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Protection Of Microgrid In Islanded Mode Using Overcurrent Relay

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Abstract

As the ever growing demand for power is on the rise, the conventional sources of power such as thermal power plant, hydro power plant cannot fully satisfy all the consumers. Such consumers seek other reliable power source such as solar based microgrid. The reliability of the grid is based on a lot of factors. Some of which are operational safety and fault prevention, mitigation and recovery. The responsibility of safeguarding a catastrophic event from happening starts from the very generation of high voltage electric energy. This thesis discusses and presents a model to implement an overcurrent protection system in a microgrid. The protection system is mainly focused in the technique of complete isolation of the faulty part of the microgrid as soon as the fault occurs to prevent any possible damage. The Protection System goes through two important phases: Fault Detection and Intervention and Isolation. As a digital system is involved in the process; both of the phases can be made more reliable and transparent as IoT and machine learning can be implemented in its future version for advanced data monitoring and control. Though Overcurrent is not a frequent occurrence, its damaging factor is quite too large and hence to be highly considered and be cautious about. One of the most damaging property of overcurrent is causing fire due to huge temperature rise in the system. Apart from that, the electromagnetic interference caused by overcurrent might be intolerable for nearby communication system and can cause failure.

Keywords: Fault Detection, Microgrid, Overcurrent, Protection

I. INTRODUCTION

The microgrid idea has been implemented in the power system due to a lot of drawbacks of the conventional power system based on fossil fuels like environmental pollution, huge expenditure for construction of power plants, transmission line losses of power etc. Microgrids are small power grid consisting of distributed energy resources(renewable or combination of renewable and conventional energies), controllable loads and energy storage systems to provide electrical energy to small urban areas and remote rural areas. They are able to operate in grid-driven manner and in island mode. An island mode microgrid was formed when it is disconnected from the main grid due to fault/disturbance or otherwise in that case the distributed energy resources of the microgrid have to supply the load demand of the local loads.

A microgrid can receive electricity from both the main grid and the smaller sources when it is linked to the electrical grid. But the major portion of the demand for load is met by the Diesel Generators of the microgrid and the balanced electricity is supplied by the utility grid. But in island modes, to maintain the load side demand, load shedding is done except the critical loads. The microgrids are designed to provide for more economical, reliable, stable, environment friendly and quality supply of electrical power supply to the consumers. They may be a DC microgrid or AC microgrid depending upon the types of the micro sources used. When a utility grid connection is made to a microgrid, the AC power is then converted to DC before passing through a static switching system, which can be found at the point of common coupling (PCC). Its done using voltage source inverter and inductor.

The management and protection of the microgrid becomes difficult due to unpredictable loads and varying line parameters due to external factors. To make it feasible for the system to work properly, some measurements are need to be done at various points in the microgrid. Measurements are done through sensors either digital sensor or analog sensor. If analog sensor is used then the signal is converted to digital signal with the help of appropriate modulator. The signals from sensors in different locations are then sent to a nearby control station which is responsible for the major decision making of the grid operation. The data sent from different interconnected sensors are then analyzed by the computer in the control station and an appropriate control signal is sent to the actuators in the microgrid system to apply any action if required. This interconnected system of actuators, sensors and control station can be achieved through IoT or Internet of Things. Internet of Things uses the technology of the internet to connect different things (or computerized devices) and make a collective decision based on the data. Such an Interconnected microgrid can be called a smart microgrid, which can easily tackle the unpredictability of the system by recoding and driving the system in real-time.

II. PROBLEM STATEMENT

In the context of the electrical engineering field, the active incorporation of DERs (distributed energy resources) has led to rise for microgrids, which are self-sustaining power systems having potential of working in both grid-connected and islanded modes. However, ensuring the reliable and secure operation of microgrids, particularly in island mode, poses a significant challenge. One crucial aspect of microgrid protection is the effective coordination of overcurrent protection devices to mitigate potential faults and protect critical equipment.

The problem at hand is the lack of a comprehensive and efficient overcurrent protection system for microgrids operating in island mode. Traditional overcurrent protection techniques employed in conventional power systems are inadequate for the dynamic and complex nature of microgrids. Existing protection systems often lack the ability to accurately detect and isolate faults, leading to prolonged downtime, damage to equipment, and compromised system stability.

To address this problem, the objective of this project is to introduce an Island Mode Microgrid Protection Using Overcurrent Relay system. The proposed system should overcome the limitations of existing overcurrent protection methods and provide enhanced fault detection, discrimination, and isolation capabilities specific to microgrids operating in island mode.

III. CALCULATION OF RMS CURRENT

The Current Measuring Device measures the instantaneous AC current of the line. This value is then compiled into RMS Current by using a moving window type RMS Approach. In this approach, a moving window is represented by the logic as an array of certain length. The array is pushed with every acquired measurement sample in a LIFO order. The contents of the array is then used to calculate the RMS Current of the line. Length of the array or length of the window is set considering the sampling rate and the frequency of the signal under observation; in our case the measured signal has a frequency of 50Hz and the sampling rate of the microcontroller's data acquisition system is 5kHz. To store a single full wave signal of 50Hz frequency (i.e. time period of 20ms) with a sampling rate of 5kHz (i.e. sampling time of 0.2ms) 100 samples are required. So to store a complete N no of full waves of the signal the length of window should be 100 times N. It is noted that, if the N is increased the calculated RMS value gets somewhat settled but the time taken for a disturbance to get noticed by the calculated RMS gets longer. After a few trials of different values of N in the simulation, an optimum value of N=5 is selected. As there are 3-phases in the system, there has to be 3 Windows keeping an account of current in each phase.

IV. DETECTION OF OVERCURRENT

The first step of an Overcurrent Protection System is to detect overcurrent in the system. In our model we have used a set value comparative technique to detect overcurrent. A set value of maximum permissible current is manually entered in the microcontroller and the microcontroller continuously compares the changing RMS Current of each phase over time with the set value. Once any of the phase current reaches equal or above the set value the microcontroller activates the overcurrent management routine.

V. DETECTION OF FAULT CURRENT

In day to day scenarios there is a possibility that a fault might occur at any point in the microgrid network. In-case there is a fault, there will be a huge inrush current towards that fault and the system will get unstable. To address this issue we first have to detect such fault location. Now considering the network graph to be comprised of pi-based distribution line, it is to be expected that some leakage current will exist due to the nature of network itself, but in case of a fault in any network the amount of current would be unusually high and the difference of receiving current and sending current through the pi section would be enough to predict whether there is a fault or not. Both the sending end and recieving end current is measured and shared to the microcontroller controlling the deginated segment. In-case a fault is detected the circuit breaker connected at the sending and receiving end will receive a trip signal and then the faulty segment will be isolated from rest of the healthy network.

VI. OVERCURRENT MANAGEMENT

The most important task of the Protection System is to secure the system from overcurrent as soon as possible. This is done securely and reliably by a device called the circuit breaker. The circuit breaker usually works with the help of a magnetic field created by the trip signal provided to it. The trip signal needs to be powerful enough to actually work and thus to make the process more reliable a Relay is connected to the circuit breaker's trip circuit. The relay plays the role of a driver for Circuit Breaker and thus makes it possible for a microcontroller to successfully trip a Circuit Breaker. The first thing that the microcontroller does when it detects an overcurrent is to send a trip signal to the relay and relay makes sure that the circuit breaker's trip signal is powerful enough. Now in-case a fault current is predicted to occur at the junction then the 2 circuit breakers surrounding the junction is tripped and therefore the faulty junction of the network is disconnected to allow normal operation of the microgrid in the unaffected parts.

VII. RESULT AND DISCUSSION

Matlab Simulation Software is used to simulate and verify the model reliability. The simulation is done in two parts. In the first part, the overcurrent protection capability is analyzed for the system by simulating a system of a single source and load. The overcurrent situation is simulated by introducing a fault at the Load side. The response time of the model is measured and is used as a merit factor of the analysis.In the second part, the whole microgrid network is introduced with pi based distribution network of the microgrid. The main motive of the second part is to analyze the fault detection and management of the distribution line involving overcurrent. A fault is introduced in a random distribution segment of the microgrid and the fault resolution response time is analyzed and is considered as merit of the model

VIII. SIMULATED MODEL

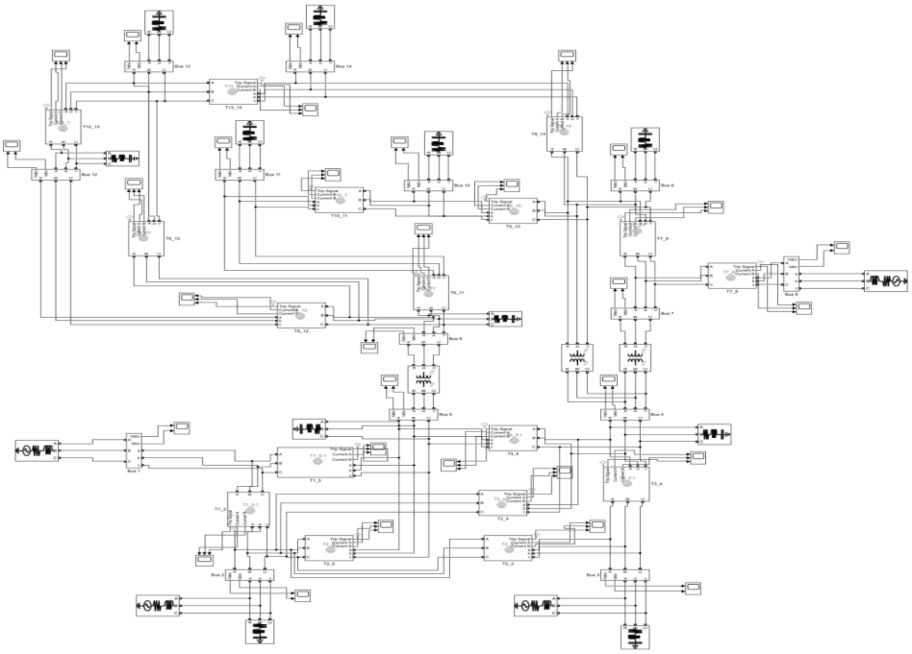


Figure 1: Overview of the Network Model

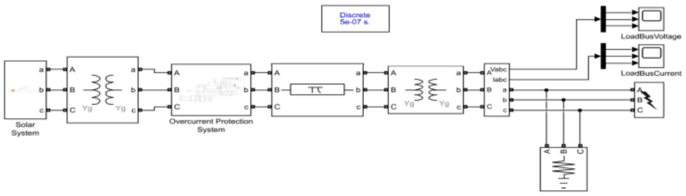


FIgure 2: Overview of the Photovoltiac Model

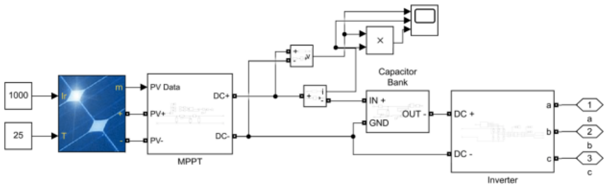


Figure 3: Solar Power Source Model

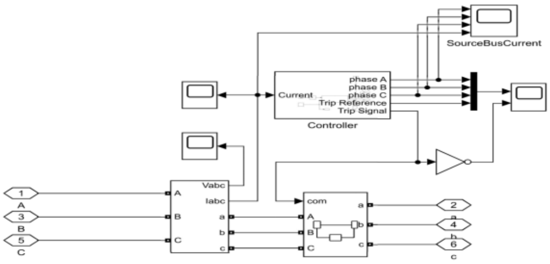


Figure 4: Overcurrent Protection System Design

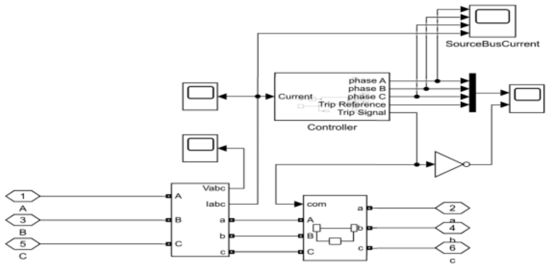


Figure 5: Overcurrent Protection System Design

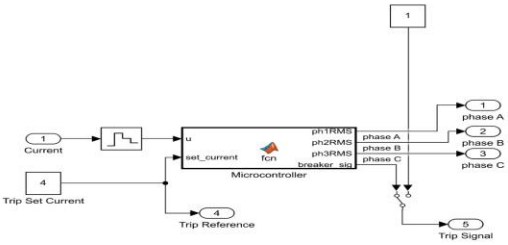


Figure 6: Controller Block Diagram

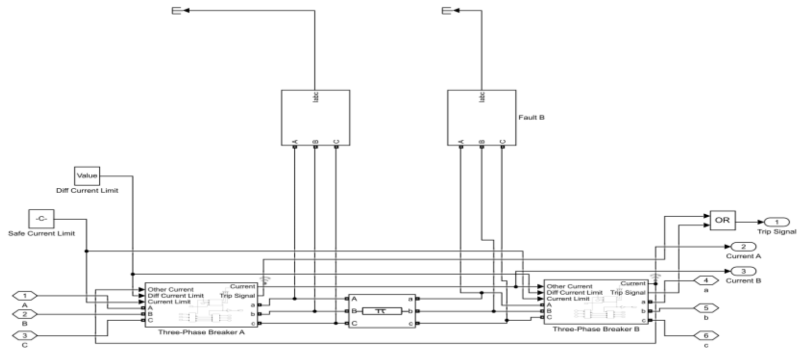


Figure 7: Network PI Section Protection System

The overview of the Network model is shown in fig 1. A 14-bus network is used to simulate the networking of the microgrid connections. The Photovoltiac model is shown in fig 2. The microgrid is mainly driven by solar power whose design is show in fig 3. The Load and Power Generation rating is taken from the 14-bus system paper. The Generation Side and Consumer side is connected by a distribution line of the microgrid. The Sending end of the Photovoltiac generation starts with a transformer which steps up the supply voltage to its distribution level voltage and the receiving side of the demand zone has a step-down transformer which steps down the distribution voltage to consumer friendly voltage which is then ready for use by the consumer. The step-up transformer is rated 2.3/11 KV and the step-down transformer is rated 11/2.3 KV. Both the transformers have a nominal power rating of 6 MVA.

An Overcurrent Protection System is introduced in the distribution line so that it can protect the system from harm of overcurrent and also prevent the failure of the whole microgrid for a point failure in a single or a few distribution lines. The Model of Overcurrent Protection System is shown in fig 4.3. In the Protection System Design, a Circuit Breaker is introduced at the sending side of the distribution line and another Circuit Breaker is introduced at the receiving end of the line. In-case a fault occurs at the distribution line, both the circuit breakers will trip which will result in complete isolation of the faulty segment thus allowing uninterrupted operation of the system. The functionality of the circuit breaker is provided by a microcontroller which is responsible at the core for protection of the microgrid. The Microgrid and its associated parameters are shown as block diagram in fig 4.4. Instantaneous current is measured by a sensor and is sampled by a zero order hold and fed to microcontroller at sampling frequency of 5 KHz. The microcontroller is responsible for the calculation of RMS value of current from the provided instantaneous value of current at the input. The microcontroller is also responsible for generating the trip signal for the circuit breaker. A LLLG fault is setup to test the model. The LLLG Fault is setup to trigger at 0.2 seconds after the start of the simulation. Now for the purpose of fault detection at the junction, the measured RMS current at one end is shared with the other end and then the difference is calculated. A difference exists even at normal working conditions due to lossy line properties such as capacitive admittance of the line. To differentiate between a normal (lossy) current difference and a faulty current difference a reference current is taken into account. If the current difference exceeds the reference then it is predicted as a fault and the circuit breakers isolate the segment.

IX. SINGLE LOAD SIMULATION WITHOUT OVERCURRENT PROTECTION

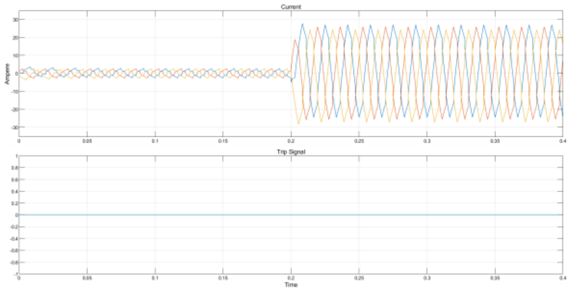


Figure 8: Current Graph for LLLG fault without protection system

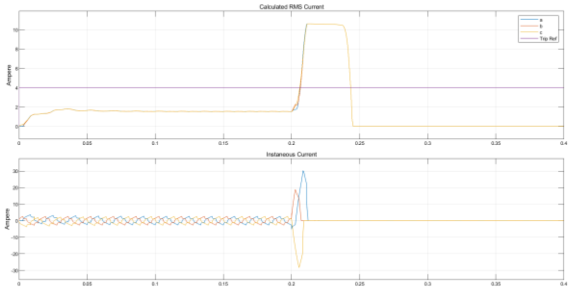


Figure 9: RMS Current Graph

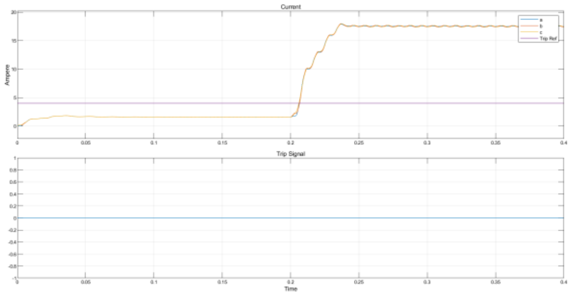


Figure 10: RMS Vs Trip Signal Graph

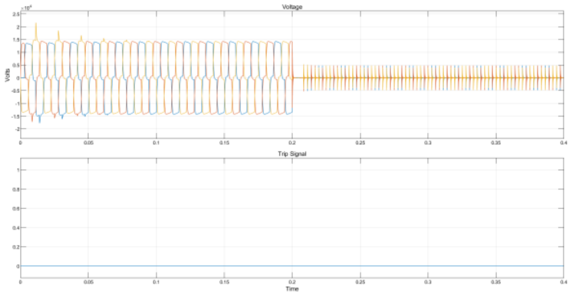


Figure 11: Voltage Graph for LLLG fault without protection system

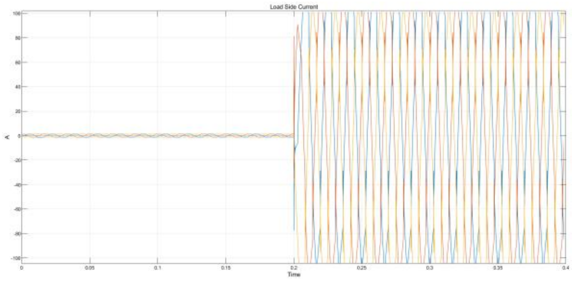


Figure 12: Current Graph On Load Side without protection system

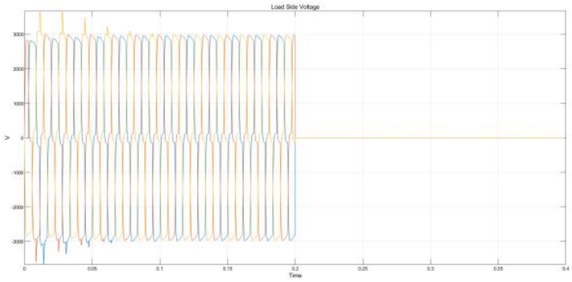


Figure 13: Voltage Graph On Load Side without protection system

X. SINGLE LOAD SIMULATION WITH OVERCURRENT PROTECTION

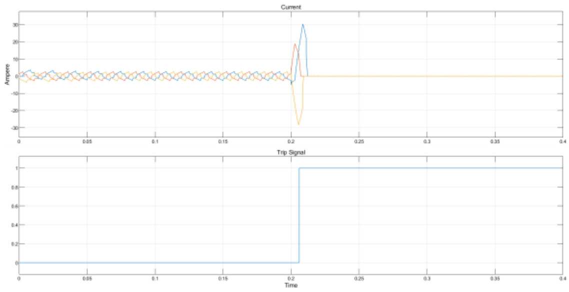


Figure 14: Current Graph for LLLG fault with protection system

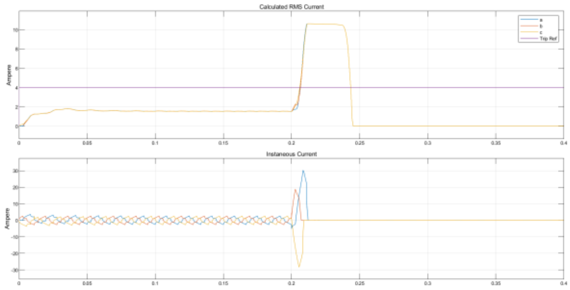


Figure 15: RMS Current Graph

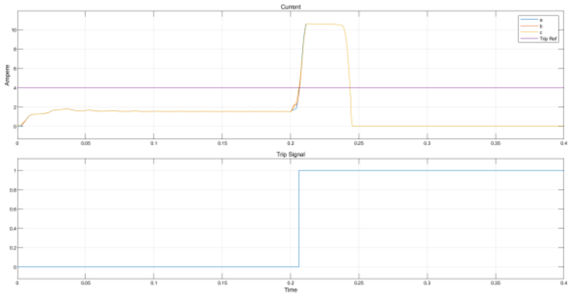


Figure 16: RMS Vs Trip Signal Graph

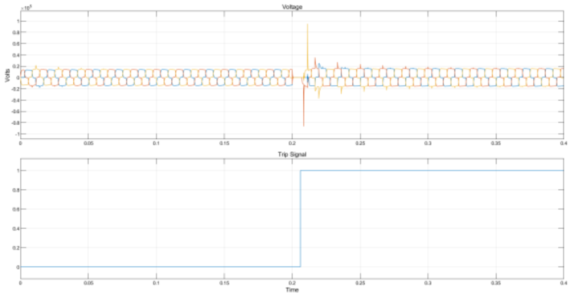


Figure 17: Voltage Graph for LLLG fault with protection system

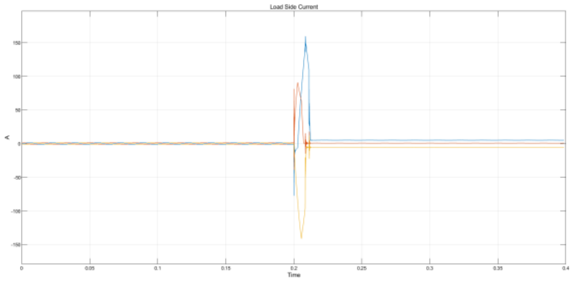


Figure 18: Current Graph On Load Side with protection system

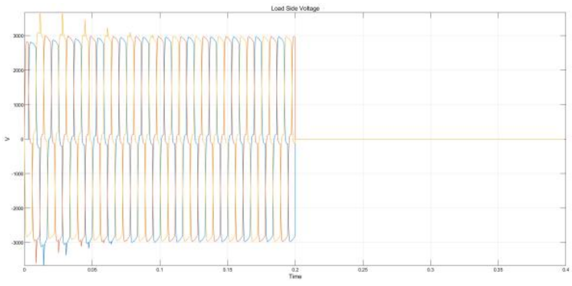
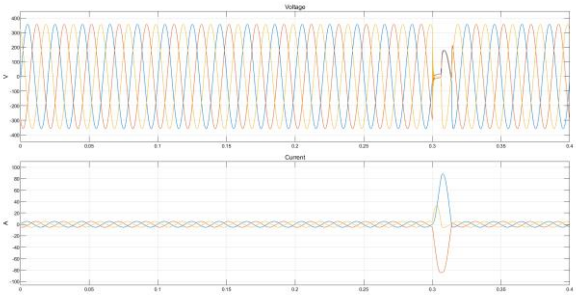


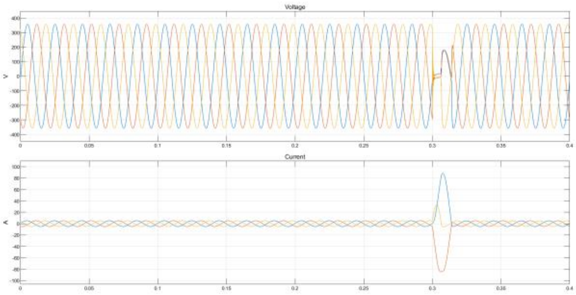
Figure 19: Voltage Graph On Load Side with protection system

The RMS current calculated by the microcontroller is shown in figure 4.12. It is clear form the graph that the calculated RMS reacts almost immediately as soon as the fault occurs. This reaction speed is very important as it is responsible for the detection of the fault by the microcontroller. According to the Graph 4.13, the detection time or the time between fault and the trip signal was 6 ms The graph 4.11 shows that the circuit isolation took about 12ms

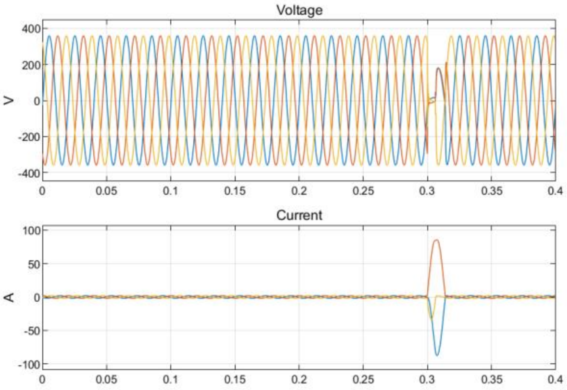
XI. NETWORK BASED SIMULATION



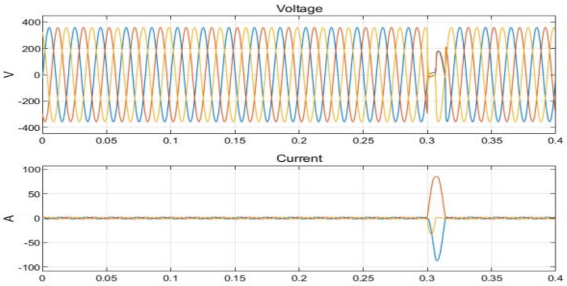
(a) Bus 1



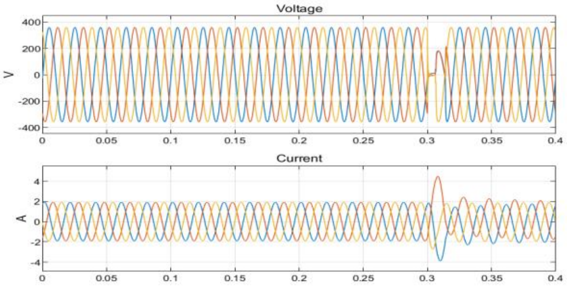
(b) Bus 2



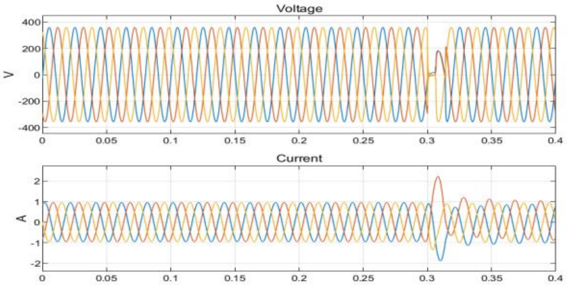
(c) Bus3



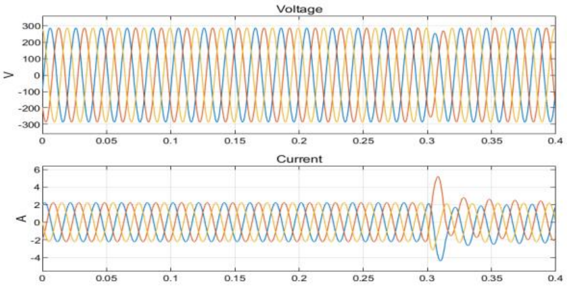
(d) Bus 4



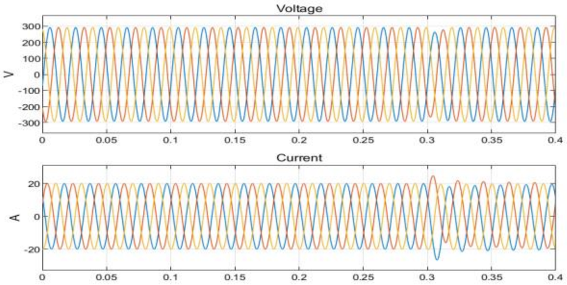
(e) Bus 5



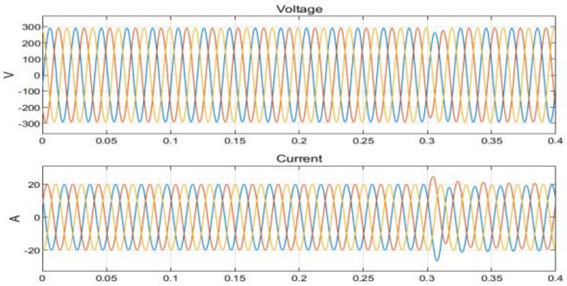
(f) Bus 6



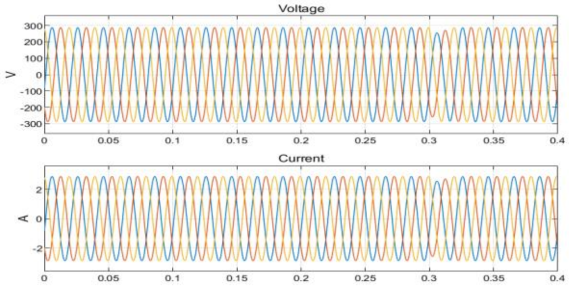
(g) Bus 7



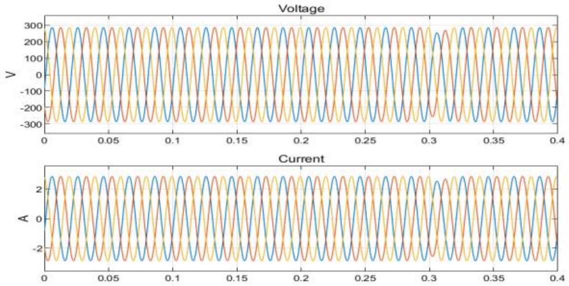
(h) Bus 8



(i) Bus 9



(j) Bus 10



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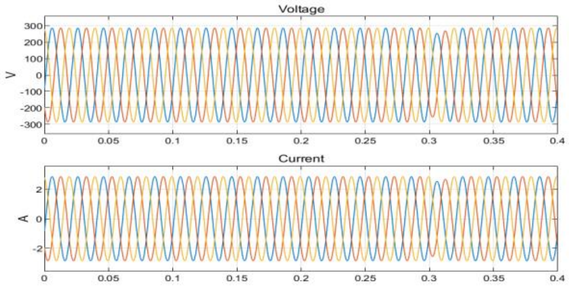
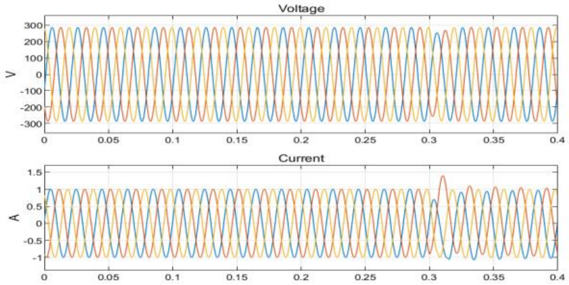
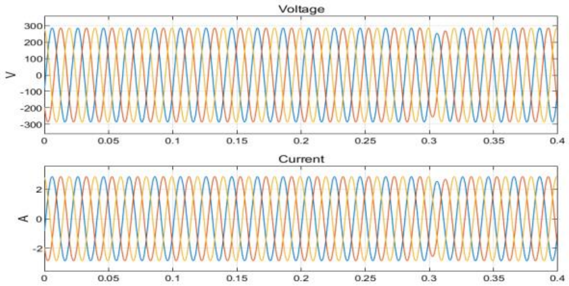


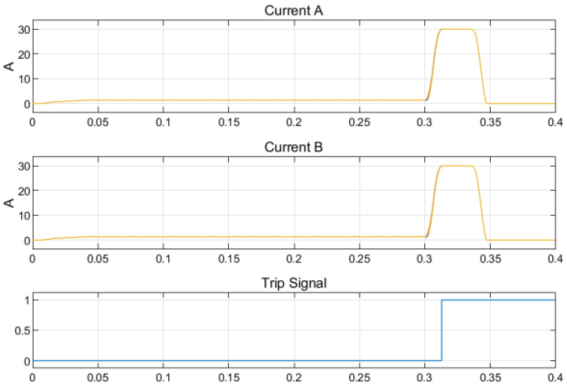
(l) Bus 12



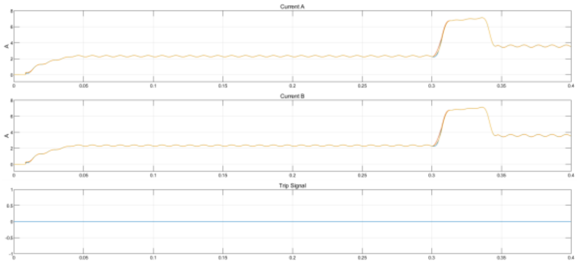
(m) Bus 13



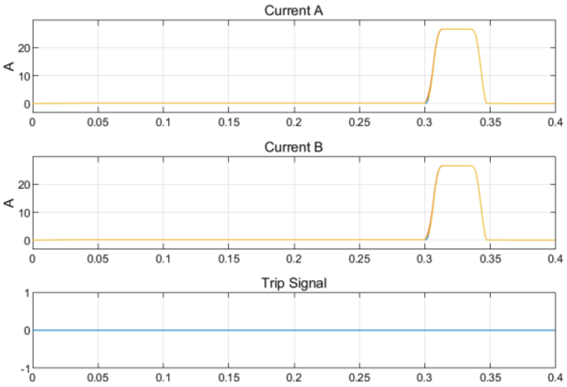
(n) Bus 14



(a) Bus 1_2



(b) Bus 1_5



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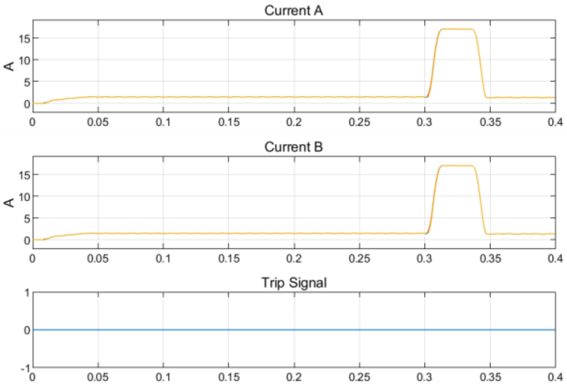

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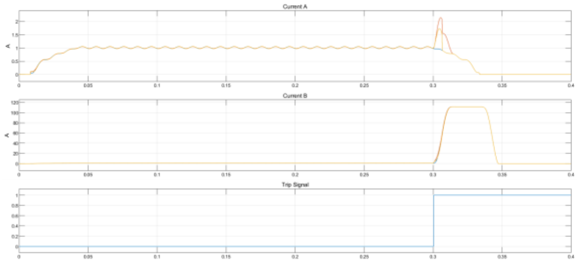

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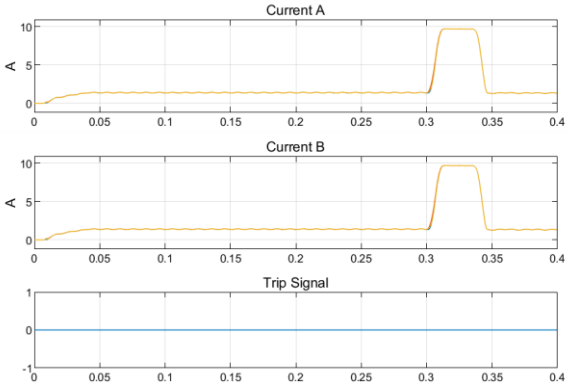

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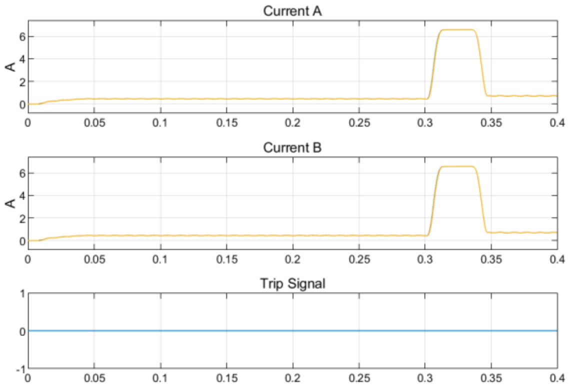

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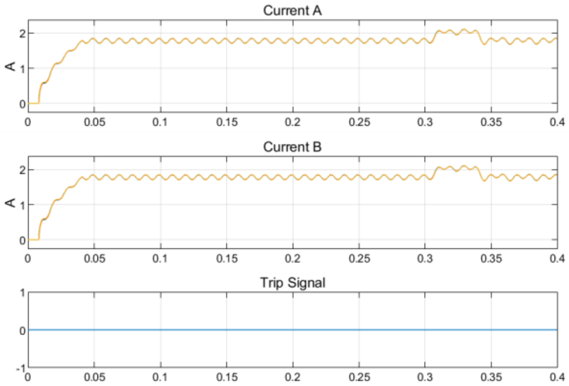

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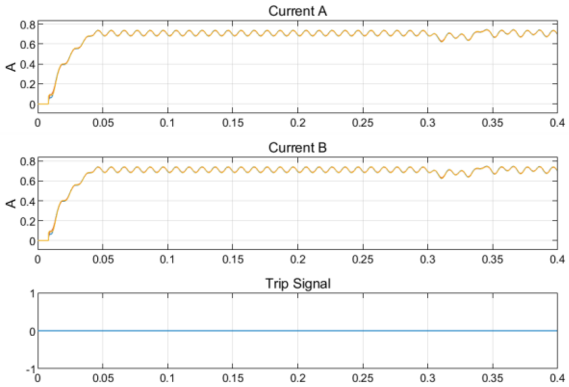

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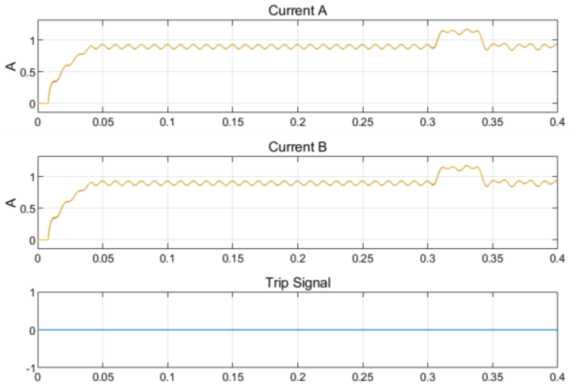

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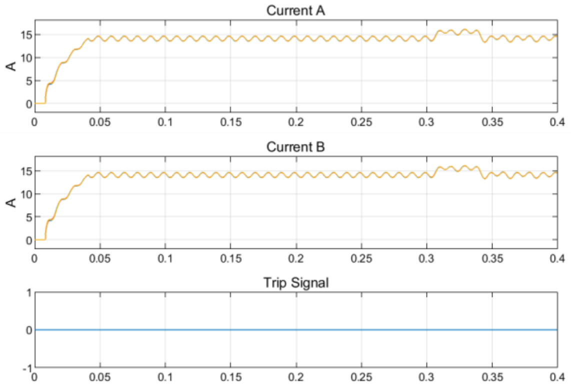
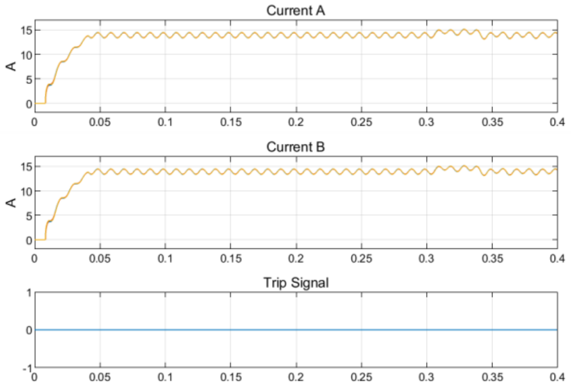


(k) Bus 7_8



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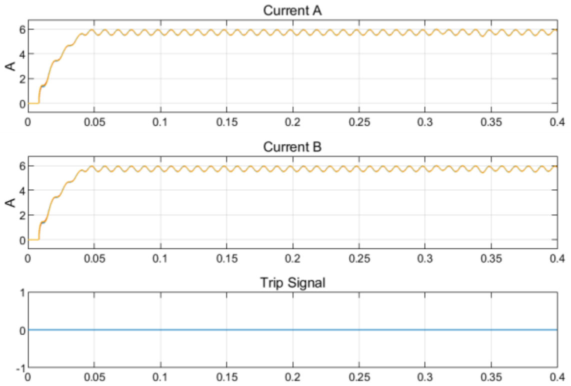

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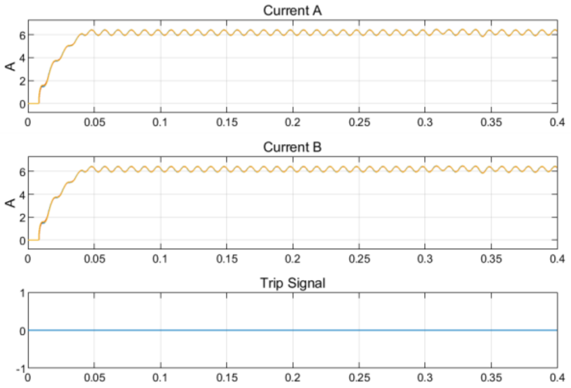

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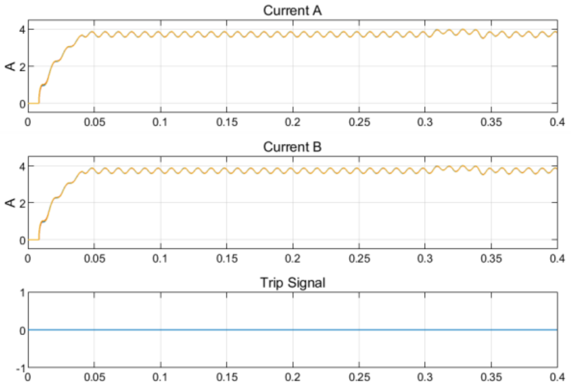

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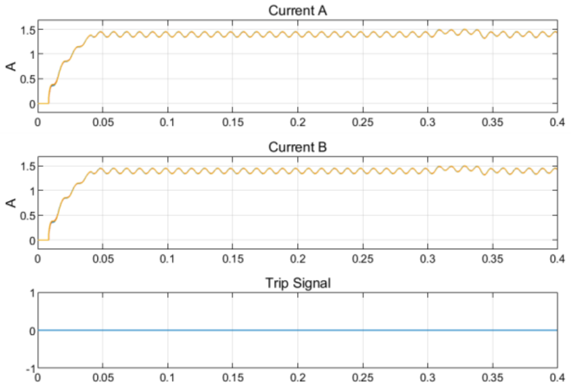
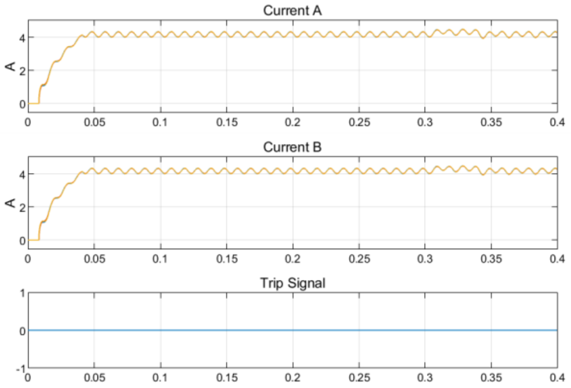


(p) Bus 12_13



(q) Bus 13_14

Figure 21: Network Pi-Section Voltages and Currents

The Differential Current is calculated by the microcontroller and the fault condition is predicted by the model based on a provided reference point for the segment.

With the revolution of digitization of systems, involving a microcontroller in the protection systems introduces versatility and innovative scopes for the project. A digital system can actively record and send the data to a computer for further analysis of the data collected which in-turn facilitates to further understand the system and manage it better. As a digital system, the process can be made more logic based rather than approach based which provides more flexibility and power.

XII. CONCLUSION

The efficiency and reliability of a protection system is strongly based on its reaction time and accuracy. The data from simulated model shows that it is efficient and reliable.

In this study, we have developed an Overcurrent Protection System for the microgrid in “Island Mode.” While the current system provides effective protection against various faults, there is scope for further improvement and expansion. One significant aspect for future research and development is the introduction of a mechanism to detect In-Rush Current. In-Rush Current, which occurs during the connection of loads or devices, can lead to voltage drops, system instability, and potential damage to equipment. The implementation of an In-Rush Current detection mechanism can enhance the reliability and efficiency of the microgrid. In-Rush Current detection is crucial for safeguarding the microgrid’s integrity and preventing disruptive consequences. By detecting In-Rush Current promptly, we can trigger appropriate protective actions to limit the impact on the system and connected loads. Various existing methods are used for In-Rush Current detection in power systems. Traditional overcurrent protection methods, such as time-overcurrent and instantaneous overcurrent relays, are commonly employed. However, these methods may not be optimized to handle the intricacies of In-Rush Currents in a microgrid. Thus, there is a need to explore dedicated techniques that can better distinguish In-Rush Currents from other types of faults or disturbances. We propose the development of a dedicated In-Rush Current detection mechanism for our microgrid. The mechanism will be designed to accurately identify In-Rush Currents and trigger appropriate responses to mitigate their effects on the system.

The proposed mechanism will leverage advanced algorithms and real-time data analysis to differentiate In-Rush Currents from other types of disturbances. Additionally, it will be designed to integrate seamlessly with the existing Overcurrent Protection System, enhancing its capabilities and overall performance.

One of the key challenges in developing the In-Rush Current detection mechanism is achieving high sensitivity and selectivity. The mechanism should be sensitive enough to detect even small In-Rush Currents, while also being selective enough to avoid false alarms triggered by other system events. To address this challenge, we will conduct rigorous testing and optimization of the mechanism, considering various scenarios and microgrid configurations.

The proposed mechanism will undergo rigorous validation and testing to ensure its effectiveness and reliability. We plan to conduct simulations using real-world data and perform tests on a microgrid prototype to validate the mechanism’s performance under different operating conditions.

An essential aspect of the proposed mechanism’s success is its seamless integration with the existing Overcurrent Protection System. We will explore the necessary modifications or adjustments required to achieve smooth integration without compromising the existing protection capabilities.

Upon successful implementation, the In-Rush Current detection mechanism will offer several advantages for the microgrid:

- Enhanced system stability and reliability.
- Reduced risk of equipment damage due to In-Rush Currents.
- Improved protection of critical loads during system restoration.

The proposed mechanism can find applications in various microgrid scenarios, including renewable energy integration, microgrid islanding, and grid-connected operation.

In addition to the development of the In-Rush Current detection mechanism, there are several promising research directions in the field of microgrid protection. Future research can explore advanced algorithms, machine learning techniques, and emerging technologies to further improve microgrid protection and enhance system resilience.

In conclusion, the introduction of an In-Rush Current detection mechanism holds significant promise for enhancing the Overcurrent Protection System in the microgrid. We anticipate that the proposed mechanism will contribute to the ongoing efforts to enhance the stability, reliability, and efficiency of microgrid operations.

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