The proposed method program has been analyzed in Matlab coding and tested on IEEE 33-bus RDS network has been generate using Figure 3.2. In this new approach, a load flow program based on the FBS concept is used to solve load flow problems in RDS, with an improvement in the element ordering that does not require the use of any complex numbering of branches or the use of any matrix calculation. Simply by devising the system element into a main line and its derivations, the flow calculation is reduced due to the use of only algebraic expressions without any trigonometric functions or matrix calculation and by ensuring minimum number of searching for connections between nodes.

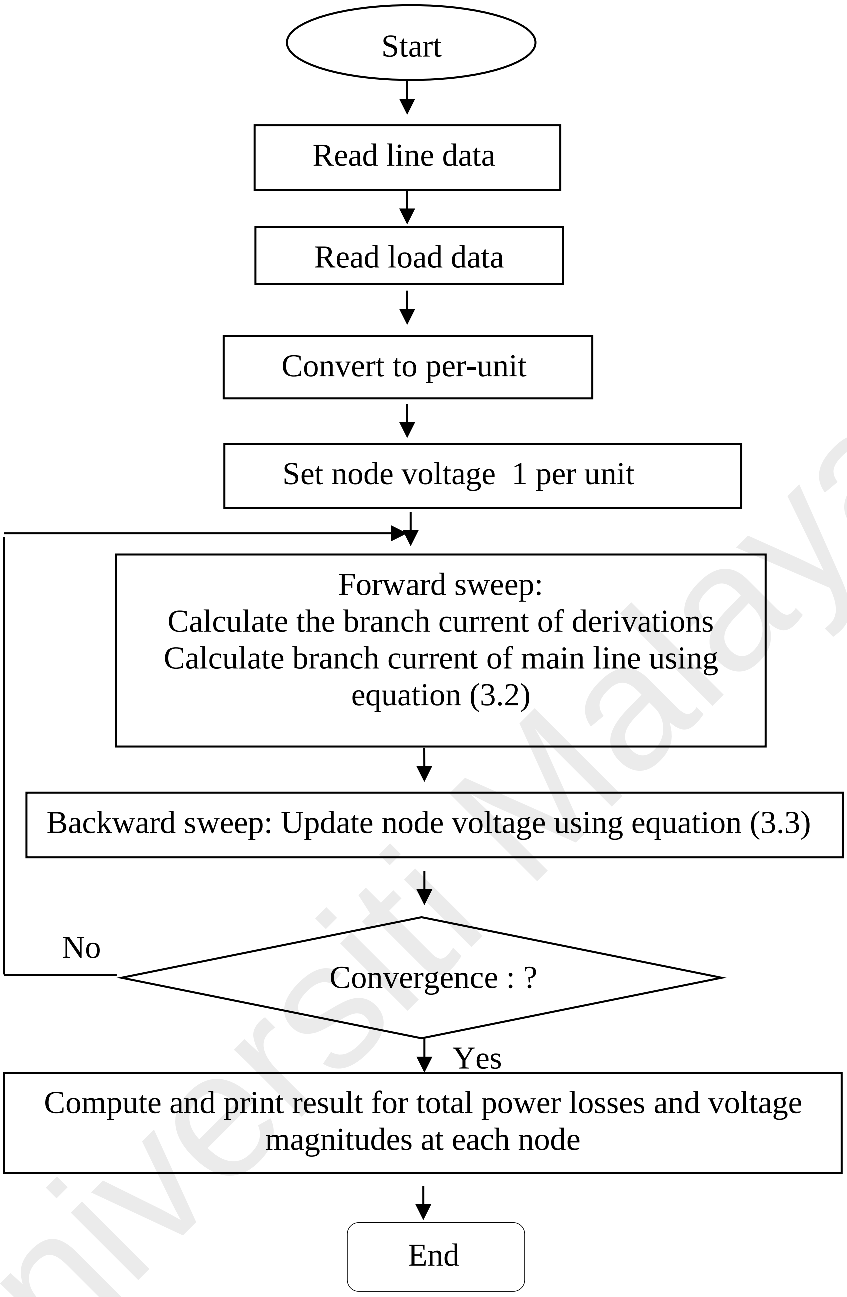


Figure 3.2 : Flowchart of FBS

3.2.3 Particle Swarm Optimization Algorithm

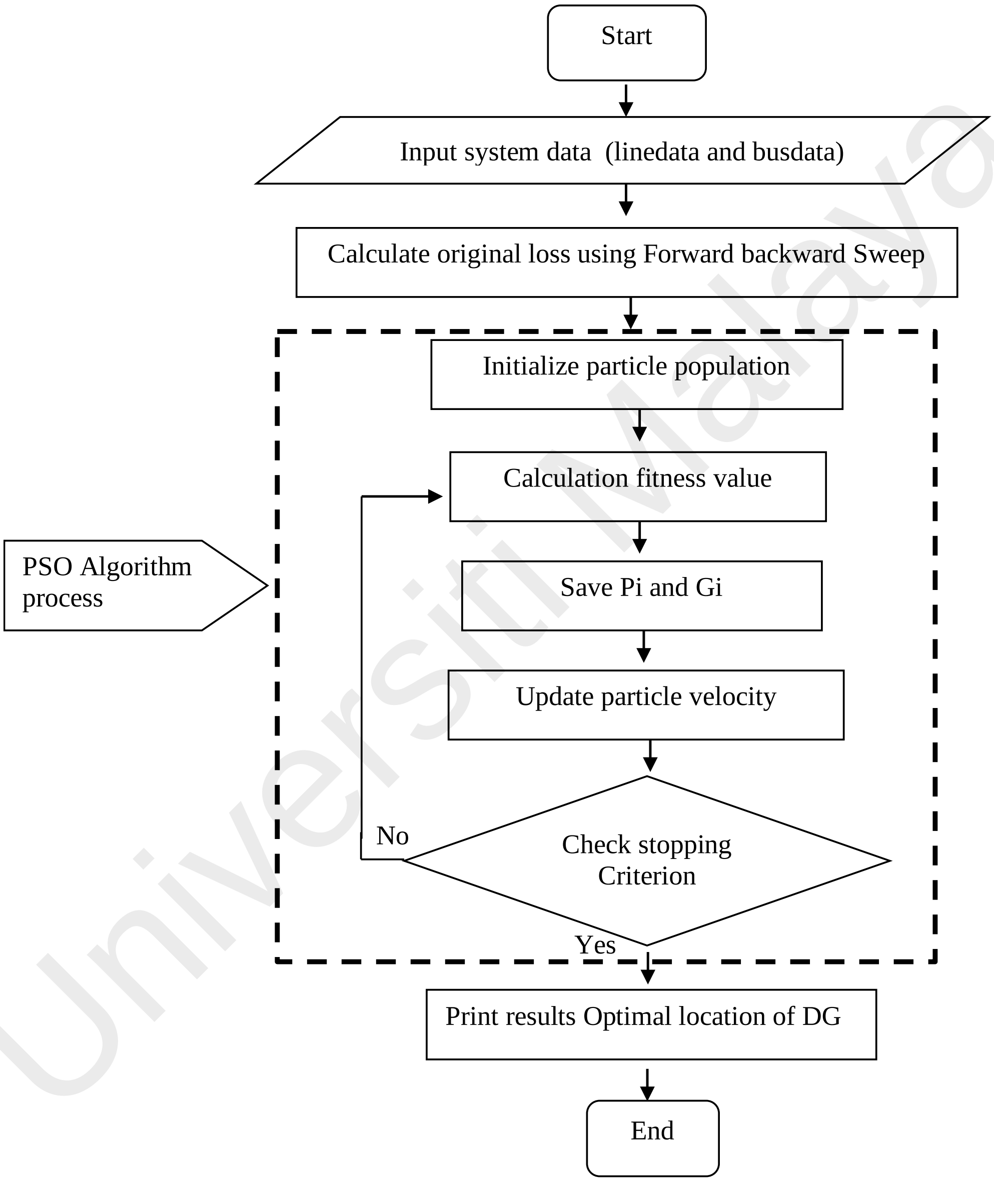
The concept of PSO algorithm in the load flow power systems is based on the minimization of the active and reactive power which mismatches the system buses. The involved variables are continuous and must remain within the specified boundaries of the tested system. PSO was inspired by the ability of a flock of birds or a school of fish to capitalize on their outside knowledge in finding food. Each swarm member or particle is affected by its own experience which has a small memory that enables it to remember the best position it found so far and its goodness. Particles are affected by their own experience where used the best found position and their neighbors' experiences which is best found position by the neighbors. (Elshamy et al.). The behavior of particles equation is described in below:

$$v_{id}\,(t+1) = w \times v_{id}\,(t) + lrn_1(rand_1)\big(p_{id}(t) - x_{id}(t)\big) + lrn_2(rand_2)\Big(p_{gd}(t) - x_{gd}(t)\Big) \tag{3.5}$$

$$x_{id}\,(t+1) = \big(x_{id}(t)\big) + v_{id}\,(t+1) \tag{3.6}$$

In (3.5), v_{id} is the velocity of particle i in dimension d. The first right hand side term corresponds to the inertia force that pushes the particle in its old direction, where w is the weight value that controls this inertia force. The second term corresponds to the cognitive or personal experience component. It attracts the particle from its current position x_{id} to its best found position so far in that dimension p_{id} affected by a learning weight lrn_1 and a uniformly distributed random variable $rand_1$ in the range (0, 1). The third term corresponds to the social influence of the neighbors on the particle. It affects the particle by attracting it from its current position x_{id} to the best position found by its neighbors p_{gd} and this influence is controlled by a learning weight lrn_2 and another independent random variable $rand_2$ uniformly distributed in the range (0, 1).

For each time step, as described by , each particle moves by a step of value v_{id} in the $d^{(th)}$dimension. A speed limit for the particles was introduced to prevent the explosion of speed values (Elshamy et al.). The flowchart of the proposed approach has been elaborated in (Bouketir et al., 2020) Figure 3.3 below :



3.3 Impacts of distributed generation in voltage profile and power losses

3.3.1 Voltage Profile

DG is supposed to support and improve the system voltage, but there are various statements that create diversity of opinions, as it has been proven that penetration of DG in the distribution system can cause more voltage or below voltage. Furthermore, specific DG technologies vary their output power level over time, as in the case of PV and WT. Moreover, over voltages and under voltages in distribution networks with DG have been reported due to the incompatibility of DGs with the existing voltage regulation methods. Moreover, methods were designed for radial (unidirectional) power flow and have been proved to be very reliable and efficient in the past. However, nowadays, the installation of DGs in distribution networks have had a substantial impact on the voltage regulation methods performance due to the meshed (bidirectional) power flow, introduced by DGs to the networks.

3.3.2 Power Losses

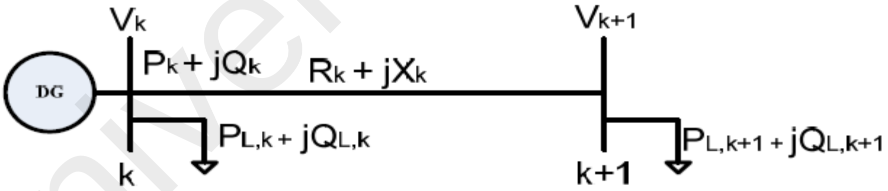
It has been proved that the DG can minimize the power losses (both real and reactive) of distribution networks due to their installation near the load canters. Demonstrated that the location and the size of a DG unit play an important role in the power losses elimination. Consequently, the specific location of a DG in a distributed network and DG’s specific capacity resulting in minimum power losses is in general identified as the optimum location. It has been proven, that in the case of networks with increased power losses, installing a relatively small DG unit strategically connected to the network, may result in substantial power losses reduction.

3.3.3 Placement of DG units considering system losses.

The main objective of the load flow is to calculate the bus voltage, line current, and PQ losses at each bus. Our proposed methods managed DG sizing and placement to improve voltage profile and loss minimization in base and reconfigured distribution system (Haider et al., 2021). Considering the penalty factor to find more accurate and actual results of the voltage profile and power loss. For example, one can assume a line section between k and k + 1 with an impedance of Rk + jXk and loads at bus k and k + 1, as shown in Figure 3.4 Pk and Qk are the real and reactive power flows from bus k to k + 1, respectively, and Vk and Vk + 1 are the complex voltages. The power loss in the feeder section between buses k and k + 1 can be computed as follows (Rao et al., 2013):

$$P_{Loss}(k, k+1) = R_K \frac{(P_K^2 + Q_K^2)}{|V_K|^2} \tag{3.7}$$

$$Q_{Loss}(k, k+1) = X_K \frac{(P_K^2 + Q_K^2)}{|V_K|^2} \tag{3.8}$$



The total active power losses of the distribution network P_{Tloss} can be calculated by summing all losses of the line segments of each , as follows (Rao et al., 2013):

$$I_k = \frac{V_k - V_{k+1}}{R_k + jXk} \tag{3.9}$$

$$V_{k+1} = V_k - (I_k)^*(Z_{k-k+1}) \tag{3.10}$$

$$S_k^* = P_k - jQ_k = V_{k+1}^* \, I_k \tag{3.11}$$

$$P_{T,LOSS} = \sum_{k=1}^{n} P_{Loss}(k, k+1) \tag{3.12}$$

Or

$$P_{T,LOSS} = R_k \, I_k^2 \tag{3.13}$$

Even though there are different methods of calculating power loss in optimization process. The objective function should be minimized and subjected to the following inequality and equality constraints.

(1) DG unit constraint: The total generation of the active power of every integrated DG unit must be less than the total active power demand of the network, as the infringement of the constraint results in a reverse power flow in the system. This constraint is expressed as follows, where P_{dg} are the active power injection and P_{Di} are the load connected to the node network, respectively.

$$0 \leq \text{size } (P_{dg}) \leq \sum_{i=1}^{N_{bus}} P_{Di} \tag{3.14}$$

$$0 \leq \text{size } (Q_{dg}) \leq \sum_{i=1}^{N_{bus}} Q_{Di} \tag{3.15}$$

(2) Voltage constraint: The absolute value of the voltage magnitude at each node must be stationed within their admissible ranges to maintain the system's power quality. It is defined as below:

$$V_i^{min} \leq V_i \leq V_i^{max} \quad , \text{i = 1,2 3…… Nbus} \tag{3.16}$$

3.4 Performance modelling of WT and PV generation system

Power generation of PV array and WT depends on their model and resource such as wind speed, Solar PV radiation, and ambient temperature. In this section modeling of WT and PV array is discussed.

3.4.1 Performance model of PV array

Generally, PV system is connected to power system by current controlled inverter. PV system only supplies active power to power system. If PV system equipped with current inverter, the current output is constant. The PV systems convert Solar Energy into Electrical energy. Their output is DC power and is converted into AC power via an inverter to be compatible with AC grid. The power output of a Solar PV panel refers to the calculation in (3.17) depends on the area (A) of the PV panel, Solar PV irradiance μ(t) and efficiency of the PV panel β (Rao et al., 2013; Yammani, 2012).

$$P_{PV}\ (t) = A\ \beta\mu(t) \tag{3.17}$$

3.4.2 Performance model of WT

Direct driven synchronous wind turbines are usually connected to grid by transducer which can control generator's active power output and reactive power, respectively. So, the direct driven synchronous and doubly fed wind turbines may be described as PQ model in flow calculations as well as power factor controlled combined heat and power generators. The type of DG is capable of injecting both real and reactive power. Fixed speed and slip controlled asynchronous wind turbines which absorb reactive power from power system to build the magnetic field, do not have the ability of voltage regulation and this will lend to the increasing of network real power losses. Generally, compensative capacities are used to supply the reactive power which asynchronous generator need. The wind turbine power output is proportional to the kinetic energy, air density. Other parameters of wind turbine include cut- in wind speed, cut-out wind speed and rated wind speed, and typical values of them are 3.5 m/s, 25 m/s, and 14 m/s respectively (Yammani, 2012). Technical Specification have been chosen in this work and the Table 3.1 details in the below:

Table 3.1: Specification of WT

Types	**Value**
Cut-in Wind Speed	3.5 m/s
Cut-out Wind Speed (10 min avg)	25 m/s
Rated Wind Speed	14 m/s
Rotor Diameter	77 m
Swept Area	4657 m^2
Swing Area	4657
air density is	1.225
Betz constant	0.59259

In this work, the average power generated by the WT can be calculated by follow the equation below:

$$P_{wind}\,(t) = 0.5\,\alpha\,\rho\,(t)A\,v(t)^3 \tag{3.18}$$

Where α is the Albert Betz constant, ρ(t) is air density, A is area swept by turbine rotor, and ν(t) is wind speed (Saber & Venayagamoorthy, 2011). The energy sources of DGs can be categorized into stable and unstable energy sources, Fuel cell and Micro-gas turbine are some of the stable energy sources, WT and Solar PV are most used unstable energy sources. Different energy sources show special output characteristics when combining with different energy converters. For example, the Induction Generator will act like a constant real power and variable reactive power generator, when it is used to convert wind energy to power grids. So, it is modelled as a variable reactive power model in load flow analysis. However, if the static electronic converter is used to convert Solar PV to power grids, it will mostly act like a generator with a constant power factor in normal operating condition. Therefore, it is modelled as constant power factor model (Bouketir et al., 2020). The maximum power rating of Solar PV station is fixed by taking average of total day Solar PV powers calculated by using equation in (3.17). Similarly maximum power rating of wind station is fixed by taking averages of all day powers calculated by using equation (3.18). In this study, the maximum capacity of DG like Solar PV and WT is calculated from the average power estimated by irradiance and wind speed, respectively. The Table 3.2 shows the data of Solar PV irradiation over 24 hours and wind speed data (Yammani, 2012). Calculate the power generated for every irradiance level and wind speed by using the equations (3.17) and (3.18) respectively. In this study the average power generated by the Solar PV is 1.191p.u and WT is 0.471p.u.

Table 3.2: Data for PV and WT for 24 hours

Time (hours)	Solar PV irradiance Data (W/m2)	Wind speed Data (m/sec)
1	0	3.0335
2	0	3.5412
3	0	4.9334
4	0	5.7063
5	0	6.5247
6	32.1779	6.3937
7	203.3411	5.256
8	406.6817	3.6345
9	575.9177	4.1387
10	733.1582	4.5555
11	872.7758	4.3235
12	737.8383	4.0157
13	815.881	2.7205
14	818.2873	2.6466
15	732.5975	3.9623
16	565.549	3.4079
17	455.1528	5.3587
18	139.9814	6.0713
19	37.669	5.2234
20	0	4.8908
21	0	2.1175
22	0	1.7315
23	0	4.7083
24	0	4.9598

CHAPTER 4: RESULTS AND DISCUSSION

This case study includes various combination of different distribution generation units such as without DG (Base Case), Solar PV only (Case 1), WT (Case 2), and combination of PV and WT (Case 3). Here, the Solar PV is modelled as a constant power factor model referring to the equation (3.17) to get the value average power for Solar PV and WT is model as a variable reactive power model referring to the equation (3.18) to get the value average power for WT. This study includes various combinations of different distribution generations, which are clearly tabulated and presented for 33 bus distribution bus system. The value of line data and load has been showed in the appendix (Table 4.10 and Table 4.11). The elaboration each examined of the DGs system has been discussed thoroughly to achieve the objective that requirement for this work.

4.1 Base Case without DG

The DG unit corresponding real and reactive power loss and reduction without DG allocation is tabulated and represented in Table 4.1.

Table 4. 1: Result data Without DG

Line Name (Branch)	Ploss	Qloss	Voltage
1	12.47	6.36	0.99
2	52.76	26.87	0.99
3	20.26	10.32	0.97
4	19.03	9.69	0.97
5	38.93	33.61	0.96
6	1.96	6.47	0.94
7	4.95	1.64	0.94
8	4.28	3.07	0.93
9	3.64	2.58	0.92
10	0.57	0.19	0.92
11	0.90	0.30	0.92
12	2.73	2.15	0.92
13	0.75	0.98	0.91
14	0.37	0.33	0.91
15	0.29	0.21	0.91
16	0.26	0.34	0.90
17	0.05	0.04	0.90
18	0.26	0.26	0.90
19	0.85	0.77	0.99
20	0.10	0.12	0.98
21	0.04	0.06	0.98
22	3.25	2.22	0.98
23	5.25	4.15	0.97
24	1.32	1.03	0.96
25	2.66	1.35	0.96
26	3.40	1.73	0.94
27	11.55	10.18	0.93
28	8.01	6.98	0.92
29	3.98	2.03	0.91
30	1.63	1.61	0.91
31	0.22	0.25	0.91
32	0.01	0.02	0.91
33	206.73	137.91	0.91

Table 4.1 above shows a comparison between system losses for resistive and reactive in the system without DG, where the total Apparent power = 206.7kW and Reactive Power = 137.9kVAR.

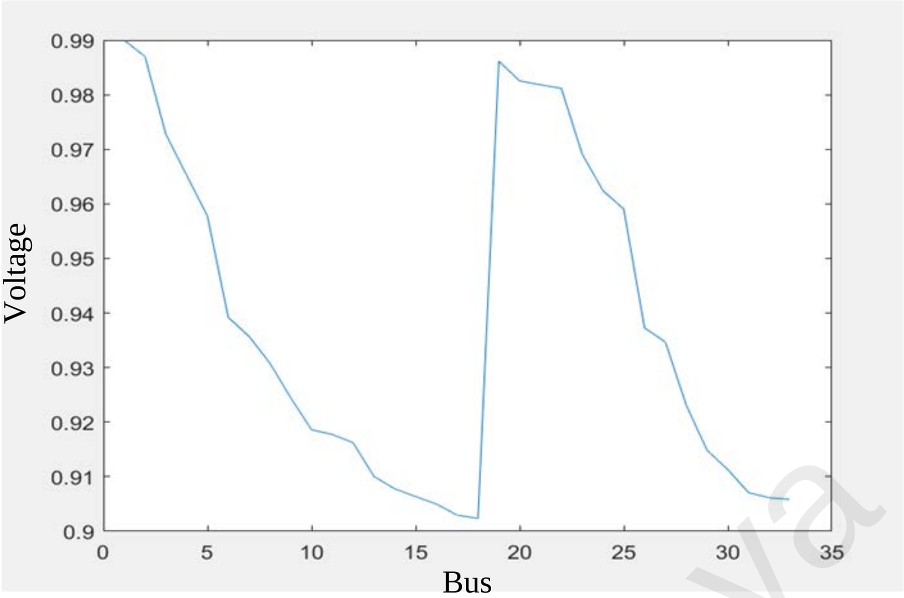


Figure 4.1: Graph represent voltage profile Without DG

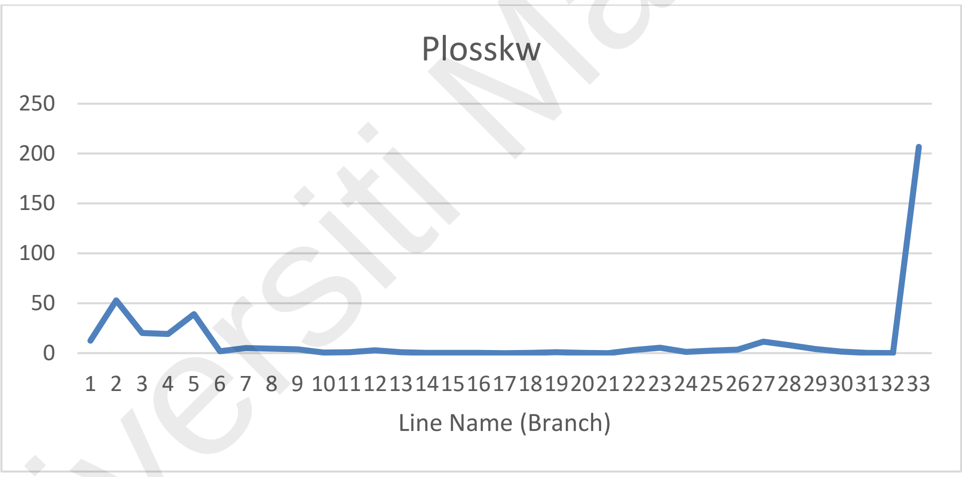


Figure 4.2: Graph represent power losses for base case scenario

The effectiveness of the proposed idea is tested on 12.66 KV radial distribution systems consisting of 33-nodes. The single line diagram of the 33-node system and thirty-two lines (branches) is shown in Figure 3.1. The network is fed by a synchronous generator, while it is loaded from 3.715 MW and 2.3 MVar. Figure 4.1 and Figure 4.2 illustrated the output voltage profile and power losses respectively referring base case which have the lowest voltage in bus 18 is a 0.90 p.u.

4.2 Case 1 with Solar PV Integration

The DG unit corresponding real and reactive power loss and reduction with PV allocation is tabulated and represented in Table 4.2.

Table 4.2: Result data with PV allocation.

Line Name (Branch)	Ploss	Qloss	Voltage
1	11.21	5.71	0.99
2	56.73	28.90	0.99
3	33.02	16.82	0.97
4	16.37	8.34	0.96
5	33.41	28.84	0.96
6	1.69	5.58	0.94
7	4.23	1.40	0.94
8	3.62	2.60	0.93
9	3.07	2.18	0.92
10	0.48	0.16	0.92
11	0.76	0.25	0.92
12	2.29	1.80	0.92
13	0.62	0.82	0.91
14	0.30	0.27	0.91
15	0.24	0.18	0.91
16	0.21	0.29	0.91
17	0.05	0.04	0.91
18	0.26	0.25	0.90
19	0.84	0.75	0.99
20	0.10	0.12	0.98
21	0.04	0.06	0.98
22	3.07	2.09	0.98
23	4.95	3.91	0.97
24	1.23	0.97	0.96
25	2.26	1.15	0.96
26	0.07	0.04	0.94
27	0.13	0.11	0.94
28	0.00	0.00	0.94
29	3.36	1.71	0.94
30	1.37	1.35	0.94
31	0.18	0.21	0.93
32	0.01	0.02	0.93
33	86.17	16.90	0.93

Table 4.2 above shows a comparison between system losses for real and reactive referring to the voltage profile in the system with PV allocation, where the details in the Table 4.3 below:

Table 4.3: Result allocation for PV

Location	29
Size (KVA)	1190
Real Losses (KW)	186
Reactive Losses (KVAr)	116

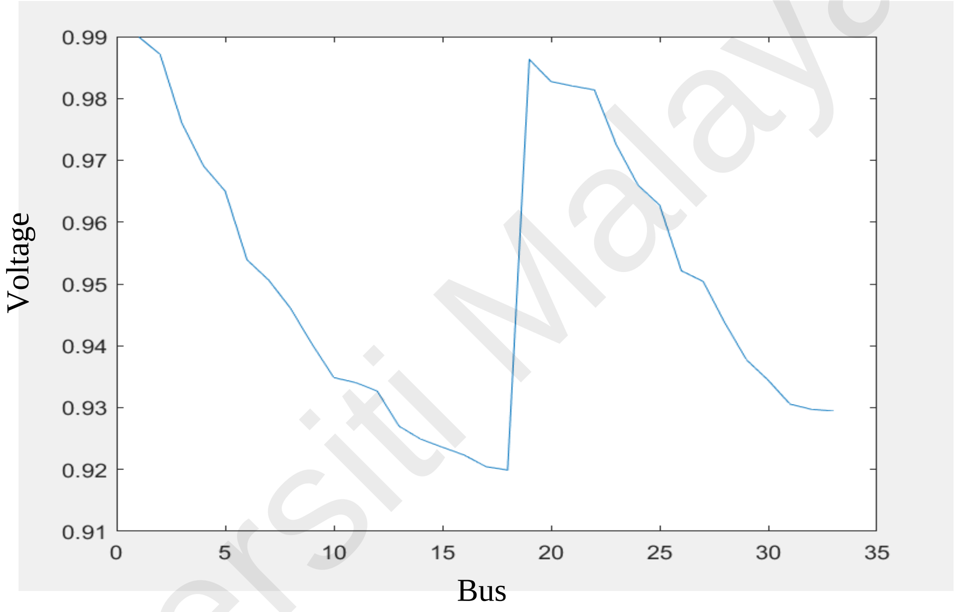


Figure 4.3: Graph represent voltage profile for case 1

Figure 4.3 Illustrated the comparison voltage level with difference case system bus. Clearly observed that bus 18 produced the lower voltage value compared from others bus. The value of Power losses also reduces 10% rather than in Base Case (without DG) system bus.

4.3 Case 2 with Wind Turbine Integration

The DG unit corresponding real and reactive power loss and voltage profile with WT allocation is tabulated and represented in Table 4.4.

Table 4.4: Result data with WT

Line Name (Branch)	Ploss	Qloss	Voltage
1	11.21	5.71	0.99
2	49.87	25.40	0.99
3	28.45	14.49	0.97
4	13.04	6.64	0.96
5	26.42	22.81	0.96
6	1.69	5.58	0.94
7	4.23	1.40	0.94
8	3.62	2.60	0.94
9	3.07	2.18	0.93
10	0.48	0.16	0.92
11	0.76	0.25	0.92
12	2.29	1.80	0.92
13	0.62	0.82	0.92
14	0.30	0.27	0.91
15	0.24	0.18	0.91
16	0.21	0.29	0.91
17	0.05	0.04	0.91
18	0.26	0.25	0.91
19	0.84	0.75	0.99
20	0.10	0.12	0.98
21	0.04	0.06	0.98
22	3.07	2.09	0.98
23	4.95	3.91	0.97
24	1.23	0.97	0.96
25	2.26	1.15	0.96
26	0.29	0.15	0.94
27	0.79	0.70	0.94
28	0.22	0.19	0.95
29	0.70	0.36	0.95
30	1.37	1.35	0.95
31	0.18	0.21	0.94
32	0.01	0.02	0.94
33	162.86	102.88	0.94

Table 4.4 above shows a comparison between system losses for real and reactive referring to the voltage profile in the system with WT allocation, where the details in the Table 4.5 below:

Table 4.5: Result allocation for WT

Location	30
Size (KVA)	471
Real Losses (KW)	162.8
Reactive Losses (KVAr)	1028

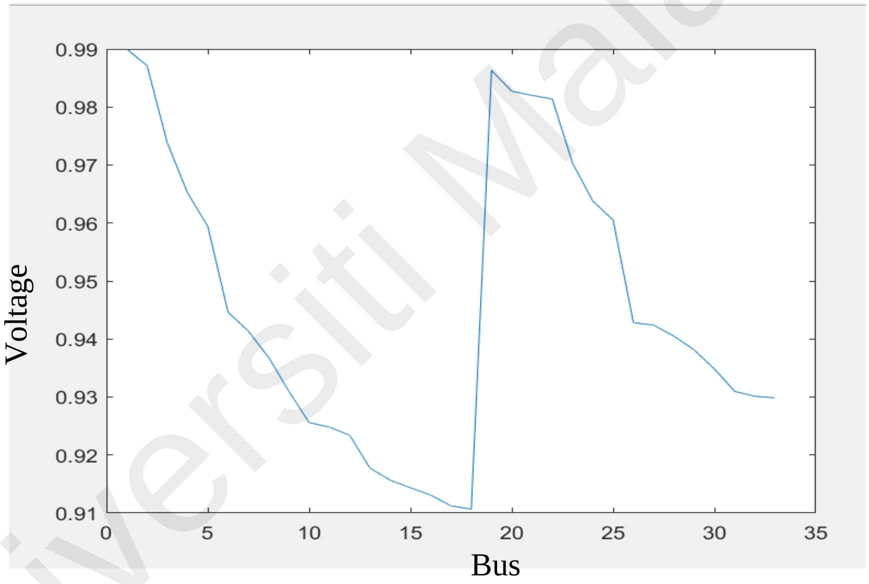


Figure 4.4: Graph represent voltage profile for case 2

The ongoing investigation has been carried out on 33-bus radial distribution test system with a total active and reactive power demand of 162.8 kW and 1028 kVAr. Figure 4.4 has shown the lowest voltage in the bus system which is 0.910 p.u and decrease the power losses 21% compared with base case.

4.4 Case 3 with PV and WT Integration

The DG unit corresponding real and reactive power loss and voltage profile with PV and WT allocation is tabulated and represented in Table 4.6.

Table 4.6: Result data for case 3 allocation

Line Name (Branch)	Ploss	Qloss	Voltage
1	11.21	5.71	0.99
2	27.93	14.23	0.99
3	15.08	7.68	0.98
4	6.07	3.09	0.97
5	12.30	10.62	0.97
6	0.18	0.58	0.96
7	0.24	0.08	0.96
8	0.31	0.23	0.96
9	0.34	0.24	0.96
10	0.07	0.02	0.96
11	0.16	0.05	0.96
12	0.84	0.66	0.96
13	0.57	0.75	0.96
14	0.82	0.73	0.96
15	0.24	0.18	0.96
16	0.21	0.29	0.96
17	0.05	0.04	0.95
18	0.26	0.25	0.95
19	0.84	0.75	0.99
20	0.10	0.12	0.98
21	0.04	0.06	0.98
22	3.07	2.09	0.98
23	4.95	3.91	0.97
24	1.23	0.97	0.97
25	2.26	1.15	0.96
26	1.82	0.93	0.96
27	7.58	6.68	0.96
28	7.11	6.19	0.95
29	3.36	1.71	0.94
30	1.37	1.35	0.94
31	0.18	0.21	0.94
32	0.01	0.02	0.94
33	110.79	71.57	0.94

Table 4.6 above shows a comparison between system losses for real and reactive referring to the voltage profile in the system with case 3 allocation, where the details of the result in the Table 4.7 below:

Table 4.7: Result allocation for case 3

Location	15, 29
Size (KVA)	471, 1190
Real Losses (KW)	110.8
Reactive Losses (KVAr)	71.56

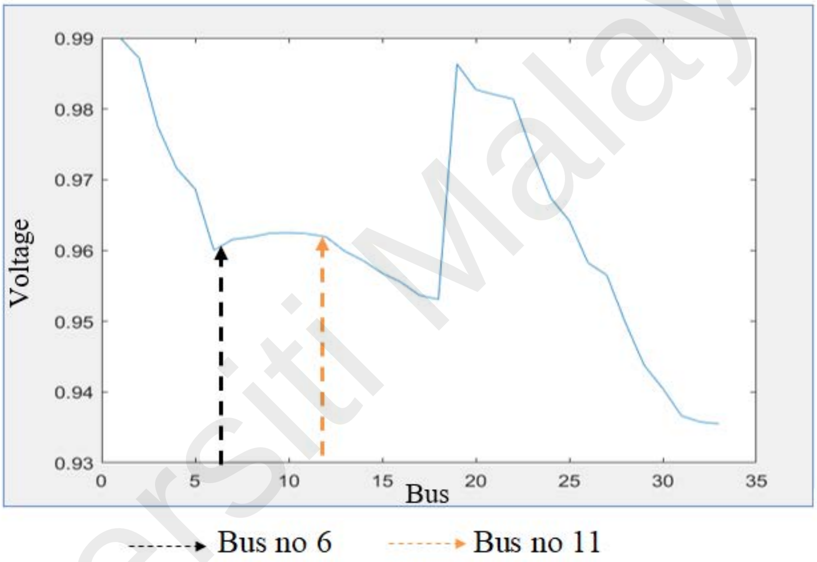


Figure 4.5: Graph represent voltage for Case 3 scenario.

Figure 4.5 shows a comparison between the voltages of the 33-bus system referring case 3. The first case we see from bus 6 the plot curve increases but, bus 11 it is starting to decrease. Suddenly it increase again after reach bus 18 which in 0.95 p.u, In this penetration level, the reduction in real losses becomes 40% compare to the base case.

4.5 Voltage Profiles

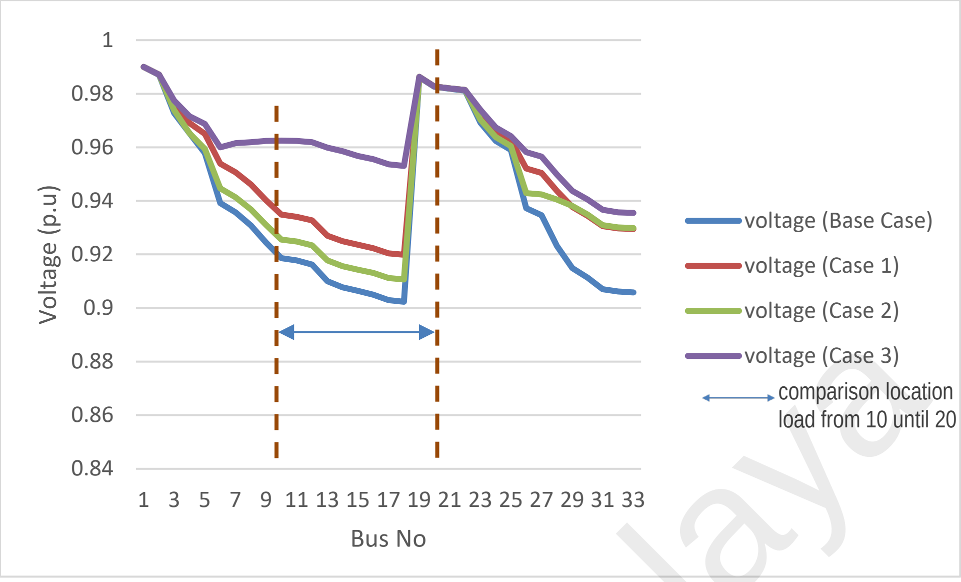


Figure 4.6: Analyzing graph from four types of penetration level.

The analyzing graph illustrated in Figure 4.6, which are from four types of cases. There are four different voltage magnitude values at each bus in the Figure 4.6 for the comparison of voltage improvement. The major comparison in the location load (Bus) from 10 until 20. All the curves show that voltage of the base case unit is always below that of three other cases. Especially, the lowest voltage of the system base case is equal to 0.902 p.u, but the highest voltage of the system in Case 3 which is 0.95 pu, respectively. The percentage difference between base case and Case 3 level voltage increase to 5%. Clearly, when has additional generation unit in a bus system with some calculation algorithm management which provide better voltage magnitude and better system than other methods. This comparison has shown the FBS method algorithm gives the proper optimization referring to the voltage profile whereas the different characteristics from three DG penetration levels concerning the base case and three types of other difference cases were investigated; these levels were well compared in term of voltage improvement. Table 4.8 focused on the Bus in 18 which has a minimum value of the voltage between bus 10 until bus 20. The value of voltage in the details below:

Table 4.8: Minimum voltage for different case studies

Case Study	Voltage (p.u)	Bus
Base Case	0.90235	18
Case 1	0.91990	18
Case 2	0.91066	18
Case 3	0.95308	18

These resulting impacts graph on the multiple DGs or without DGs have affected curve plot in the layout graph refer Figure 4.6. Multiple DG enhanced the voltage level at the location load in the bus 18. This result gives the impact of penetration level of voltage on the simple radial grid to understand the behavior of the optimal location in the distribution network which can give the effect on power loss minimization and voltage profile enhancement.

4.6 Discussion of Results

Figure 4.7 shown the network characteristics which results obtained from four difference voltage level which is base case, Case 1, Case 2, and Case 3 in the 33 bus systems. The computational performance of the proposed approach has shown the voltage magnitude with optimal placement and appropriate size of the DGs is improved significantly. When the capacity load of DG increases the voltage profile improves because of the injected reactive power. The reference voltage referring to the base case (blue color) which installed in the system whereas showed the lowest voltage has been generated if the system depends on the main grid only or without additional DG. The bus number 13-18,30-33,36 and 38 busses, has generated low voltage value rather than another busses which the significance of DG integration is clearly observed. Voltage profile enhanced for location load from 27 until 33 when installed the case 3 which is reaching the maximum value over 0.94 p.u. From this observation can be conclude that for this situation the number of DGs can add within a limit such as four or five DGs. The optimization placement of the 33-bus system which different cases of voltage level studied good to be applied in the rural areas because a greater distance from the main grid will enhance power losses. Voltage profile improves by optimally locating and sizing PV and WT generation which describes the impact of integration in the time domain for the distribution system with the change in load demand.

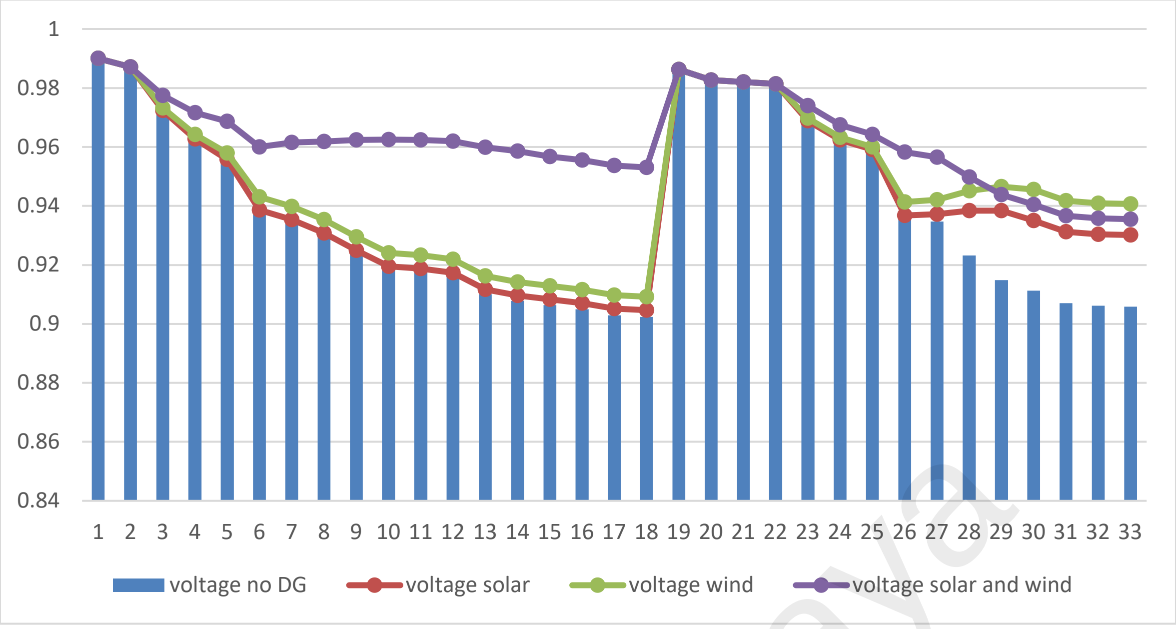


Figure 4.7: Penetration levels in the 33 bus RDS

Table 4.9: Optimal power losses, DG location and size in the 33-bus system

Types different of DG level	**DG location**	**Optimal size (kW)**	**Power loss with DGs**	**Minimum Voltage**
Base Case	-	-	206.7	0.902
Case 1	29	1190	186	0.919
Case 2	30	471	162.8	0.911
Case 3	15,29	471, 1190	110.8	0.94

In this study, three DG penetration levels with respect to the base case were investigated in Table 4.9, these levels were well compared in term of loss reduction, optimal size, DG location, and voltage improvement. The DG units can be placed most sensitive bus to improve the bus voltages without violating DG unit size limit, the current and voltage limits. The Power loss has decrease and voltage profile increase when multiple penetration capacity lever of DGs has been installed in the system. Optimal size of DG is found on each bus and bus with minimum objective function is selected most appropriate bus for integrating DG. Multi DG cases are also considered, and results are compared. The results obtained confirmed that the increase in the capacity of DGs improves the voltage of the system as compared with the base case are installed. The difference result value for minimum voltage between base case and another type of cases has higher range voltage deviation. This works demonstrated that increasing number of DGs in the network be able to reduces power losses and voltage deviation significantly.

CHAPTER 5: CONCLUSION AND FUTURE WORKS

5.1 CONCLUSION

The method proposed in this work is to utilize the number of DG units for voltage improvement and enhanced the power losses is applied for 33 bus distribution system. In all IEEE buses distribution system, the results indicate that the DG unit allocation improve the voltage and reduces the system losses. The system power losses increase by improper placement of DG unit and voltage profile of the system gets reduced or overvoltage. This work presented a 33 bus DG in RDS using a calculation of FBS for improve voltage profile, PSO for optimal placement and combination of PV and WT in the bus system which utilizes efficiently. This method had been study from comparison of the obtained results with those obtained using different methods found in literature review whereas showed the effectiveness of the proposed algorithm in the 33 bus RDS.

The proposed PSO with FBS is enabled with PV and WT functionality to control the power losses and voltage within the prescribed limits. Results show that the proposed the step calculation strategy will inject fewer power losses in the phase voltages when compared to the other methods. A method is also suggested to accurately evaluate the size of energy capacity in kWh considering the inequality constraints. Therefore, PSO method of optimization with sweep method of load flow analysis can be used to determine the size of DG unit and its best location for loss minimization. The proposed PSO approach for optimal placement of multiple types of RDGs not only reduces the power losses but also improved the voltage profile of RDGs with the satisfaction of the voltage limits. In this study, three DG penetration levels with respect to the base case were investigated; these levels were well compared in term of loss reduction and voltage improvement. The additional DG units such as PV or WT can be placed in most sensitive bus or higher load bus to improve the bus voltages without violating DG unit size limit, the current and voltage limits. In addition, an analysis on variation of multiple penetration level for a different level of bus is carried out. Moreover, a recommendation on combination WT and PV with limitation penetration level for an economical microgrid operation is also suggested and confirmed that the increase in the capacity of DGs improves the voltage of the system as compared with the base case installed.

The overall operation of 33 bus RDS allocation of PV and WT using PSO and FBS technique for active power compensation to minimize the active power losses in the 33-bus which has an enhanced voltage considering the size of penetration level is found to be quite satisfactory. The results clearly indicate that proposed method minimizes the power losses effectively.

5.2 FUTURE WORKS

Future research areas may focus on the optimal power factor of DGs, balanced or unbalanced system, reactive power limits of DGs, specific selection criterion of weighting factors, uncertainty in load and renewable source of DGs without violating power system operational constraints. Further reviews of PSO will be carried out based on other objectives such as reliability improvement, reduction in greenhouse gas emission and enhanced economic benefits due to different objectives functions. Another proposes method can using grey wolf optimization (GWO) algorithm combined with PSO to study the optimal allocation and sizing of DG systems in radial distribution system. Moreover, include comparison of results by different optimization techniques, including more objective functions and cost to benefit analysis of DGs.

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