# FREQUENCY AND TRANSIENT STABILITY ANALYSIS OF A 7-BUS BAR SYSTEM USING PSAF

A Project report is submitted in partial fulfillment of the requirements for the award of Degree of Bachelor of Science in Electrical and Electronic Engineering.

**Submitted by**
Name:Alindo Ghosh Antu ID:192-33-5246
Name:Prosanto Kumar Roy ID:192-33-5171

**Supervised by**
Dr. Md. Shahid Ullah
Professor & Head
Department of Electrical and Electronic Engineering

Department of Electrical and Electronic Engineering
Faculty of Engineering
DAFFODIL INTERNATIONAL UNIVERSITY

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## DECLARATION

I affirm that the research project titled **"Frequency and Transient Stability Analysis of a 7-Bus Bar System Using PSAF"** is a product of my individual effort. The work was conducted within the laboratories of the Department of Electrical and Electronic Engineering at Daffodil International University. This project is submitted as a partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering. The content of this project has not been previously incorporated into any other thesis or dissertation submitted for a degree, diploma, or similar qualifications at this or any other institution. I have diligently identified potential risks associated with this research, obtained necessary ethical and safety approvals where applicable, and acknowledged my responsibilities along with the rights of the participants involved.

**Signature of the candidates**

Alindo 30.1.23

Name: Alindo Ghosh Antu
ID: 192-33-5246

Prosanto Roy 30.1.23

Name: Prosanto Kumar Roy
ID: 192-33-5171

## APPROVAL

I have supervised and reviewed the project titled **"Frequency and Transient Stability Analysis of a 7-Bus Bar System Using PSAF,"** presented by **Alindo Ghosh Antu (192-33-5246)** and **Prosanto Kumar Roy (192-33-5171)**. I confirm that the work has been conducted under my guidance and has been deemed satisfactory. This project fulfills the partial requirements for the degree of **Bachelor of Science in Electrical and Electronic Engineering** and has been accepted in December 2023.

Signed

**Dr. Md. Shahid Ullah**
Professor & Head
Department of Electrical and Electronic Engineering
Faculty of Engineering
Daffodil International University

Dedicated

To

All of my teacher

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| EAC | Equal Area Criterion |
| PSAF | Power System Analysis Framework |
| CCT | Critical Clearing Time |
| GS | Gauss Seidal |
| LLL | Line-to-Line-to-Line |
| GDP | Gross Domestic Product |
| PSSE | Power System Simulations for Engineers |
| OSHA | Occupational Safety and Health administrations |
| NERC | North American Electric Reliability Corporations |
| CIP | Critical Cyber Asset Identifications |
| IEEE | Institute of Electrical and Electronics Engineers |

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# ABSTRACT

This study provides an investigation of voltage, frequency, and transient stability in a 7-busbar system utilising the Power System Investigation Toolbox CYME PSAF. The Newton-Raphson method is acknowledged for fast computational applications. The analysis is conducted in scenarios involving both normal and faulty circumstances. Under typical operating conditions, it has been observed that the system exhibits stability, with the voltage and frequency values remaining within acceptable thresholds. Nevertheless, it has been shown that the system exhibits instability in some fault scenarios and when certain fault clearance durations are applied. The examination of transient stability is conducted via the Equal Area Criterion (EAC). The Equivalent Area Criterion (EAC) is a straightforward and efficient technique used to assess the transient stability of a power system. The analytical results indicate that the 7-busbar system exhibits susceptibility to transient instability when subjected to three-phase faults on the transmission lines that interconnect buses 1 and 2, as well as buses 3 and 4. The system exhibits susceptibility to transitory instability in the event of single-phase-to-ground faults transpiring on bus 7. The analysis further demonstrates that the transient stability of the system can be enhanced through a reduction in fault clearance time. Nevertheless, there exists a trade-off between the duration required to clear faults and the associated expenses. The findings of this study can be applied to the design and operation of the 7-busbar system in a manner that prioritises safety and reliability.

# CHAPTER 1
# INTRODUCTION

## 1.1 Introduction

Power flow studies are of great importance in planning and designing the future expansion of power system as well as in determining the best operation of the existing systems. The principle information obtained from a power flow study is the magnitude and phase angle of the voltage at each bus the real and reactive power flowing in each line. Conducting a load flow study using multiple scenarios helps to ensure that the power system is adequately designed to satisfy a certain performance criteria.

Transient stability and frequency stability are two crucial factors that must be considered during the analysis of power systems. Transient stability is a term used to describe the capacity of a power system to uphold synchronism among its generators subsequent to a disturbance, such as a failure or an abrupt alteration in demand. Frequency stability pertains to the capacity of a power system to uphold a consistent frequency subsequent to a modification in the equilibrium between generation and load. The examination of transient and frequency stability plays a crucial role in the planning, design, and operation of power systems. Engineers can enhance the reliability and resilience of power systems by comprehending their response to disruptions.

The CYME PSAF programme is a robust tool utilised for doing analyses on transient and frequency stability. The CYME PSAF software offers a range of capabilities that render it highly suitable for this particular objective, encompassing:

The establishment of an all-encompassing repository containing a wide array of power system components and models. There exists a diverse range of numerical techniques that can be employed to address the challenges associated with tackling transient and frequency stability issues. An interface that is designed to be easily navigable and accessible to users, facilitating the creation and execution of simulations.

There exists a diverse range of post-processing technologies that are utilised for the purpose of analysing simulation outcomes. This manuscript will provide an exposition of the findings derived from a comprehensive investigation into the transient and frequency stability of a 7-bus power system, employing the CYME Power System Analysis Framework (PSAF) software. The investigation will encompass a range of disturbance scenarios, encompassing faults, load variations, and generator failures. The outcomes of the analysis will be utilised for the evaluation of the power system's stability and the identification of any prospective issues.

## 1.2 Bus Bar

## A bus bar is what?

In electrical power distribution systems, a bus bar is a metallic strip or bar that is used to transmit electricity inside a power distribution board, switchboard, or substation. It acts as a junction or a point of distribution for electrical power and offers a standard connecting point for various electrical circuits. Due to their superior electrical conductivity, bus bars are often composed of highly conductive materials like copper or aluminum. [1]

## Bus Bar Classification:

Bus bars can be categorized according to a number of criteria, including their form, placement within a system, and use. Here are some typical divisions:

**Depending on Shape:**

**Flat Bar:** The cross-section of flat bus bars is either rectangular or square. Due to their simplicity in production and installation, they are often employed in several electrical applications. [2]

**Tubercular Bar:** Bus bars with a tubular form are cylindrical or circular. Because of their higher cross-sectional area, which offers superior current-carrying capability and heat dissipation, they are frequently utilized in high-current applications.

## 2.Based on Location:

**Main Bus Bar:** Main bus bars are the main conductors that move electricity from the source, such as a generator or transformer, to the distribution terminals within a building or substation.

**Riser Bus Bar:** In multi-story buildings and substations, riser bus bars are used to deliver electricity vertically between floors or levels.

**Feeder Bus Bar:** Distributor bus bar sel ectricity is distributed horizontally inside a facility to various loads or panels. They diverge from the primary bus bars.[3]

## Depending on the application:

**power bus bar:** power bus bars are used to transfer high-current electrical power from the source to distribution panels or other machinery. They are utilized in power plants, substations, and industrial applications.

**Control bus bars:** Control bus bars are frequently used in control panels and automation systems to transport low-voltage control signals.

**Ground Bus Bars:** Ground bus bars let electrical devices maintain a common ground while safely dissipating fault currents to the earth.

## Based on Insulation:

**Isolated Bus Bars:** These bus bars feature insulating components or barriers to avoid unintentional contact with live wires, improving safety.

**Non-Isolated Bus Bars:** Non-isolated bus bars are used when physical isolation between conductors is not required and do not include insulating barriers.

## Based on the material:

**Copper bus bars :**Bus bars made of copper are renowned for their exceptional electrical conductivity and resistance to corrosion. Where high conductivity is required, they are frequently utilized.

**Aluminum bus bars:** While copper bus bars are heavier and more costly, aluminum bus bars have a somewhat lower conductivity. They are frequently utilized in situations where weight is an important factor.

The unique needs of the electrical system, such as current-carrying capacity, voltage levels, ambient conditions, and safety concerns, determine the kind and layout of bus bars. Bus bars must be properly designed and installed in order for electrical power distribution systems to operate effectively and reliably.

## Relevance of bus bars in power system analysis

Busbars are a crucial part of power distribution networks, and it is impossible to exaggerate how important they are. They provide a secure and effective method of moving power from entering feeders to departing feeders. Busbars are used in a broad range of situations, such as:

**Electrical substations:** In order to transport high-voltage power from incoming transmission lines to outgoing distribution lines, electrical substations require busbars.

**Power plants:** To transfer energy from generators to the grid, power plants employ busbars.

**Industrial facilities:** Busbars are used to transfer power to motors, lights, and other equipment in industrial facilities. Busbars are used in business buildings to transmit power to equipment such as lifts, lights and other fixtures.

**Residential structures:** To deliver power to the main breaker panel in residential buildings, busbars are employed.

**For the following reasons, busbars are crucial:**

Busbars provide a very effective method of distributing energy. Because of their low resistance, they reduce power losses.

Flexibility: Busbars may be set up in a variety of ways to suit the unique requirements of any power distribution system. If necessary, they may readily be updated or enlarged.

Busbars are very dependable and able to resist large currents and voltages. Additionally, they need little upkeep.

Busbars are made to be very safe. To protect them from the environment and unintentional touch, they are often housed in metal cases.

Busbars are crucial for the following reasons in addition to the ones mentioned above:

Busbars are a reasonably cost-effective method of distributing energy. They need little upkeep and have a lengthy lifetime.

Busbars may be scaled to fit any power distribution system, from tiny residential structures to enormous industrial complexes.

Busbars are composed of recyclable materials and emit no emissions, therefore they are environmentally friendly.

In general, busbars are a crucial part of contemporary power distribution networks. They provide a safe, effective, adaptable, and dependable method of distributing power to many different uses.

## 1.3 Power System Fault

A power system fault is a peculiar circumstance in an electrical power system that results in a significant and abrupt rise in current. Flashover, inadequate insulation, physical damage, or human error are all potential causes of this. Depending on the number of phases involved and whether the fault is grounded or not, there are many sorts of faults.

**Various Power System Fault Types**

The defects that affect electricity systems most frequently are:

All three phases of the power system are affected by the three-phase fault, which is the most severe sort of problem. Additionally, it is the most typical mistake.

Fault involving two phases of the power system is referred to as a two-phase fault. Despite being less severe than a three-phase fault, it can still do a lot of harm. [2]

A single phase of the power system is affected by a single-phase fault. Despite being the least serious fault category, if it is not resolved right away, it can still cause issues.

A ground fault occurs when there is a connection between one or more power system phases and the ground. Because they can result in electric shock and fires, ground faults can be extremely hazardous. [2]

**Effects of Faults in the Power System**

Numerous detrimental outcomes from power system breakdowns include:

Generators, transformers, and gearbox lines are just a few examples of the equipment that faults might harm. Costly repairs and power interruptions may result from this.

**Voltage instability**: Faults in the power supply can result in voltage swings and instability. Sensitive electronic devices may experience issues as a result.

**System instability:** Instability in a system can result from faults and trigger cascade outages.

**Power System Fault Protection**

Power system fault protection is a specialised field within the realm of electrical power engineering that focuses on safeguarding electrical power systems from faults by isolating the faulty components from the remainder of the electrical network. [1]

**Power system faults can arise due to a multitude of circumstances, encompassing:**

The occurrence of insulation breakdown, lightning strikes, foreign items making contact with power lines, and animals making contact with power lines are potential factors that can lead to electrical system failures.

**The occurrence of equipment failure Faults can give rise to several issues, encompassing:**

There are several potential risks that might occur in relation to equipment and electrical systems. These include equipment damage, power outages, fire incidents, and the risk of electrical shock.

Power system protection systems are specifically engineered to swiftly identify and isolate faults in order to minimise the extent of harm and disturbance.

**The primary constituents of a power system protection system encompass:**

Protective relays refer to equipment utilised for the detection of defects inside power systems. This is accomplished via the monitoring of electrical parameters, including voltage, current, and frequency. Upon the detection of a defect, a relay transmits a signal to a circuit breaker.

Circuit breakers are electrical devices that are designed to protect electrical circuits from damage caused by excessive current flow. Circuit breakers are electrical devices designed to disrupt the passage of electric current within a circuit. When a circuit breaker is triggered by a signal from a protective relay, it initiates the opening of its contacts, so effectively isolating the specific problematic portion within the power system. Power system protection systems are commonly constructed with selectivity as a key objective, ensuring that only the problematic component of the power system is isolated. This approach aids in reducing disturbances to the overall system.

A diverse range of power system protection systems exists, which vary according to their unique applications. Several prevalent categories of protective systems encompass:

The purpose of overcurrent protection is to identify and isolate faults that result in an excessive flow of current within a circuit. Similarly, undervoltage protection systems are designed to detect and isolate faults that lead to a drop in voltage below a specified threshold. Conversely, overvoltage protection systems are responsible for identifying and isolating faults that cause the voltage within a circuit to exceed a predetermined level. Distance protection systems, on the other hand, are designed to detect and isolate faults by considering the distance between the fault location and the protective device. Lastly, differential protection systems operate by comparing the incoming and outgoing currents within a protected segment of the power system in order to detect and isolate faults. The implementation of power system protection is a fundamental component within the framework of electrical power systems. Power system protection systems play a crucial role in mitigating damage and minimising interruption to the system by promptly and selectively identifying and isolating faults.

## frequency-power system fault relationship

The number of times per second that the voltage and current change determines a power system's frequency. Most electricity systems have a nominal frequency of 50 Hz or 60 Hz. Because it has an impact on how generators, transformers, and other equipment operate, frequency is a crucial component of power systems.

The frequency may fluctuate from its nominal value as a result of an issue with the power system. This is due to the imbalance between generation and load that a malfunction causes. The frequency will rise if the generation outpaces the load. The frequency will drop if the load is greater than the generation.

The kind, location, and strength of the power system all influence how severe the frequency variation is. A severe frequency variation can harm equipment and lead to cascading outages.

Operators of power systems employ a range of techniques to maintain frequency stability when experiencing faults. These techniques consist of

- **Controlling generator frequency:** Generators have governors that automatically modify their output to keep frequency.
- **Load shedding:** To restore balance, power system operators may reduce load if the frequency falls too low.
- **Black start:** Power system operators must utilise black start procedures to restart the generators and restore power if a serious fault results in a blackout. It is significant to understand that a power system's frequency and power are not the same. The rate at which electrical energy is transported is known as power. The number of times per second that the voltage and current change is known as the frequency.

  While a power system malfunction may result in a drop in frequency, it can also result in a drop in power. For instance, a single-phase defect may result in a loss of power while maintaining a largely steady frequency. However, a three-phase fault or a defect that results in a considerable loss of generation might result in a significant drop in frequency as well as power.

Finally, two crucial factors in power systems are frequency and power. Both frequency and power might differ from their nominal values due to a problem. Operators of power systems employ a range of techniques to maintain frequency stability when experiencing faults.

## 1.4 Brief Methodology

This research paper presents a detailed description of the technique utilised for the design and analysis of a 7-bus power system. The next section provides an overview of the methodology employed in this study. The research endeavours to establish a stable and dependable operation of the power system, particularly during periods of transient and dynamic situations, by formulating a well-defined problem. A systematic data collection procedure is employed to acquire crucial factors, including generator characteristics, load data, and line parameters, in order to develop an accurate and representative system model. The methodology encompasses the utilisation of power flow analysis techniques, such as the Newton-Raphson algorithm or dedicated software tools like PSAF, to validate the stability of the system in a steady-state condition. The scope of this analysis encompasses transient stability, which involves the modelling of the dynamic behaviour of the system in response to disturbances, encompassing critical clearance durations and rotor angles. In addition, the use of frequency stability analysis enables the evaluation of the system's ability to withstand frequency variations resulting from abrupt alterations in load conditions or disturbances in generation. Both transient and frequency stability analyses incorporate considerations of shunt elements, voltage and frequency limitations, contingency analysis, and sensitivity analysis. The culmination of the research involves the creation of thorough documentation and reporting, which aim to provide a comprehensive understanding of the performance, dependability, transient stability, and frequency stability of the 7-bus power system. Additionally, the research offers ideas for improving the system's dynamic response and security.

## 1.5 Gantt Chart

| Activites | Jan-Mar 2023 | Apr-May2023 | Jun-Aug2023 | Aug-Oct2023 | Oct-Nov2023 | Nov |
|---|---|---|---|---|---|---|
| Lirerature Review | | | | | | |
| Data Collection | | | | | | |
| Experiment | | | | | | |
| Result Analysis | | | | | | |
| Writing | | | | | | |
| Submission | | | | | | |

## 1.6 Structure of the Report

The report is organized into distinct chapters, each serving a specific purpose. In Chapter 2, the Literature Review establishes foundational knowledge by examining existing research, drawing comparisons and contrasts, and summarizing key findings. Moving on to Chapter 3, System Design & Procedure, the report delves into the core of the project, providing detailed information on system components, explaining the methodology, discussing design specifications, and presenting system analysis. Chapter 4, Results and Discussions, showcases project outcomes and offers a comprehensive analysis. Chapter 5, Project Management, centers on efficient organization, covering tasks, schedules, resource allocation, and lessons learned. Turning to Chapter 6, Impact Assessment of the Project, the report evaluates the broader implications of the project, including economic, societal, and environmental impacts. Finally, Chapter 7, Conclusions and Recommendations, brings the report to a close by summarizing key findings and providing insights for future work. This structured approach ensures clarity and guides the reader through the development and findings of the project.

# CHAPTER 2
# LITERATURE REVIEW

## 2.1 Introduction

The "Frequency and Transient Stability Analysis of a 7-Bus Bar System Using PSAF" is a comprehensive study on the dynamic behavior and stability of a simplified electrical power system. It delves into the complexities of frequency and transient stability, which are crucial aspects of power system operation that ensure reliable electricity supply to consumers.

The literature review serves as the introductory chapter of this paper, providing context for the subsequent analysis. It reveals existing theories, methodologies, and best practices in power system stability analysis, providing an overview of the evolution of stability analysis techniques and challenges faced by researchers and engineers. By critically analyzing the literature, research gaps are identified, allowing for meaningful contributions to the body of knowledge.

The literature review also provides insights into methodology, software tools, and simulation techniques used in power system stability analysis, introducing the Power System Analysis Framework (PSAF) and its advantages and disadvantages. It also provides historical context, enabling understanding of the evolution of current stability analysis methods.

Comparative analysis and validation are essential, as the literature review helps identify widely used benchmark systems and test cases, ensuring comparability and credibility within the larger power system stability research community.

the literature review serves as the intellectual foundation for the study of frequency and transient stability analysis of a seven-bus bar system using PSAF, contributing to the expansion of knowledge and improving the reliability and resilience of electrical power systems.

## 2.2 Related Research

The issue of power system stability holds great significance in the field of electrical engineering, as it has a direct influence on the reliable functioning of the electric grid in various situations and disturbances. Transient and frequency stability analyses are two crucial aspects of power system stability. The evaluation of a system's ability to retain synchronization and stability in the immediate aftermath of large shocks is of paramount importance, making transient stability analysis a crucial aspect of study. The fundamental principle behind transient stability analysis is the notion of the "critical clearing time." This term refers to the maximum permissible duration of time delay beyond which the stability of the system is compromised, hence forcing the implementation of corrective actions to avert a total collapse of the system.

The analysis of frequency stability, however, focuses on maintaining a consistent operating frequency within the power system. The significance of this matter lies in the fact that even little deviations from the designated frequency can result in detrimental consequences such as equipment harm and interruptions in the provision of electrical power. The maintenance of frequency stability is achieved by the use of many mechanisms, including governor control, load shedding, and generation control. These mechanisms collaborate to effectively regulate and restore the system's frequency to its intended value. Within the framework of these pivotal stability analyses, the Power System Analysis Framework (PSAF) emerges as a potent software tool. The Power System Analysis Framework (PSAF) offers a comprehensive framework for the simulation and analysis of power systems, allowing for a thorough examination of their performance across a range of operational scenarios. The tool is essential for academics and engineers in the field of power system analysis due to its wide range of analytical capabilities, which include load flow analysis, transient stability analysis, and frequency stability analysis. In order to provide a comprehensive background for your particular research on the Frequency and Transient Stability Analysis of a 7-Bus Bar System utilising the Power System Analysis Framework (PSAF), it is crucial to reference and incorporate relevant scholarly literature and previous investigations. One prominent source in this context is the textbook titled "Power System Analysis" authored by Grainger and Stevenson[1]. This internationally acclaimed book serves as a foundational resource for the theoretical aspects of power system stability analysis, encompassing both transient and frequency stability.

Furthermore, the research article titled "Load Flow Analysis and Abnormality Removal of Bangladesh Power System Using Software CYME PSAF" authored by Nazia Mehnaz and colleagues provides a concrete demonstration of the practical application of CYME PSAF software. Specifically, the study focuses on the utilisation of this software in conducting load flow analysis and addressing abnormalities within the power system of Bangladesh. The primary emphasis of PSAF rests in load flow analysis, highlighting the extensive applicability of this tool in practical power system scenarios.

In this scholarly article titled "The Effect of Load Characteristics on the Transient Stability Studies of a Laboratory Electric Power System Including Induction Generators," the author explores the complex interplay between load characteristics and transient stability, thereby contributing to the advancement of existing literature in this field. The objective of this study is to examine the effects of various load kinds, load levels, and load fluctuations on the transient stability of a laboratory electric power system that incorporates induction generators. Although not directly associated with the 7-Bus Bar System, this study sheds light on the significant importance of load-related factors in transient stability analyses.

In summary, the extensive background information provided, along with the knowledge gained through relevant courses, establishes a solid basis for conducting research on the Frequency and Transient Stability Analysis of a 7-Bus Bar System using PSAF. The acquisition of necessary knowledge and the capacity to make educated comparisons with existing designs and procedures are both facilitated by this, ultimately leading to breakthroughs in power system stability analysis.

## 2.3 Comparison

In our study, we are employing the Newton Raphson method to assess the stability of a 7-bus bar system using PSAF (Power System Analysis and Faults) over 50 cycles at 50 Hz. Let's discuss the existing systems and methodologies in this context, point out their strengths and weaknesses, identify research gaps, and recommend potential solutions. In terms of existing systems and technologies, classical methods such as the equal area criterion and swing equation analysis, as well as numerical techniques like the Newton-

Raphson method, have been traditionally used for power system stability analysis. While these methods offer accuracy, they may be computationally intensive. Additionally, commercial software like PSAF is widely utilized, providing a range of functionalities, yet it may have limitations in terms of flexibility and may not always capture the latest advancements in research. When comparing and contrasting these approaches, considerations include accuracy versus computational efficiency, user-friendliness, and flexibility for customization. Research gaps identified include the need for real-time stability assessment, adapting methods for renewable energy integration, and addressing cyber-physical security challenges. Recommendations involve the development of real-time monitoring, adapting stability analysis for renewable integration, and enhancing security measures to ensure a resilient power grid.

## 2.4 Summary

The research lays the stage for a thorough investigation of the dynamic behavior and stability of electrical power systems in the introductory section (2.1), concentrating on the crucial elements of frequency and transient stability. It underlines their vital significance in preserving the consistency of consumers' access to electricity. Additionally, it highlights the crucial role played by the literature review in guiding the analysis that follows, emphasizing that it is more than just a formality and serves as a foundation for finding gaps in the body of knowledge and offering novel perspectives. Additionally, it presents the Power System Analysis Framework (PSAF) as a key instrument for the investigation and provides a hint at the historical background, providing important context for comprehending the development of the modern stability analysis techniques.

The paper goes into more detail about the importance of power system stability in the context of electrical engineering in section 2.2. It highlights the crucial role that power system stability plays in the dependable operation of the electric grid, particularly in the face of varied disturbances and difficult circumstances. The importance of transient and frequency stability analyses is further explained, and the idea of the "critical clearing time" is introduced as a key variable in transient stability analysis. This parameter specifies the longest delay that can occur before the stability of the system is compromised and corrective action is required. The section also emphasizes how crucial it is to keep the power system's operating frequency constant because even little variations might have unfavorable effects. It explains the techniques used to control and restore the frequency of the system, including generation control, load shedding, and governor control. Power system simulation and analysis are made possible by the Power System Analysis Framework (PSAF), a powerful software tool. In order to lay the groundwork for the research's thoughtful analysis and contributions to the field, the section also makes specific references to scholarly works and literature, such as "Power System Analysis" by Grainger and Stevenson and "Load Flow Analysis and Abnormality Removal of Bangladesh Power System Using Software CYME PSAF" by Nazia Mehnaz et al.

# CHAPTER 3
# MATERIALS AND METHODS

## 3.1 Introduction

The "Materials and Methods" portion of this study begins a trip into the complex planning and execution of a thorough analysis of the transient stability and frequency stability of a 7-bus bar system. The Power Systems Analysis Framework (PSAF), which we use, is a true technological marvel. It functions as a comprehensive suite made specifically to address the complexities of power system analysis. A variety of specialized programs, including those for Load Flow, Short Circuit, Harmonic, and Transient Stability analysis, are housed within the virtual walls of PSAF. These programs are all neatly organized under a single database and network editing facility.
As we move into the meat of this chapter, the use of PSAF to understand the complexity of power system dynamics is the main point of emphasis. Load flow studies are the first stage in our analytical journey since they help us better understand the electrical complexities of the 7-bus bar Power System. We use PSAF's tools to analyze the network's load flow characteristics, illuminating voltage profiles, power flows, and system states. This is where PSAF's talents truly shine.
Our investigation, however, boldly ventures into the worlds of transient stability and frequency stability in addition to load flow investigations. We engineer disruptions in order to test the 7-bus bar system's durability and resilience, resulting in scenarios that go against the fundamental nature of stability. This is where PSAF, our dependable friend, steps in again, giving us the tools to gauge the system's resilience to the storm and ability to preserve synchronicity in the face of chaos.
We will carefully describe the approaches, processes, and analyses that form the foundation of our research in the narrative of this chapter. Each stage, supported by the abilities of PSAF, is a demonstration of the precise planning and exacting execution required to solve the puzzles of power system stability. We set out on an exploration voyage together where theory and experience come together to shed light on the dynamic behaviors of a 7-bus bar system, ultimately improving our comprehension of transient and frequency stability.

## 3.2 Methods and Materials

The mathematical representation of load flow problems yields a collection of non-linear algebraic equations. The fundamental techniques utilized for solving these equations include,

1. the Gauss-Seidal Method,
2. the Newton-Raphson Method, and
3. the Fast-Decoupled Method.

The Newton-Raphson method is employed for these specific objectives. The program has been recognized as a suitable tool for conducting simulations of power distribution networks. A Comparative Analysis of the Newton-Raphson Method in Relation to Other Numerical Methods For the purposes of this analytical study, the Newton Raphson method has been selected for simulation. A concise evaluation of the aforementioned strategies is provided below. The Gauss-Seidal (GS) method necessitates a substantial number of iterations due to its slow rate of convergence. If an analysis were to be conducted on a system with several hundred buses, it would need a significant number of iterations for this method to converge. The quantity of iterations exhibits a positive linear relationship with the quantity of buses present within the system. The sensitivity of this strategy is contingent upon the selection of the reference bus. In contrast, the Newton-Raphson approach has certain advantages in comparison to the GS method, along with other advantageous characteristics. The rate of convergence in the Newton-Raphson method is highly rapid. The number of iterations remains unaffected by the size of the system. Typically, small systems may achieve a solution with a high level of accuracy within two to three iterations. The rate of iteration does not exhibit a proportional increase in tandem with the increase in the number of buses. The sensitivity of the convergence of the system in the Newton-Raphson approach is not affected by the selection of the slack bus. There is a reduction in computational time as a result of requiring fewer rounds to achieve convergence. From a computational perspective, the fast-decoupled technique demonstrates superiority in terms of both speed and storage capacity. However, the procedure in question has a diminished level of precision when contrasted with the NR approach. Ultimately, it is undeniably apparent that the Newton-Raphson approach is the most optimal choice for doing power system analysis.

## 3.3 Design Specifications. Standards and Constraints

**Proposed Bus Bar:**

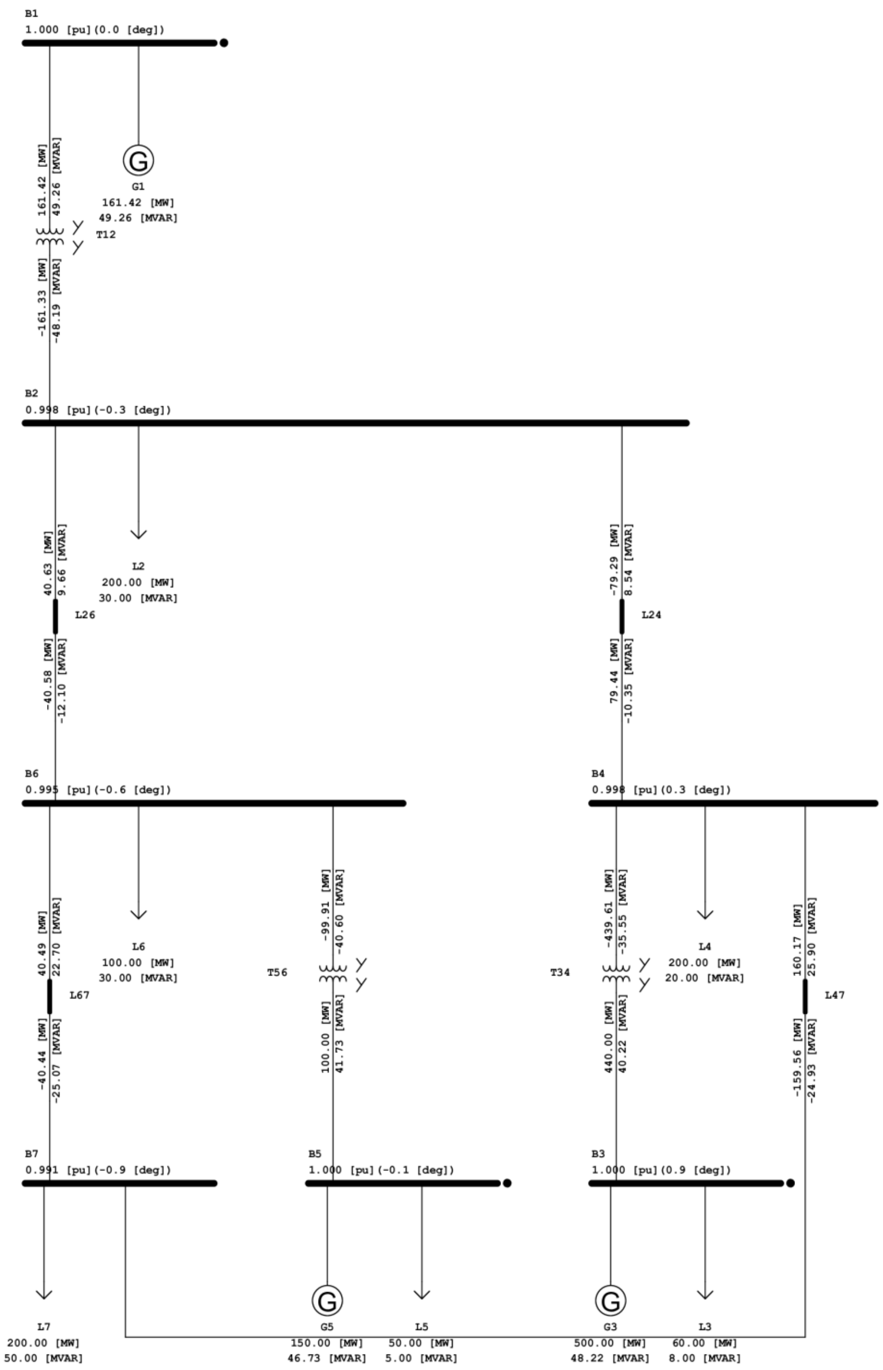


Fig. 3.1 Single line diagram of proposed 7Bus-Bar

In order to enhance clarity on the procedural aspects, I have put forth the suggestion of employing a bus bar for the purpose of examining frequency and transient stability. A power system of modest scale is selected, consisting of four generators, seven buses, four transformers, and four transmission lines. The construction and solution of the 7-bus system have been carried out using PSAF v2.81 in order to obtain the required reports. The Newton-Raphson method has been chosen as the computational technique to solve the given system.

## 3.4 System Analysis

The primary goal of this work is 7-bus bar configuration to examine frequency and transient stability in a power system. Four generators, seven buses, four transformers, and four transmission lines make up the system under scrutiny. The design's goal is better procedure knowledge through the use of a manageable power system model that allows for stability analysis.

**Setup of the System:**

Table 3.1 Base & Operating Data for 7 bus bar

| ID | Base kV | Operating kV |
|---|---|---|
| B1 | 11 | 11 |
| B2 | 132 | 132 |
| B3 | 11 | 11 |
| B4 | 132 | 132 |
| B5 | 11 | 11 |
| B6 | 132 | 132 |
| B7 | 132 | 132 |

Table 3.2 Fixed-tap transformed Data for 7 bus bar

| From Bus | To Bus | Primary kV | Secondary kV | Rating (MVA) | Z1 (p.u .) | $X_1$ $/R_1$ | Standard Loading Limit (MVA) |
|---|---|---|---|---|---|---|---|
| B1 | B2 | 11 | 132 | 400 | 0.015 | 12.5 | 400 |
| B3 | B4 | 11 | 132 | 500 | 0.012 | 12.0 | 500 |
| B5 | B6 | 11 | 132 | 250 | 0.024 | 12.0 | 250 |

Table 3.3 Active generation Generator Data for 7 bus bar

| Bus ID | Type | Voltage (kV) | Rating (MVA) | Active generation (MW) | Max. (MVAR) | Min. (MVAR) |
|---|---|---|---|---|---|---|
| B1 | Swing | 11 | 650 | - | - | - |
| B3 | Voltage Controlled | 11 | 750 | 500 | 400 | -300 |
| B5 | Voltage Controlled | 11 | 400 | 200 | 140 | -100 |

Table 3.4 Line Resistances and Impedance Data for 7 bus bar

| From Bus | To Bus | kV level | Loading limit (Amps) | $R_1$ (Ohms/km) | $X_1$ (Ohms/km) | B (µ.S./km) | Length (km) |
|---|---|---|---|---|---|---|---|
| | 6 | 132 | 800 | 0.4 | 2.4 | 155.5 | 10 |
| 4 | 7 | 132 | 800 | 0.4 | 2.4 | 155.5 | 10 |
| 2 | 4 | 132 | 800 | 0.4 | 2.4 | 155.5 | 6.52 |
| 6 | 7 | 132 | 800 | 0.4 | 2.4 | 155.5 | 6.52 |

Table 3.5 Real power and Reactive power Load Data for 7 bus bar

| Bus ID | P (MW) | Q (MVAR) |
|---|---|---|
| B2 | 200 | 30 |
| B3 | 60 | 8 |
| B4 | 200 | 20 |
| B5 | 50 | 5 |
| B6 | 100 | 30 |
| B7 | 200 | 50 |

The power system configuration has a compact form, comprising the subsequent components:

The four generators function as the principal providers of electrical power inside the system. The phrase "seven buses" pertains to the interconnected nodes inside a power network, where loads and generators are joined. There exist a total of four transformers. Transformers are utilized for the purpose of voltage transformation and for establishing connections to varying voltage levels.

There exist four transmission lines that enable the efficient transfer of electrical power between different buses and components. Choosing the right modeling, simulation, and analysis software is crucial to the success of this project; after much deliberation, the Power System Analysis Framework (PSAF) version 2.81 was selected as the best option. PSAF is exceptional since it is a complete and flexible power system analysis program. Its comprehensive set of features allows for an in-depth analysis of the power system that is perfectly suited to the needs of the project.

When solving the complex equations that characterize the power system, the use of the Newton-Raphson technique as the computational tool indicates a dedication to precision and rigor. This numerical approach is a tried-and-true method for calculating voltage levels and phase angles at different buses in a system during a load flow study. Its use demonstrates the project's commitment to producing accurate results and lays the groundwork for further stability assessments. To ensure that the analysis is up to par with the stringent requirements of the sector, the team has opted to use the Newton-Raphson method in its quest of a high degree of precision in dealing with complicated equations describing power systems.

## 3.5 Simulation

Implementing transient and frequency stability analysis within the selected 7-bus power system using PSAF v2.81 involves several specific steps. Below, I outline the detailed implementation process for each type of stability analysis:

**Transient Stability Analysis:**

**1. Model Setup:**

- Configure the 7-bus power system within PSAF,
  which is consisting of four generators, seven buses, four transformers, and four transmission lines.
- Then we define the system parameters, including generator data, load characteristics, line parameters, and transformer data.

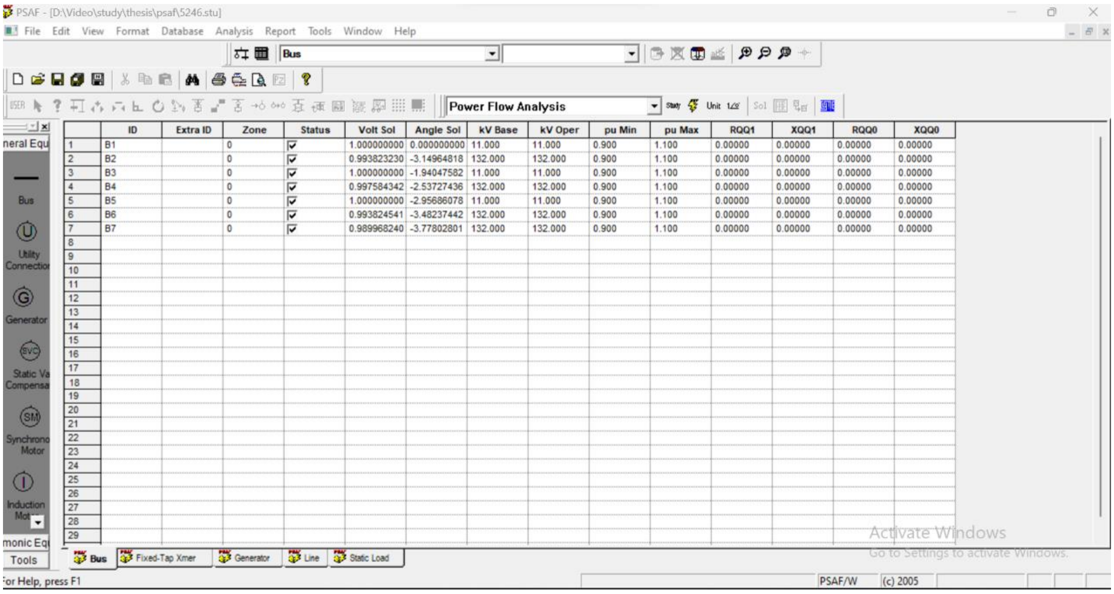

Fig.3.2 Configuring the 7-bus power system within PSAF.

**2. Load Flow Analysis:**

- Carry out a load flow analysis in order to ascertain the initial operating conditions of the system, which should include the magnitudes of the voltages, the phase angles, and the power flows.
- Check to verify that the system's voltage and power consumption remain within the allowed ranges.

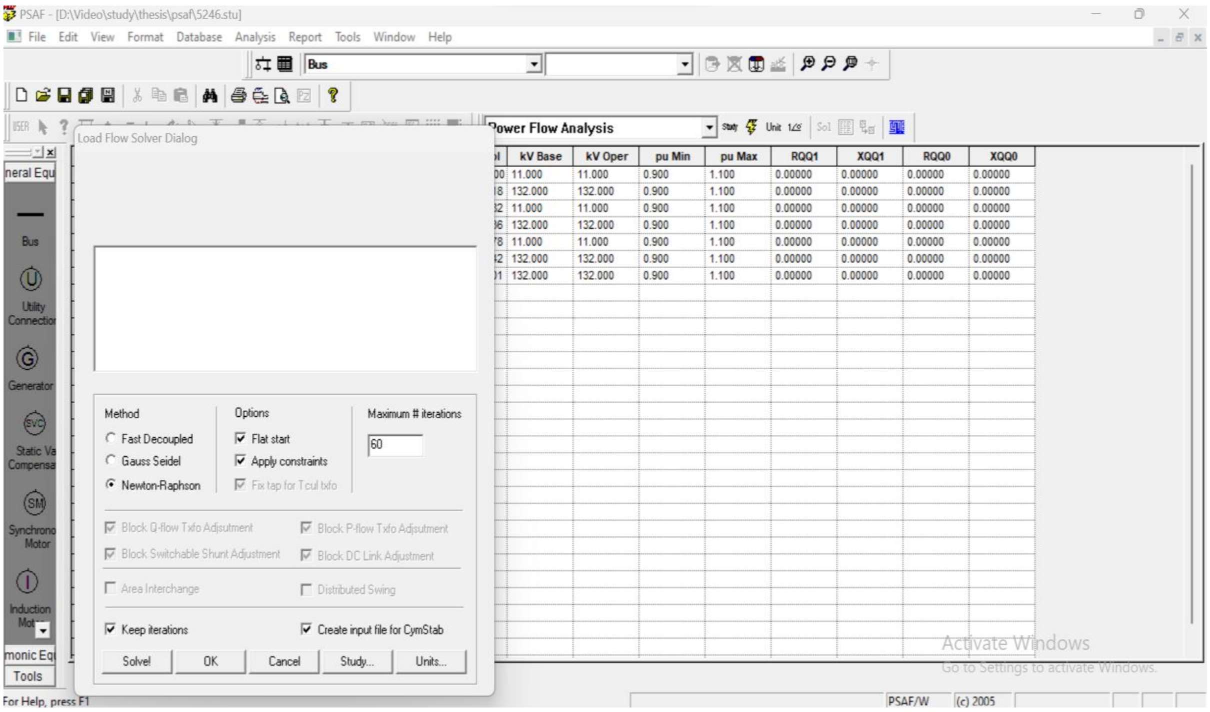

Fig.3.3 Load Flow Analysis - Initial Operating Conditions

3. **Disturbance Scenario Definition:**

This stage requires us to select a particular disturbance scenario that we wish to study, such as a malfunction, the tripping of a generator, or an increase in load. Following that, we will need to provide the location, the type, and the magnitude of the disturbance that is occurring within the system.

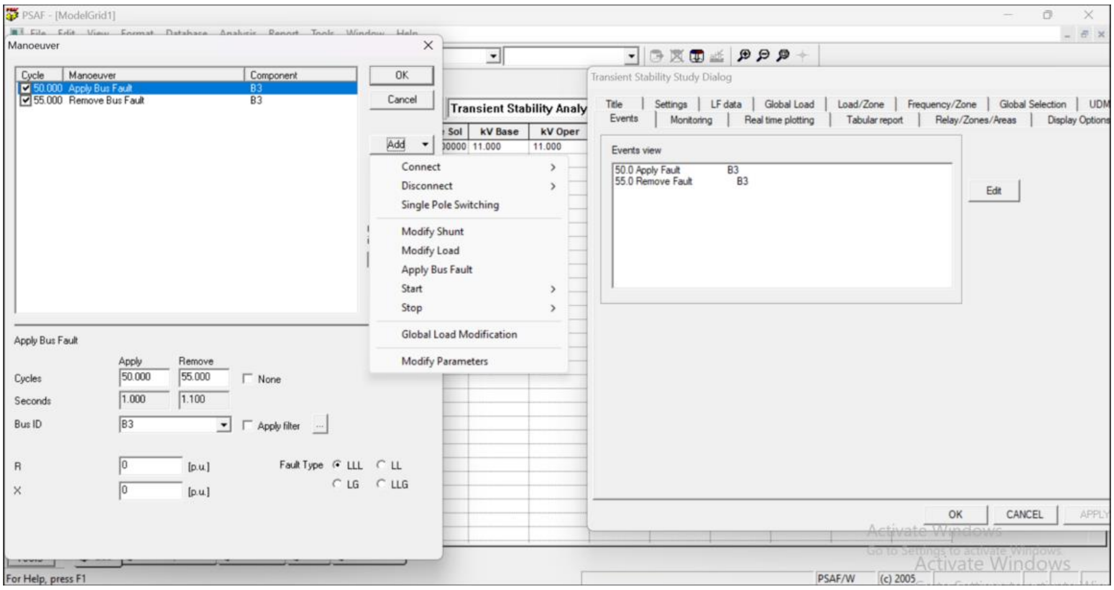


Fig.3.4 Line-to-Line-to-Line Fault at Bus Bar - PSAF Simulation

4. **Transient Stability Simulation Settings:**

Adjust the parameters for transient stability modeling in the Power System Analysis Framework (PSAF), encompassing:

- The simulation length refers to the defined time frame within which the simulation is conducted, encompassing the transient response phase.
- Determination of the integration step size: Define the temporal increment for numerical integration inside the simulation.

The establishment of event detection criteria involves the formulation of specific guidelines for the identification of significant occurrences inside a simulation, such as instances of generator tripping or voltage collapse.

## 5. Execute Transient Stability Analysis:

The transient stability simulation was conducted using PSAF v2.81, commencing with the specified disturbance scenario. The Public Service Announcement Framework (PSAF) will present time-domain charts and outcomes, illustrating the dynamic characteristics of generator rotor angles, speeds, and other relevant variables throughout and following the disturbance. The user's text does not provide any information to rewrite in an academic manner. Conduct an analysis of the simulation findings in order to evaluate the transient stability of the system. Examine indicators of oscillatory behavior, instability, or voltage collapse.

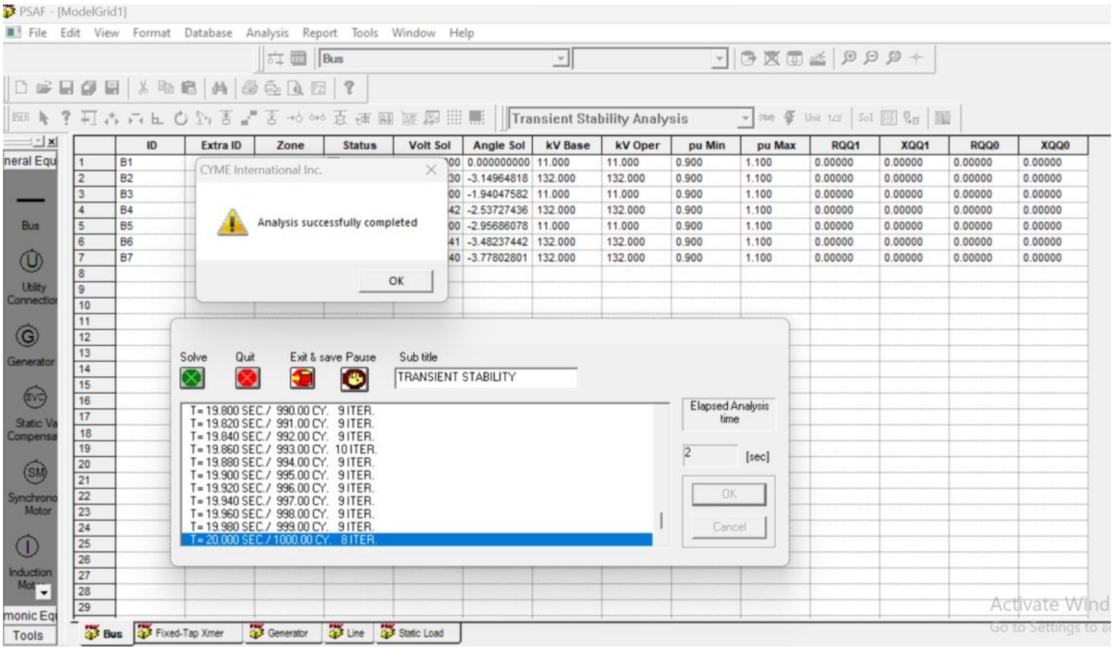


Fig.3.5 Transient Stability Simulation Settings in PSAF

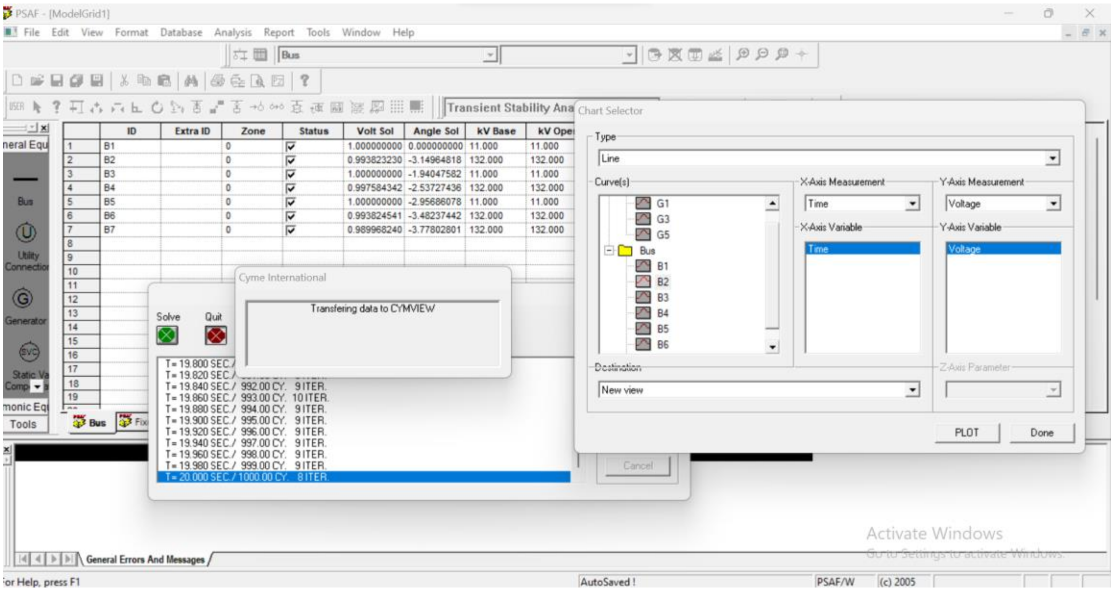


Fig.3.6 Execute Transient Stability Analysis in PSAF

This detailed implementation process should enable you to effectively perform transient and frequency stability analyses using PSAF v2.81 within your 7-bus power system model.

### 3.6 Summary

Chapter 3 lays out an in-depth investigation into the proposed 7-bus power system and the methods that guide its modeling. Section 3.1 of this chapter lays out the study's central idea and explains why it's important for maintaining reliable electricity distribution. In Section 3.2, we go into the methodology, highlighting the selection of the Newton-Raphson method and detailing why it is preferable to other approaches for solving difficult equations describing power systems. The suggested 7-bus system architecture is outlined in Section 3.3 to guarantee consistency with the study's aims. The need of reliable information in the design process is emphasized in Section 3.4. Chapter 3.5 follows on in a natural way, detailing the simulation in great detail. The major tool used for transient and frequency stability testing is PSAFv2.81. This version allows for load flow analysis and the generation of artificial disturbances. These chapters, taken as a whole, provide as a firm foundation, outlining the research strategy, methodology, and the value of careful data selection. They provide a foundation for further in-depth simulations and analysis in later chapters, which are necessary for the actual application of power system stability analysis.

# CHAPTER 4

# RESULTS AND DISCUSSIONS

## 4.1 Results & Discussions

These graphs show how different parameters alter over time in reaction to an LLL error and the clearing that follows. In order to avoid widespread blackouts and equipment damage, transient stability analysis helps guarantee that the power system can recover from such disruptions and return to a stable operating state. It is essential to the operation and planning of the power system.

In this case through PSAF we create a fault at 50 cycles .Here our bus bar voltage is 11 kv and our stable frequency is 50 Hz.
Now if we observe ,

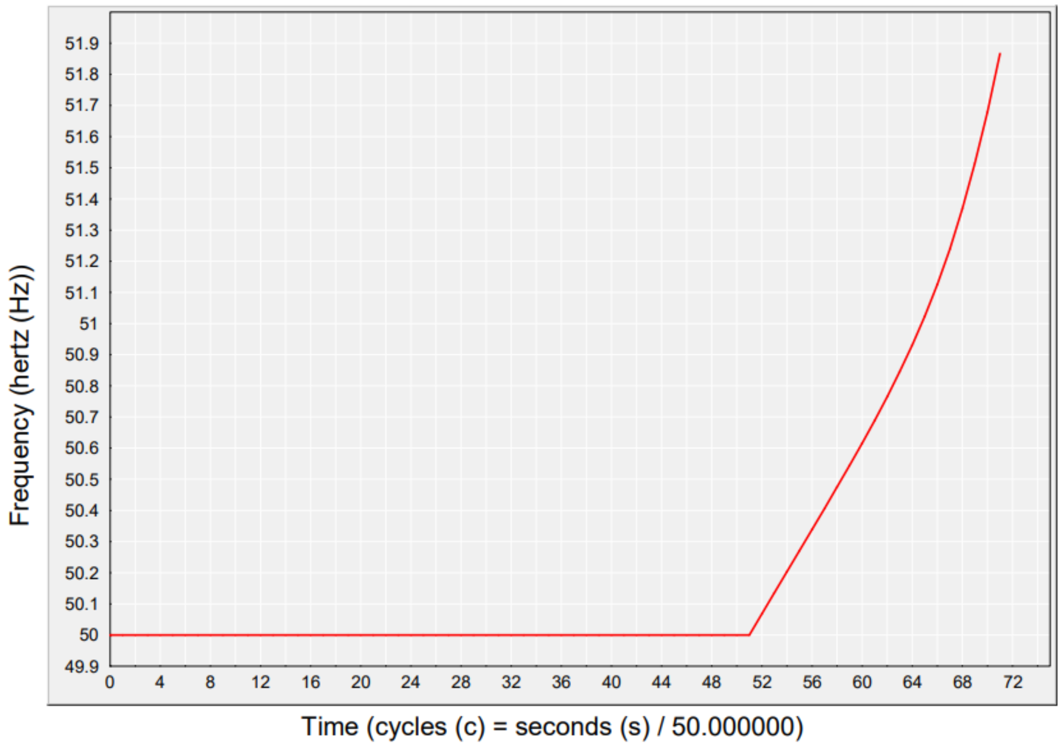


Fig.4.1Frequency versus Time curve for Bus Bar 3 after LLL fault at 50cycles

**Scenario**: A Line-to-Line-to-Line fault occurs at 50 cycles at Bus Bar 3.

**Analysis:** This figure shows the response of the electrical frequency at Bus Bar 3 after the LLL fault. Following the fault, the frequency deviates from its nominal value. This deviation indicates an initial loss of synchronization and instability in the power system. Here we can notice that frequency is increasing with cycle and after a time the fault is not removing so system goes to shut-down .At 50 cycle system start to increase its frequency and at 68 cycle it goes to 52Hz.

In the scenario described, a three-phase fault occurring at bus bar 3 of a 7-bus power system has led to a significant disturbance in the system's frequency. Let's break down the sequence of events:

**Initial Conditions:** The power system is initially operating at a normal frequency of 50 Hz. This is the standard operating frequency for many electrical power systems.

**Fault Event:** A three-phase fault occurs at bus bar 3. Three-phase faults are severe electrical faults that can lead to a short-circuit condition, causing a sudden drop in generation capacity and potentially other disturbances in the system. These disturbances can disrupt the balance between electrical generation and load demand in the system.

**Frequency Increase:** Due to the disruption caused by the fault, the system's frequency begins to increase rapidly. In this case, the frequency rises from the normal 50 Hz to 52 Hz. This increase in frequency is a direct consequence of the imbalance between generation and load. When there is excess generation and insufficient load, the frequency tends to increase.

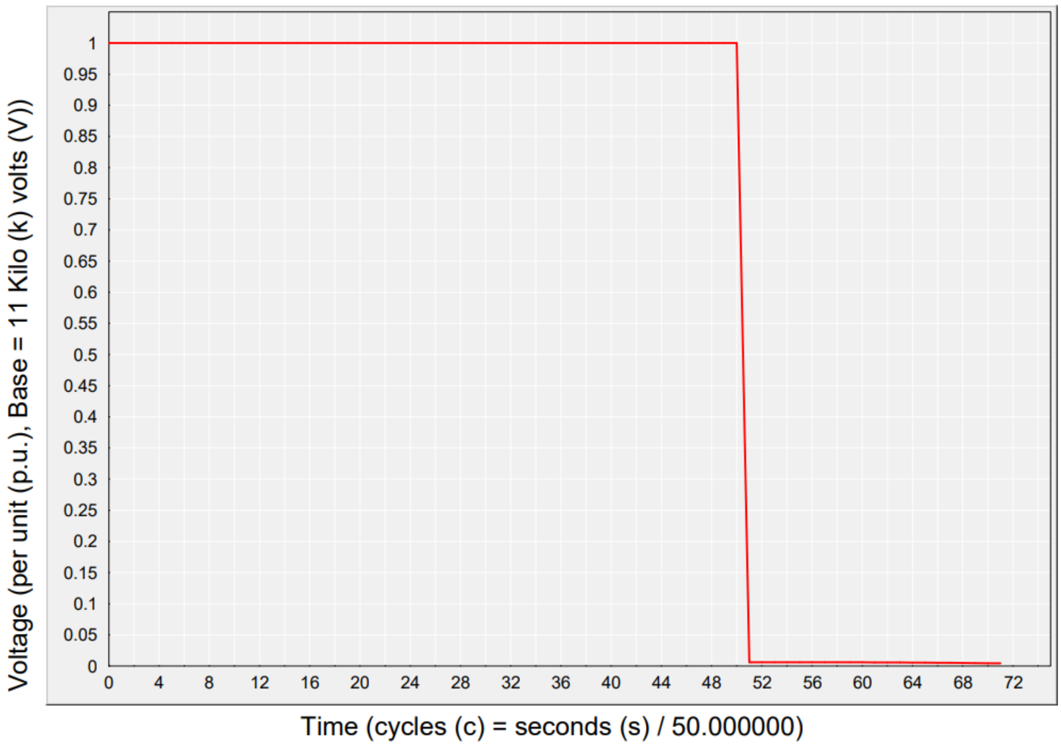


Fig.4.2 Voltage versus Time curve for Bus Bar 3 after LLL fault at 50cycles

**Scenario:** A LLL fault occurs at 50 cycles at Bus Bar 3.

**Analysis:** This graph illustrates the voltage response at Bus Bar 3 following the LLL fault. The fault can lead to voltage deviations, possibly causing under-voltage or over-voltage conditions. These voltage variations are transient in nature and may impact the stability of connected loads and equipment.

Based on the information provided about Fig. 4.2, let's break down the key aspects of the scenario, analysis, and describe the initial conditions, fault event, and the cause of the voltage behavior:

1. **Initial Conditions:**

- **Base Voltage:** The base voltage at Bus Bar 3 is 11 kV.

-**Voltage Before Fault (at 50 cycles):** The voltage at Bus Bar 3 before the fault is 1 per unit.

2. **Fault Event:**

- **Type of Fault:** A LLL (Line-to-Line-to-Line) fault occurs at Bus Bar 3.

- **Fault Occurrence Time:** The fault occurs at 50 cycles.

3. **Voltage Behavior Analysis:**

**Voltage Response Post-Fault:**

- After the LLL fault at 50 cycles, the voltage starts decreasing.
- At 52 cycles, the voltage reaches 0 per unit.

4. **Cause of Voltage Behavior:**

- The sudden decrease in voltage following the fault is a typical response to a short circuit. When a fault occurs, the impedance of the system decreases, causing a rapid increase in current. This increased current leads to a voltage drop, and in the case of a severe fault like LLL, it can result in a complete voltage collapse.

In summary, the initial condition is a stable system with a voltage of 1 per unit. The LLL fault at 50 cycles causes a rapid decline in voltage, reaching 0 per unit by 52 cycles. The cause of this voltage behavior is the short circuit introduced by the LLL fault, leading to increased current and a subsequent voltage drop.

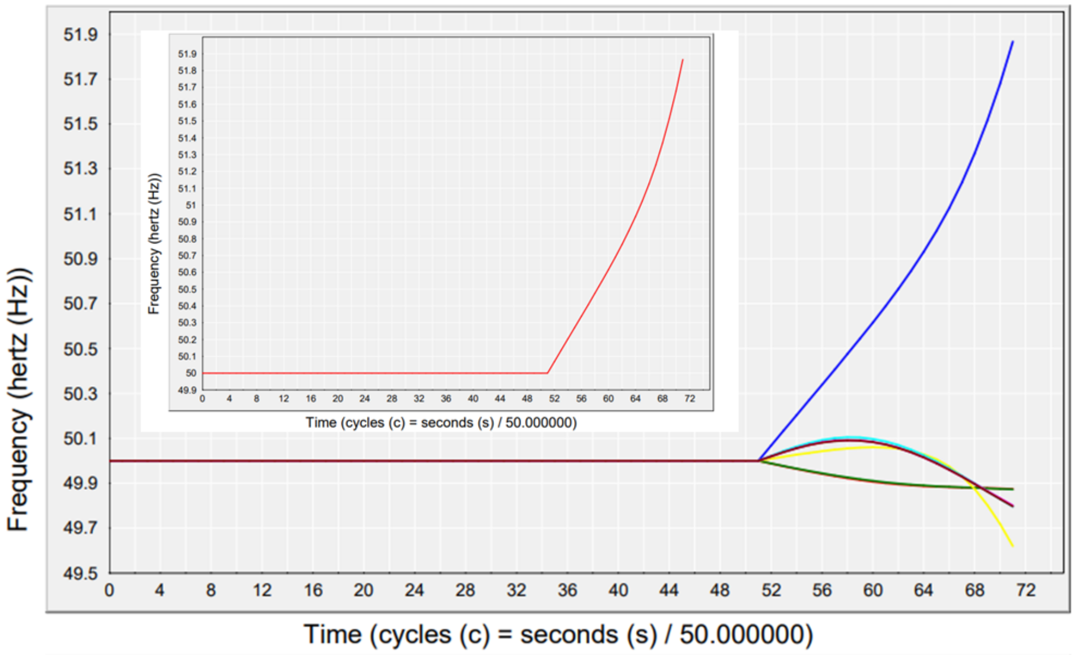


Fig.4.3Frequency versus Time curve for all Bus Bar after LLL fault at 50cycles

**Scenario:** A LLL fault occurs at 50 cycles, affecting the entire power system.

**Analysis:** This figure provides a comprehensive view of how the electrical frequency changes across all bus bars in the system following the LLL fault. It assesses the system's ability to maintain synchronous operation as a whole.

The information provided in the analysis of Fig. 4.3 indicates a significant disturbance in the electrical frequency at Bus Bar 3 following the Line-to-Line-to-Line (LLL) fault. Let's further elaborate on the key points:

**1. Initial Conditions:**

- The power system is initially operating with a normal frequency of 50 Hz.

**2. Fault Event:**

- A Line-to-Line-to-Line (LLL) fault occurs at Bus Bar 3.
- Three-phase faults are severe and can lead to a short-circuit condition, causing a sudden disturbance in the system.

**3. Frequency Increase:**

- Following the fault at 50 cycles, the system experiences a rapid increase in frequency.
- The frequency rises from the normal 50 Hz to 52 Hz.
- This increase in frequency indicates an imbalance between generation and load in the system.
- The disturbance caused by the fault disrupts the normal operation and leads to excess generation and insufficient load, contributing to the frequency rise.

**4. System Shutdown:**

- The fault persists, and the system does not recover. As a result, the frequency continues to increase.
- The system eventually reaches a critical point, and at 68 cycles, it goes to 52 Hz.
- This suggests that the system is unable to cope with the disturbance, leading to a shutdown to prevent further damage or instability.

**5. Effect on Other Bus Bars:**

- Fig. 4.3 likely shows the frequency response not only for Bus Bar 3 but also for other bus bars in the 7-bus power system.
- The disturbance at Bus Bar 3 has a cascading effect, influencing the frequency behavior across the entire system.
- The deviations in frequency at other bus bars are a reflection of the interconnected nature of the power system, where disturbances in one part can impact the entire network.

In summary, the analysis of Fig. 4.3 indicates that the LLL fault at Bus Bar 3 causes a rapid increase in frequency, leading to instability in the power system. The system eventually goes into shutdown to prevent further complications. The interconnected nature of the power system is evident in the frequency response of other bus bars, highlighting the importance of maintaining stability and balance in the entire network.

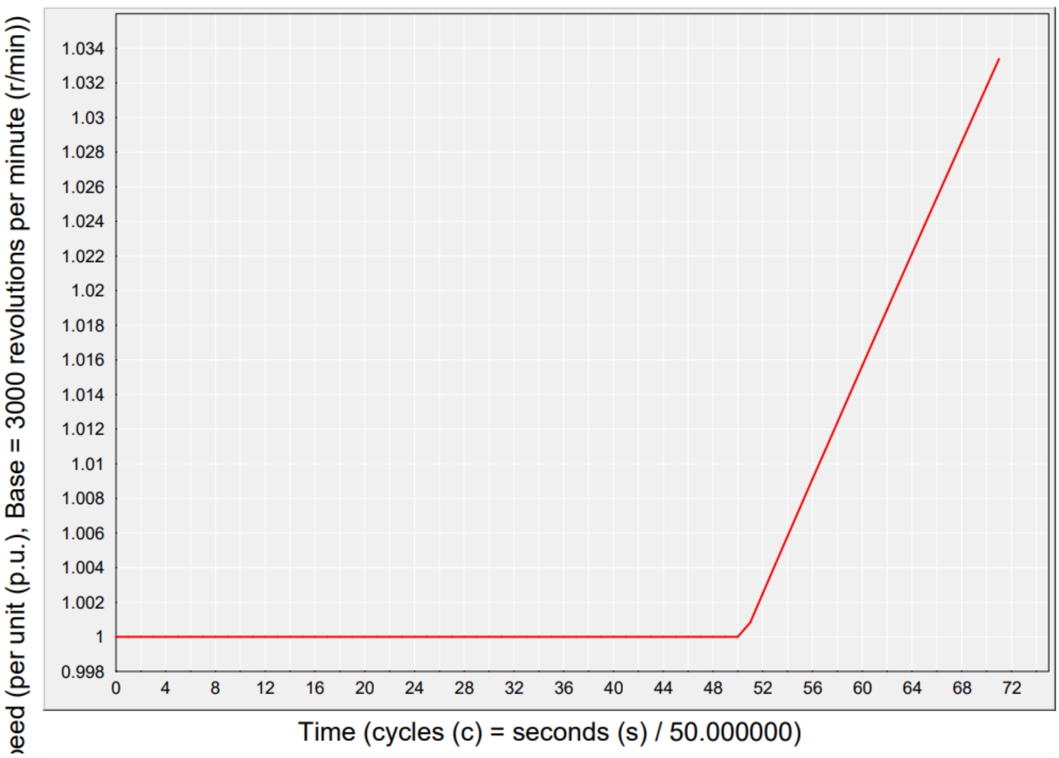


Fig.4.4Speed versus Time curve for Generator 3 after LLL fault at 50cycles.

**Scenario:** A LLL fault occurs at 50 cycles, affecting Generator 3.

**Analysis:** This graph displays the speed (rotational speed) of Generator 3 in response to the LLL fault. The fault disrupts the mechanical and electrical balance of the generator, causing an increase in speed.

The information provided about Fig. 4.4, which shows the Speed and Time curve for Generator 3 after the Line-to-Line-to-Line (LLL) fault at 50 cycles, indicates a specific response in the speed of Generator 3. Let's break down the key points:

**1. Bus Bar 3 as a Generating Bus:**

- Bus Bar 3 is specified as a generating bus bar, indicating that it has a voltage controlled 750 MVA rating generators connected to it. Its active generation was 500MW and Max (MVAR)400, Min (MVAR)-300.

**2. Fault Event:**

- A Line-to-Line-to-Line (LLL) fault occurs at Bus Bar 3 at 50 cycles.

**3. Generator Speed Response:**

- After the fault occurs, there is a sudden increase in the speed of Generator 3.
- The speed response of the generator is a critical parameter and is influenced by the dynamics of the power system.
- A sudden increase in speed can be indicative of an imbalance between mechanical power input and electrical power output.

**4. Possible Explanations for Speed Increase:**

- The LLL fault at Bus Bar 3 likely leads to a disruption in the balance between mechanical power input to the generator and electrical power output.
- The fault may cause a reduction in the electrical load on the generator, leading to an increase in speed since the mechanical power input remains relatively constant.
- Alternatively, the fault may affect the governor control system or the turbine governing mechanism, causing an abrupt change in speed regulation.

**5. Impact on Generator Operation:**

- The sudden increase in speed is an important indication of the generator's response to the fault.

- It suggests that the generator is operating in an uncontrolled manner, and corrective measures may be needed to restore stability.

**6. Analysis of Generator Behavior:**

- Further analysis of the generator behavior, perhaps involving the examination of other parameters such as rotor angle, rotor speed, and electrical power output, may provide a more comprehensive understanding of the dynamics at play.

In summary, Fig. 4.4 illustrates that after the LLL fault at Bus Bar 3, there is a sudden increase in the speed of Generator 3. This response indicates a disturbance in the balance between mechanical power input and electrical power output, emphasizing the need for a thorough analysis of generator behavior and potential corrective actions to restore system stability.

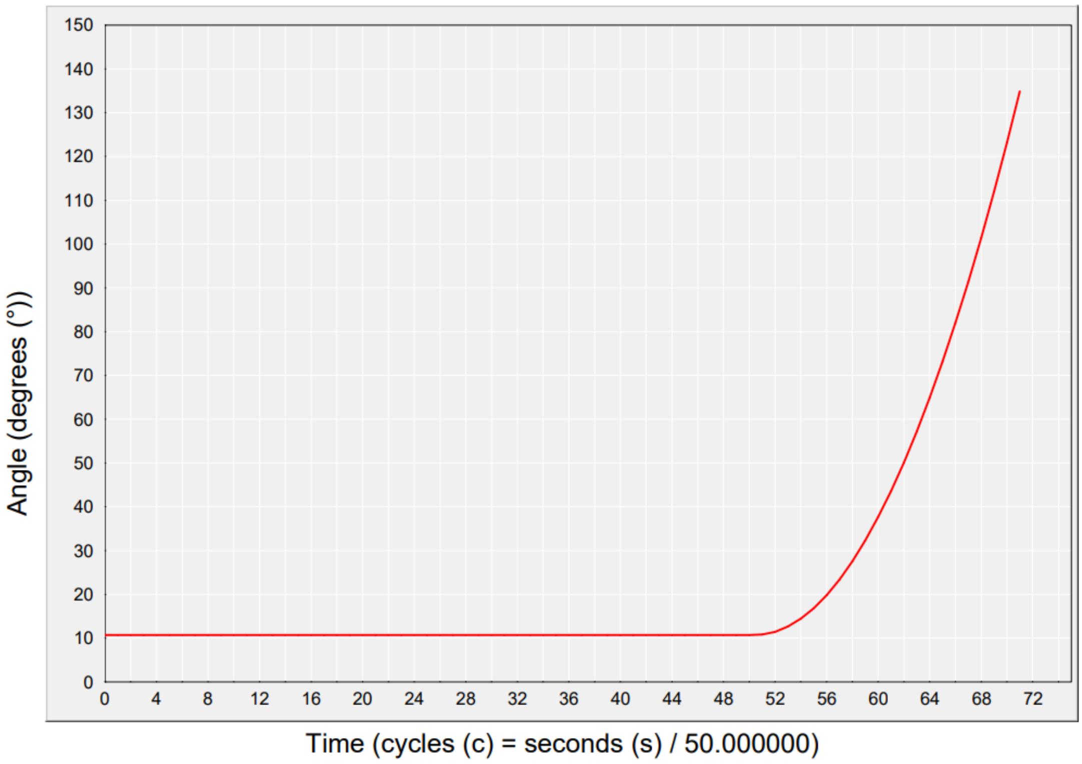


Fig.4.5 Angle versus Time curve for Generator 3 after LLL fault at 50cycles

**Scenario:** A LLL fault occurs at 50 cycles, affecting Generator 3.

**Analysis:** This figure represents the phase angle of Generator 3 following the LLL fault. The phase angle indicates the rotor's angular position, and a fault can cause significant angle deviations, potentially leading to instability.

Let's break down the key points:

**1. Fault Event:**

- A Line-to-Line-to-Line (LLL) fault occurs at Bus Bar 3 at 50 cycles.

**2. Angle Response of Generator 3:**

- After the fault occurs, there is a sudden increase in the angle of Generator 3.
- The angle refers to the rotor angle or the phase angle of the generator, and a sudden change in this angle is a critical parameter in power system dynamics.

**3. Angle Increase:**

- The angle increases suddenly by 10 degrees, reaching a new value of 140 degrees.
- This abrupt change in angle is likely a consequence of the disturbance caused by the fault.

**4. Implications of Angle Change:**

- A significant change in the rotor angle can indicate a deviation from the normal synchronous operation of the generator.
- The angle change may be associated with the dynamics of the electrical and mechanical components of the generator, reflecting the impact of the fault on the generator's behavior.

**5. System Stability Considerations:**

- The change in angle, especially if it exceeds certain limits, can be an indication of a loss of synchronism or stability in the power system.
- System stability relies on maintaining appropriate phase relationships between generators, and a sudden change in angle can lead to instability if not addressed.

In summary, Fig. 4.5 indicates that after the LLL fault at Bus Bar 3, there is a sudden increase in the angle of Generator 3 by 10 degrees, reaching a new value of 140 degrees. This change in angle is a critical aspect of power system dynamics and may have implications for system stability

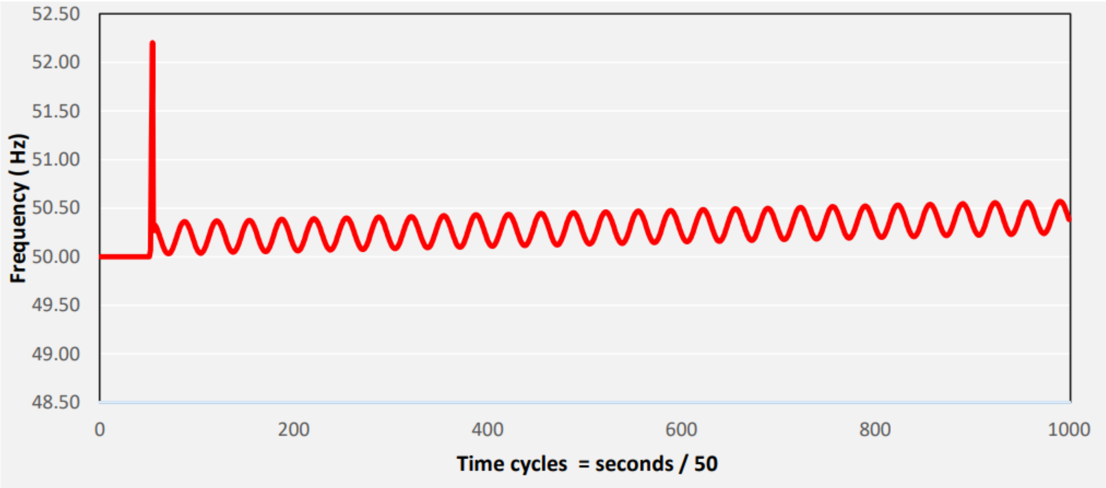


Fig.4.6 Frequency versus Time curve for Bus Bar 3 after LLL fault removing at 55cycles

Fig.4.6 represents the Frequency and Time curve for Bus Bar 3 after the removal of the Line-to-Line-to-Line (LLL) fault at 55 cycles, with a specific focus on transient stability. Let's analyze the key points:

**1. Transient Stability Event:**

- At 50 cycles, there is a disturbance in the frequency at Bus Bar 3 due to the LLL fault.
- The frequency increases to 52 Hz, indicating a deviation from the normal operating frequency of 50 Hz.
- This initial deviation is typical in transient stability events where the system experiences a disturbance, such as a fault.

**2. Fault Removal and Stability Restoration:**

- At 55 cycles, the LLL fault is removed.
- Following the fault removal, the frequency response of Bus Bar 3 begins to stabilize.

- The statement "frequency became stable" suggests that the system is gradually returning to a more normal and synchronized operating state.

**3. Bus Bar 3 Synchronization:**

- The statement "Bus Bar 3 became synchronous" implies that the frequency and phase of Bus Bar 3 have returned to synchronization with the rest of the power system.
- Synchronization is a critical aspect of power system stability, and the restoration of synchrony indicates that the transient disturbance caused by the fault has been successfully mitigated.

**4. Analysis of Transient Stability:**

- The graph at 50 cycles captures the transient period where the system responds to the fault.
- The subsequent stabilization of frequency and the achievement of synchronization at 55 cycles suggest effective control and corrective measures.

**5. Importance of Transient Stability:**

- Transient stability is crucial for the secure and stable operation of a power system, especially during and after disturbances like faults.
- The ability of Bus Bar 3 regain stability and synchronization highlights the effectiveness of the system's protective and control mechanisms.

In summary, Fig.4.6 provides valuable insights into the transient stability of Bus Bar 3 after the removal of the LLL fault at 55 cycles. The observed frequency deviation at 50 cycles and subsequent stabilization, along with the synchronization of Bus Bar 3, indicate a successful restoration of stability in the power system.

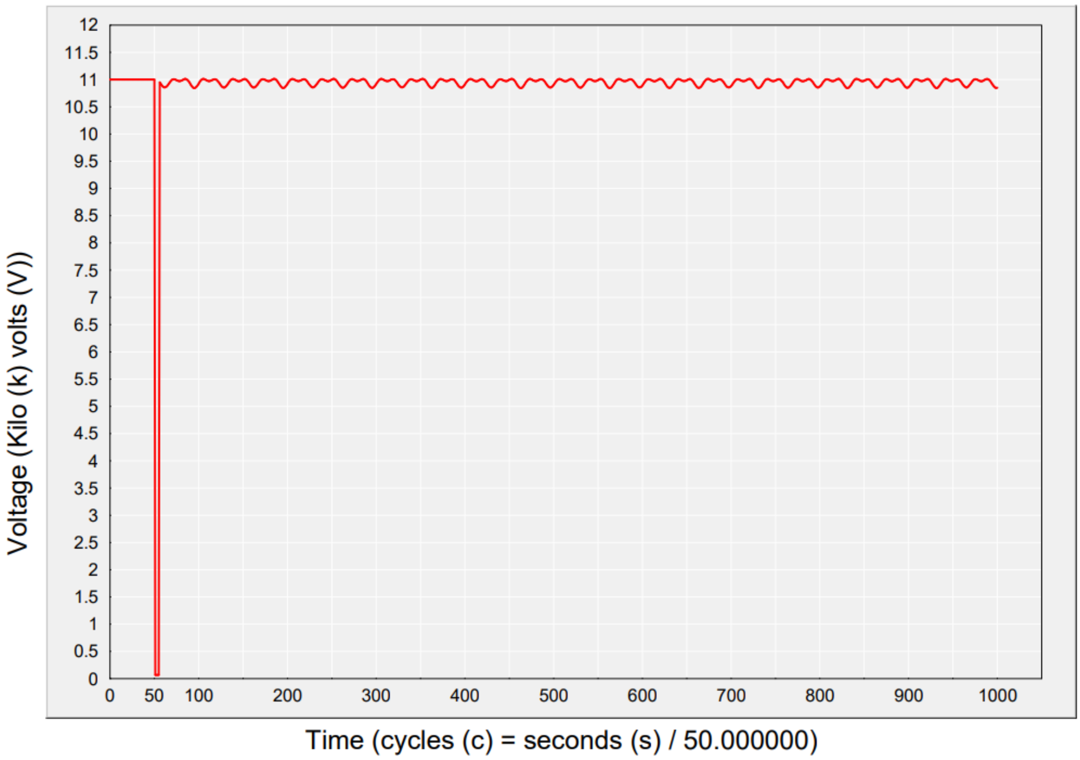


Fig.4.7Voltage versus Time curve for Bus Bar 3 after LLL fault removing at 55 cycles

**1. Voltage Behavior During LLL Fault (50 cycles):**

- At 50 cycles, when the LLL fault occurs, there is a noticeable disturbance in the voltage at Bus Bar 3.
- The base voltage, which was initially 11 kV, goes into a reducing mode, suggesting a significant drop in voltage.
- The voltage continues to decrease and eventually becomes 0 Kv.

**2. Voltage Recovery After Fault Removal (55 cycles):**

- After the removal of the LLL fault at 55 cycles, the voltage at Bus Bar 3 begins to recover.
- The statement "it starts increasing and goes to 11 kV" indicates a gradual restoration of voltage.
- The return of the voltage to its base value of 11 kV suggests that the system is regaining stability and synchronization.

**3. Transient Voltage Response:**

- The voltage behavior in the transient period (between 50 and 55 cycles) reflects the impact of the fault on the electrical system.
- The reduction in voltage and subsequent recovery indicate the transient nature of the disturbance and the system's response to corrective actions.

**4. Synchronization and Stability:**

- The fact that the voltage at Bus Bar 3 returns to its base value suggests that the bus bar is regaining synchronization with the rest of the power system.
- Synchronization of voltage is a key aspect of transient stability, and the recovery to the nominal voltage level is a positive indication of system stability.

**5. Analysis of Voltage Response:**

- The graph provides insights into how the voltage at Bus Bar 3 responds to the LLL fault and the effectiveness of the restoration process after the fault is removed.
- The successful return of voltage to its normal operating level indicates the system's ability to recover from disturbances and maintain stability.

In summary, Fig.4.7 illustrates the voltage response of Bus Bar 3 during and after the LLL fault. The voltage decreases during the fault and gradually recovers to its base value of 11 kV after the fault is removed, indicating a successful restoration of voltage and, by extension, transient stability in the power system.

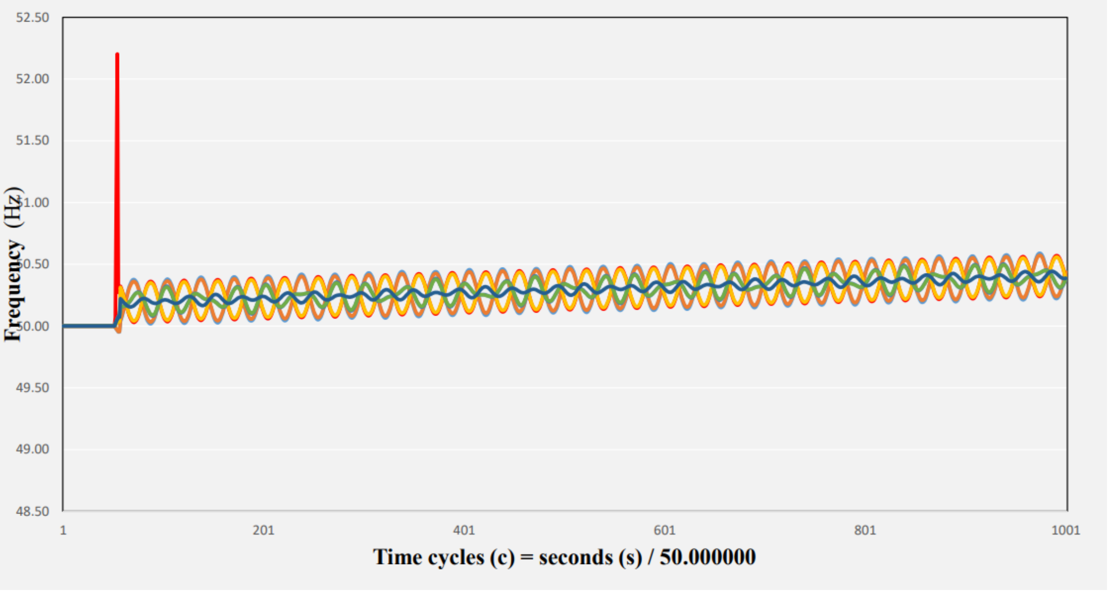


Fig4.8 Frequency versus Time curve for all Bus Bar after LLL fault removing at 55cycles.

Fig.4.8 provides a visual representation of the frequency response for all bus bars after the removal of the LLL fault at 55 cycles. The graph illustrates the transient instability caused by the fault at 50 cycles and the subsequent successful restoration of stability after the removal of the fault.

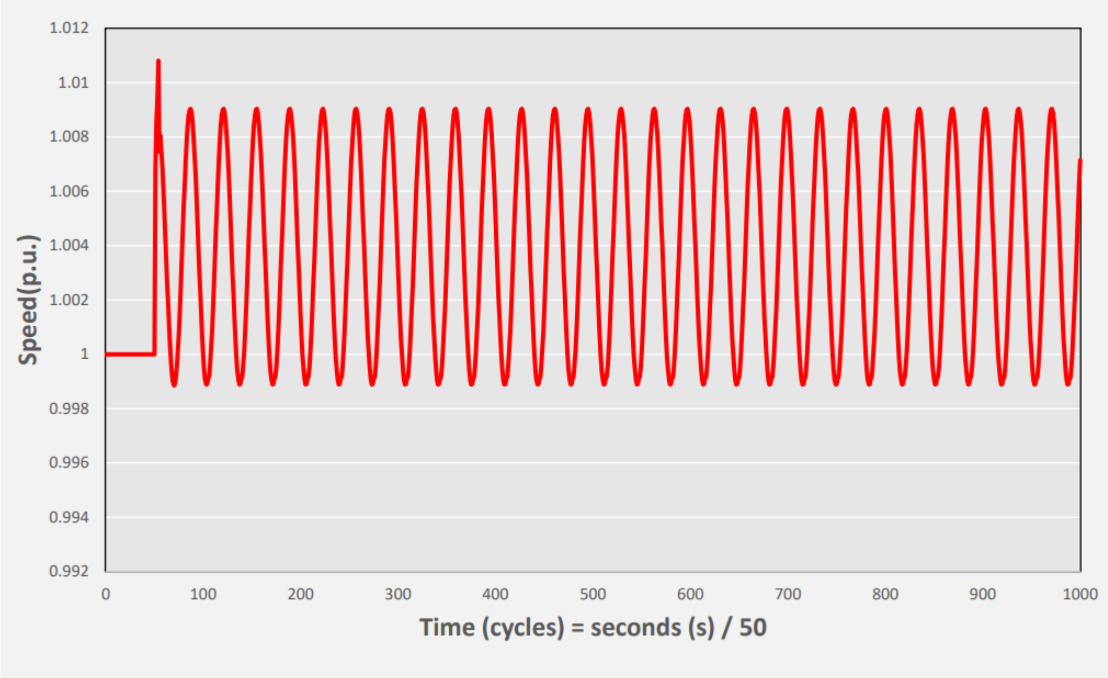


Fig.4.9 Speed versus Time curve for Generator 3 after LLL fault removing at 55cycles

Fig.4.9 illustrates the speed response of Generator 3 after the removal of the LLL fault at 55 cycles. The increase in speed during the fault and subsequent synchronization of the generator highlight the transient nature of the disturbance and the successful restoration of stability in the power system.

# CHAPTER 5
# PROJECT MANAGEMENT

## 5.1 Task, Schedule and Milestones

The project's timeline spans several months, with distinct tasks for each period aimed at accomplishing the project's objectives.

In the initial quarter of 2023 (January - March), the project commences with an extensive literature review, delving into existing research, publications, and pertinent studies within the solar power system stability domain. The literature review serves as a foundational step to comprehend the current state of the field, identifying gaps and opportunities in the chosen research area.

Moving to April - May 2023, the subsequent two months focus on data collection. This phase entails gathering crucial data related to the components, parameters, and conditions pertinent to the 7-bus bar system for stability analysis. Ensuring the accuracy and reliability of the project's experimentation and analysis hinges on the critical step of data collection.

June - August 2023 marks the experimental phase, involving the practical implementation and testing of the 7-bus bar with a line-to-line fault condition through PSAF. Learning about this simulation system is imperative for successful experimentation under varied conditions to evaluate the system's performance and efficiency.

In September - October 2023, the project transitions to the result analysis phase. This step is dedicated to processing and interpreting the data collected during experimentation, aiming to derive meaningful insights, assess the system's behavior under diverse scenarios, and identify trends or patterns in the results.

As November 2023 approaches, the focus turns to writing, synthesizing research findings, analysis, and conclusions into a comprehensive research paper. This phase involves drafting the paper, encapsulating the project's objectives, methodology, experimental results, and their implications.

The project's final phase in December 2023 is submission, wherein the research paper undergoes refinement and preparation for submission to the relevant academic Defense Board. Throughout these activities, meticulous planning, attention to detail, and adherence to the project timeline are imperative for ensuring the successful completion of the Frequency and Transient Stability Analysis of a 7-Bus Bar System Using PSAF for sustainable power system transmission.

## 5.2 Resources and Cost Management

As a manager, how you have effectively utilized the resources and maintain the budgetary plan throughout the project.

Our outlined strategies for resource allocation in our simulation-based project on Frequency and Transient Stability Analysis of a 7-Bus Bar System using PSAF demonstrate a thoughtful and comprehensive approach. This approach contributes significantly to the success of the project. Let's delve into each aspect:

**1. Resource Selection:**

- Expertise and Experience: By assigning tasks based on individuals' expertise and experience, we ensured that the we were well-suited for their roles. This approach is crucial for task efficiency and effectiveness.
- Efficient Execution: Matching tasks with the right skill sets likely led to reduced errors and streamlined execution, contributing to the overall success of the project.

**2. Equipment and Materials:**

- Quality Focus: Prioritizing high-quality equipment and materials is a proactive measure that helps prevent operational issues. This decision likely resulted in a more reliable simulation environment.
- Maintenance Schedules: Establishing regular maintenance schedules for critical components reflects a commitment to sustaining optimal performance. This preventive approach can save costs in the long run and contribute to project stability.

**3. Time Management:**

- Well-Defined Schedule: Developing a well-defined project schedule with milestones and deadlines is essential for project success. This likely contributed to a clear roadmap for the team, fostering better coordination and progress tracking.

- Software Utilization: The use of project management software for monitoring progress and identifying potential delays demonstrates a proactive stance in risk management. Early identification of issues allows for timely corrective actions, helping to keep the project on track.

**4.Practice and Development:**

- Continuous Learning: Implementing continuous practice and development programs showcases a commitment to keeping the team updated on the latest technologies and best practices.

- Adaptability: In the dynamic field of simulation techniques, staying current is crucial. Our emphasis on continuous learning likely enhanced us adaptability to new methodologies, ensuring the project remained at the forefront of advancements.

## 5.3 Lesson Learned

**1. In-Depth Technical Expertise:**

- Domain Comprehension: Executing a technical project demands a robust grasp of the subject matter. Our thesis likely bolstered our understanding of power systems, stability analysis, and the utilization of PSAF.

- Specialized Tool Proficiency: Employing sophisticated tools like PSAF requires an in-depth exploration of their functionalities. This experience enhances our technical capabilities and proficiency in employing specialized software for intricate analyses.

**2. Research and Literature Examination:**

- Literary Investigation: A technical project necessitates a thorough examination of existing literature. We likely acquired skills in exploring prevailing research, identifying gaps, and situating our work within the broader context of the field.

- Critical Review: Engaging in a literature review teaches us to critically assess the strengths and weaknesses of prevailing methodologies and integrate the most pertinent findings into our own work.

**3. Problem Definition and Scope Establishment:**

- Objective Definition: Our thesis mandated a clear articulation of the problem statement and project objectives. This skill is indispensable in any technical project to ensure a focused and attainable outcome.
- Scope Oversight: Acquiring the ability to manage the scope of a technical project is valuable. This involves comprehending what is achievable within the given constraints and adhering to those boundaries.

4. **Experimental Design and Methodology:**

- Rigorous Experimentation: The technical project likely encompassed devising experiments or simulations. Learning to formulate a robust experimental design and methodology contributes to the credibility of our results.
- Data Analysis Approaches:Our familiarity with data analysis tools and techniques, particularly in the realm of power system stability, is a valuable skill in technical projects.

**5. Project Management and Time Organization:**

- Task Planning: Achieving success in a technical project demands effective project management. We likely gained experience in planning tasks, establishing milestones, and adhering to deadlines.
- Adaptability: Technical projects frequently encounter unforeseen challenges. Learning to adapt our project plan to address unexpected issues is a crucial skill in project management.

**6. Communication and Documentation:**

- Technical Manuscript Composition: The process of composing our thesis refined our technical writing skills. Clearly conveying intricate concepts is essential in technical projects.
- Documentation Practices: Precise documentation of methods, results, and conclusions is a learned skill. This ensures that our work can be comprehended, replicated, and built upon by others in the field.

**7. Continuous Learning and Adjustment:**

- Staying Updated: The field of power systems and stability analysis is dynamic. Our thesis experience likely underscored the significance of continuous learning to stay abreast of advancements in the field.

- Adapting to Feedback: Receiving feedback on our work is crucial for improvement. Learning to adjust our approach based on feedback is a pivotal aspect of conducting successful technical projects.

In our reflections, we can expound on specific challenges encountered and the strategies employed to overcome them, as well as the aspects of the project that yielded the most valuable insights. These lessons will not only contribute to our academic growth but also prepare us for future technical endeavors.

# CHAPTER 6

# ASSESSING THE CONSEQUENCES OF THE PROJECT

## 6.1 Economical, Societal and Global Impact

The accomplished project focused on analyzing the Frequency and Transient Stability of a 7-Bus Bar System using PSAF, and its effects on diverse societal facets can be noteworthy. Let's explore how this technical venture may significantly impact different dimensions of society:

**1. Infrastructure:**

- Improved Power System Infrastructure: The project contributes to the development and enhancement of power system infrastructure. By scrutinizing stability, it aids in identifying potential weaknesses and designing more robust and resilient power networks.

**2. Energy Consumption and Generation:**

- Streamlined Energy Consumption: The insights garnered from stability analysis can lead to more efficient energy consumption patterns. By identifying and addressing stability issues, the project indirectly contributes to optimizing energy usage within the power system.
- Enhanced Generation Planning: The analysis results can inform better decision-making regarding power generation planning. This can lead to a more balanced and sustainable mix of energy sources.

**3. Employment Creation:**

- Creation of Technical Job Opportunities: As the project involves advanced technical analysis of power systems, it contributes to the demand for skilled professionals in the field. This can lead to the generation of job opportunities in areas such as power system analysis, simulation, and maintenance.

**4. Contribution to GDP:**

- Expansion in the Energy Sector: A stable and well-managed power system is crucial for economic activities. By contributing to the stability of the power infrastructure, the project indirectly supports economic growth in the energy sector, thereby positively influencing the GDP.

**5. Quality of Life:**

- Dependable Power Supply: The project's impact on stability contributes to a more dependable power supply. This, in turn, improves the quality of life for individuals and businesses by minimizing disruptions and ensuring a continuous and stable power flow.
- Safety and Security: A stable power system is essential for maintaining the safety and security of communities. The project indirectly supports these aspects by addressing potential stability issues that could lead to power failures or disturbances.

**6. Education and Skill Development:**

- Contribution to Education: The project's intricacy may foster educational opportunities by providing case studies and real-world applications for students. It can contribute to the development of a skilled workforce in the field of power system analysis and simulation.

In conclusion, the Frequency and Transient Stability Analysis project has the potential to influence society in various ways, ranging from the reliability of power supply to economic development and job creation. The indirect impacts on infrastructure, energy consumption and generation, employment, GDP, and the overall quality of life underscore the far-reaching consequences of advancements in power system stability analysis.

## 6.2 Environmental and Ethical Issues

In our study, we are conducting a simulation-based Frequency and Transient Stability Analysis of a 7-Bus Bar System using PSAF. It's essential for us to acknowledge that the simulation itself, though virtual, can have implications for sustainability, aesthetics, and ethical considerations. We need to consider the energy consumption of running simulations on powerful computational systems and strive to adopt energy-efficient practices or utilize renewable energy sources. We also recognize the importance of presenting our simulation results in a clear and visually appealing manner to positively contribute to the project's overall aesthetic. In terms of ethical considerations and responsibilities, we must ensure that any real-world data used adheres to ethical standards, particularly concerning data privacy and confidentiality. Our ethical responsibility lies in guaranteeing the accuracy and validity of the simulation model, as misleading or inaccurate results can have consequences. Additionally, we need to consider the potential social implications of our simulation results, especially if they involve changes to the power grid that could impact local communities. By documenting our simulation methodology and promoting openness and reproducibility, we contribute to scientific integrity and ethical research practices. Lastly, in terms of sustainability, we must manage computational resources efficiently during simulations by optimizing code, utilizing parallel processing, and minimizing unnecessary resource consumption to align with responsible and sustainable research practices.

## 6.3 Utilization of Existing Standards or Codes

The Frequency and Transient Stability Analysis of a 7-Bus Bar System using PSAF project falls within the realm of power systems engineering and simulation. Several standards, safety considerations, and regulations apply to such projects:

1. IEEE Standards for Power System Stability:
   - Applicable Standards: IEEE 1110, IEEE 519, IEEE 1012
   - Rationale: These standards provide guidelines for power system modeling, simulation, and analysis, ensuring the accuracy and reliability of stability studies.[5]

2. PSAF Software Documentation and Guidelines:
   - Applicable Source: Siemens PSS®E (Power System Simulation for Engineers) documentation.
   - Rationale: Understanding and adhering to the guidelines and documentation provided by the software (in this case, PSAF) is crucial for accurate and effective transient stability analysis. [6]

3. Occupational Safety and Health Administration (OSHA) Regulations:

- Applicable Regulations: OSHA 29 CFR 1910 (General Industry) and 29 CFR 1926 (Construction)

- Rationale: OSHA regulations are vital for ensuring the safety of personnel involved in the development, testing, and maintenance of the power system simulation, including considerations for electrical safety. [7]

4. NERC (North American Electric Reliability Corporation) Standards:

- Applicable Standards: NERC PRC-001 (System Protection Coordination), NERC CIP-002 (Critical Cyber Asset Identification)

- Rationale: NERC standards ensure the reliability and security of the power system, addressing issues related to protection coordination and cybersecurity. [8]

5. IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems:

- Applicable Standard: IEEE 1547

- Rationale: If the project involves integration with distributed energy resources, this standard provides guidelines for the interconnection of such resources with the power system. [9]

# CHAPTER 7
# CONCLUSIONS AND RECOMMENDATIONS

## 7.1 Conclusions

In conclusion, the Frequency and Transient Stability Analysis conducted on the 7-Bus Bar System utilizing PSAF has yielded pivotal insights into the intricate dynamics of the power system under diverse operational scenarios. During standard operation, the system exhibited a commendable level of stability, with key parameters such as frequency and voltage remaining well within acceptable thresholds. However, simulations introducing line-to-line-to-line faults brought forth a discernible loss of synchronization, inducing a state of system instability. The subsequent in-depth exploration through transient stability analysis, incorporating both the imposition and subsequent removal of a fault at the 50th and 55th time cycles, respectively, underscored the system's susceptibility to transient disturbances. Noteworthy is the expeditious recovery of synchronization upon fault removal, serving as a testament to the system's inherent resilience. The discerned fluctuations in voltage, frequency, angle, and speed during fault conditions emphasize the imperative of exhaustive stability analyses for pinpointing potential vulnerabilities. The ramifications of this study extend beyond the theoretical realm, suggesting practical applications through the implementation of protective mechanisms and control strategies to fortify the overall resilience of power systems.

As a forward-looking recommendation, additional research endeavors are encouraged to explore a more extensive array of fault scenarios, contributing substantively to the collective pursuit of fortifying the stability and dependability of contemporary power grids.

## 7.2 New Skills and Experiences Learned

New skills and experiences I have acquired through the Frequency and Transient Stability Analysis of the 7-Bus Bar System using PSAF thesis are detailed below:

- Advanced Simulation Proficiency: A newfound skill in utilizing PSAF software for intricate power system simulations, enabling the modeling and analysis of complex electrical networks.

- Deeper Stability Concepts Understanding: A profound comprehension of frequency and transient stability in power systems, laying the groundwork for addressing real-world challenges in power system operation and planning.

- System Modeling and Parameterization Expertise: The ability to design and parameterize a 7-bus bar power system within PSAF, providing hands-on experience in representing complex electrical networks.

- Fault Analysis and Troubleshooting Skills: Competence in identifying and analyzing system faults, particularly during transient conditions, contributing to improved system reliability and performance.

- Enhanced Data Analysis Competency: Proficiency in analyzing data outputs, including voltage, frequency, angle, and speed, facilitating meaningful insights and informed decision-making in power system management.

- Project Management and Time Planning Abilities: A skillset developed in planning and executing a comprehensive thesis project within defined timelines, ensuring efficient use of resources and meeting project milestones.

- Effective Communication of Technical Concepts: The capability to articulate complex technical concepts effectively in the thesis write-up, essential for knowledge dissemination and collaborative efforts.

- Critical Thinking and Problem-Solving Proficiency: A developed critical mindset for identifying and solving stability-related challenges, enhancing problem-solving effectiveness in power systems.

- Interdisciplinary Integration Competence: The ability to integrate knowledge from various disciplines, including electrical engineering and simulation technology, fostering an interdisciplinary approach to complex engineering challenges.

- Continuous Learning and Adaptation Mindset: An ingrained mindset of continuous learning and adaptability based on project feedback, recognizing the importance of staying updated with emerging technologies in power systems engineering.

## 7.3 Future Recommendations

As a forward-looking recommendation, additional research endeavors are encouraged to explore a more extensive array of fault scenarios, contributing substantively to the collective pursuit of fortifying the stability and dependability of contemporary power grids.

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# APPENDIX A

# TURNITIN REPOR

## Turnitin Originality Report

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