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"Short Circuit Fault Detection and Protection of DC Microgrid"

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ABSTRACT

This paper presents a fault simulation on DC microgrid based on direct current was designed using solar PV, battery and fuel cell as a source in MATLAB/Simulink. The power produced by different sources is combined on the same DC bus and given to a DC load. The framework avoids potential risk against some undesired circumstances. In case of a fault, the failed section of microgrid has been separated rapidly using circuit breaker and restore using protective devices.

The short circuit is the one of the faults which affect the stability of system. we need to make sure to this type of faults don't affect the stability and reliability of system. Thus, we make the short circuit protection circuit, this circuit don't affect the stability and reliability of system.

In this circuit, over current relays for detection and circuit breakers for protection and for extra protection, FCL i.e., fault current limiter in PV array side is used.

Also fuel cell and PV array are taken at the source side and for backup lithium-ion battery is taken. For battery, bi-direction converter is designed. Initially battery is charged up to 70% and at this time bidirectional converter work as a boost converter and when battery discharges till 30 %, battery starts charging and then bi-directional converter act as buck converter and battery remain charging mode.

We take circuit breaker for each source and also for load also to protect it from fault.

Keywords— Short-circuit fault; FCL; MPPT; Circuit Breaker; bidirectional converter

I. INTRODUCTION

A microgrid is a neighborhood electrical framework containing sources and loads. The meaning of a microgrid is a group of dispersed assets which can work self-governingly. Microgrids are being used to bring electricity into areas where transmission lines cannot reach. A conventional framework with age in one spot and afterward dissemination at high voltages is intended for high energy thickness petroleum derivatives. Distributed generation can be used to increase the reliability of a system and allow for the integration of renewables. Appropriated age is a substantially more reasonable strategy for power dissemination for renewables because of their lower energy thickness when contrasted with petroleum derivatives and since the force age is on site losses due to transmitting electricity are proportionally eliminated. Energy storage can be used in microgrids to improve the power quality and smooth out the fluctuations of renewable energy generation. The new pattern in renewables is to utilize conveyed power sources and fuel stockpiling to frame a microgrid. DC microgrids are not extremely far and wide however can possibly introduce numerous benefits as far as working with environmentally friendly power reconciliation and further developing force quality. DC microgrids usually contain distributed energy resources (DER), loads and energy storage. Renewable energy sources such as photovoltaic modules and wind turbines are typically connected to the DC bus via power electronic converters. These converters have the ability to control the output voltage of DER in order to stabilize the bus voltage and extract maximum power. There are power electronic converters that have the ability to increase or decrease the output voltage. DC loads can be straightforwardly associated with the DC bus and if an AC load is required an inverter would be required to modify the DC bus voltage into a usable AC voltage. Batteries are typically used in DC microgrids due to their relatively cheap price and longer backup times. A more drawn-out reinforcement time and low misfortunes are attractive for energy stockpiling advances for microgrids which contain environmentally friendly power age all together for the heap to be met. The problem with batteries is that their service life is relatively short and therefore they need to be changed out more often. Charge controllers are used in order to control the flow of power in the microgrid. Devices are needed to control when

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power is sent to the batteries or sent to power the load. These controllers also help to improve the power quality in the microgrid. Why fault occur in DC microgrid? Due to the low impedance nature of DC microgrid system, the capacitive filters associated with converters will rapidly discharge into a fault, resulting a large current surge within very short duration.

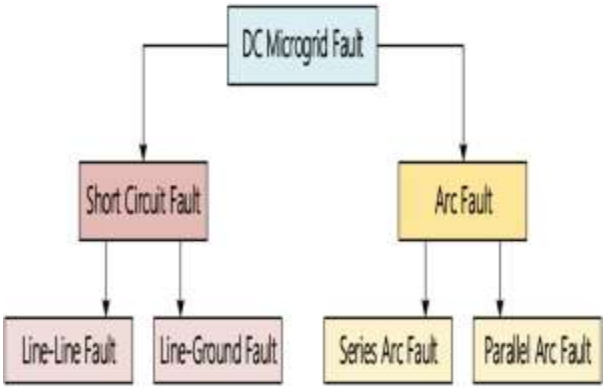

Fig 1 Types of faults

DC microgrid protection is an important part of the power system studies. One of the significant destinations of DC microgrids is working on the general dependability of the framework. This is an unpredictable test in DC Microgrid, yet to conquer this mind-boggling challenge, and insurance to it, requires different circuits with confounded plans to be added to the matrix. The essential thing which is needed for insurance is to become more acquainted with are the place where it ought to be given, what segment to be utilized, what boundary shouldn't be adjusted while planning the circuit so the DC Microgrid functions according to the assumption. DC Microgrid enjoys various benefits contrasted with AC Microgrid, so planning a suitable security circuit for the DC microgrids stays to be a critical test. So, to address the challenges of DC microgrid protection, accurate fault detection strategy, fault current limiting method, proper grounding design and a DC circuit breaker are required. In this model, we have utilized an ordinary Circuit Breakers which are accessible in MATLAB Simulink, and by utilizing the Power electronic gadgets like MOSFET and IGBT as, control switch in the converters. When planning a suitable flaw recognition procedure, the boundary which ought to be assessed adequately are cost, calculation, and execution. MATLAB/Simulink was utilized to plan and recreate the individual segments of the microgrid. Power electronic converters were designed and simulated for the use with photovoltaic (PV) modules and maximum power point tracker (MPPT) in order to extract maximum power from the solar resource. The perturb and observe (P&O) algorithm was designed in MATLAB environment for the MPPT. A bidirectional converter was likewise intended to permit ability to stream/to battery which was constrained by converter by PI strategy. A customary buck-help converter couldn't be utilization of bidirectional converter because of essence of diodes in their plan. The charge regulator effectively controlled the bidirectional converter permitting ability to move from/to the battery to accomplish voltage adjustment. A lead-destructive battery was found to be most monetarily insightful option for coordination into the microgrid. A lift converter was likewise intended for sun-based PV and energy unit to support up the voltage according to the prerequisite. An insurance model against hamper for direct current (DC) microgrid utilizing MATLAB/Simulink is planned.

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II. BLOCK DIAGRAM

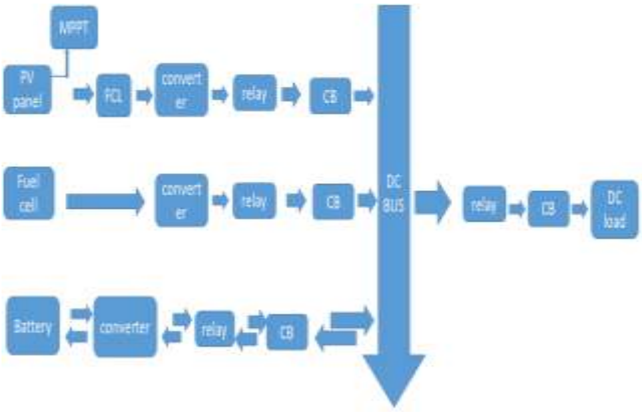

Fig.2 Microgrid system block diagram

Fig.2 represents the block diagram of DC microgrid system for short circuit fault detection and protection where two generating sources are taken which are solar PV& fuel cell and battery is connected in parallel.

As we know solar PV has many advantages but it has very low energy conversion efficiency. To overcome this problem, PV is connected to MPPT (Maximum Power Point Tracker) in order to extract maximum power from solar array during unfavourable condition. Solar PV is also connected with FCL (Fault current limiter) to limit the fault current without complete disconnection. Solar PV and fuel cell connected to boost converter in order to maintain the DC bus voltage and battery is connected with bidirectional converter which allows power to flow from battery or to battery to achieve voltage stabilization. Solar PV, fuel cell and battery is connected with relay and Circuit breaker. Whenever, fault occurs in the system, relay gives signal to the Circuit Breaker. As soon as the Circuit Breaker receives the signal it trips and separates the faulty section from DC bus so that fault does not proceed further or damage any equipment.

III. DESIGN AND SIMULATION:

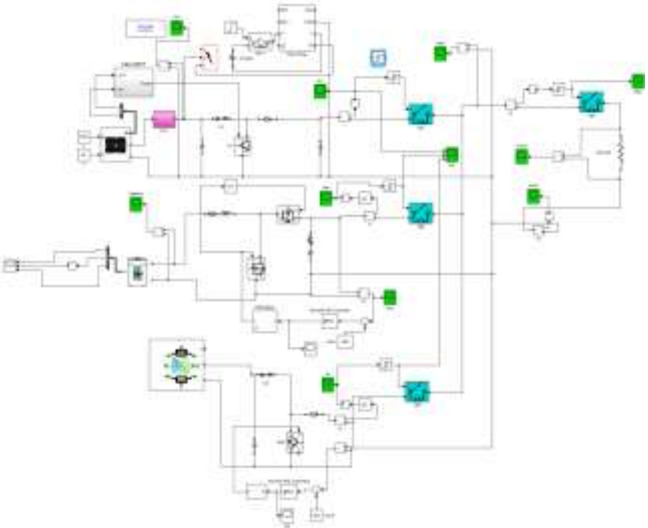

Fig.3 Distributed Generation system Simulink model

The above is the test system of the proposed topology with one PVA source, one battery source and fuel connected in parallel feeding the DC load. The PVA is operated by MPPT technique connected to booster converter for voltage stability. Battery is connected with bidirectional DC-DC converter controlled by voltage-oriented control. Fuel is operated by PWM technique connected to a booster converter. The rated DC voltage is set at 500V. In this research, grid connected system is used. At the source side, photovoltaic source (PV) and fuel cell are demonstrated and the battery for back up is taken and DC loads is connected at the load side.

The PV source is connected with fault current limiter (FCL). FCL is a fault current limiter also known as a fault current controller is a device which limits the prospective fault current when a fault occurs in photovoltaic source. PV source is also connected to a P&O MPPT in order to extract maximum power from PV. Fuel Cell and PV both the sources are connected with the converters which will boost up the voltage and will supply it to the DC load through the DC bus.

A. Maximum Power Point Tracker

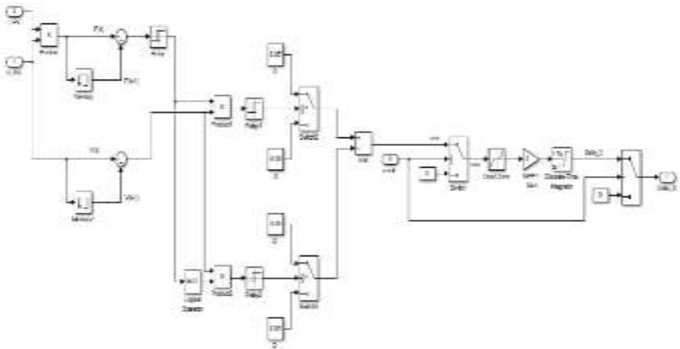

Fig.4 Simulation diagram of Maximum Power Point Tracker

The photovoltaic framework has a non-direct current-voltage and force voltage attributes that constantly shifts with illumination and temperature. To follow the ceaselessly fluctuating greatest force point of the sunlight-based cluster the MPPT (most extreme force point following) control method assumes a significant part in the PV frameworks. The errand of a greatest force point following (MPPT) network in a photovoltaic (PV) framework is to ceaselessly tune the framework so it draws most extreme force from the sun powered cluster paying little heed to climate or burden conditions. Lately, countless strategies have been proposed for following the greatest force point (MPP). In a MPPT technique and its execution and execution are introduced. Two existing disadvantages experienced while creating power from PV frameworks are: the first that the proficiency of electric force age is extremely low, particularly under low radiation states, and the other downside is the measure of electric force produced by sun-based exhibits is continually changing with climate conditions, i.e., illumination and temperature. it tends to be seen that the yield power qualities of the PV framework as capacity of irradiance and temperature is nonlinear and is significantly affected by sun-based illumination and temperature. The Maximum Power Point (MPP) of the PV cluster changes ceaselessly; thusly, the PV framework's working point should change to augment the energy created. Accordingly, a Maximum Power Point Tracking (MPPT) is a fundamental piece of the PV framework to guarantee that framework works at the most extreme force of the PV exhibit.

As per the hypothesis of most extreme force move, the force conveyed to the heap is greatest when the source inner impedance coordinates with the heap impedance (ZS=ZL). In this way, the impedance seen from the converter side requirements to coordinate with the inside impedance of the sun-based exhibit.

The activity of MPPT can't be accomplished except if a tuneable coordinating with network is utilized to interface the heap to the PV cluster. The primary constituent parts of a PV framework are power stage and regulator as displayed in fig.1 the force stage is acknowledged utilizing switch mode DC-DC converters (help, buck-support), utilizing PWM control. The control boundary is obligation proportion δ which is utilized for the tuning of the organization for most extreme extraction of force. The P&O calculation is additionally called "slope climbing", while the two names insinuate a comparative relying upon how it is carried out. Slope climbing comprise of an annoyance on the obligation pattern of the force converter and P&O a bother in the working voltage of the DC connects between the PV cluster and the force converter. On account of the Hill-climbing, annoy the obligation pattern of the force converter suggests adjusting the voltage of the DC connect between the PV exhibit and the force converter, so the two names allude to a similar method.

In this technique, the indication of the last irritation and the indication of the last addition in the force are utilized to choose what the following annoyance ought to be on the left of the MPP augmenting the voltage expands the force while on the right decrementing the voltage builds the force. On the off chance that there is an addition in the force, the annoyance ought to be kept a similar way and assuming the force diminishes, the following bother ought to be the other way. In view of these realities, the calculation is carried out. The cycle is rehashed until the MPP is reached. Then, at that point the working point sways around the MPP.

Be that as it may, P and O have certain restrictions. In a circumstance where the irradiance changes quickly, the MPP likewise continues onward the right-hand side of the bend. The calculation accepts it as a change because of bother and in the following emphasis it alters the bearing of irritation and thus disappears from the MPP.

In any case, in this calculation we utilize just a single sensor, that is the voltage sensor, to detect the PV cluster voltage thus the expense of execution is less and henceforth simple to carry out. The time intricacy of this calculation is extremely less yet on coming to exceptionally near the MPP it doesn't stop at the MPP and continues irritating in both the ways. At the point when this occurs, the calculation has reached extremely near the MPP and we can draw a suitable mistake line or can utilize a stand by work which winds up expanding the time intricacy of the calculation.

B. Fault Current Limiter (FCL)

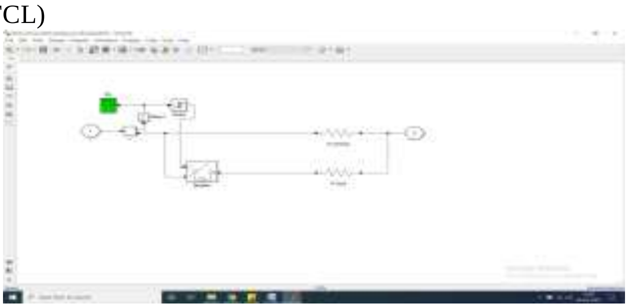
Fig 5 FCL internal modelling

The Fig.5 is the modelling of FCL connected at PVA controlled by relay trip signal depending on short circuit current.

Fault Current Limiters (FCLs) go about as an extra high impedance to restrict high issue flows to a worthy level. In ordinary activity, FCLs have basically no impedance and are "imperceptible" to the framework. In contrast to wires or disconnectors, FCLs don't totally disengage in short circuit current case. After the deficiency current vanishes, they can get back to ordinary activity. Because of their exceptionally short response time, FCLs can act and decrease the short out current so the electrical switch can act in their ostensible presentation range, if necessary. Ordinarily, FCLs are utilized in low and medium voltage levels.

Benefits and field application

By introducing FCLs, framework administrators or business clients can streamline the framework by use of standard arrangements with explicit (low) ostensible short out ebbs and flows. Significant benefits include:

•Reduction of the short out current of the framework, permitting the circuit breakers to act in their ostensible exhibition range

•Reduction of voltage lists and glimmer because of the lower absolute source impedance

•Reduction of music because of the lower all out-source impedance

C. Battery

A lithium-ion battery or Li-ion battery is a kind of battery-powered battery. In the batteries, lithium particles move from the negative anode through an electrolyte to the positive terminal during release, and back while charging. Li-particle batteries utilize an intercalated lithium compound as the material at the positive terminal and regularly graphite at the negative anode. Lithium-particle batteries have become the most encouraging answers for applications in microgrid networks because of their high energy thickness and high-power thickness. It is feasible to acknowledge fuel reserve funds of 50 to 75 percent. Li-particle battery frameworks have arisen as the innovation of decision for energy stockpiling. Lithium-particle based Battery Energy Storage System (BESS) assume a significant part in taking care of force supply issues in miniature lattices because of their presentation qualities like high force, high productivity, low self-release, and long-life expectancy.

Benefits of Li-ion battery

•Maintenance: Unlike overflowed lead-corrosive batteries with water levels that should be checked, lithium-particle batteries don't should be watered.

This lessens the upkeep expected to keep the batteries functional, which additionally dispenses with preparing new colleagues on the methodology and observing machines to guarantee that water levels are right. Lithium-particle batteries additionally dispense with motor support.

•Longevity: The normal lithium-particle battery life expectancy for a huge limit battery pack can be up to at least eight years. A long assistance life gives a profit from your interest in lithium-particle battery innovation.

•Easy and Fast Charging: Using quick charging lithium-particle batteries mean less vacation for a machine while it's anything but's a charging station. In a bustling office, obviously, the less time a machine needs to sit inactive, the better. Additionally, diminishing personal time for a machine, the lithium-particle battery can be opportunity charged. This implies that cleaning strategies don't need to be planned around the need to permit a battery to completely charge in the middle of employments, and furthermore works on preparing for colleagues.

•Safer Facilities: Improve indoor air quality and decrease the danger of mishaps by wiping out openness to combustible energizes and sulfuric acid with lithium-particle innovation. Additionally, appreciate calm activity with low dBa sound levels.

•Environmental Impact: Lithium-particle batteries give critical natural advantages over other non-renewable energy source options. With the consistent expansion in electric vehicles, we are seeing a prompt effect in the decrease of fossil fuel by-products.

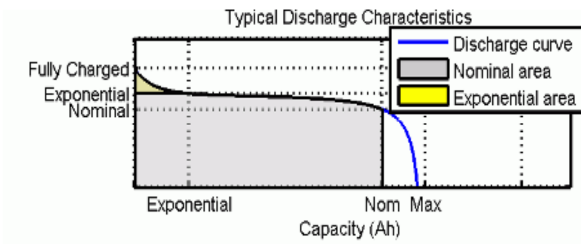

Fig6 Discharge characteristics of battery

The principal segment addresses the remarkable voltage drop when the battery is charged. The width of the drop relies upon the battery type. The subsequent segment addresses the charge that can be removed from the battery until the voltage dips under the battery ostensible voltage. At long last, the third area addresses the complete release of the battery, when the voltage drops quickly.

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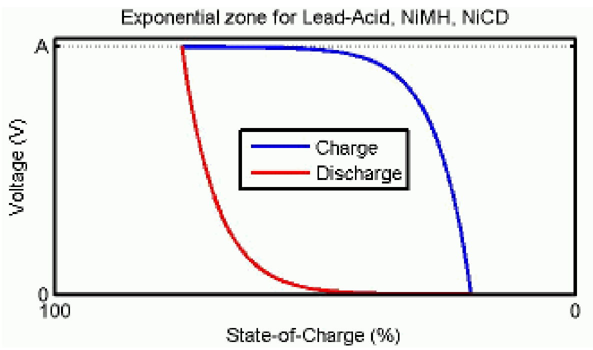

Fig.7 Battery's State of charge (SOC)

The condition of charge (SOC) for a battery is a proportion of battery's charge, communicated as a percent of the full charge. The profundity of release (DOD) is the mathematical commendation of the SOC, with the end goal that DOD = 100% - SOC.

For example, if the SOC is:

- 100% — The battery is fully charged and the DOD is 0%.
- 75% — The battery is 3/4 charged and the DOD is 25%.
- 50% — The battery is 1/2 charged and the DOD is 50%.
- 0% — The battery is having 0 charge and the DOD is 100%.

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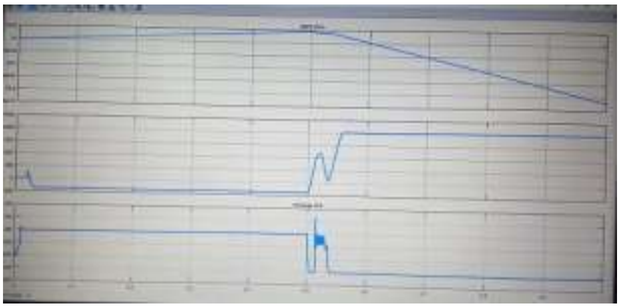

Fig.8 SOC during Simulation

Initially battery is charged up to 70% and slowly it starts discharging as it supplies power to DC bus and DC load.

IV. RESULT

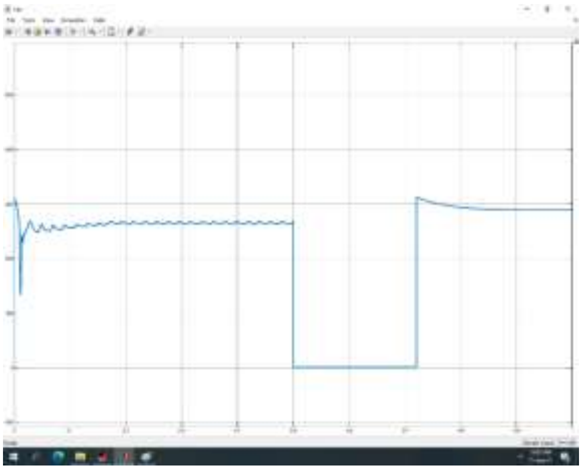

Fig.9 PV source voltage magnitude

The test system is introduced with fault on PV source at 0.5sec due to which voltage is reduced zero and using fault controller at 0.7 sec the voltage starts restoring and the results are observed. Due to FCL the current of the PVA is not increased and maintained at nominal value.

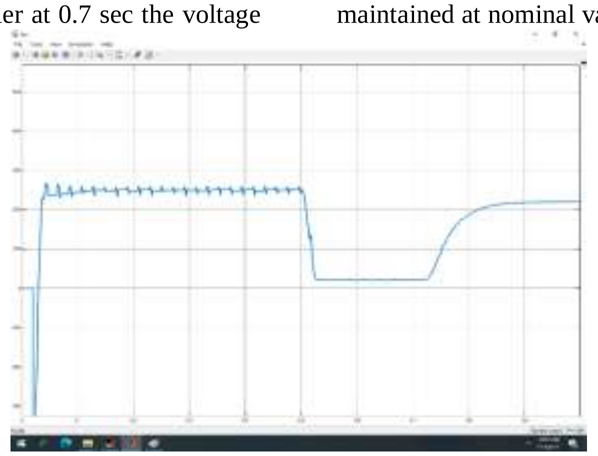

Fig.10 PV current magnitude

Similarly, PV source current is also reduced to zero during fault.

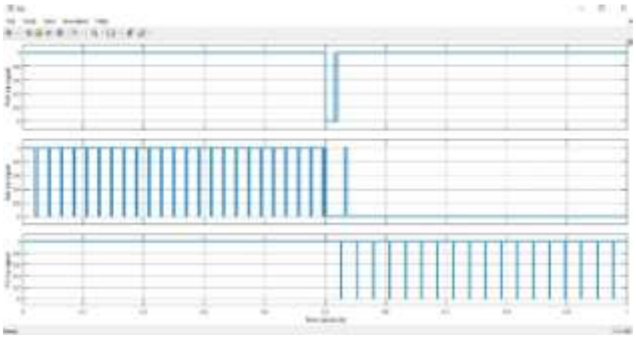

Fig.11 Trip signal of the PV, battery and fuel cell breaker

The trip signal of the PVA is recovered as FCL is present on the source side.

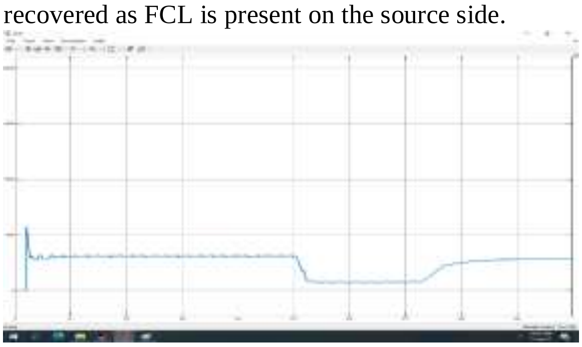

Fig.12 Battery current magnitude

Battery current is also reduced during fault as it is connected in parallel with PV source.

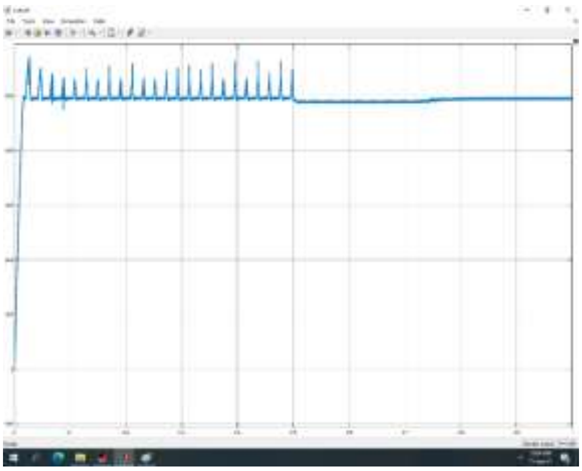

Fig.13 Output voltage

The failed section of microgrid has been separated from grid rapidly using breakers located at each energy sources and also at the output side to protect DC load and meanwhile the other two sources continue to fed the power to the load.

V. CONCLUSION

A DC microgrid model has been designed and simulated that comprises a protection model for multiple energy sources. At the time equal to 0.5 the system detects the fault at PV array and with help of circuit breaker and relay the PV array is separated from the system immediately and at the time equal to 0.7 the PV array starts restoring.

This model is used to protect the DC microgrid under short circuit fault. Whenever the fault occurs at any section of the DC microgrid then the system is protected against it rapidly using protective devices and also the system is restored quickly, maintaining the continuity of the power supply to the DC load. As a result of all these studies, its shown that the system has speed respond time against faults.

In DC microgrid time-based fault cannot be implemented directly in MATLAB, it must be developed in future. This model can be used for either industrial purpose or for any small-scale area.

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