OPTIMAL RELAY COORDINATION FOR POWER SYSTEM CONNECTED TO DISTRIBUTION GENERATORS USING PARTICLE SWARM OPTIMIZATION

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DEDICATION

This report is dedicated to My master Imam Mahdi, who taught me that the best kind of knowledge that brings you closer to God, and the best faith is waiting for divine justice. It is also dedicated to my father, mother, and wife, who taught me that even the largest task can be accomplished if it is done one step at a time.

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ABSTRACT

The electrical system consists of a group of parts that together form an integrated system that can be relied upon in providing electrical energy to the consumer. Due to the expansion of the electrical network, the inability to install huge generating stations in different areas, and electrical losses due to increased load consumption, the Distributive generators appeared. Despite the benefits of distributed generators in terms of increasing the reliability of the electrical system and saving energy in peak times and many others, connecting distribution generators leads to a clear defect in the coordination of the operating between the protection devices in the system due to the bidirectional current flow which affects the reduction or increases the operating time for each relay and the lack of continuity of sequential coordination in the work between the relays. This research aims to study the impact of connecting distribution generators on the protection devices in the system and how to reduce and treat this effect in different ways and compare them to determine the best and fastest methods. Two methods will be used to coordinate the relays in the system: the conventional method and the PSO algorithm method. There are two scenarios for each method: connecting the distributed generators and not connecting the distributed generators. The TMS values and operating time for all relays will be calculated, and a comparison between the two methods will be performed to determine the optimal possible operating time, and this will be done using MATLAB to run the algorithm and ETAP software to verify the results obtained in the two methods. it was found that the conventional method is usually easy in procedures, but complex in implementation, as it requires accuracy in transmitting information and dealing with many parameters, and any error at any stage will negatively affect the values obtained in the following stages, and we also noticed that the operating period of the relays last for a long time, which causes a danger to the system, while in PSO method the total operating time of the relays was reduced to about 19.38 seconds when the distribution generators were not connected, while the time difference between the two methods was about 34.67 seconds when the distribution generators were connected, with the coordination time interval remaining around 0.4 seconds. This technology has achieved exceptional success in coordinating relays for diverse topologies and kinds of electrical networks.

ABSTRAK

Untuk membekalkan tenaga elektrik kepada pengguna, sistem elektrik terdiri daripada beberapa komponen yang, apabila digabungkan, membentuk sistem bersepadu. Terdapat peningkatan dalam penggunaan penjana Pengedaran berikutan peningkatan permintaan terhadap elektrik serta ketidakmungkinan untuk menubuhkan stesen penjanaan besar di pelbagai bahagian bandar. Walaupun terdapat banyak kelebihan menggunakan penjana teragih, seperti meningkatkan kebolehpercayaan sistem elektrik dan mengurangkan penggunaan tenaga puncak, aliran arus dua arah yang berlaku apabila penjana disambungkan menyebabkan kecacatan yang jelas dalam penyelarasan operasi peranti perlindungan sistem, mengakibatkan kesan buruk pada masa operasi untuk geganti individu dan kekurangan kesinambungan urutan. Matlamat kajian ini adalah untuk mengkaji kesan penyambungan penjana pengedaran pada peranti perlindungan sistem, serta pelbagai strategi untuk mengurangkan dan merawat kesan ini, untuk mewujudkan pendekatan yang paling berkesan dan cekap. Pendekatan tradisional dan kaedah algoritma PSO akan digunakan untuk menyelaraskan geganti dalam sistem. Menyambung dan tidak menyambungkan penjana tersebar adalah dua kemungkinan berbeza untuk setiap teknik. Apabila nilai TMS geganti dan masa berjalan dibandingkan untuk mendapatkan masa operasi terbaik yang boleh dilaksanakan, ia akan dilakukan menggunakan perisian MATLAB dan membandingkan hasil kedua-dua pendekatan menggunakan perisian ETAP. Kami mendapati bahawa kaedah konvensional adalah mudah apabila ia berkaitan dengan prosedur, tetapi amat sukar untuk dilaksanakan kerana ia memerlukan tahap ketepatan yang tinggi dalam penghantaran data dan pengurusan pelbagai parameter; sebarang kesilapan pada mana-mana peringkat mempunyai kesan negatif ke atas keputusan seterusnya. Kami juga mendapati bahawa masa operasi geganti adalah berlebihan, meletakkan sistem dalam risiko, manakala dalam kaedah PSO, jumlah masa operasi dikurangkan dengan ketara. 17 saat tanpa penjana teragih dan 35saat apabila ia disambungkan. Menggunakan teknik ini, rangkaian elektrik pelbagai topologi dan jenis telah dapat menyelaraskan geganti dengan prestasi yang luar biasa.

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LIST OF ABBREVIATIONS

APS	-	Adaptive Protective System
CT	-	Current transformer
CTI	-	Cooardination Time Interval
DEMO	-	The Differential Evolution Multi-Objective (DEMO)
DG	-	Distributive Generator
DOCR	-	Over Current Directional Relay
FCL	-	Fault Current Limiter
GA	-	Genetic Algorithm
IDMT	-	Inverse Definite Minimum Time Relay (IDMT)
MG S	-	Microgrids (MGs)
MTA	-	Maximum Torque Angle (MTA)
O V	-	Overcurrent
OCR	-	Over current relay
OLTC	-	On Load Tap Changer
PDs	-	Protective Devices (PDs).
PS	-	Pick up Current
PS	-	Plug setting
PSM	-	Plug Setting Multiplier
PSO	-	Particle Swarm Optimization
RDN	-	Radial Distribution Network
SHS	-	Self-Healing System
TCC	-	Time Current Characteristics
TCC	-	Time Current Characteristics
TDS	-	Time Dial Setting
TSM	-	Time Setting Multiplier
VT	-	Voltage transformer
VBC	-	Polarization Voltage
WLS_SVM	-	Weighted Least Square Supper Vector

LIST OF SYMBOLS

A	-	Amper
I	-	Current
kV	-	Kilo volt
kW	-	Kilo watt
P	-	Active power
Q	-	Reactive power
S	-	Apparent power
Sec	-	second

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CHAPTER 1

INTRODUCTION

1.1 Problem Background

Power systems are designed to serve electric energy to end-users in light of quality and regulations standards. Other factors like cost and safety are raised [1]. Mainly, losses are the major obstacles while maintaining costs directly proportion to economical worthiness. Power substitution is a reliable means to reduce losses, including injecting predefined amounts of power into the grid.

Renewable energies such as solar and wind power plants are the common alternatives for energy substitution, folded under the so-called distributed generators (DGs)[2]. Interconnecting of DGs in the power grid has noteworthy advantages, including lowering environmental impact, reducing power loss, enhancing voltage profile, improving power quality, and uplifting overall efficiency. DG is important in reducing the losses of the electrical network, especially since most of this type of generation is close to the load centers. Thus, there is no current passage in long distances, which leads to reduced losses[3]. However, the combination of DG units has a significant impact on the power system, which lies in protection relays miscoordination.

The presence of DG will produce additional current in the network in the opposite direction to the main supply current, which causes a lack of coordination in the overcurrent relays; this effectively affects the change in the value of the impedance in the line, confusing the distance relays as well. This project aims to analyze and reduce the impacts of DG linked to the radial distribution system. Furthermore, it aims to review and analyze the protection coordination of a distribution network for identifying the setting of the overcurrent relay using load flow and short circuit analysis in radial systems. This work's scope supports the possibilities of using DGs in the electrical network without any lack of coordination within the protection system.

1.2 Integrated Distributed Generation

Distributed generation (DG) is representing all alternative energy sources, whether central or decentralized. Despite the diversity of these sources and their different names, it is not a new concept. DG two types grid-connected or island-based. Similar to the latter approach, distributed generation has existed since the commercialization of the power production sector. Until alternating current transmission became physically viable, direct current production and transmission were common but too inefficient and costly because of the size of the wires and towers required to transport power over large distances. As a consequence, generating sources were required in every few miles, closer to high load consumers.

nowadays one of the common procedures for large industrial settings to retain a power production setup for emergency or some others loads, which is analogous to disconnecting type (islanding) used at the inception of energy generation. Due to the small scale and frequency of application of such isolated and distant generating setups, their consequences have been essentially minimal.

Private power Operators (PPO) are now able to financially manage small renewable units as a result of recent energy market restructuring and developments in renewable technologies including solar, wind generators, and battery storage. Because of deregulation and other factors, these resources have been integrated into the grid, substantially altering the architecture of the earlier power system. Figure 1.1 depicts a power system with integrated Distributed Generation.

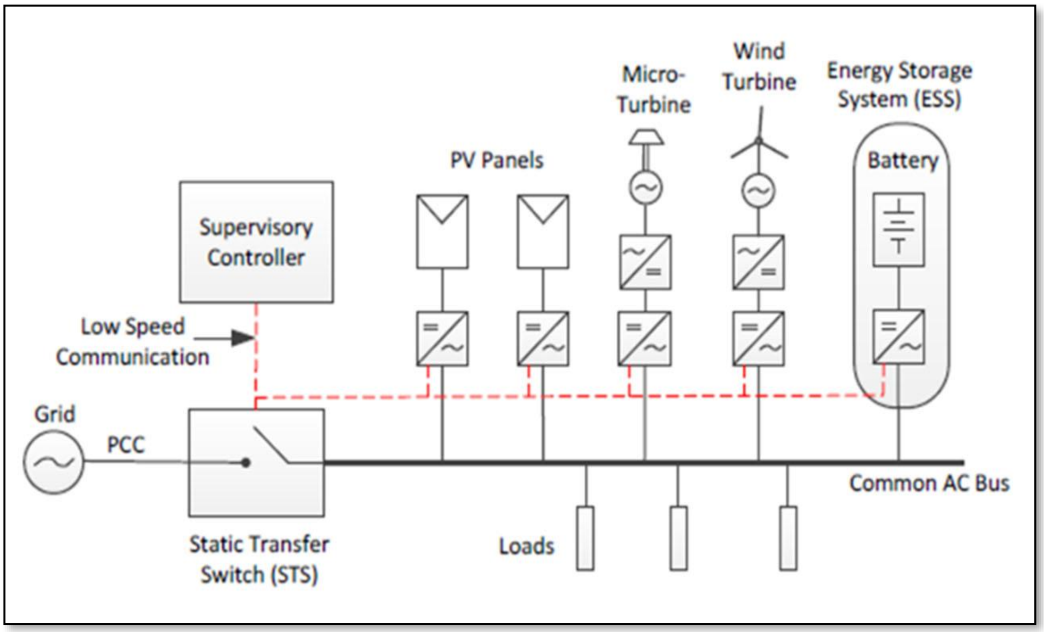

Figure 1.1 Typical configuration of integrated distributed generator

1.3 Distributed Integrated Generation's Advantages

Enhancing the distribution system's dependability via the availability of backup generation, lowering carbon emissions, resolving environmental problems connected with conventional fossil fuel and nuclear power facilities, enabling grid expansion to be postponed, enhancing the quality of electricity, and optimizing financial and trade efficiency are the most advantages can be obtained from the connection the distributed generate the electric power system, as Figure 1.2.

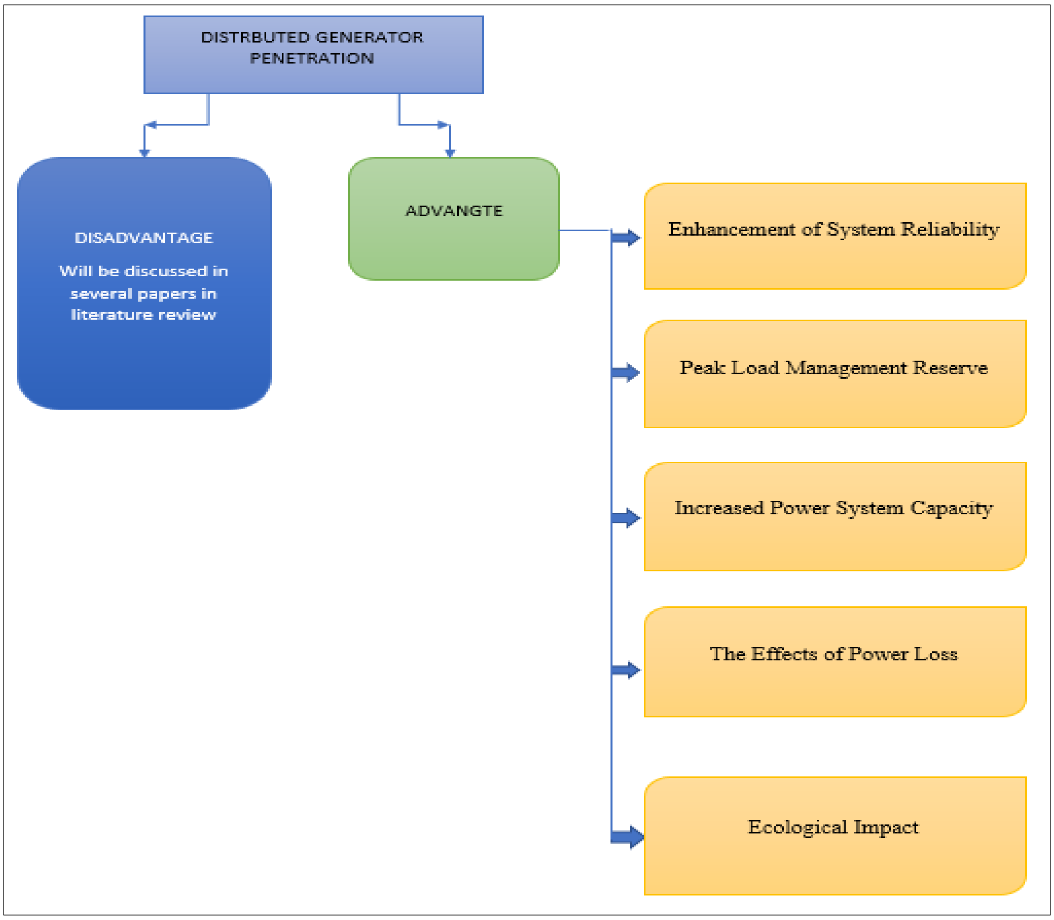

Figure 1.2 Distributed Integrated Generation's Advantages

1.3.1 Enhancement of System Reliability

Distribution system operators and customers alike benefit from strategically placing dispersed producing resources inside a power network when the system is disrupted due to faulty circuits, operator error, or circuit-protection device failure. When a distributed resource is present, an islanded mode of operation may be enabled, which lowers the SAIDI (system average interruption duration index) and the CAIDI (customer average interruption duration index) and increases overall system dependability.

1.3.2 Peak Load Management Reserve

Consumers near circuit ends may find it challenging to maintain the appropriate voltage level during periods of heavy power consumption. Higher (I^2 R) losses occur from increased current flow, therefore even customers with enough installed capacity may see voltage variations from nominal values. As a result of placing dispersed generation closer to its peak demand, a circuit's voltage profile improves during periods of high demand.

1.3.3 Increased Power System Capacity

Extending current power grids with renewable energy sources is interesting for several reasons. The first benefit is that distributed resources reduce transmission and distribution losses. Proximity to load centres reduces (I^2R) losses. This reduces the problem of reserves when huge units are kept operating to take up a load at a moment's notice. Smaller units may reach full load in minutes, but larger centralized generators need hours to warm up. The time necessary to create and commission a system employing scattered resources is also decreased. Due to their relative size, numerous units may be produced before the project is completed. Locating near fuel position supplies or water sources for cooling is another benefit. Area approval for dispersed generators, they are small and do not need large cooling towers, dust baghouses, or smokestacks.

1.3.4 The Effects of Power Loss

Multiple advantages accrue from strategically locating Renewable Resources in a distribution system. Typically, voltage sags occur in power distribution networks during periods of high demand or long-distance transmission. The formula S = I*V indicates that when the voltage values is decreases from the nominal value for the same apparent value of power, a greater current must flow. Heat is a sort of transmission loss that is increased with the square values of the current in system. Thus, the improvement index of voltage associated with a renewable resource's strategic placement acts as a mitigation tool for such losses.

1.3.5 Ecological Impact

Environmental friendliness is a major benefit of increasing renewable energy capability. Solar photovoltaic panels and hydrogen fuel cells are examples of renewable energy sources that provide power with minimal or no carbon emissions. They also produce less noise than centralized generators. They are suitable for placement near residential and industrial load centres due to their low noise production. Landfills are also profitable due to their compact size. Landfills supply cheap gas that may be used to power DG resources. New and tougher limitations on industrial and centralized power generation greenhouse gas emissions.

1.4 Distributed Integrated Generation's Disadvantages

While distributed generation integration provides several advantages for optimizing and expanding current power systems, it also introduces new obstacles. For one thing, flowing of power is unidirectional in a centralization type of power generating and electric system. When a system of dispersed generating resources is integrated, the current will become bidirectional.

The primary disadvantage of this configuration is that protective instruments become low in sensitivity or altogether incapable of sensing and isolating damaged circuits, a phenomenon is known as relay blindness, when exist fault settings are used. In many situations, protective relays need several configurations to match the system's operating mode: parallel or islanded. In certain circumstances, trip settings must be revised or completely replaced to account for the bidirectional current flow in the power circuit.

While alternative energy supply boost system capacity, they also introduce the possibility of changes in the system's fault current and short circuit ratio. A considerable rise in the system current level may expose protective instruments and wires to agreater current range than their original design requirements during a short circuit event.

Distributed generation is potentially contributed to power quality concerns in the grid due to the intrinsic feature of switching devices employed in power electronics. Miscoordination and malfunction relays are also prevalent difficulties in system with a high penetration of dispersed generating.

1.5 Problem Statement

Power system expansion due to population growth forced more challenges on the power generation industry. DG is used in different penetration to inject power into load busbars to stabilize the power system. DG reduces the power losses and enhances the voltage profile once integrated into the known location/busbar in a predefined penetration level. Despite DG integration, has a lot of advantages but will affect the protection of equipment

Protection devices are mainly concerned with fault clearance and reducing the damaging effect of high-level currents. Uncertainty of both faults and systems topology has made the paramount challenge in the protection tasks. Those challenges are manifested in microgrids where power networks and DGs are involved which provide a need for changing the operating characteristic for these devices for different faults, particular settings exist for the protection devices, e.g. (over current relays). Unexpected fault impacts the coordination for main and backup overcurrent relays. To overcome the issue of overcurrent relay coordination, many strategies have been used, Heuristic algorithms are used to optimize the coordination task in overcurrent relays in the existence of DG as specified in [3]. However, for different network topologies, algorithms such as the standard Genetic Algorithm (GA) cannot rely on relay optimization.

At [4], a multi-stage none linear programming method is used to tackle the miscoordination caused by microgrid two-mode operations. This method applies a large computational payload to the system, which shoots up the cost and creates economical disadvantages. Large processing delay might be forced when too many parameters are required to optimize (big fitness function as in [1]). The same worsens the coordination problem by involving extra processing delay. However, the bi-directional fault current generated by DG deployed in the network affects the overcurrent protection system's performance.

Therefore, the presence of distributed generators in the system will lead to a miscoordination between the relays, either through a sequence between the main relay and the backup relay , or a change in the operating time between them, and leads to a change of discrimination time interval between the two relays, all because of the bidirectional current .The impact of distributed generation in the system on the coordination of the protection relays has not been fully explained and needs analysis and in-depth study.

1.6 Research Objectives

This work is aimed to address the power system protection relays violation caused by distributed generators through the fulfilment of the following objectives:

(a) To study the impact of DG on the primary and backup relays coordination and to implement computer vision (programable) Using the conventional method and the PSO algorithm to get the relays coordination coefficients.

(b) To validate the data obtained from the conventional and PSO methods by using ETAP software to test and compare the accuracy of the resulting data for obtaining the ideal values for relays coordination in both cases before and after connecting the distributive generator.

1.7 Research Scope

This study is aimed to enhance the performance of the power distribution system when bidirectional power flow is experienced. However, this study is keen on the protection field in power systems and motivated by the dramatic expansion of power consumption which posed lumpsum of undesirable events such as faults, topology fluctuation, protection failures, etc. the PSO algorithm and the conventional coordination approach will be compared in this study. Calculating protection settings coefficients for a distribution network with DGs linked to the distribution system will be done using two different topologies IEEE 33buses and a study case with 16 buses. Only the directional overcurrent relays are taken into account in this study.

1.8 Proposed Work

1.8.1 16 bus case study

To coordinate the directional relays for 16 bus case study topologies without distribution generators as in Figure1.3 by finding the values of time setting multiplayer and operating time by using the conventional method, after that, the distributive generator is connected and its effect on the coordination between the main and back up relays is studied and the proposed methods are used to mitigate the effect of the distributive generator and re-coordination the relays possibly and correctly.

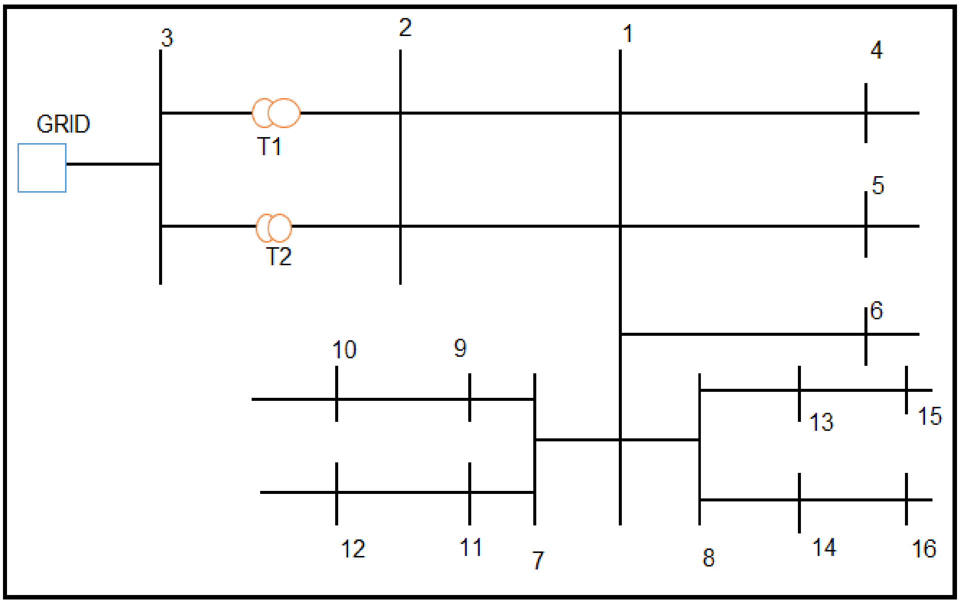

Figure1.3 16 bus case study

1.8.2 IEEE 33 bus system

(a) Coordination of all directional relays of the IEEE 33 bus system shown in Figure 1.4 without connecting the distribution generators using the conventional method, then the PSO algorithm is used to obtain the required coordination value for the system by relying on the fitness function of the system and comparing the two methods in terms of operating time for all relays and determining which is better and faster.

(b) Connecting the distributive generators to the IEEE 33 bus system as shown in Figure 1.5 and recalculating the TDS and operating time of relays in the system in two ways, conventional and PSO algorithm, comparing the two techniques in terms of operating time and deciding which two approaches are better and quicker

(c) Using Etap software to check all the values obtained from all the proposed methods to determine the validity of the results and their conformity with the calculated values manually or using MATLAB.

(d) Specify the fastest and most accurate way to obtain the required coordination values in both cases when connecting distribution generators and when separating them from the system, giving reasons for determining which of the two methods is better.

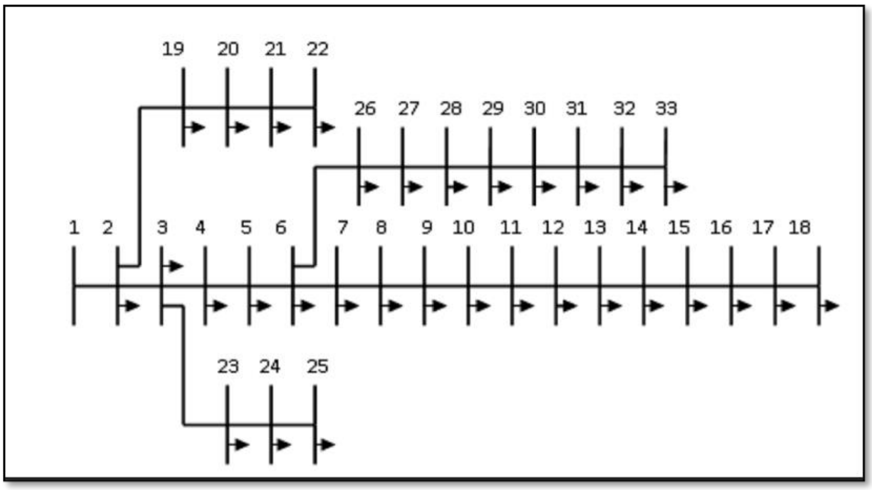

Figure 1.4 IEEE 33 bus system

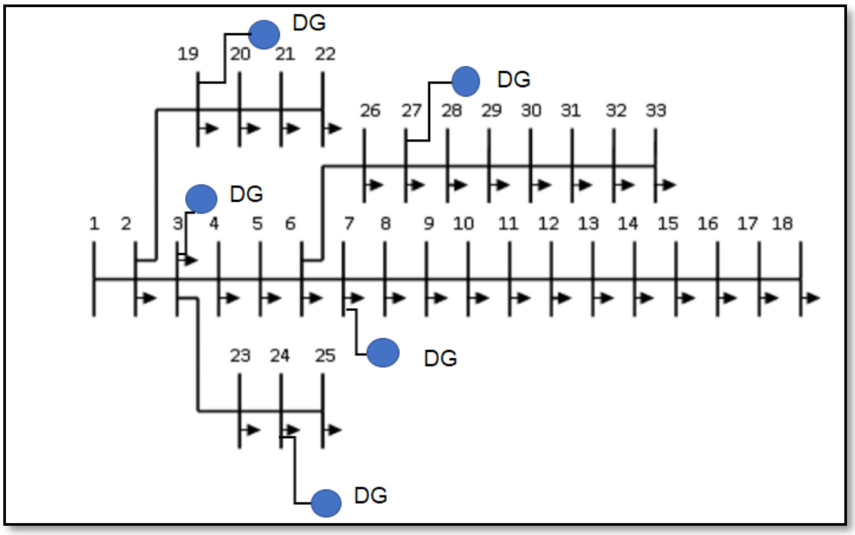

Figure 1.5 IEEE 33 bus system with distribution generators connected.

1.9 Thesis Organization

This dissertation report consists of five chapters that prescribe the proposed methodology and technologies of distribution generator coordination with the power grid. On the other hand, the impact of loads and other performance degradation on the power system will be discussed. Therefore, the structure of this dissertation report can be divided to:

a) chapter 1: Introduction

Includes a summarized introduction of the distributed generator coordination problem and illustrating the problem statement and the objectives of the project.

b) Chapter 2: Literature Survey

Demonstrates the previous attempts made in the interest of power system performance enhancement by optimizing of protection system coordination.

c) Chapter 3: Methodology

Illustrates the infrastructure of the distribution system as well as the methods adopted for coordinating the protection components.

d) Chapter 4: Results and Discussions

Reviews with the required discussions the results obtained after involving the coordination optimization procedure.

e) Chapter 5: Conclusion

The results obtained from the project are discussed and compared with each other to determine which is the easiest, fastest, and most accurate way to obtain the results and to study the development of the proposed methods through the proposed future work of the system.

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