Modeling of a DC Microgrid and its Protection from Faults by using the fuzzy logic controller

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Abstract

This work's main goal is to analyze DC microgrid protection with different types of faults and effects on power electronics devices such as voltage source converters (VSC), and DC-DC converters and the effect on power loads. The first case is PV connected to the battery (off-grid), the second case is PV connected to the main grid (on-grid), and the last case is PV and battery connected to the main grid, then a case failure analysis study is carried out for them. A normal circuit breaker was used for protection, and we can use different types of protection for DC microgrids in the future. The simulations are obtained using MATLAB/SIMULINK, and the results for all cases have been discussed, for sections one and two all figures are in normal operation and the last cases show the effects of the fault on the transmission lines and all the equipment needed for the DC microgrid. The fault affects the bus, and the circuit breaker (CB) protects the bus from the current fault, but the fault current is very high, we need to design a new method to protect the DC microgrid .

Keywords: Dc Microgrid, DC Converter, Voltage source Converter, fault analysis, Matlab.

Introduction:

A DC microgrid is a small-scale electrical power distribution network that operates using direct current (DC) rather than the more common alternating current (AC). Microgrids are often used to provide localized power generation and distribution, and DC microgrids are gaining popularity due to their increased efficiency and reliability compared to AC systems. DC microgrids can be designed to operate independently of the larger grid, or they can be interconnected with the main power grid. They typically incorporate multiple energy sources such as solar panels, wind turbines, and batteries, which are connected to a central control system. This system monitors the energy demand and supply and manages the power flow between the different sources and loads to ensure that the microgrid operates at optimal efficiency. Advantages of DC microgrids include increased efficiency due to the elimination of AC-to-DC and DC-to-AC conversion losses, improved reliability due to the reduced complexity of the system, and the ability to easily integrate renewable.energy sources such as solar and wind power. Additionally, DC microgrids can help to reduce greenhouse gas emissions and promote sustainable energy practices.

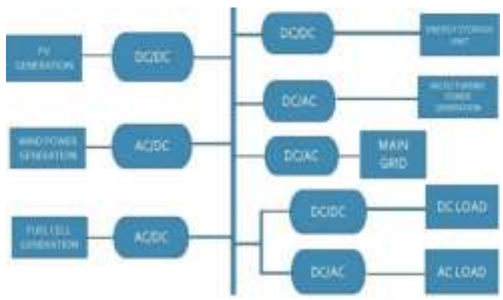


Fig 1: Block diagram of dc micro-grid

Methodology:

In this section, we discuss in detail the design of the DC microgrid. There are different designs for DC Microgrid architectures considering specific design requirements and suggested applications, figure below shows this type of DC microgrid Photovoltaic (PV) and energy storage system (ESS) has been connected to a DC-DC converter before being connected to a bus for both of them, for AC grid has been connected to voltage source converter (VSC) before connected to the bus. The following figure shows the DC-DC converter.

After modeling and designing a DC-DC converter for PV & ESS, we need to design an AC-DC inverter for the main grid (AC) but in this paper it was replaced by a Fuzzy logic controller with that we can obtain the simulation result without any delay and improves the system performance and reduces the loss factor.

Proposed model:

When the system fault occurs, VSC produces a large DC fault current due to the discharge of a large DC link capacitor. In a normal situation, the main purpose of the VSC is to link DC systems and AC systems in one system, and this system is called a microgrid.

In the proposed system of this project, we have utilized a voltage source inverter. By using of this more harmonic distortions will occur and the power quality is low. So, to overcome these issues, in the place of VSI, we are going to place multilevel inverters. These MLIs will reduce the harmonics and improves the system performance.

Design of DC microgrid and fault analysis

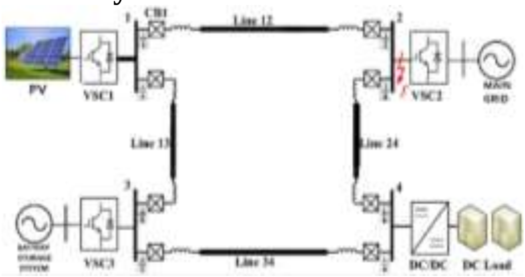


Fig 2: Design of DC microgrid and fault analysis

In a DC microgrid, faults can occur due to various reasons such as short circuits, overloads, and voltage dips. The protection system is designed to detect and isolate faults to prevent damage to the equipment and ensure the safe operation of the microgrid. The protection system typically consists of fuses, circuit breakers, and relays. Fuses are used to protect the VSC and other components of the microgrid from over-current conditions. Circuit breakers are used to isolate faulty sections of the microgrid and prevent further damage. Relays are used to detect faults and trigger the circuit breakers.

A DC microgrid is a self-contained power system that includes renewable energy sources, energy storage, and loads, operating at a low-voltage DC level. The Voltage Source Converter (VSC) is one of the most commonly used power electronic devices in DC microgrids. It is used for power conditioning, voltage regulation, and fault management. In this response, we will discuss the modeling of a DC microgrid using a VSC and protection from faults

In the modeling of the DC microgrid, we design three cases and introduce fault in the third case.

Case one: P V with Battery:

In this case, PV was connected with the battery (off-grid), and all results are shown in the figures below. The energy produced by solar panels depends on radiation, and part of this energy goes to charge the battery and the other to feed the load.

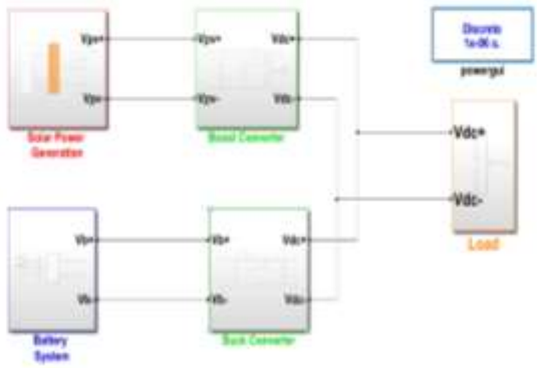


Fig 3: PV connected to Battery

Case two: PV with Main Grid

In this case, When the system is connected to the load the consumption of energy is produced from PV first, and then the energy produced from the main grid.it is on-grid.

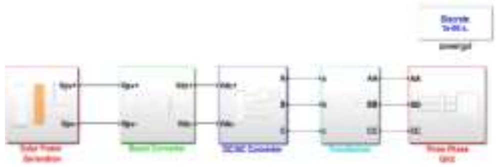


Fig 4: PV connect to the main grid

Case three: P V with a Battery connected to Main Grid:

In this case, PV & battery have been connected and then synchronized to the main grid by VSC. When a fault happens (3-phase fault) in the system a large current is produced in the transmission line and this current directly affects the VSC and increased the voltage.

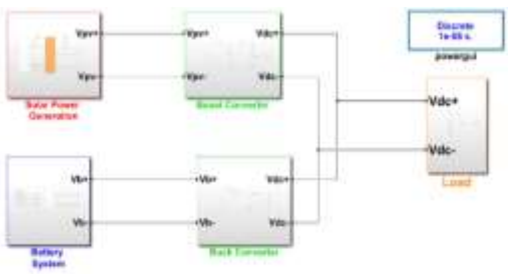


Fig 5: PV and battery connected to the grid

Fuzzy logic controller

A fuzzy logic controller (FLC) is a type of control system that is designed to handle systems with uncertain or imprecise inputs and outputs. It uses a set of linguistic rules and mathematical functions to make decisions based on the input data and produce output values.

Fuzzy logic controllers can be used in voltage source converters (VSCs) to improve their performance and control characteristics. VSCs are power electronic devices used in various applications, such as renewable energy systems, electric vehicles, and industrial automation. The main function of a VSC is to convert DC voltage into an AC voltage waveform of variable frequency and amplitude. Fuzzy logic controllers use linguistic rules and reasoning to provide a flexible and adaptive control strategy for VSCs. Unlike traditional controllers, which rely on precise mathematical models and parameters, fuzzy logic controllers can
handle uncertainties and imprecise information. This makes them well-suited for controlling VSCs in real-world applications, where operating conditions can be complex and unpredictable. the time taken by the Dc link voltage in fuzzy control is less and also achieves higher stable voltage compared to the PI controller.

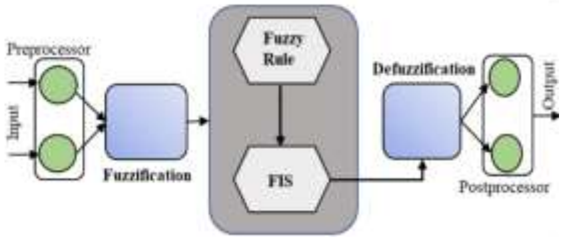


Fig 6: Fuzzy logic controlle

Simulation and Results

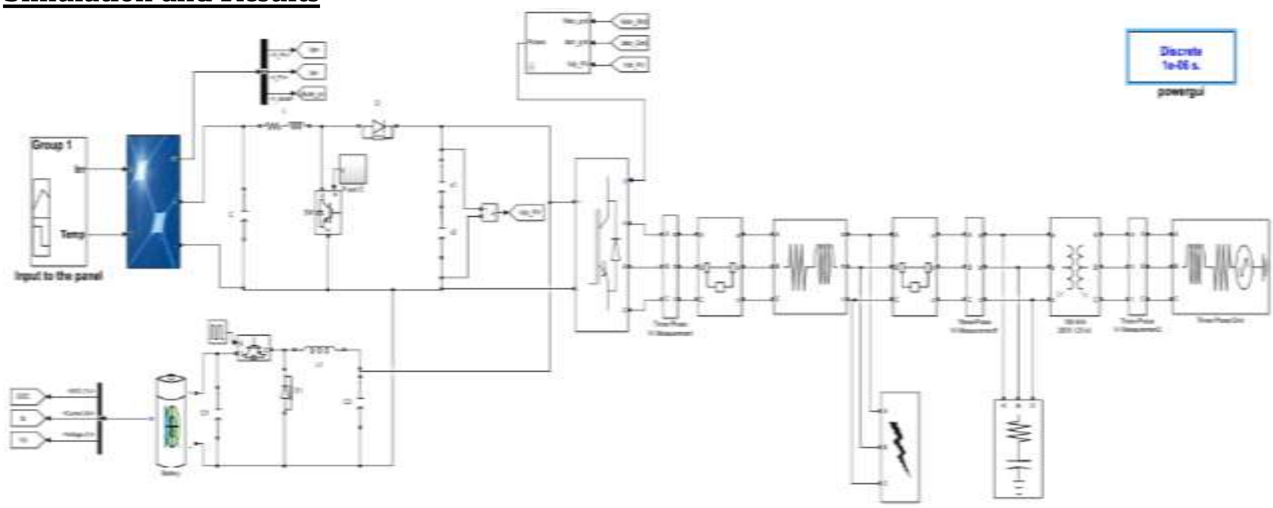


Fig 7: simulation of Dc microgrid under fault condition by using a fuzzy logic controller

In the voltage source converter, we use a fuzzy logic controller in VDC regulator. Vdc regulator compares the actual measure and reference voltage and is gives to the current regulator. To regulate the dc link voltage, we have implemented the fuzzy logic controller in vdc regulator.we consider voltage and current and its converts to the angular frequency in the vsc main controller. all angular frequency are added with sin and multiplied with product then the reference voltage comes with modulation and both are given to the pulse generator for generating pulses. That pulse is given to the inverter. In this dc microgrid, we use 100 KVA, 440V/33KV and we introduce a 3-phase LLLG fault in this dc microgrid.

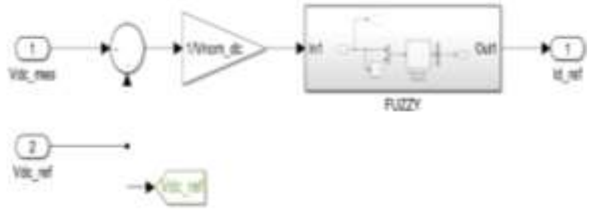


Fig 8: VDC controller

Results of dc microgrid analysis

Case one:PV and battery connect to load

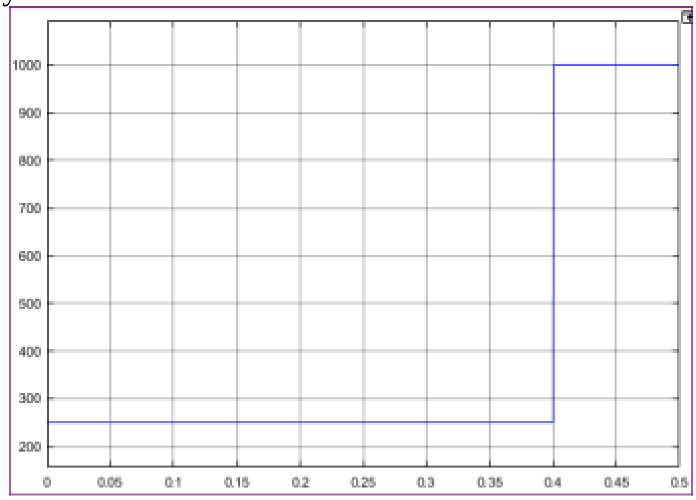


Fig.9: I-V for PV array

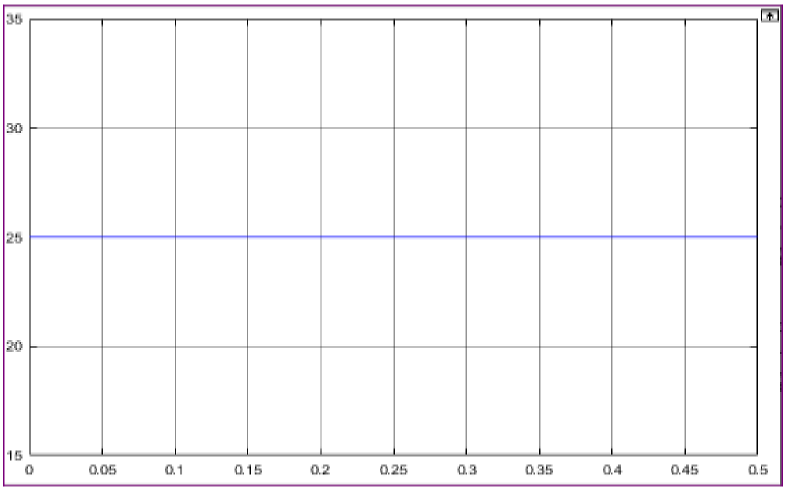


Fig 10: Temperature

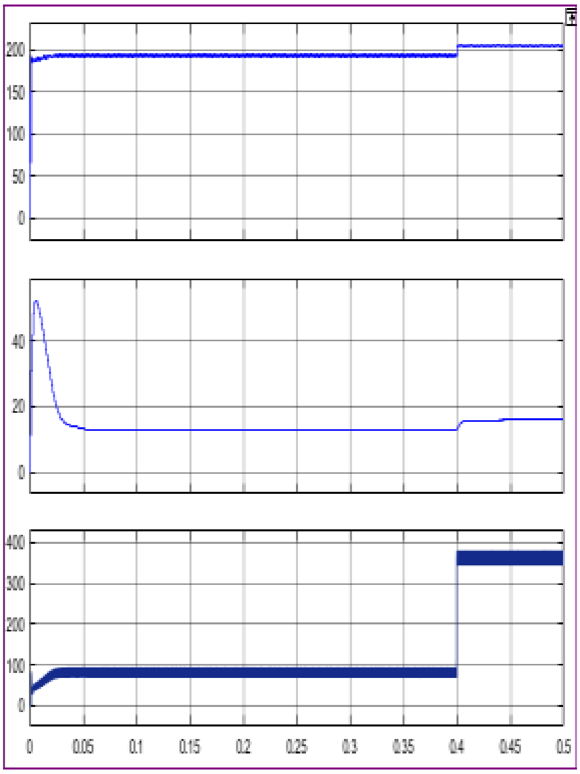


Fig 11: solar panel outputs

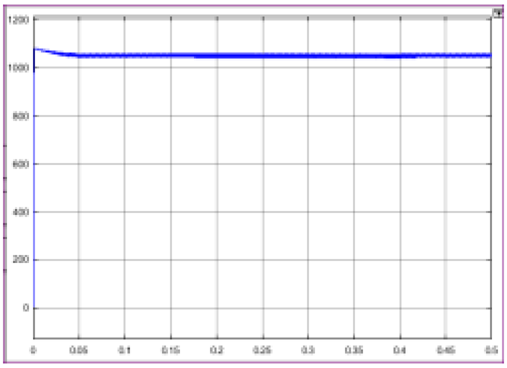


Fig:12 battery charging current and voltage

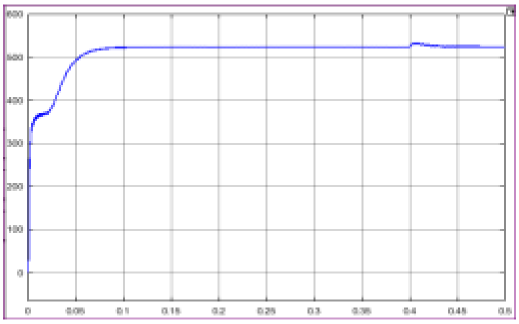


Fig. 13: output voltage

The solar generates 200v from solar energy through irradiance of light. The 200V output from a solar panel is given to the boost converter and that is to boost the voltage to 500v dc. and current is raised in the starting and set to below 20 A. and its shown in fig.11. the battery is charged with 1000v and converts to 500v through a buck converter and given to the load & it's shown in Fig. 13 that whenever PV doesn't generate energy that battery will given supply to the load.

Case two: PV with Main Grid (AC)

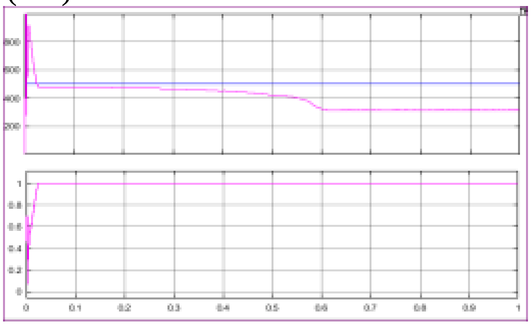


Fig. 14: Reference voltage and Mod. Index

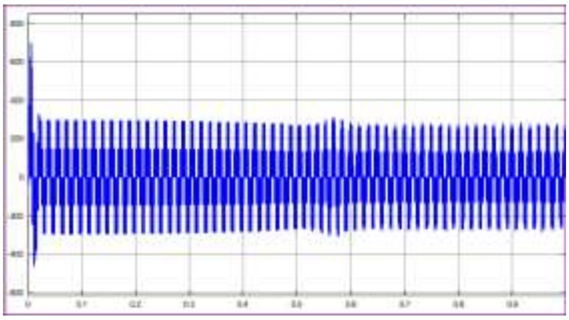


Fig 15: voltage for VSC

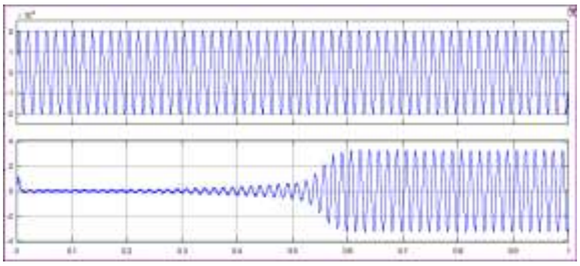
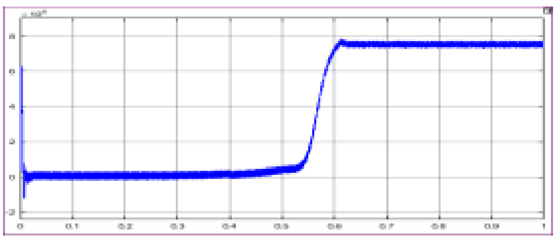


Fig 16: voltage and current for main grid bus



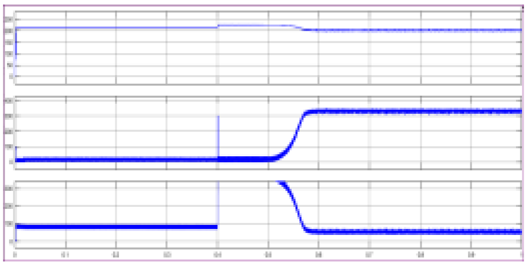


Fig.17:: Power for Main Grid busFig:18: V,I, diode current for the PV array

Case three: P V with a Battery connected to Main Grid

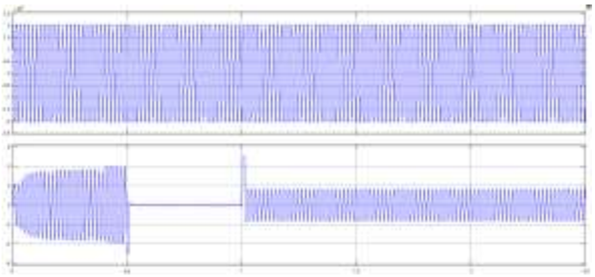


Fig 19: Voltage and currents of bus

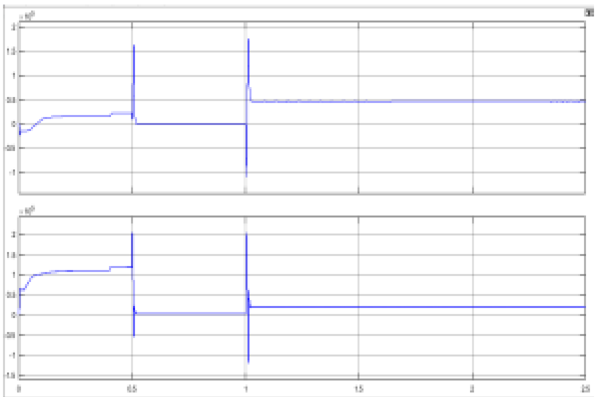
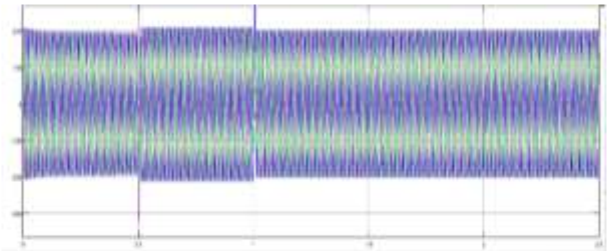


Fig 20: Active and reactive power



Bus voltage_1

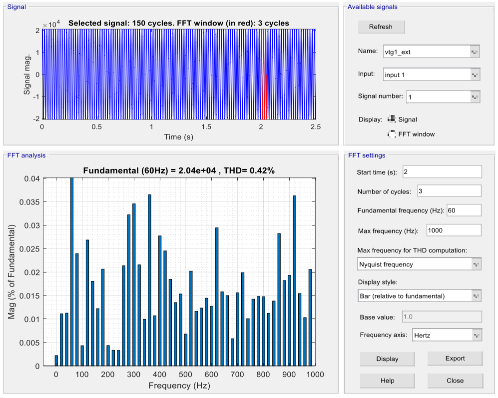
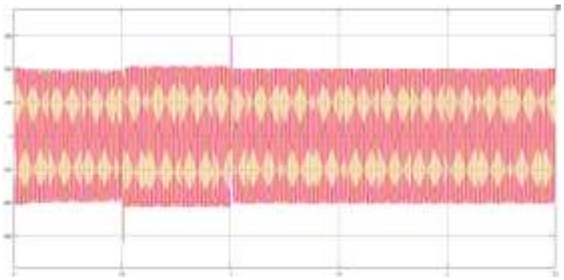


Fig 21:THD of bus_1 voltage



Bus voltage_2

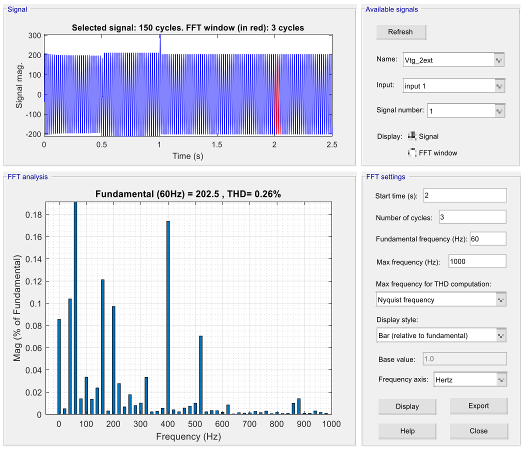
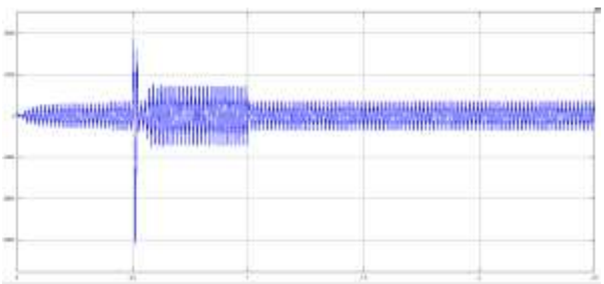


Fig 22: THD of bus voltage_2



Bus voltage_3

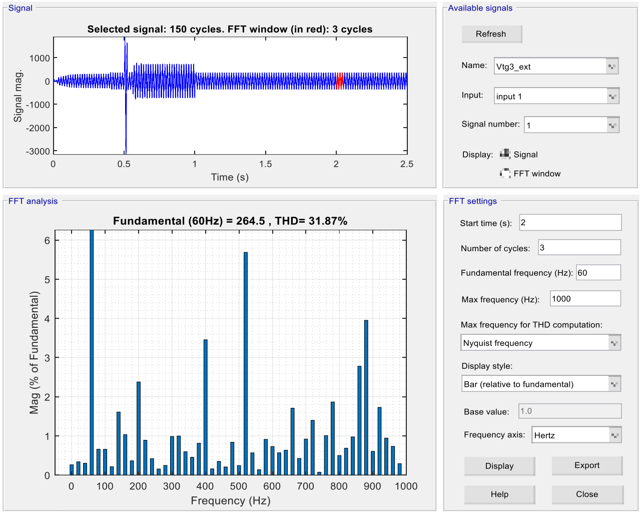


Fig 23: THD of bus voltage_3

Conclusion

This paper presents the analysis of modeling, simulation, and fault protection of DC microgrids. There are three cases that has been discussed in this paper, the first case is PV connected to the battery (off-grid), the second case is PV connected to the main grid (on-grid) and the last case is PV & battery connected to the main grid, then develop a fault analysis study for these cases. A normal circuit breaker was used for protection and in the future, we can use different types of protection systems for DC microgrids. The results for all cases obtained using MATLAB/SIMULINK are presented in the figures above. Figures for case one and two depict normal operation, whereas the last case shows the effects of the fault on the transmission lines and all the equipment required for the DC microgrid. The fault affects the bus, and the circuit breaker (CB) safeguards the bus against the current fault. However, the fault current is very high, which necessitates the design of a new protection method for the DC microgrid. In the event of a system fault, the VSC generates a large DC fault current due to the discharge of a large DC link capacitor. The primary function of the VSC in a normal situation is to link DC and AC systems to form a microgrid.

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