|  |  |  |
| --- | --- | --- |
|  | Tanta University  Faculty of Engineering  Electrical Power and Machines Engineering Department |  |

Islanding Scenarios for High Reliable Operation of Distribution Networks

Thesis submitted in partial fulfillment of the requirement for the degree of

Master of Science in Engineering

(Electrical Power and Machines Engineering)

By

**Eng. Ahmed Mohamed Abdel Hakim Elkholy**

Teaching assistant at Faculty of Engineering

|  |
| --- |
| ****Supervisors**** |
| **Prof. Ahmed Mohamed Refaat Azmy**  **Electrical Power and Machines Engineering Department**  **Vice Dean for Community Service and Environment Development**  Dr. Hossam Abd El-Wahed Abd el-Ghany Saleh  **Electrical Power and Machines Engineering Department** |

June 2024

|  |  |  |
| --- | --- | --- |
|  | Tanta University  Faculty of Engineering  Electrical Power and Machines Engineering Department |  |

**Islanding Scenarios for High Reliable Operation of Distribution Networks**

Thesis submitted in partial fulfillment of the requirement for the degree of

Master of Science in Engineering

(Electrical Power and Machines Engineering)

By

Eng. Ahmed Mohamed Abdel Hakim Elkholy

Teaching assistant at Faculty of Engineering – Tanta University

The Examining Committee:

|  |  |  |
| --- | --- | --- |
| No. | Name | Position |
| 1 | Prof. Shaaban Mabrouk Ahmed Osheba | Electrical Engineering Department, Faculty of Engineering, Menofiya University |
| 2 | Prof. Ahmed Mohamed Refaat Azmy | Electrical Power and Machines Engineering Department, Faculty of Engineering, Tanta University |
| 3 | Prof. Ahmed Anas EI Wogoud Helal | Elec. and control Eng. department, Collage of Eng. and Technology, Arab Academy for Science, Technology & Maritime Transport |

The Examining Date: 22/4/2019

Signatures:

|  |  |  |
| --- | --- | --- |
| No. | Name | Signature |
| 1 | Prof. Shaban Mabrouk Ahmed Osheba |  |
| 2 | Prof. Ahmed Mohamed Refaat Azmy |  |
| 3 | Prof. Ahmed Anas EI Wogoud Helal |  |

June 2024

To those who inspired it

and will not read it

Abstract

Islanding is considered important problem that faces distributed generation. This problem occurs when the protection system takes a correct action to disconnect the fault as a result of that new isolated system is formed. This study introduces a methodology for performing intentional islanding with maximum possible benefits for distribution systems.

Summary

Due to the increase in load demand, the utilization of DG technology became a necessity in recent years.

s.

Acknowledgments

All praises and thanks are to Allah, the Lord of the world for helping me to accomplish this work.

I seize this opportunity to express

Contents

[1 Introduction 1](#_Toc170488442)

[1.1 Motivation 1](#_Toc170488443)

[1.2 Distribution System Reliability 1](#_Toc170488444)

[1.3 Distributed Generations (DGs) 2](#_Toc170488445)

[1.3.1 DG definition 3](#_Toc170488446)

[1.3.2 DG Types 5](#_Toc170488447)

[1.3.3 The advantage of the DGs 5](#_Toc170488448)

[1.3.4 Challenges facing the DG 6](#_Toc170488449)

[1.4 Concept of Islanding 7](#_Toc170488450)

[1.4.1 Unintentional islanding 7](#_Toc170488451)

[1.4.2 Intentional islanding 8](#_Toc170488452)

[1.5 Load Shedding Technique 11](#_Toc170488453)

[1.5.1 Undervoltage load shedding (UVLS) 11](#_Toc170488454)

[1.5.2 Under-frequency load shedding (UFLS) 11](#_Toc170488455)

[1.6 Literature Review and Background 12](#_Toc170488456)

[1.7 Thesis Objectives 14](#_Toc170488457)

[1.8 Thesis Organization 14](#_Toc170488458)

[2 Investigated Network 17](#_Toc170488459)

[2.1 System Description 17](#_Toc170488460)

[3 Proposed Load Shedding Algorithm 19](#_Toc170488461)

[3.1 Procedures and results of the load shedding 19](#_Toc170488462)

[3.2 Summary 19](#_Toc170488463)

[4 Results of Transient Behaviour 21](#_Toc170488464)

[4.1 Island Configuration 21](#_Toc170488465)

[4.2 Summary 21](#_Toc170488466)

[5 Results of Small Signal Stability Analysis 22](#_Toc170488467)

[5.1 Small Signal Stability Analysis for Islands 23](#_Toc170488468)

[6 Conclusions and Suggestions for Future Work 25](#_Toc170488469)

[6.1 Conclusions 25](#_Toc170488470)

[6.2 Suggestions for Future work 25](#_Toc170488471)

[7 References 27](#_Toc170488472)

[8 Publications 35](#_Toc170488473)

[9 Appendices 37](#_Toc170488474)

[Appendix A: 33-Bus System Data 37](#_Toc170488475)

List of Tables

[Table ‎1‑1: Reliability Indices 1](#_Toc170488476)

[Table ‎1‑2: Definition of Distributed Generation [14] 4](#_Toc170488477)

[Table ‎5‑1: Generators and Loads in Different Island Combinations 22](#_Toc170488478)

List of Figures

[Fig ‎1‑1: DGs Categories According to Size [13]. 4](#_Toc170488479)

[Fig ‎1‑2: Varies Types of DGs in Power System 6](#_Toc170488480)

[Fig ‎1‑3: Islanding Detection Methods 8](#_Toc170488481)

[Fig ‎1‑4: Island Types [27] 10](#_Toc170488482)

List of Symbols and Abbreviations

**Symbols**

|  |  |  |
| --- | --- | --- |
| Symbol | Description | Unit |
| f | Frequency of electromagnetic radiation | Hz |
| P | Active power | MW |
|  | Connected active power | MW |
| Q | Reactive power | Mvar |
| R | Resistance |  |

**Abbreviations**

|  |  |
| --- | --- |
| Abbreviation | Description |
| AC | Alternating current |
| AVR | Automatic Voltage Regulator |
| DC | Direct current |
| DCS | Distributed Control System |
| DER | Distributed Energy Resource |
| DG | Distributed generation |
| SCADA | Supervisory Control and Data Acquisition |
| WT | Wind turbines |

Chapter 1

# Introduction

## Motivation

In the modern world, electricity has become the lifeblood of civilization. The quick escalating demand and the high dependability on electricity necessitate reliable operation of the utilities especially for industrial loads. Generally, the continuity of providing electrical power is vital. To achieve the continuity of supplying electrical power to customers, researches recommend many solutions such as upgrading old utilities, converting the traditional systems to smart systems via installing automation equipment [[1](#_ENREF_1)], and installing distributed generation (DG) near load centers. Adding new DGs increases the power system reliability [[2](#_ENREF_2)].

.

## Distribution System Reliability

According to IEEE (PES definition) [[6](#_ENREF_6)], reliability of power systems is defined as: “more specific, ref. [[7](#_ENREF_7)] introduces another definition to power system reliability which is “quantifying the ability of a power system to provide an adequate and secure supply of electrical energy”.

The reliability of the power system is a statistical problem [[8](#_ENREF_8)]. Most of the probabilistic techniques for reliability assessments are with respect to adequacy assessments. There are three hierarchical levels for reliability analysis. These levels are: reliability assessment of “generation”, “generation and transmission” and “generation, transmission, and distribution”. Reliability has five **major indices** [[9](#_ENREF_9)] as indicated in Table ‎1‑1.

Table ‎1‑1: Reliability Indices

|  |  |  |
| --- | --- | --- |
| Index Term | Abbreviation | Short note |
| System Average Interruption Frequency | SAIFI |  |
| System Average Interruption Duration | SAIDI |  |
| Customer Average Interruption Frequency | CAIFI |  |
| Customer Average Interruption Duration | CAIDI | or |
| Customer Total Average Interruption Duration | CTAIDI |  |

All the mentioned indices in Table ‎1‑1 measure interruptions of the network (hours or times). In conclusion, decreasing the duration of interruptions increases the reliability of the distribution system [[10](#_ENREF_10)]. One of the most important benefits from adding DGs in the system is the increase of adequacy of the distributions systems [[10](#_ENREF_10)].

## Distributed Generations (DGs)

In the last decade, technological innovations and changes in economic and regulatory environments have resulted in a renewed interest for the distributed generation [[11](#_ENREF_11)]. DG, as a concept, is not new because the first power station was a small generating unit used to supply local loads and, thus, it could be commonly called DG.

Most world countries, such as China and USA, are suffering from pollution and greenhouse gases. The utilities encourage customers to increase the dependency on renewable energy sources, where most of the modern DGs are based on renewable energy resources. The DGs technology commonly uses DC systems because these systems use energy storage and power electronics in their operations [[12](#_ENREF_12)].

Ref [[11](#_ENREF_11)] listed five major factors that contribute to this evolution, i.e., developments in distributed generation technologies, constraints on the construction of new transmission lines, increased customer demand for highly reliable electricity, the electricity market liberalization and concerns about climate changes [[11](#_ENREF_11)].

### DG definition

Because of different governor regulations, the definition and size of DGs are different from one country to another. For example, in the United Kingdom, the turbine must be less than 100 MW to be considered as a DG [[13](#_ENREF_13)]. In Germany, the local utility built a 300 MW unit to provide heat and electricity that are consumed locally and, so, this unit is considered as a DG. In literature, many terms and definitions are used regarding DG [[13](#_ENREF_13)]. Table ‎1‑2 describes different definitions of the DG.

There are many terms that are used to express this technology or this type of generation. As an example, in Anglo-American, the term “Embedded generation” is used, while the term “Dispersed generation” is used in North America countries and the term “Decentralized generation” is used in Europe and part of Asia. Some authors define generation between 1 kW and 1 MW as the dispersed generation. The term embedded generation seems to be more appropriate to describe the DG whose power is consumed locally [[13](#_ENREF_13)]. The DGs can be categorized according to the type and rating. Some authors recommend the categories shown in Fig ‎1‑1.

Table ‎1‑2: Definition of Distributed Generation [[14](#_ENREF_14)]

|  |  |
| --- | --- |
| Source | Definition |
| Distributed Power Coalition of America (DPCA) | “Any small-scale power generation technology that provides electric power at a site closer to customers” |
| International Conference on High Voltage Electric Systems (CIGRE) | The distributed generation is   1. Not centrally planned 2. Usually connected to the distribution network 3. Smaller than 50 or 100 MW |
| International Energy Agency (IEA) | “The distributed generation is generating plant serving customers on-site or providing support to distribution level voltage” |
| US Department of Energy (US. DOE) | “Distributed generation small, modular electricity generators sited close to the customer load can enable utilities to defer or eliminate costly investments in transmission and distribution (T&D) system upgrades, and provides customers with better quality, more reliable energy supplies and a cleaner environment” |
| Institute of Electrical and Electronic Engineers (IEEE) | “Sources of electric power that are not directly connected to a bulk power transmission system and the DR includes generator and energy storage technologies” |
| American Gas Association (AGA) | “Strategic placement of small power generating units (5 kW to 25 MW) at or near customer loads” |

Fig ‎1‑1: DGs Categories According to Size [[13](#_ENREF_13)].

### DG Types

The objective of power system operation is to supply the load demand at all locations within the power system economically and reliably as possible. The traditional power system is based on centralized power stations such as steam, gas, hydro and nuclear power plants [[15](#_ENREF_15)]. The DG technology has been appeared due to the drawbacks of centralized stations. Currently, many DG technologies are available in the market and few types are still in the research and development stage [[15](#_ENREF_15)]. The DGs, which are currently available in the market, are reciprocating engines, micro-turbines, combustion gas turbines, fuel cells, photovoltaic and wind turbines. Each of them has its own befits and limitations. Fig ‎1‑2 indicates examples of DGs types.

### The advantage of the DGs

Several published papers [[16](#_ENREF_16)] confirm the feasibility of adding distributed DG in electrical distribution networks. Moreover, many researchers increase the benefits of these units by selecting the optimal locations of DGs to improve the performance of distribution systems [[17](#_ENREF_17)]. There are many advantages gained from adding DG to the distribution system. This section details some of these advantages.

1. DG will reduce loadings on substation power transformers during peak hours and, thereby, extending the useful life of these equipment and deferring planned substation upgrading.
2. Utilizing DG units reduces the necessity to build new transmission and distribution lines or to upgrade existing ones.
3. Utilizing DG units reduces transmission and distribution line losses and improves power quality and voltage profile of the system.

Fig ‎1‑2: Varies Types of DGs in Power System

### Challenges facing the DG

There are many challenges facing the insertion of distributed generation in the electric utilities [[18](#_ENREF_18)]. The following points summarize some potential problems that face DG technologies.

1. One of the major challenges that face the DG utilization is the relatively high capital costs per kW of installed power compared to large central plants. The financial cost problem exists because the technologies used in the DG fabrications are expensive. For instance, fabrication of efficient solar cells [[19](#_ENREF_19)], large-scale wind farms [[20](#_ENREF_20)] or efficient fuel cells [[21](#_ENREF_21)] need a large amount of money in the research stages and in the design stage.
2. The second important problem that is facing the DG insertion is the difficulty of controlling the system frequency after the insertion of the DG.
3. The relation between DG and power quality is an ambiguous one. Regardless of the advantages gained of adding DG to the distributed network, the abovementioned drawbacks regarding system voltage and frequency represent the harmful effect of DG insertion on the power quality.
4. The disadvantage of inserting distributed units on the protection schemes operations is stated as the follows:
   1. Changing power flow affects the short-circuit level in the distribution system and, so, the protection relays mal-operate. In this case, the directional overcurrent protection must be used [[22](#_ENREF_22)].
   2. The existence of automatic recloser in case of the DG could cause damage to the equipment.
5. Islanding or loss of mains is also a challenge that faces the DG penetration. Unplanned islanding situations affect the safety of human and equipment. Damage may occur with any attempt to reconnect the island with the distribution system as mentioned earlier. The following section will explain this phenomenon in detail.

## Concept of Islanding

Loss of mains, or islanding, means that a portion of the electrical system is isolated from the main grid intentionally or unintentionally. So, islanding can be classified into two types: intentional and unintentional islanding [[5](#_ENREF_5), [17](#_ENREF_17)].

### Unintentional islanding

Unintentional islanding means that the system is divided into subsystems when protective relaying detects abnormal conditions and takes corrective action to isolate the faulty part forming small systems or islands. The Distributed Energy Resource (DER) may not be suited to control the voltage and frequency of the isolated system. This means that the power quality cannot be guaranteed by the utility. The voltage and frequency can go out of range that could destroy the power system equipment. Even if the DER can control voltage and frequency, the dispatch center of the utility may not be able to supervise the DG.

The first precaution to overcome the drawbacks of unintentional islanding is to detect the islanding condition. Then, the DG must be disconnected until the fault is fixed and the current returns to flow. Now, the DG can be resynchronized again with the system [[23](#_ENREF_23)].

The main philosophy of detecting an islanding situation is to monitor the DG output variables (voltage and frequency) and system variables and decide whether an islanding situation has occurred from the changes in these variables. Islanding detection techniques can be divided into remote and local techniques, where local techniques can further be divided into passive, active and hybrid techniques as shown in Fig ‎1‑3.

Fig ‎1‑3: Islanding Detection Methods

### Intentional islanding

The intentional islanding means that the network operator decides to divide the distribution system into small parts because of a significant disturbance or schedule maintenance [[24](#_ENREF_24)]. In this case, the intentional islanding is planned in advance and the system and equipment are designed to manage the situation. The DER has to be well suited to control voltage and frequency in the islanded grid. Intentional islanding often exist in industrial plants, where the process has surplus energy that can be used to produce electricity. Examples are found in paper mills, sugar mills, cement factories, oil fields and fertilizing factories that are often capable of producing a large part of their electricity needs internally. During thunderstorms or other adverse weather situations, these plants can be switched to local production of electricity and isolate themselves from the surrounding grid. By performing this islanding, the risk of disturbances due to lightning strokes and other faults affecting the vulnerable process is limited. This type of islanding requires the system to be equipped with monitoring, information exchange, and control (MIC) equipment. Thus, it reduces the restoration time and decreases the financial loss [[25](#_ENREF_25)].

#### Intentional islanding benefits

Disconnecting DGs causes economic losses since the DGs mainly depend on renewable energy resources [[26](#_ENREF_26), [27](#_ENREF_27)]. Many system supervisors operate the new island as a standalone system. This way of control increases the system reliability and security and guarantees service continuity for important loads [[28](#_ENREF_28)]. Intentional islanding has many benefits such as [[24](#_ENREF_24), [27](#_ENREF_27)]:

1. Improving reliability by providing energy to the islanded portion of the electric power system during abnormal conditions or disturbances
2. Decreasing the power system restoring time and cost
3. Supplying the island at acceptable power quality regardless of the status of the main network
4. Maintaining supplying energy to important customers

#### Islands Types

According to IEEE standard [[27](#_ENREF_27)], there are many types of islands such as facility island, secondary island, lateral island, circuit island, substation island, substation bus island, and adjacent circuit island [[27](#_ENREF_27)]. Fig ‎1‑4 indicates these types.

A close up of a map

Description generated with high confidence

Fig ‎1‑4: Island Types [[27](#_ENREF_27)]

For creating a new island, the following consideration must be applied [[27](#_ENREF_27)].

1. The generator rating must be larger than load demand or a load shedding strategy is applied to disconnect the loads to maintain power balance.
2. The voltage and frequency level must be within allowed levels.
3. The voltage and frequency control strategies could be modified when needed to ensure the overall stability.

## Load Shedding Technique

The power system is designed for transmitting the power from generation area to load locations under normal conditions and the system should withstand contingency conditions [[29](#_ENREF_29)]. One of the ways to decrease the effect of the contingency problems is to disconnect the less important loads (load shedding). Load shedding means deliberately disconnecting loads to ensure a good power quality for remaining part of the power system [[29](#_ENREF_29)]. This disconnection could be either based on voltage level or frequency level of the system to prevent all system blackout. So, the load shedding is classified into two categories:

1. Undervoltage load shedding (UVLS)
2. Under-frequency load shedding (UFLS)

### Undervoltage load shedding (UVLS)

The under-voltage load shedding is that scheme which disconnects some of the loads to prevent voltage collapse and ensure the voltage stability in the system. For these types, the system must be monitored by MIC. The main factors affecting the voltage stability or causing voltage collapse are [[29](#_ENREF_29)]:

1. Transmission system limitation
2. Load behavior, including load tap changer performance
3. The influence of protection and control systems

### Under-frequency load shedding (UFLS)

Unlike UVLS, the under frequency load shedding (UFLS) is that type of schemes that disconnects the load to maintain the frequency in the limited range and prevent frequency collapse, which can lead to a cascading outage. UFLS is defined as a coordinated set of controls, which results in the decrease of electrical loads in the power system [[30](#_ENREF_30)].

The objective of an under-frequency load shedding scheme is to quickly recognize generation deficiency within any system and automatically shed a minimum amount of load. At the same time, it provides a quick, smooth and safe transition of the system from an emergency situation to a post-contingency condition such that a generation-load balance is achieved and the nominal system frequency is restored [[30](#_ENREF_30)].

## Literature Review and Background

Many attempts are recorded to operate a part of a certain system as an isolated system to achieve economic and technical benefits [[26](#_ENREF_26), [31](#_ENREF_31)]. In this case, the system must be monitored to guarantee successful islanding transition with achieving a power balance between the generation and the load. In many situations, the balance can be achieved via load shedding. After the transition to the island state, the stability of the island must be maintained under small or large disturbances. Therefore, these considerations must be taken into account in the planning stage [[26](#_ENREF_26)].

In [[26](#_ENREF_26)], an economic study is introduced for intentional islanding, where some aspects related to the deregulated market are clarified. It is concluded that the system is split during islanding and each island will have its own market price according to a non-competitive situation. In this study, the economic effect of disconnecting the DG is not taken into consideration.

A comparison between distributed control and supervisory control is introduced in [[32](#_ENREF_32)]. The authors also introduced Micro-Grid Management Systems (MGMS) and control functions such as voltage control, frequency control, operation cost optimization and other protective actions. This reference introduced the actual timing for islanding before the protection system trips the local DG. The timing for each function is detailed in hierarchical order and the authors also clarified the differences between each function. These functions are realized through either a centralized or a distributed MGMS framework.

A droop control method is introduced in [[33](#_ENREF_33)], where an intelligent control method is introduced using the Global Positioning System (GPS). The control system in [[33](#_ENREF_33)] described the relationship between the active and reactive power with voltage and frequency. Authors of [[33](#_ENREF_33)] showed the relationship between the P-Q circle of a DG unit and P-f and Q-E droops. This control wise, with two droops, enhanced the overall stability of the controller. But in this paper [[33](#_ENREF_33)], the stability[[33](#_ENREF_33)][[33](#_ENREF_33)][[33](#_ENREF_33)][[32](#_ENREF_32)][[31](#_ENREF_31)][[30](#_ENREF_30)][[29](#_ENREF_29)] is investigated for the radial system only.

Authors in [[31](#_ENREF_31)] introduced a control scheme to enhance intentional islanding. In this work, the control for inverter-based DG and the conditions for transition to island state were the limitations of voltage and frequency control. Another control strategy is introduced in [[28](#_ENREF_28)] for inverter-based DG. These controllers did not introduce a solution for power mismatch between the generators and loads or the penetration levels for DGs. Authors in [[34](#_ENREF_34)] introduced a load shedding mechanism to control the intentional islanding operations without considering DG penetration level or percentage load shedding. Also, authors of [[35](#_ENREF_35)] suggested some factors for assessing the successful island operation. The study in [[36](#_ENREF_36)] considers reliability assessment of islands.

Two control strategies for islanding are discussed in detail in [[24](#_ENREF_24), [31](#_ENREF_31)]. However, the quality of the supplied power is not considered in these studies. Another control strategy is introduced in [[28](#_ENREF_28)] and [[37](#_ENREF_37)] without considering load shedding to achieve the balance between the loads and the generated power. A load shedding algorithm has been discussed in [[38](#_ENREF_38), [39](#_ENREF_39)] but the authors did not introduce a validation for this load shedding on test systems.

The applications of load shedding in the distribution system are discussed in [[40](#_ENREF_40)]. This study did not test the load shedding in dynamic transition and did not introduce a way for its implementation in real situations.

## Thesis Objectives

The main objectives of the thesis can be summarized as follows:

1. Proposing general framework that enables the intentional islanding for the distribution systems
2. Increasing the flexibility for decision-making by the system operator by introducing many scenarios with priorities for the islanding process
3. Evaluating the success of the load shedding algorithm to provide acceptable dynamic behaviour during the transition moment.
4. Evaluating the small signal stability for all possible cases to give priorities for different island alternatives.

## Thesis Organization

In addition to [**chapter 1**](#_Introduction), which is the introduction of the thesis, the thesis comprises five chapters that are organized as follows:

[**Chapter 2**](#_Investigated_Network) introduces the dynamic modeling, the system description, and optimal DG allocations for the case study. Also, this chapter introduces the load flow calculations for the case study to validate the results of the optimal DG allocations for the IEEE 33-bus system.

[**Chapter 3**](#_Load_Shedding_Mechanism) presents a description of the proposed framework for load shedding algorithm. The rest of this chapter presents a full example to illustrate the intentional islanding process.

[**Chapter 4**](#_Dynamic_Study_Result) introduces the simulation results for the transition moment from the normal grid-connected mode to island mode. This chapter introduces the results of the load shedding required to form islands and island combinations. The island configuration is used to study the transition process to island operation with some constrains such as maximum DGs penetration level and maximum percentage shed loads.

[**Chapter 5**](#_Small_Signal_Stability) presents the small signal stability analysis for the islands and island combinations. Also, this chapter compares the minimum damping factors of eigenvalues for all islands and island combinations.

[**Chapter 6**](#_Conclusions) gives the conclusions and recommendations for future work that can be carried out related to this thesis.

Chapter 2

# Investigated Network

This chapter comprises three sections. The first section introduces the system description and optimal DG allocations, while the second section introduces the dynamic modeling for the DGs components. The dynamic models include the models of generators, turbines and excitation system. The third section introduces the load flow calculations for the case study to validate the results of the optimal DG allocations.

## System Description

Chapter 3

# Proposed Load Shedding Algorithm

To ensure a successful transition to island mode, the corresponding precautions must be satisfied. **Firstly**, the power balance must be satisfied between the loads and DGs. This balance can be achieved via the load shedding mechanism. **Secondly**, there are certain methods to control the voltage and frequency via the exciter Q-E droop and the turbine P-f droop speed (R), respectively. **Thirdly**, the time for load disconnection in the load shedding algorithm must be quick. Other precautions that are not mentioned here could be assumed as found in IEEE 1547.4 [[27](#_ENREF_27)].

## Procedures and results of the load shedding

## Summary

This chapter introduced LSA to enhance the intentional islanding operations. It introduced also full dynamic analysis for four islands with highlighting the control philosophy of the voltage and frequency.

chapter 4

# Results of Transient Behaviour

This chapter introduces the dynamic analysis for the transition moment from normal mode (grid-connected mode) to isolated mode (island mode). The chapter illustrates the island configuration for the case study and the load shedding results for all possible island and island combinations. Finally, the results of the dynamic behavior of four islands are introduced.

## Island Configuration

Choosing the island configurations is a challenging problem. Many researchers propose new methodologies to choose the island configurations such as the research introduced in [[35](#_ENREF_35)], which introduced a probabilistic approach to increase the probability of proper operation of the new islands.

## Summary

This chapter introduced the IEEE 33-bus Island configurations also the dynamic of four island at the average loading conditions. In this chapter, the timing for the transition moment is introduced. The transition moment includes change in speed droop ration in case of island 1 and island 2. The rotor angle difference for island 4 is monitored hence this island contains more than two DG units. As conclusion for this chapter, the LSA succeed to enhance the dynamic of the transition moment.

Chapter 5

# Results of Small Signal Stability Analysis

This chapter introduces the results of the small signal stability of islands and island combinations. The mathematical algorithm is found in [[52](#_ENREF_52), [57](#_ENREF_57)]. The eigenvalue analysis is performed to all islands in the system under various loading conditions to evaluate the stability degree for the system. After that, the results are used to compare between alternative islands in the IEEE 33-bus system. The total number of islands and island combinations is 10 as detailed in Table ‎5‑1. For these configurations, the small signal stability is evaluated for 16 loading conditions representing a daily change in the load profile. The hourly load variation through one day is shown in the load profile graph in **Error! Reference source not found.**. As mention before, the 24 load cases are grouped into 16 groups according to the percentage load shedding and one case is chosen from each group.

Table ‎5‑1: Generators and Loads in Different Island Combinations

|  |  |  |  |
| --- | --- | --- | --- |
| No | Island | Generators Number | Load Number |
| 1 | Island 1 | 1 | 4 |
| 2 | Island 2 | 1 | 5 |
| 3 | Island 3 | 2 and SVC unit | 8 |
| 4 | Island 4 | 3 | 13 |
| 5 | Island 1&2 | 2 | 9 |
| 6 | Island 1&4 | 4 | 17 |
| 7 | Island 3&4 | 5 and SVC unit | 21 |
| 8 | Island 1&3&4 | 6 and SVC unit | 25 |
| 9 | Island 1&2&4 | 5 | 13 |
| 10 | Island 1&2&3&4 | 7 and SVC unit | 30 |

The following sections discuss the small signal stability analysis for four islands to assess their stability. The analysis for islands combinations is detailed in a separate section to compare these configurations.

## Small Signal Stability Analysis for Islands

Chapter 6

# Conclusions and Suggestions for Future Work

## Conclusions

The dynamic transition to island operation is extensively investigated for different islands regarding the IEEE 33-bus system. With 50% pentation level of DGs units and 30% maximum limit for load shedding for each island, a successful transition to island mode is achieved.

## Suggestions for Future work

The following points could be investigated in future studies:

1. Converting the system to fully automated system considering possibility of islanding.
2. Studying the effect of renewable energy resources instead of the GAST turbine model.
3. Studying the effect of intentional islanding on the protection system.

# References

[1] A. G. Phadke and J. S. Thorp, *Synchronized phasor measurements and their applications*. Springer International Publishing AG: Springer International Publishing, 2017, pp. XIII, 285.

[2] M. Fotuhi-Firuzabad and A. Rajabi-Ghahnavie, "An analytical method to consider DG impacts on distribution system reliability," in *Transmission and Distribution Conference and Exhibition: Asia and Pacific, 2005 IEEE/PES*, 2005, pp. 1-6: IEEE.

[3] J. P. Lopes, N. Hatziargyriou, J. Mutale, P. Djapic, and N. Jenkins, "Integrating distributed generation into electric power systems: A review of drivers, challenges and opportunities," *Electric power systems research,* vol. 77, no. 9, pp. 1189-1203, 2007.

[4] J. Driesen and R. Belmans, "Distributed generation: Challenges and possible solutions," in *Power Engineering Society General Meeting, 2006. IEEE*, 2006, p. 8 pp.: IEEE.

[5] P. Mahat, Z. Chen, and B. Bak-Jensen, "Review of islanding detection methods for distributed generation," in *Electric Utility Deregulation and Restructuring and Power Technologies, 2008. DRPT 2008. Third International Conference on*, 2008, pp. 2743-2748: IEEE.

[6] Y. Sun, L. Cheng, X. Ye, J. He, and P. Wang, "Overview of power system operational reliability," in *Probabilistic Methods Applied to Power Systems (PMAPS), 2010 IEEE 11th International Conference on*, 2010, pp. 166-171: IEEE.

[7] R. Billinton and R. N. Allan, *Reliability evaluation of engineering systems*. Springer Science+Business Media New York: Springer US, 1992, pp. XVI, 453.

[8] Billinton and W. Li, *Reliability Assessment of Electric Power Systems Using Monte Carlo Methods*. Springer Science+Business Media New York: Springer US, 1994, pp. XVI, 352.

[9] R. Billinton and J. Billinton, "Distribution system reliability indices," *IEEE Transactions on Power Delivery,* vol. 4, no. 1, pp. 561-568, 1989.

[10] M. Kreishan, G. Fotis, V. Vita, and L. Ekonomou, "Distributed generation islanding effect on distribution networks and end user loads using the load sharing islanding method," *Energies,* vol. 9, no. 11, p. 956, 2016.

[11] G. Pepermans, J. Driesen, D. Haeseldonckx, R. Belmans, and W. D’haeseleer, "Distributed generation: definition, benefits and issues," *Energy policy,* vol. 33, no. 6, pp. 787-798, 2005.

[12] A. Bermudez-Contreras, M. Thomson, and D. G. Infield, "Renewable energy powered desalination in Baja California Sur, Mexico," *Desalination,* vol. 220, no. 1-3, pp. 431-440, 2008.

[13] T. Ackermann, G. Andersson, and L. Söder, "Distributed generation: a definition1," *Electric power systems research,* vol. 57, no. 3, pp. 195-204, 2001.

[14] F. Gonzalez-Longatt and C. Fortoul, "Review of the distributed generation concept: Attempt of unification," in *International Conference on Renewable Energies and Power Quality (ICREPQ 05), España*, 2005, pp. 16-18.

[15] R. C. Dugan and T. E. Mcdermott, "Distributed generation," *IEEE industry applications magazine,* vol. 8, no. 2, pp. 19-25, 2002.

[16] R. Viral and D. Khatod, "Optimal planning of distributed generation systems in distribution system: A review," *Renewable and Sustainable Energy Reviews,* vol. 16, no. 7, pp. 5146-5165, 2012.

[17] H. M. Dola and B. H. Chowdhury, "Intentional islanding and adaptive load shedding to avoid cascading outages," in *Power Engineering Society General Meeting, 2006. IEEE*, 2006, p. 8 pp.: IEEE.

[18] N. Hadjsaid, J.-F. Canard, and F. Dumas, "Dispersed generation impact on distribution networks," *IEEE Computer Applications in power,* vol. 12, no. 2, pp. 22-28, 1999.

[19] W. C. J. R. E. Sinke, "Development of photovoltaic technologies for global impact," vol. 138, pp. 911-914, 2019.

[20] M. Præst Knudsen, T. L. Tranekjer, N. J. I. Bulathsinhala, and Innovation, "Advancing large-scale R&D projects towards grand challenges through involvement of organizational knowledge integrators," vol. 26, no. 1, pp. 1-30, 2019.

[21] I. Staffell *et al.*, "The role of hydrogen and fuel cells in the global energy system," vol. 12, no. 2, pp. 463-491, 2019.

[22] H. A. Abdel-Ghany, A. M. Azmy, N. I. Elkalashy, and E. M. Rashad, "Optimizing DG penetration in distribution networks concerning protection schemes and technical impact," *Electric Power Systems Research,* vol. 128, pp. 113-122, 2015.

[23] F. Noor, R. Arumugam, and M. Vaziri, "Unintentional islanding and comparison of prevention techniques," in *Power Symposium, 2005. Proceedings of the 37th Annual North American*, 2005, pp. 90-96: IEEE.

[24] R. Caldon, A. Stocco, and R. Turri, "Feasibility of adaptive intentional islanding operation of electric utility systems with distributed generation," *Electric Power Systems Research,* vol. 78, no. 12, pp. 2017-2023, 2008.

[25] B. Archer and J. B. Davies, "System islanding considerations for improving power system restoration at Manitoba Hydro," in *Electrical and Computer Engineering, 2002. IEEE CCECE 2002. Canadian Conference on*, 2002, vol. 1, pp. 60-65: IEEE.

[26] H. Zeineldin, K. Bhattacharya, E. El-Saadany, and M. Salama, "Impact of intentional islanding of distributed generation on electricity market prices," *IEE Proceedings-Generation, Transmission and Distribution,* vol. 153, no. 2, pp. 147-154, 2006.

[27] "IEEE Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems," *IEEE Std 1547.4-2011,* pp. 1-54, 2011.

[28] J. P. Lopes, C. Moreira, and A. Madureira, "Defining control strategies for microgrids islanded operation," *IEEE Transactions on power systems,* vol. 21, no. 2, pp. 916-924, 2006.

[29] R. Verayiah, A. Mohamed, H. Shareef, and I. Z. Abidin, "Review of under-voltage load shedding schemes in power system operation," *Przegląd elektrotechniczny,* vol. 90, pp. 99-103, 2014.

[30] A. M. Zin, H. M. Hafiz, and M. Aziz, "A review of under-frequency load shedding scheme on TNB system," in *Power and Energy Conference, 2004. PECon 2004. Proceedings. National*, 2004, pp. 170-174: IEEE.

[31] I. J. Balaguer, Q. Lei, S. Yang, U. Supatti, and F. Z. Peng, "Control for grid-connected and intentional islanding operations of distributed power generation," *IEEE transactions on industrial electronics,* vol. 58, no. 1, pp. 147-157, 2011.

[32] Z. Cheng, J. Duan, and M.-Y. Chow, "To Centralize or to Distribute: That Is the Question: A Comparison of Advanced Microgrid Management Systems," *IEEE Industrial Electronics Magazine,* vol. 12, no. 1, pp. 6-24, 2018.

[33] J. M. Guerrero, M. Chandorkar, T.-L. Lee, and P. C. Loh, "Advanced control architectures for intelligent microgrids—Part I: Decentralized and hierarchical control," *IEEE Transactions on Industrial Electronics,* vol. 60, no. 4, pp. 1254-1262, 2013.

[34] A. M. Elkholy, H. A. A. El-Ghany, and A. M. Azmy, "A proposed load shedding mechanism for enhancing intentional-islanding dynamics of distribution systems," in *Power Systems Conference (MEPCON), 2017 Nineteenth International Middle East*, 2017, pp. 870-875: IEEE.

[35] R. A. Osama, A. Y. Abdelaziz, R. Swief, M. Ezzat, and A. F. Zobaa, "A probabilistic approach for maximizing the islanding success of microgrids," in *Power Systems Conference (MEPCON), 2017 Nineteenth International Middle East*, 2017, pp. 392-396: IEEE.

[36] S. Wang, Z. Li, L. Wu, M. Shahidehpour, and Z. Li, "New metrics for assessing the reliability and economics of microgrids in distribution system," *IEEE transactions on power systems,* vol. 28, no. 3, pp. 2852-2861, 2013.

[37] R. Bose and J. James, "Control schemes for intentional islanding operation of distributed generation," in *Power Signals Control and Computations (EPSCICON), 2014 International Conference on*, 2014, pp. 1-6: IEEE.

[38] P. Mahat, Z. Chen, and B. Bak-Jensen, "Underfrequency load shedding for an islanded distribution system with distributed generators," *IEEE Transactions on Power Delivery,* vol. 25, no. 2, pp. 911-918, 2010.

[39] P. Fuangfoo, W.-J. Lee, and M.-T. Kuo, "Impact study on intentional islanding of distributed generation connected to radial subtransmission system in Thailand's electric power system," in *Industry Applications Conference, 2006. 41st IAS Annual Meeting. Conference Record of the 2006 IEEE*, 2006, vol. 3, pp. 1140-1147: IEEE.

[40] N. Sapari, H. Mokhlis, J. A. Laghari, A. Bakar, and M. Dahalan, "Application of load shedding schemes for distribution network connected with distributed generation: A review," *Renewable and Sustainable Energy Reviews,* vol. 82, pp. 858-867, 2018.

[41] M. Ghazavi Dozein, H. Monsef, J. Ansari, and A. Kazemi, "An effective decentralized scheme to monitor and control the reactive power flow: a holonic‐based strategy," *International Transactions on Electrical Energy Systems,* vol. 26, no. 6, pp. 1184-1209, 2016.

[42] W. El-Khattam and M. M. Salama, "Distributed generation technologies, definitions and benefits," *Electric power systems research,* vol. 71, no. 2, pp. 119-128, 2004.

[43] M. A. Saad, H. A. A. El-Ghany, and A. M. Azmy, "Optimal DG deployment to improve voltage stability margin considering load variation," in *Power Systems Conference (MEPCON), 2017 Nineteenth International Middle East*, 2017, pp. 765-771: IEEE.

[44] M. A. Eltawil and Z. Zhao, "Grid-connected photovoltaic power systems: Technical and potential problems—A review," *Renewable and Sustainable Energy Reviews,* vol. 14, no. 1, pp. 112-129, 2010.

[45] M. Ropp, J. Newmiller, C. Whitaker, and B. Norris, "Review of potential problems and utility concerns arising from high penetration levels of photovoltaics in distribution systems," in *Photovoltaic Specialists Conference, 2008. PVSC'08. 33rd IEEE*, 2008, pp. 1-6: IEEE.

[46] P. Dandeno *et al.*, "IEEE guide for synchronous generator modeling practices and applications in power system stability analyses," *IEEE Std. 1110–2002,* pp. 1-72, 2003.

[47] P. Pourbeik, "Dynamic models for turbine-governors in power system studies," *IEEE Task Force on Turbine-Governor Modeling,* no. 2013, 2013.

[48] S. K. Yee, J. V. Milanovic, and F. M. Hughes, "Overview and comparative analysis of gas turbine models for system stability studies," *IEEE Transactions on power systems,* vol. 23, no. 1, pp. 108-118, 2008.

[49] "IEEE Recommended Practice for Excitation System Models for Power System Stability Studies," *IEEE Std 421.5-2016 (Revision of IEEE Std 421.5-2005),* pp. 1-207, 2016.

[50] V. Jerković, K. Miklošević, and Š. Željko, "Excitation system models of Synchronous generator," in *SiP 2010 28th International Conference Science in Practice*, 2010.

[51] M. Crenshaw, K. Bollinger, R. Byerly, R. Cresap, L. Eilts, and D. Eyre, "Excitation system models for power system stability studies," *IEEE TRANS. POWER APPAR. AND SYS.,* vol. 100, no. 2, pp. 494-509, 1981.

[52] B. Busarello. (2019). *Cott+ Partner AG. NEPLAN, power system analysis*. Available: <https://www.neplan.ch/>

[53] A. Mondal and M. S. Illindala, "Improved frequency regulation in an islanded mixed source microgrid through coordinated operation of DERs and smart loads," *IEEE Transactions on Industry Applications,* vol. 54, no. 1, pp. 112-120, 2018.

[54] H. M. Ayres, W. Freitas, M. C. De Almeida, and L. C. P. Da Silva, "Method for determining the maximum allowable penetration level of distributed generation without steady-state voltage violations," *IET Generation, Transmission & Distribution,* vol. 4, no. 4, 2010.

[55] M. Dreidy, H. Mokhlis, and S. Mekhilef, "Application of Meta-Heuristic Techniques for Optimal Load Shedding in Islanded Distribution Network with High Penetration of Solar PV Generation," *Energies,* vol. 10, no. 2, 2017.

[56] z. inc. (2018, Access Date 15-Jan-2019). *Breaker timing (1 ed.)*. Available: <https://www.zensol.com/en/circuit-breaker-testing/breaker-timing/>

[57] P. Kundur, N. J. Balu, and M. G. Lauby, *Power system stability and control*. New York: McGraw-hill 1994, pp. xxi,1167.

[58] Y. C. Choo, M. A. Kashem, and M. Negnevitsky, "Assessment of small disturbance stability of a power system," in *Australasian Universities Power Engineering Conference (AUPEC)*, 2006, pp. 1-6.

# Publications

**Conference**

1. A. M. Elkholy, H. A. A. El-Ghany, and A. M. Azmy, "A proposed load shedding mechanism for enhancing intentional-islanding dynamics of distribution systems," Nineteenth International Middel East Power System Conference (MEPCON), 2017, pp. 870-875.
2. A. M. Elkholy, H. A. A. El-Ghany, and A. M. Azmy, "An Advanced Load Shedding Algorithm to Enhance Intentional-Islanding Dynamics," Twinty International Middel East Power System Conference (MEPCON), 2018.

**Journal**

1. A. M. Elkholy, H. A. A. El-Ghany, and A. M. Azmy, "Enhancing Distribution System Reliability using Intentional Islanding," Electric Power Components and Systems. (under review)

# Appendices

## Appendix A: 33-Bus System Data

Table A: 33-Bus System Data

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Line Data | | | | Bus Data | | |
| From | To | R () | () | Bus | P (MW) | Q (Mvar) |
| 1 | 2 | 0.0575 | 0.0293 | 2 | 0.1 | 0.06 |
| 2 | 3 | 0.3076 | 0.1567 | 3 | 0.09 | 0.04 |
| 3 | 4 | 0.2284 | 0.1163 | 4 | 0.12 | 0.08 |
| 4 | 5 | 0.2378 | 0.1211 | 5 | 0.06 | 0.03 |
| 5 | 6 | 0.511 | 0.4411 | 6 | 0.06 | 0.02 |
| 6 | 7 | 0.1168 | 0.3861 | 7 | 0.2 | 0.1 |
| 7 | 8 | 0.4438 | 0.1467 | 8 | 0.2 | 0.1 |
| 8 | 9 | 0.6426 | 0.4617 | 9 | 0.06 | 0.02 |
| 9 | 10 | 0.6514 | 0.4617 | 10 | 0.06 | 0.02 |
| 10 | 11 | 0.1227 | 0.0405 | 11 | 0.045 | 0.03 |
| 11 | 12 | 0.2336 | 0.081 | 12 | 0.06 | 0.035 |
| 12 | 13 | 0.9159 | 0.7206 | 13 | 0.06 | 0.035 |
| 13 | 14 | 0.3379 | 0.4448 | 14 | 0.12 | 0.08 |
| 14 | 15 | 0.3687 | 0.3282 | 15 | 0.06 | 0.01 |
| 15 | 16 | 0.4657 | 0.34 | 16 | 0.06 | 0.02 |
| 16 | 17 | 0.8042 | 1.0738 | 17 | 0.06 | 0.02 |
| 17 | 18 | 0.4567 | 0.3581 | 18 | 0.09 | 0.04 |
| 2 | 19 | 0.1023 | 0.0976 | 19 | 0.09 | 0.04 |
| 19 | 20 | 0.9385 | 0.8457 | 20 | 0.09 | 0.04 |
| 20 | 21 | 0.2555 | 0.2985 | 21 | 0.09 | 0.04 |
| 21 | 22 | 0.4423 | 0.5848 | 22 | 0.09 | 0.04 |
| 3 | 23 | 0.2815 | 0.1924 | 23 | 0.09 | 0.05 |
| 23 | 24 | 0.5602 | 0.4424 | 24 | 0.42 | 0.2 |
| 24 | 25 | 0.559 | 0.4374 | 25 | 0.42 | 0.2 |
| 6 | 26 | 0.1267 | 0.0645 | 26 | 0.06 | 0.025 |
| 26 | 27 | 0.1773 | 0.0903 | 27 | 0.06 | 0.025 |
| 27 | 28 | 0.6607 | 0.5826 | 28 | 0.06 | 0.02 |
| 28 | 29 | 0.5017 | 0.4371 | 29 | 0.12 | 0.07 |
| 29 | 30 | 0.3166 | 0.1613 | 30 | 0.2 | 0.6 |
| 30 | 31 | 0.608 | 0.6009 | 31 | 0.15 | 0.07 |
| 31 | 32 | 0.1937 | 0.2258 | 32 | 0.21 | 0.1 |
| 32 | 33 | 0.2127 | 0.3308 | 33 | 0.06 | 0.04 |

**الفصل الأول**: ويتناول مقدمة عن الرسالة ويشمل مقدمة عن اعتمادية الشبكة الكهربية ومقدمة عن كيفية فصل الأحمال للحفاظ على الجهد والتردد.

**الفصل الثاني**: ويتناول الحالة التي ستخضع للدراسة وأيضا توزيع الأحمال خلال اليوم والأماكن المُثلي التي أضيف عندها الوحدات الموزعة وأيضا التشكيلات التي تم اقتراحها للجزر.

**الفصل الثالث**: ويتناول الخوارزمية المقترحة للحفاظ على استمرارية الخدمة للعملاء ذوي الأولوية.

**الفصل الرابع**: ويتناول دراسة السلوك العابر للجزر في حالة الانتقال إلى حالة الجزر المعزولة.

**الفصل الخامس**: ويتناول النتائج الخاصة بدراسة مدي استقرار الجزر وأيضا مقارنة بين الجزر المنفردة وتكوينات الجزر معا.

بينما يتناول **الفصل الأخير** خلاصة ما تم التوصل إليه في هذه الدراسة وما قد ينبثق منها من نقاط بحثية تتم دراستها في المستقبل.

ملخص الرسالة

نظراً للزيادة في الطلب على الطاقة الكهربية في السنوات الأخيرة، يتجه العاملون في الشبكة الكهربية إلى الاستفادة من التطور التكنولوجي للوحدات الموزعة حيث أن إضافة تلك الوحدات الموزعة تزيد من اعتمادية نظم الطاقة وتعمل عل تقليل المفاقيد في الشبكات وتعزز من مستوي الجهود. ومع ذلك، هناك تحديات تواجه إدخال الوحدات الموزعة في نظم الطاقة مثل مشاكل منظومة الحماية الكهربية وانفصال جزء من المنظومة عن الشبكة الرئيسة (التجزر). وجرت العادة على اتخاذ احتياطات تقليدية بعد عملية التجزر وهي فصل هذه الوحدات لضمان التشغيل الأمن للشبكة. في هذه الحالة، تقل اعتمادية الشبكة وتصبح عملية اعادة التشغيل من الامور المعقدة. ولذلك، يُفضِل العديد من أصحاب الوحدات الموزعة السيطرة على عملية التجزر، وتحسين خرج الوحدات الموزعة لضمان تغذية الأحمال القريبة لهذه الوحدات. ومن هنا, ظهر مفهوم التجزر المتعمد والذي يعني فصل بعد الأجزاء من الشبكة مع ضمان تغذية الجزء الاكبر من الاحمال بها فيما يسمى بالجزيرة. ولكي تتم تلك العملية، لابد أن تكون منظومة التوزيع مزودة بنظم للرصد والمراقبة تساعد على الكشف عن حالة فقدان الاتصال بالشبكة الرئيسة أو تساعد مشغلي الشبكة على تكوين تشكيلات متعمدة للجزر.

تقدم هذه الدراسة منهجية جديدة للتعامل مع التجزر المتعمد لزيادة اعتمادية نظم التوزيع. وتستند هذه المنهجية على خوارزميات لفصل الأحمال الزائدة عن خرج المولدات لتحقيق توازن بين المولدات والأحمال. بالإضافة إلى ذلك، فان هذه الدراسة تقدم أيضا استراتيجية للسيطرة على الجهد والتردد لضمان الانتقال السلس من حالة الاتصال بالشبكة إلى وضع الجزيرة. ويمكن للخوارزميات تحسين اعتمادية نظام التوزيع ككل من خلال ضمان تغذية الأحمال الهامة وذات الاولوية حتى في حالات صيانة الشبكة بالإضافة إلى تقديم تحليل ديناميكي مفصل لشبكة التوزيع في حالة التجزر. وقد تمت هذه الدراسة الديناميكية في أسوأ ظروف التحميل وأثبتت النتائج نجاحها للانتقال إلى حالة عزل الجزيرة عن الشبكة. يمكن لنظام الرقابة المحلية (DCS) للجزيرة تعديل تردد المولد وأيضا جهده لضمان جودة الطاقة المُزودة للأحمال في كل نظام معزول جديد. بالإضافة إلى ذلك، لابد من تقييم الاستقرار في الجزر الجديدة لتقييم أدائها وإعطاء الأولوية ما بين البدائل المختلفة سواء كانت للجزر بذاتها أو مجموعات متآلفة منها.

تُقدم هذه الرسالة على هيئة خمسة فصول يمكن استعراض محتوياتها الأساسية فيما يلي:

المستخلص

تقدم هذه الرسالة طريقة جديدة للتعامل مع التجزر المتعمد وذلك لزيادة الاعتمادية لشبكات التوزيع. تعتمد هذه الطريقة بالأساس على اقتراح خوارزمية جديدة لفصل الاحمال لتحقيق الاتزان المنشود ما بين القدرة المُولدة والاحمال في نفس الجزيرة وأيضا تم تقديم طريقة للتحكم في خرج المولدات (الجهد والتردد) لكي توائم الحالة الجديدة. تتضمن هذه الرسالة أيضا دراسة الأداء الديناميكي المفصل للحظة الانتقال الي حالة التجزر المتعمد. وقد تم اختبار هذا الانتقال عند أقصى تحميل لكل جزيرة حيث اثبتت النتائج فعالية هذه الطريقة المقترحة. ويمكن تلخيص ما تم تقديمه في الرسالة فيما يلي:

أولا: الاختيار الأمثل لأماكن الوحدات الموزعة في الشبكة الكهربية.

ثانيا: اختيار تكوينات من الجزر وفقا للحد الأدنى من معدل فصل الأحمال.

ثالثا: اقتراح خوارزمية لفصل الأحمال في كل جزيرة بحيث لا يزيد معدل الفصل عن 30% ويكون الفصل سريع لكي يناسب ان تعمل هذه الخوارزمية في حالات التشغيل الفعلي.

رابعا: رصد لحظات الانتقال العابر من النظام العادي إلى حالات التجزر.

خامساً: التحقق من جودة القدرة (الجهد والتردد) وتعديل التحكم في المولدات لتنظيم الجهد والتردد إذا لزم الأمر.

سادسا: التحقق من استقرار النظام المعزول الجديد (الجزيرة) عند زيادة الأحمال تدريجياً في الجزيرة.

وقد تم تطبيق هذه الخطوات بهدف زيادة اعتمادية أنظمة التوزيع والمحافظة على استمرار الخدمة للأحمال الهامة وخفض معدل المفاقيد في الطاقة خلال الشبكة.

الي ملهم هذا العمل الذي لم يقرأه أبدا....

|  |  |  |
| --- | --- | --- |
|  | جامعة طنطا  كلية الهندسة  قسم هندسة القوى والآلات الكهربية |  |

**لجنة الحكم والمناقشة لرسالة الماجستير المقدمة من**

**المهندس/ أحمد محمد الخولي**

معيد في كلية الهندسة جامعة طنطا، طنطا، جمهورية مصر العربية

بعنوان

**سيناريوهات التجزر للتشغيل عالي الإعتمادية لشبكات التوزيع**

للحصول على درجة ماجستير العلوم في الهندسة

**(هندسة القوى والآلات الكهربية)**

لجنة الحكم والمناقشة:

|  |
| --- |
| **أ.د/ شعبان مبروك أحمد عشيبة**  أستاذ متفرغ – قسم الهندسة الكهربية - كلية الهندسة بشبين الكوم– جامعة المنوفية (رئيسا) |
|  |
| **أ.د / أحمد محمد رفعت عزمي**  أستاذ بقسم هندسة القوى والآلات الكهربية - كلية الهندسة - جامعة طنطا (عضوا عن المشرفين) |
|  |
| **أ.د/ أحمد أنس الوجود هلال**  أستاذ بقسم القوى الكهربية والتحكم - كلية الهندسة والتكنولوجيا - الاكاديمية العربية للعلوم والتكنولوجيا والنقل البحري (عضوا) |

تاريخ المناقشة: 22/4/2019 م

توقيعات لجنة الحكم والمناقشة:

|  |  |  |
| --- | --- | --- |
| م | الاسم | التوقيع |
| 1 | أ.د/ شعبان مبروك أحمد عشيبة |  |
| 2 | أ.د / أحمد محمد رفعت عزمي |  |
| 3 | أ.د/ أحمد أنس الوجود هلال |  |

ابريل 2019

|  |  |  |
| --- | --- | --- |
|  | جامعة طنطا  كلية الهندسة  قسم هندسة القوى والآلات الكهربية |  |

سيناريوهات التجزر للتشغيل عالي الإعتمادية لشبكات التوزيع

مقدمة الى قسم هندسة القوي والآلات الكهربية - كلية الهندسة - جامعة طنطا

إيفاءًا جزئياً لشرط الحصول على درجة ماجستير العلوم في الهندسة

(هندسة القوى والآلات الكهربية)

مقدمة مـــــن

**م. أحمد محمد عبد الحكيم الخولي**

معيد في كلية الهندسة جامعة طنطا، طنطا، جمهورية مصر العربية

لجنة الاشراف

**أ.د / أحمد محمد رفعت عزمي**

أستاذ بقسم هندسة القوي والآلات الكهربية - كلية الهندسة - جامعة طنطا

وكيل الكلية لشئون المجتمع وتنمية البيئة

**د. حسام عبد الواحد عبد الغني صالح**

مدرس بقسم هندسة القوي والآلات الكهربية - كلية الهندسة - جامعة طنطا

ابريل 2019