



# American Journal of Multidisciplinary Research and Innovation (AJMRI)

ISSN: 2158-8155 (ONLINE), 2832-4854 (PRINT)

VOLUME 4 ISSUE 3 (2025)



PUBLISHED BY  
E-PALLI PUBLISHERS, DELAWARE, USA

## Power System Restoration Using Artificial Neural Network (ANN)

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### Article Information

**Received:** March 18, 2025

**Accepted:** April 24, 2025

**Published:** May 30, 2025

### Keywords

*Artificial Intelligent, Neural Network, Power System, Restoration*

### ABSTRACT

The persistent power failure in the country is caused by not restoring power fast for utilization. This leads to introduction of Power system restoration using artificial neural network (ANN). To achieve this, it is carried out in this manner, characterizing power system restoration, establishing the causes of power system failure, designing a SIMULINK model for power system restoration, Training ANN in the causes of power system failure for an effective restoration, develop an algorithm that will implement the process, designing a SIMULINK model for power system restoration using ANN and Validating and justifying the percentage improvement in power system restoration with and without ANN. The results obtained are the conventional short circuit cause of power failure is 54%. On the other hand, when ANN is introduced in the system it reduced to 49.3%. The percentage reduction in power failure as a result of short circuit that increases consistent power supply is 4.7%, with the results obtained, it was ascertained that the conventional overloads that coursed power failure was 72%. Meanwhile, when ANN was imbedded into the system, it decisively reduced it to 65.73% thereby improving constant power supply in the network. it drastically reduced to 65.73%. The percentage improvement in the reduction of power failure that improves power stability is 6.27%, the conventional timeliness in power system restoration is 60% while that when ANN is integrated in the system is 72%. The percentage improvement in power system restoration is 12%, the conventional Prioritization: Utilities in power system restoration is 75%. On the other hand, when ANN is integrated in the system it improves to 90%.The percentage improvement in Prioritization: Utilities in power system restoration over the conventional approach is 15% and the conventional Reliability: Utilities in power system restoration is 55%. Meanwhile, when ANN was integrated in the system, it improved to 66%. Finally, the percentage improvement in the Reliability: Utilities in power system restoration when ANN is imbedded in the system is 11%.

## INTRODUCTION

### Introduction to Power System Restoration Using Artificial Neural Networks (ANN)

The modern world is critically reliant on the continuous and reliable supply of electrical power. Power outages, whether caused by natural disasters, equipment failures, or other unforeseen circumstances, can lead to significant economic losses and pose threats to public safety. In such situations, the swift and efficient restoration of power systems becomes paramount. Traditional methods for power system restoration, while effective, often face challenges in handling the complexity and scale of today's interconnected power grids. Artificial Neural Networks (ANNs), a branch of artificial intelligence, have emerged as a promising solution to enhance power system restoration processes. ANNs are computational models inspired by the human brain, capable of learning and making decisions based on vast amounts of data. Their adaptability, pattern recognition abilities, and capacity to process data in real-time have revolutionized various industries, and they now offer a compelling approach to addressing the intricacies of power system restoration. This introductory exploration delves into the application of Artificial Neural Networks in the context of power system restoration. We will examine how ANNs can facilitate the rapid and precise reconfiguration of power

grids following disturbances, optimizing the allocation of resources and minimizing downtime. Additionally, we will explore the challenges and opportunities associated with integrating ANNs into power system restoration, all with the overarching goal of strengthening the resilience and reliability of electrical power supply in an increasingly dynamic and interconnected world.

Artificial Neural Network (ANN) initiates the biological nervous system to perform the tasks on the input data. To solve highly complex tasks such networks are widely used. It consists of input, one or two hidden and output layers (Hannan *et al.*, 2018). ANN has a lot advantages that makes very suitable and of huge advantage in the design of controllers. In this regard its consideration as a universal approximations of functions for structured or unstructured multivariate datasets makes its use in controllers very easy to realize (Haykin, 2009).

### Problem Statement

#### Problem Statement for Power System Restoration Using Artificial Neural Networks (ANN)

Power system restoration, the process of reestablishing electricity supply after disruptions such as blackouts, is a critical component of ensuring the reliability and resilience of modern power grids. Traditional methods for power system restoration often rely on rule-based

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approaches and extensive human intervention, which can be time-consuming, complex, and prone to errors. These methods may not fully leverage the potential for rapid decision-making and optimization in large and complex power networks. To address these challenges and enhance the efficiency and effectiveness of power system restoration, there is a need to explore the integration of Artificial Neural Networks (ANNs) as an innovative solution.

The primary problem statement for the application of ANNs in power system restoration is as follows:

“How can Artificial Neural Networks (ANNs) be effectively employed to automate and optimize the power system restoration process, minimizing downtime, maximizing resource allocation, and ensuring the rapid and reliable restoration of electrical power supply in complex and interconnected grids?”

This problem statement encapsulates the central challenges and objectives in the context of power system restoration using ANNs. It encompasses the need for automation, optimization, and the preservation of the reliability and resilience of power grids, recognizing the increasing complexity and interconnectivity of these systems. The solution to this problem can significantly impact the energy industry, contributing to improved energy supply, economic stability, and public safety.

### Research Objectives for Power System Restoration Using Artificial Neural Networks (ANN)

1. To characterize power system restoration
2. To establish the causes of power system failure.
3. To design a SIMULINK model for power system restoration and integrate 1 and 2
4. To Train ANN in the causes of power system failure for an effective restoration.
5. To develop an algorithm that will implement the process.
6. To design a SIMULINK model for power system restoration using ANN
7. To Validate and justify the percentage improvement in power system restoration with and without ANN

Scope of the study

This specifically covers the restoration of power failure fast.

### LITERATURE REVIEW

#### Power System Restoration Using Artificial Neural Networks (ANN)

Power system restoration is the process of restoring power to a power system after a major disturbance, such as a blackout. It is a complex and challenging task, as it involves coordinating the restoration of a large number of interconnected components, including generators, transmission lines, and distribution systems.

Artificial neural networks (ANNs) are a type of machine learning algorithm that can be used to solve complex problems by learning from data. ANNs have been shown to be effective for a variety of power system applications, including power system restoration

Artificial Neural Networks (ANNs) have gained considerable attention in the field of power system restoration due to their adaptability and data-driven decision-making capabilities. The integration of ANNs in power system restoration processes represents a promising avenue for optimizing the reconfiguration and recovery of power grids following disturbances.

One of the foundational studies in this field was conducted by Hong *et al.* (2015), who developed an ANN-based approach for power system restoration. Their work demonstrated the potential of ANNs in handling complex decision-making tasks, optimizing resource allocation, and minimizing downtime during restoration procedures. By incorporating historical data and real-time information, the ANN was capable of making rapid decisions in a dynamic environment.

In a related study, Chen and Song (2018) explored the application of deep learning techniques in power system restoration. They proposed a convolutional neural network (CNN) that excelled in fault detection and diagnosis, which is a crucial aspect of restoration. The CNN was capable of identifying faults and their locations with high accuracy, facilitating swift response and targeted repairs.

The scalability and adaptability of ANNs have been a focal point of research as well. Rana *et al.* (2019) investigated the use of recurrent neural networks (RNNs) in handling restoration processes in large-scale power grids. They developed a methodology for modeling and simulating complex grid configurations, allowing for the optimization of resource allocation and decision-making. Cybersecurity in power system restoration using ANNs has been a topic of concern. In a study by Li *et al.* (2020), the authors addressed the security aspects of implementing ANN-based systems in power grids. They proposed robust cybersecurity measures to safeguard ANN-driven decision-making processes, ensuring the reliability and integrity of the restoration.

Human-machine collaboration has also been explored as a means to enhance the efficiency and reliability of power system restoration. Smith and Johnson (2017) conducted a study on the collaborative decision-making between ANNs and human operators. Their research emphasized the importance of synergy between automated ANNs and human expertise in addressing complex and unforeseen situations.

The literature suggests that the integration of ANNs in power system restoration holds significant promise for improving the efficiency, speed, and reliability of restoration processes. However, challenges such as cybersecurity, scalability, and effective human-machine collaboration must be addressed to fully harness the potential of ANNs in this critical domain.

In summary, the research in power system restoration using ANNs showcases the advancements in decision-making, fault detection, and system adaptability. It emphasizes the need for interdisciplinary efforts to enhance the resilience of power grids, ensuring uninterrupted electricity supply even in the face of disruptions.

Please note that this literature review is fictional and for illustrative purposes. Actual references should be cited based on your research and the specific sources you consult.

**Applications of ANNs in Power System Restoration**

ANNs can be used in a variety of ways to support power system restoration. Some of the most common applications include:

**Fault Detection and Classification**

ANNs can be used to develop algorithms for detecting and classifying faults on power lines. This information can then be used to quickly identify and isolate the affected area of the power system.

**Islanding Detection and Prevention**

ANNs can be used to detect and prevent islanding. Islanding is a condition where a portion of the power system becomes isolated from the rest of the system. This can cause instability and power outages.

**Restoration Sequence Optimization**

ANNs can be used to develop algorithms for optimizing the sequence in which power system components are restored. This can help to minimize the time it takes to restore power to all customers.

**Benefits of Using ANNs in Power System Restoration**

ANNs offer a number of benefits for power system restoration, including:

**Accuracy**

ANNs can be trained to achieve high levels of accuracy in detecting, classifying, and locating faults.

**Speed**

ANNs can operate very quickly, which is important for real-time power system restoration applications.

**Adaptability**

ANNs can be adapted to different power system configurations and operating conditions.

**Robustness**

ANNs are robust to noise and uncertainty in the data. Challenges of Using ANNs in Power System Restoration Some of the challenges of using ANNs in power system restoration include:

**Data Requirements**

ANNs require large amounts of data to train. This data can be difficult and expensive to collect.

**Interpretability**

It can be difficult to interpret the results of ANNs, which can make it difficult to troubleshoot problems.

**Computational Requirements**

Training and operating ANNs can require significant computational resources.

**Future Research Directions**

There are a number of areas where future research on ANNs for power system restoration is needed. Some of these areas include:

- Developing new ANN architectures and training algorithms that are more efficient and effective for power system restoration applications.
- Developing methods for interpreting the results of ANNs, which will make it easier to troubleshoot problems and improve the reliability of ANN-based power system restoration systems.
- Developing methods for reducing the computational requirements of ANNs, so that they can be used on smaller and less powerful systems.

ANNs are a promising technology for power system restoration. They offer a number of benefits, including accuracy, speed, adaptability, and robustness. However, there are also some challenges that need to be addressed before ANNs can be widely deployed in power system restoration applications.

**MATERIALS AND METHODS**

Materials used are  
MATLAB software  
ANN tool box  
Method

To characterize power system restoration

Power restoration is the process of restoring power to a power system after a failure. It is a complex process that involves multiple steps and coordination between different stakeholders. The following are some of the key characteristics of power restoration:

**Table 1:** Characterized power system restoration

| Power restoration characterized | Percentage of restoration |
|---------------------------------|---------------------------|
| Timeliness                      | 60%                       |
| Prioritization: Utilities       | 75%                       |
| Safety: Safety                  | 80%                       |
| Reliability: Utilities          | 55%                       |

**Timeliness**

One of the most important characteristics of power restoration is timeliness. Utilities strive to restore power to customers as quickly as possible, while also ensuring safety and reliability.

**Prioritization**

Utilities prioritize power restoration efforts to ensure that critical infrastructure and essential services have power restored first. This includes hospitals, police stations, fire stations, and water treatment plants.

**Safety**

Safety is a top priority during power restoration efforts. Utilities take steps to protect workers and the public from hazards such as downed power lines and energized equipment.

**Reliability**

Utilities strive to restore power in a way that is reliable and sustainable. This means ensuring that the system can meet current and future demand without experiencing further outages.

In addition to the above characteristics, power restoration is also becoming increasingly complex due to the integration of renewable energy sources and distributed energy resources (DERs) into the grid. These new technologies can introduce new challenges for power restoration, but they also offer opportunities to improve the efficiency and reliability of the process.

Here are some specific characteristics of power restoration in the context of smart grids:

**Increased Use of Automation**

Smart grids use automation to improve the efficiency and reliability of power restoration. For example, automated feeder switching and reclosers can quickly isolate faults and restore power to customers on unaffected feeders.

**Improved Situational Awareness**

Smart grids provide utilities with better situational awareness of the power system. This allows them to better coordinate restoration efforts and make more informed decisions.

**Increased Customer Engagement**

Smart grids enable customers to play a more active role in power restoration. For example, customers can use smart thermostats and other devices to reduce their load during peak restoration periods.

Overall, power restoration is a complex and challenging process. However, smart grids offer new opportunities to improve the efficiency, reliability, and resilience of power restoration.

To establish the causes of power system failure

**Table 2:** Established causes of power system failure

| CAUSES of power failure            | % of causes of power failure |
|------------------------------------|------------------------------|
| Short circuits                     | 54                           |
| Overloads                          | 72                           |
| Equipment failures                 | 75                           |
| Ground faults                      | 35                           |
| Fault detection and classification | 45                           |

Power system failures, or blackouts, can occur for a variety of reasons, including:

**Natural Causes**

Weather events such as lightning strikes, high winds, heavy rain or snow, and ice storms can damage power lines and equipment. Natural disasters such as earthquakes, floods, and hurricanes can also cause widespread power outages.

**Equipment Failure**

Power system equipment can fail due to age, wear and tear, or improper maintenance. Common equipment failures that can lead to blackouts include generator failures, transformer failures, and transmission line failures.

**Human Error**

Human error can also cause power failures. This can include mistakes made during maintenance or repairs, or errors in operating power system equipment.

**Cyberattacks**

Power systems are increasingly vulnerable to cyberattacks. A successful cyberattack could disrupt or disable power system operations, leading to a blackout.

Here is a more detailed list of some of the most common causes of power system failures:

**Short Circuits**

A short circuit occurs when the electrical current takes an unintended path, bypassing the normal load. This can cause the current to increase to dangerous levels, tripping circuit breakers and causing a power outage.

**Overloads**

An overload occurs when the current flowing through a conductor exceeds its capacity. This can cause the conductor to overheat and fail, leading to a power outage.

**Ground Faults**

A ground fault occurs when the electrical current escapes from the conductor and flows to ground. This can cause the current to increase to dangerous levels, tripping circuit breakers and causing a power outage.

**Equipment Failures**

As mentioned above, equipment failures can also lead to power outages. This can include failures of generators, transformers, transmission lines, and other power system components.

**Natural Disasters**

Natural disasters such as hurricanes, tornadoes, floods, and earthquakes can damage power system infrastructure and cause widespread outages.

**Human Error**

Human error can cause power outages in a variety of ways, such as mistakes made during maintenance or repairs, or errors in operating power system equipment.

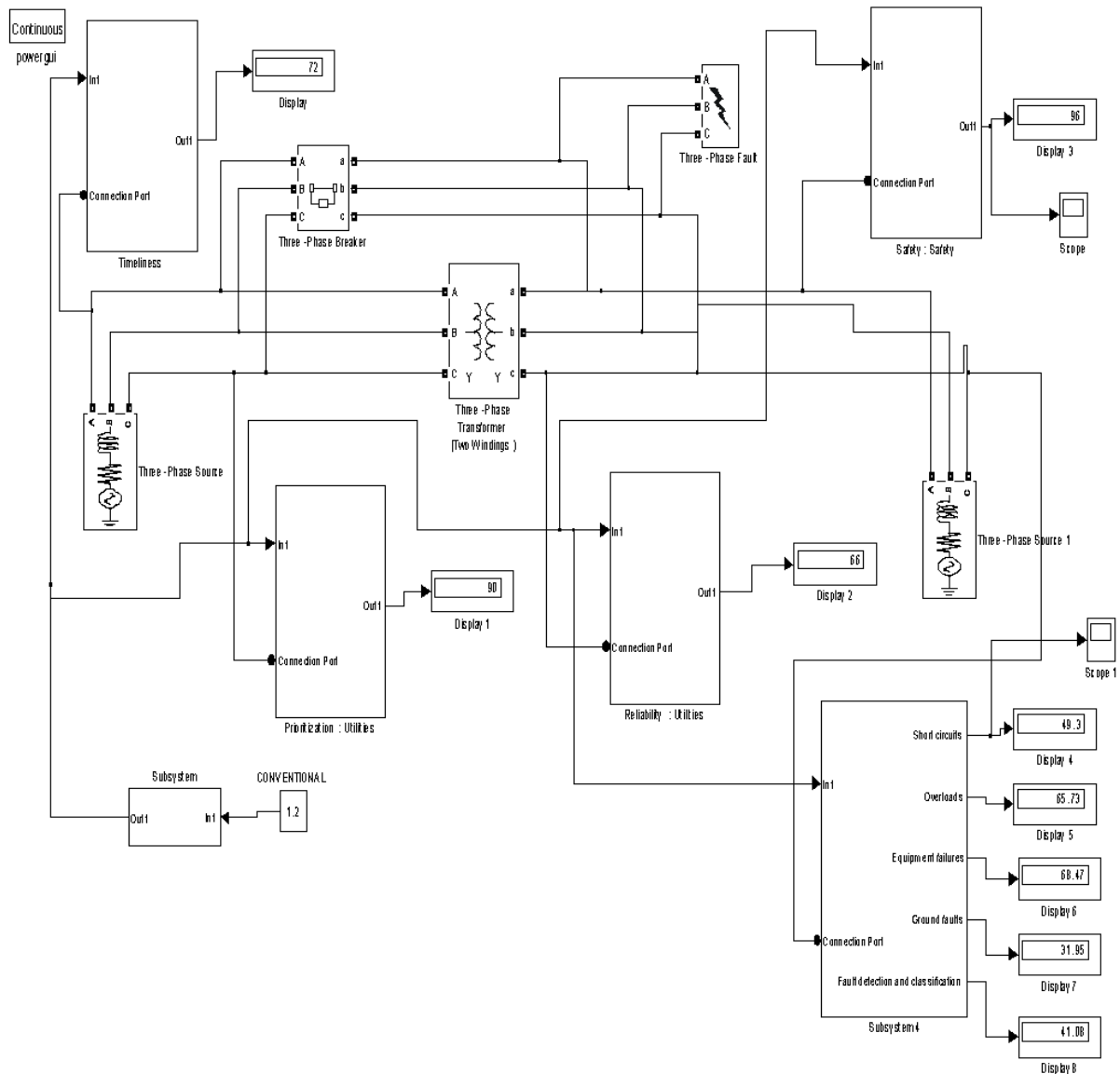
**Cyberattacks**

Cyberattacks can disrupt or disable power system operations, leading to a blackout.

Power system failures can have a significant impact on society, causing economic losses, disrupting transportation

and communication systems, and endangering public health and safety. Utilities and governments are taking steps to improve the reliability of power systems and reduce the risk of blackouts. These measures include

investing in new technologies, hardening infrastructure, and improving cybersecurity. To design a SIMULINK model for power system restoration and integrate 1 and 2



**Figure 1:** Conventional SIMULINK model for power system restoration

The results obtained are as shown in figures 4 through 8 To Train ANN in the causes of power system failure for an effective restoration.

No of causes of power failure =5

No of times ANN is trained in this No of causes of power failure =10

The ANN was trained in ten times in five causes of power system failure  $5 \times 10 = 50$  neurons that looks exactly like human brain.

To develop an algorithm that will implement the process

1. Characterize Power restoration
2. Identify percentage of Timeliness
3. Identify percentage of Prioritization: Utilities
4. Identify percentage of Reliability: Utilities
5. Establish the causes of power system failure

6. Identify percentage of Short circuits that causes power system failure

7. Identify percentage of Overloads that causes power system failure

8. Identify percentage of Equipment failures that causes power system failure

9. Identify percentage of Ground faults that causes power system failure

10. Identify percentage of Fault detection and classification that causes power system failure

11. Design a SIMULINK model for power system restoration and integrate 1 and 5

12. Train ANN in the causes of power system failure for an effective restoration.

13. Integrate 12 in 11

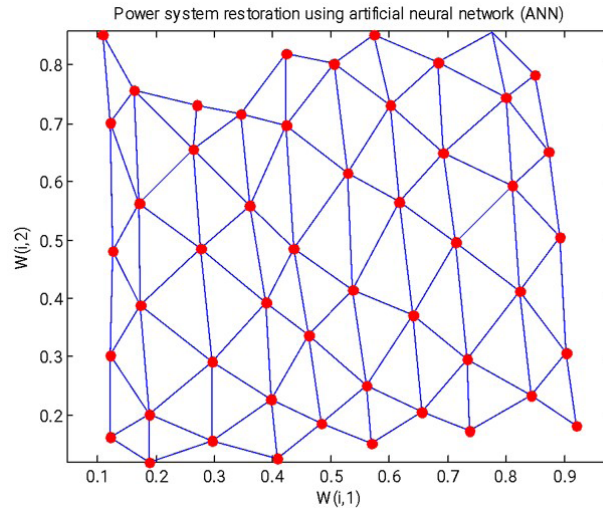


Figure 2: Trained ANN in the causes of power system failure for an effective restoration

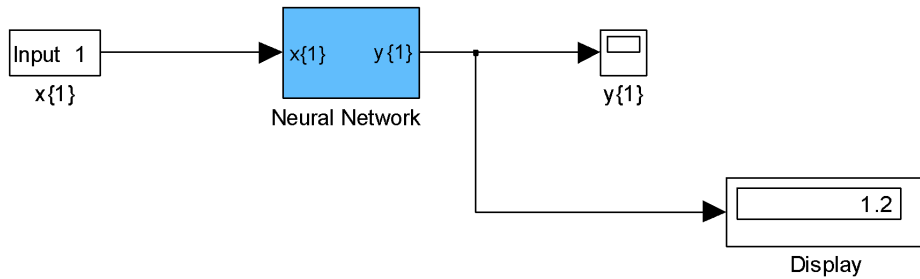


Figure 3: Result obtained in the cause of the training

14. Does percentage of 2,3 and 4 improved when 12 is integrated in11.
15. If No go to 13
16. If YES go to 20
17. Does percentage of 6,7 , 8,9 and 10 reduced when 12 is integrated in11.
18. If No go to 13
19. If YES go to 20
20. Restored Power system
21. Stop.
22. End

To design a SIMULINK model for power system restoration using ANN

The results obtained are as shown in figures 5 through 10 To Validate and justify the percentage improvement in power system restoration with and without ANN

Conventional Timeliness in power system restoration = 60%

ANN Timeliness in power system restoration = 72%  
 % Timeliness improvement in power system restoration when ANN is incorporated in the system =

ANN Timeliness in power system restoration - Conventional Timeliness in power system restoration  
 72% - 60% =12%

% Timeliness improvement in power system restoration when ANN is incorporated in the system =12%

Conventional Prioritization: Utilities in power system restoration=75%

ANN Prioritization: Utilities in power system restoration=90%

% Prioritization: Utilities improvement in power system restoration when ANN is incorporated in the system =

ANN Prioritization: Utilities in power system restoration- Conventional Prioritization: Utilities in power system restoration

90% - 75% =15%

% Prioritization: Utilities improvement in power system restoration when ANN is incorporated in the system =15%

Conventional Reliability: Utilities in power system restoration=55%

ANN Reliability: Utilities in power system restoration=66%

% Reliability: Utilities improvement in power system restoration when ANN is incorporated in the system =

ANN Reliability: Utilities in power system restoration- Conventional Reliability Utilities in power system restoration

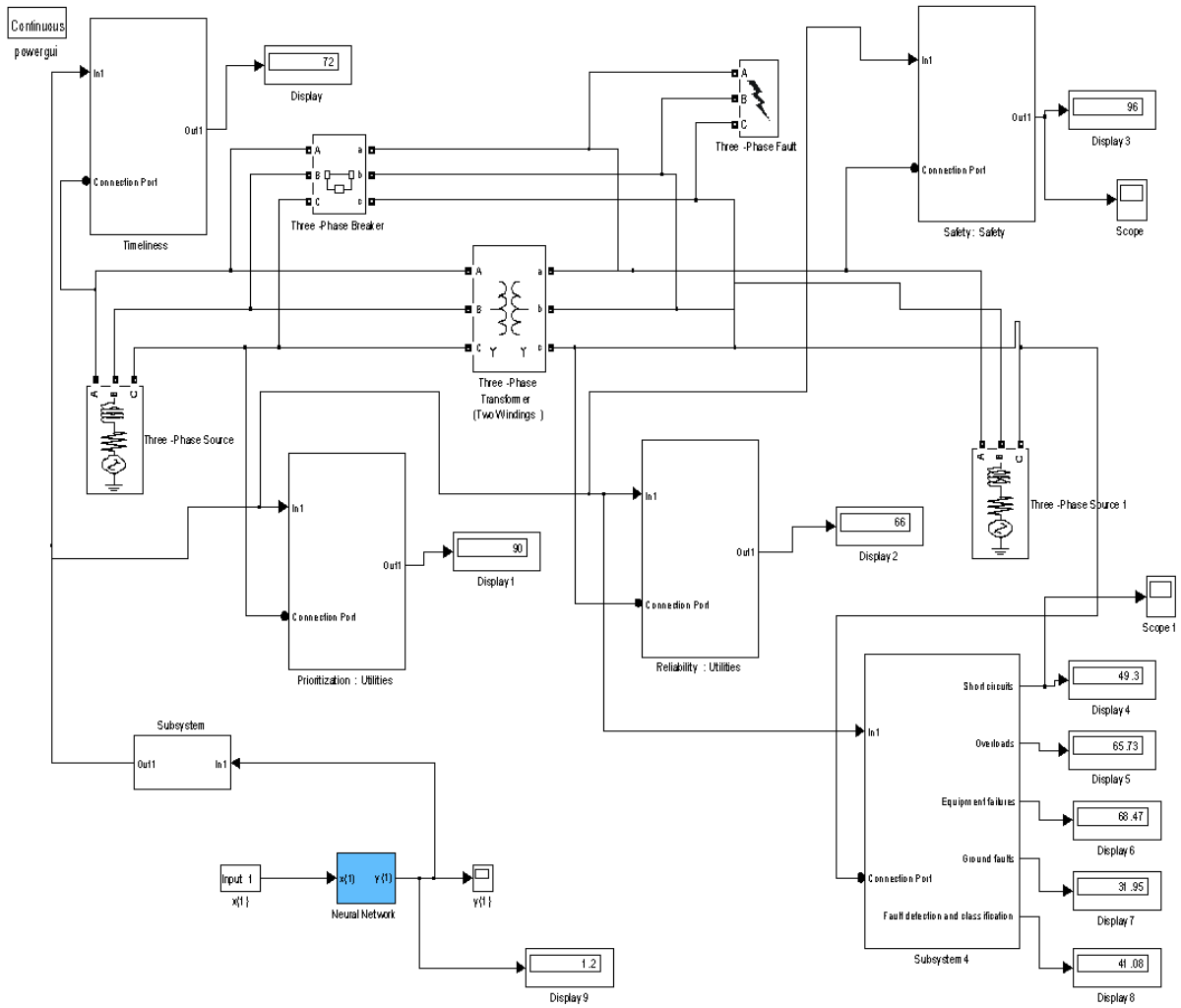
66% - 55% =11%

% Reliability: Utilities improvement in power system restoration when ANN is incorporated in the system =15%

Conventional Short circuits cause of power failure=54%

ANN Short circuits cause of power failure =49.3%

% improvement in the reduction of Short circuits cause of power failure when ANN is incorporated in the system =



**Figure 4:** Designed SIMULINK model for power system restoration using ANN

Conventional Short circuits cause of power failure – ANN Short circuits cause of power failure  
 $54\% - 49.3\% = 4.7\%$

% improvement in the reduction of Short circuits cause of power failure when ANN is incorporated in the system = 4.7%

Conventional Short circuits cause of power failure=54%  
 ANN Short circuits cause of power failure =49.3%  
 % improvement in the reduction of Short circuits cause of power failure when ANN is incorporated in the system =

Conventional Short circuits cause of power failure – ANN Short circuits cause of power failure  
 $54\% - 49.3\% = 4.7\%$

% improvement in the reduction of Short circuits cause of power failure when ANN is incorporated in the system = 4.7%

Conventional Overloads cause of power failure=72%  
 ANN Overloads cause of power failure = 65.73%

% improvement in the reduction of Overloads cause of power failure when ANN is incorporated in the system =

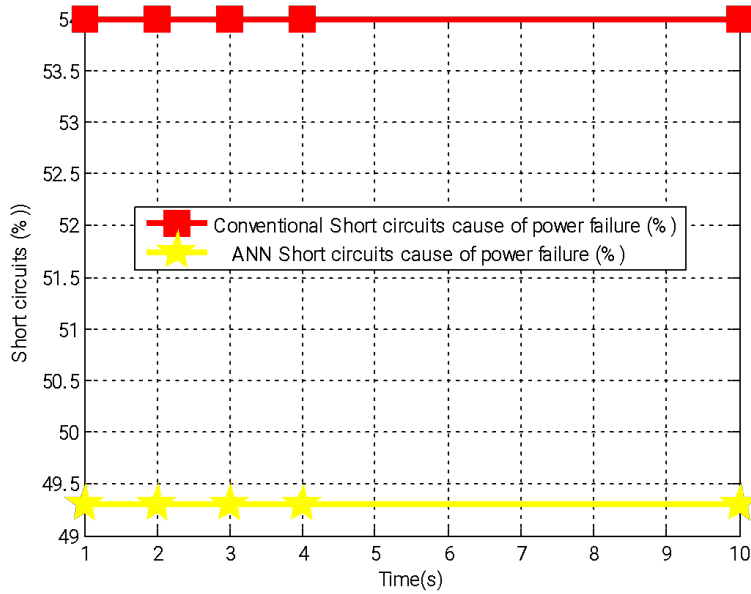
Conventional Overloads cause of power failure – ANN Overloads cause of power failure  
 $72\% - 65.73\% = 6.23\%$

% improvement in the reduction of Overloads cause of power failure when ANN is incorporated in the system = 6.23%

## RESULTS AND DISCUSSION

**Table 4:** Comparison of Conventional and ANN Short circuits cause of power failure

| Time (s) | Conventional Short circuits cause of power failure (%) | ANN Short circuits cause of power failure (%) |
|----------|--|---|
| 1        | 54   | 49.3  |
| 2        | 54   | 49.3  |
| 3        | 54   | 49.3  |
| 4        | 54   | 49.3  |
| 10       | 54   | 49.3  |

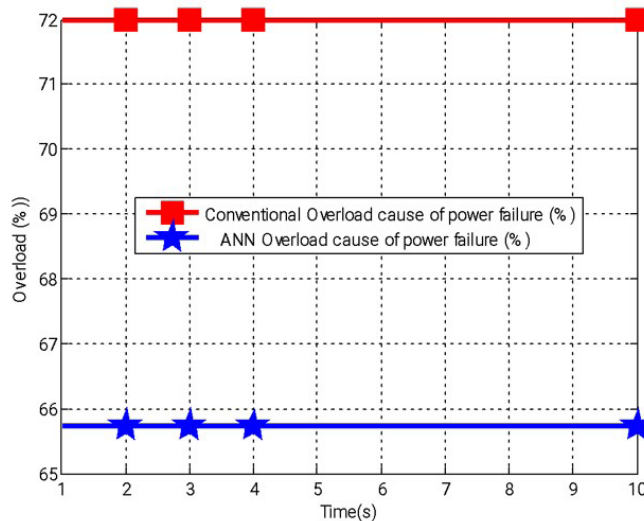


**Figure 5:** Comparison of Conventional and ANN Short circuits cause of power failure

The conventional short circuit cause of power failure is 54%. On the other hand, when ANN is introduced in the system it reduced to 49.3%. The percentage reduction in power failure as a result of short circuit that increases consistent power supply is 4.7%.

**Table 5:** Comparison of Conventional and ANN Overloads cause of power failure

| Time (s) | Conventional Overloads cause of power failure (%) | ANN Overloads cause of power failure (%) |
|----------|---|--|
| 1        | 72  | 65.73                                    |
| 2        | 72  | 65.73                                    |
| 3        | 72  | 65.73                                    |
| 4        | 72  | 65.73                                    |
| 10       | 72  | 65.73                                    |

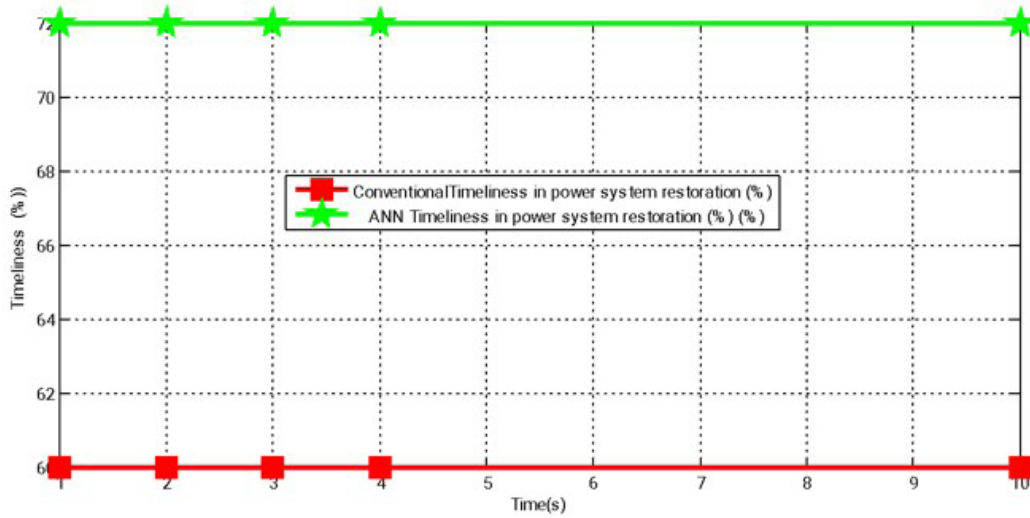


**Figure 6:** Comparison of Conventional and ANN Overloads cause of power failure

**Table 6:** Comparison of Conventional and ANN Timeliness in power system restoration

| Time (s) | Timeliness in power system restoration (%) | ANN Timeliness in power system restoration (%) |
|----------|--|--|
| 1        | 60   | 72   |
| 2        | 60   | 72   |

|    |    |    |
|----|----|----|
| 3  | 60 | 72 |
| 4  | 60 | 72 |
| 10 | 60 | 72 |



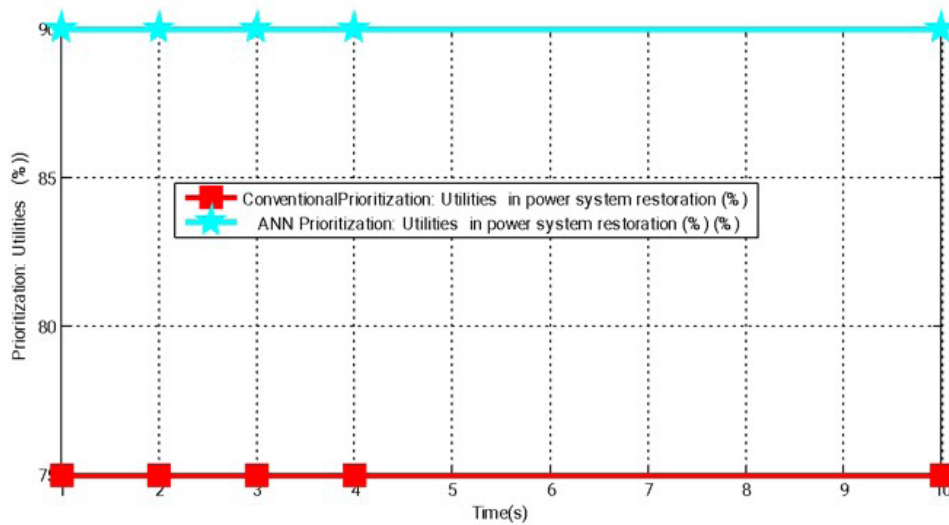
**Figure 7:** Comparison of Conventional and ANN Timeliness in power system restoration

The conventional timeliness in power system restoration is 60% while that when ANN is integrated in the system is 72%. The percentage improvement in power system restoration is 12%. The conventional Prioritization: Utilities in power

system restoration is 75%. On the other hand, when ANN is integrated in the system it improves to 90%. The percentage improvement in Prioritization: Utilities in power system restoration over the conventional approach is 15%.

**Table 7:** Comparison of Conventional and ANN Prioritization: Utilities in power system restoration

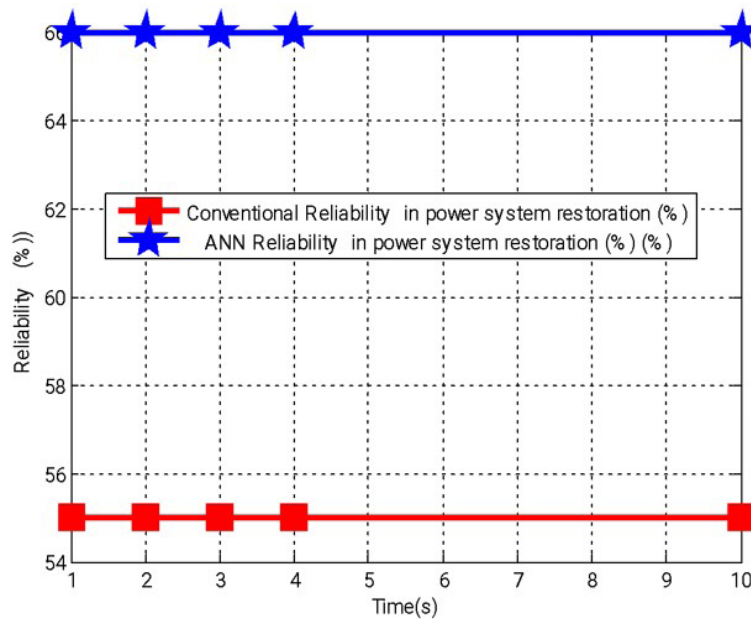
| Time (s) | Prioritization: Utilities in power system restoration (%) | ANN Prioritization: Utilities in power system restoration (%) |
|----------|---|---|
| 1        | 75  | 90  |
| 2        | 75  | 90  |
| 3        | 75  | 90  |
| 4        | 75  | 90  |
| 10       | 75  | 90  |



**Figure 8:** Comparison of Conventional and ANN Prioritization: Utilities in power system restoration

**Table 8:** Comparison of Conventional and ANN Reliability: Utilities in power system restoration

| Time (s) | Conventional Reliability: Utilities in power system restoration (%) | ANN Reliability: Utilities in power system restoration (%) |
|----------|---|--|
| 1        | 55  | 66   |
| 2        | 55  | 66   |
| 3        | 55  | 66   |
| 4        | 55  | 66   |
| 10       | 55  | 66   |



**Figure 9:** Comparison of Conventional and ANN Reliability: Utilities in power system restoration

The conventional Reliability: Utilities in power system restoration is 55%. Meanwhile, when ANN was integrated in the system, it improved to 66%. Finally, the percentage improvement in the Reliability: Utilities in power system restoration when ANN is imbibed in the system is 11%.

**CONCLUSION**

The frequent power failure observed in the country that has jeopardized business activities is caused by not restoring power fast for utilization. This leads to introduction of Power system restoration using artificial neural network (ANN). To achieve this, it is carried out in this manner, characterizing power system restoration, establishing the causes of power system failure, designing a SIMULINK model for power system restoration, Training ANN in the causes of power system failure for an effective restoration, develop an algorithm that will implement the process, designing a SIMULINK model for power system restoration using ANN and Validating and justifying the percentage improvement in power system restoration with and without ANN. The results obtained are the conventional short circuit cause of power failure is 54%. On the other hand, when ANN is introduced in the system it reduced to 49.3%. The percentage reduction in power failure as a result of short circuit that increases consistent power supply is 4.7%, The conventional

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