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Short Circuit Fault Detection and Protection of DC Microgrid

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Abstract: ***Due to inherent advantages of DC system over AC system such as compatibility with renewableenergy sources, storage devices and modern loads, Direct Current Microgrid (DCMG) has been one of the key research areas from last few years. In the proposed work power has been produced by using solar pv and fuel cell which is combined on the same dc bus and given to a dc load. DC microgrid protection is an important part of power system studies. The basic think which is required for protection is to get to know, where it should be provided and which component must be used. So, to address the challenges of dc microgrid protection accurate faultdetection strategies, fault current limiting method and dc circuit breaker has been used. The electricity load of the microgrid is satisfied by the power form fuel cell, pv array and battery altogether. 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 in charging mode.***
Keywords: Short Circuit , DC Microgrid, PV, MPPT, Battery etc.

I. INTRODUCTION

A microgrid is a local electrical grid containing sources and loads. The microgrid is a cluster of distributed resources which have the ability to operate autonomously. Microgrids are being usedto bring electricity into areas where transmission lines cannot reach. A traditional system with generation in one place and then distribution at high voltages is designed for high energy density fossil fuels. Distributed generation can be used to increase the reliability of a system and allow for the integration of renewables. Distributed generation is a much more suitable method of electricity distribution for renewables due to their lower energy density as compared to fossil fuels and since the power generation 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 recent trend in renewables is to use distributed power sources and energy storage to form a microgrid. DC microgrids are not very widespread but have the potential to present many advantages in terms of facilitating renewable energy integration and improving power 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 directly connected to the DC bus and if an AC load is required an inverter would be needed in order to invert the DC bus voltage into a usable AC voltage. Batteries are typicallyused in DC microgrids due to their relatively cheap price and longer backup times. A longer backup time and low losses are desirable for energy storage technologies for microgrids which contain renewable energy generation in order for the load 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 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 shortduration.

II. PROBLEM STATEMENT

The solution for the protection issues of the DC microgrid is not readily available by a conventional method, for certain reasons such as bidirectional power flow in the microgrids, by withdrawing the fault current during the islanded mode of operation, renewable energy resources characteristics and their types. Hence the main problem of DC Microgrid is the protection issues.

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III. OBJECTIVE

The objective of this thesis is to propose a model for short circuit fault detection and protection of DC microgrid consisting of renewable energy generation. A DC microgrid model has been designed and simulated that comprises a protection model for multiple energy sources and equipments. The components of the DC microgrid and the protective devices will be modelled then whole DC microgrid will finally be simulated.

IV. METHODOLOGY

DC microgrid is a super high quality electric power system with using dc distribution. The main components of a microgrid are: Distributed generation sources such as photovoltaic panels, wind turbines, fuel cells, diesel and gas micro turbines etc. Distributed energy storage devices such as batteries, ultra-capacitors, etc., In addition, several distributed generations are also connected to DC line in the system through DC/DC converter.

Photovoltaic system (PV) is connected to DC grid via DC-DC boost converter. The DC voltageis fixed 500V. The boost converter is controlled by Maximum Power Point Tracking (MPPT) to keep its efficiency high. MPPT technique is used to improve the efficiency of the solar panel. MPPT controller is based on the “incremental conductance” technique. And then, battery & fuel cell is connected to DC distribution line through DC/DC converter. DC microgrid distributes DC power that transmit load side. DC load is connected to the DC grid.

1) Faults in DC microgrid -

Most of the faults that occur on power system of overhead lines are unsymmetrical faults which may consist of single line to ground fault and line to line fault. In this paper, line to line fault is analyzed.

2) Line to line fault -

This is most harmful fault for the system than single line to ground fault. This fault is rarely occurring in the system. In overhead distribution lines, a double line fault occurs when objects falling across the positive and negative line and shorted them. In underground cables, this fault occurs because of insulation failure. Line to line fault between positive and negative line is shown in fig 3.1.

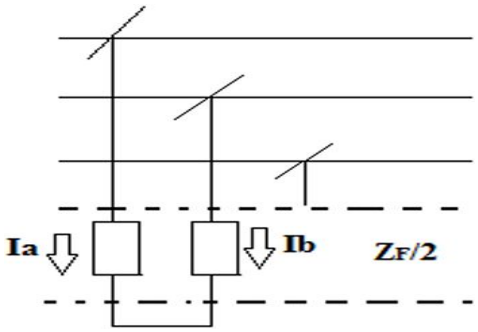


Figure 1. Line to line fault

In order to confirm the control strategies of the DC microgrid, computer simulations were carried out by using the MATLAB. The main parameters of this system show in Table 1 and the simulation circuit is shown in Figure 1.

Component	Rating
Solar PV	100 KW
Fuel cell	300 V,80A
Battery	250V
Boost Converter	C(i/p)=100µf, L=5mH,C(o/p)=12000µf
Bidirectional Converter	L=160.95mh,C=220µf
Relay	250A,90A,7A
DC Load	100Ω

Table 1 Rating of components

In order to confirm the control strategies of the DC microgrid, computer simulation was carried out by using the MATLAB.

In this research, grid connected system is used. At the source side, photovoltaic source (PV) andfuel cell are demonstrated and the battery for back up is taken and DC loads is connected at the load side.

V. SIMULATIONS AND RESULTS

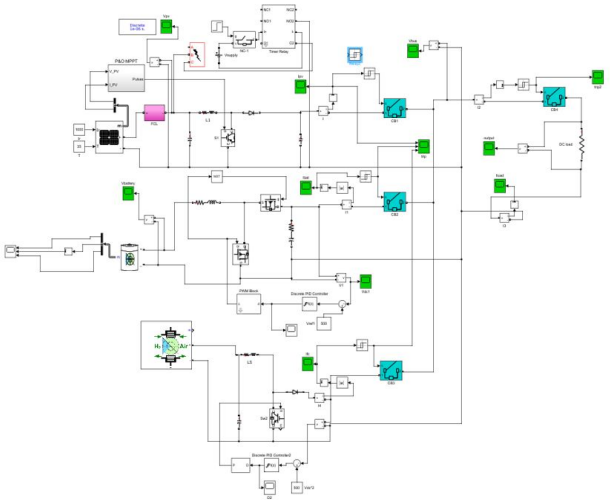


Figure 2. Simulation model for fault detection of DC microgrid

The above is the test system of the proposed topology with one PVA source, one fuel cell andone battery source connected in parallel feeding the DC load. The PVA is operated by MPPT technique connected to booster converter for voltage stability and fuel cell is also connectedwith booster
convert for voltage stability. Battery is connected with bidirectional DC-DC converter controlled by voltage-oriented control. The rated DC voltage is set at 500V.

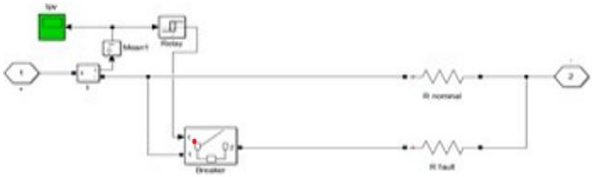


Figure 3. FCL internal modeling

The above is the modeling of FCL connected at PVA controlled by relay trip signal dependingon short circuit current.

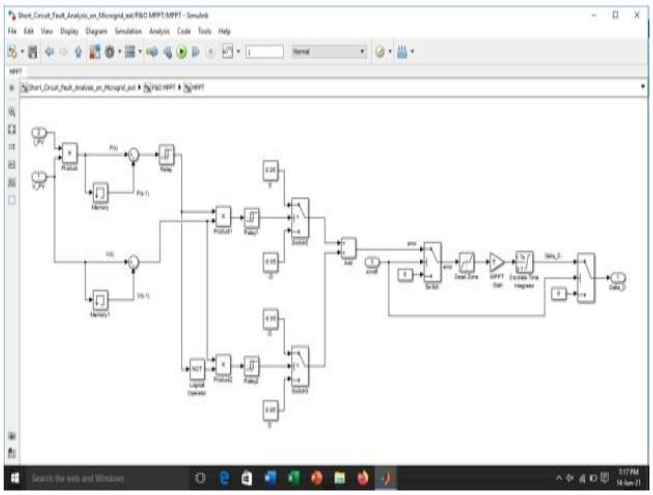


Figure 4. MPPT modeling in MATLAB/Simulink

Fig 4.3 shows the P&O MPPT modelling for extracting maximum power from solar PV and for giving pulse to IGBT of boost converter from duty cycle.

VI. RESULT ANALYSIS

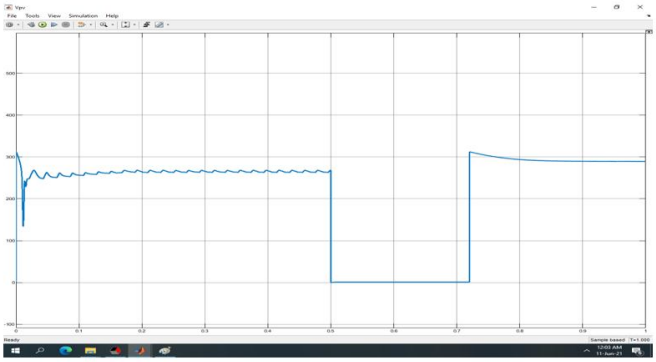


Figure 5. PV Source voltage magnitude

The test system is introduced with fault on PV source at 0.3 sec due to which voltage is reducedto zero and after 0.7 sec the voltage gets restore, maintaining constant supply to the load as shown in fig.5. Due to FCL the current of the PVA is not increased and maintained at nominalvalue.

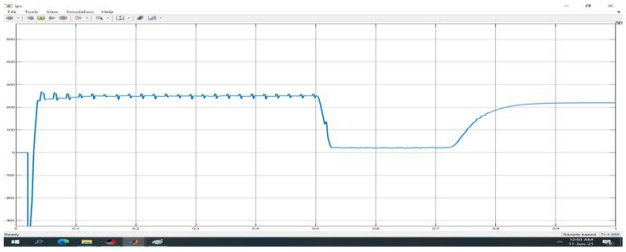


Figure 6. PV source current magnitude

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

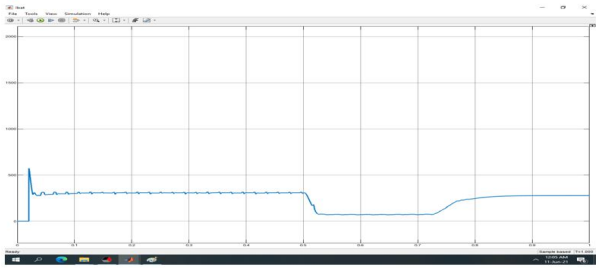


Figure 7. Battery current magnitude

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

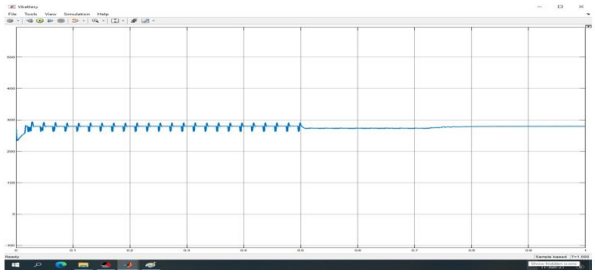


Figure 8. Battery voltage magnitude

Battery voltage is constant, as it continues to supply power to load during fault as well as duringnormal condition.

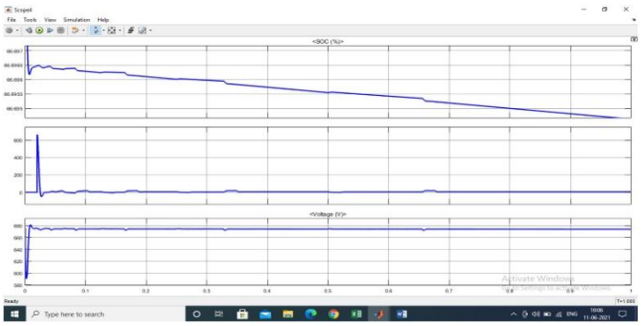


Figure 9. SOC of battery

Fig 9 shows the discharging of battery as it supplies power to the load. Initially, battery is charged up to 70% and slowly it starts discharging.

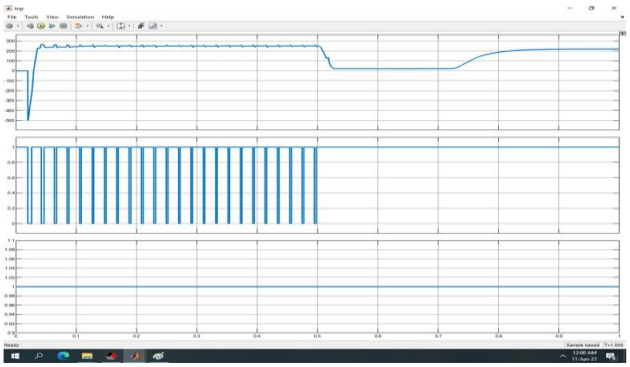


Figure 10 Trip voltage of energy sources

Fig 10 shows that when fault occurs on PV source at 0.5 sec it gets separated immediately with the help of circuit breaker and meanwhile fuel cell and battery continue to supply power to DC load. Using fault controller, the fault of PV source is removed and PV source voltage is restoredback normal.

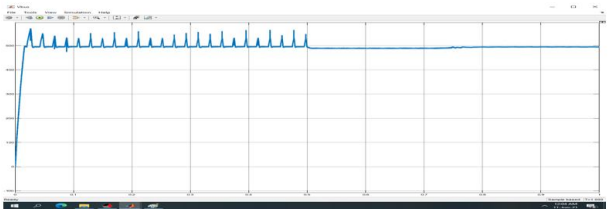


Figure 11. DC bus voltage

DC Bus voltage is constant even during faulty condition because fuel cell and battery continuesto supply power to the DC bus and load.

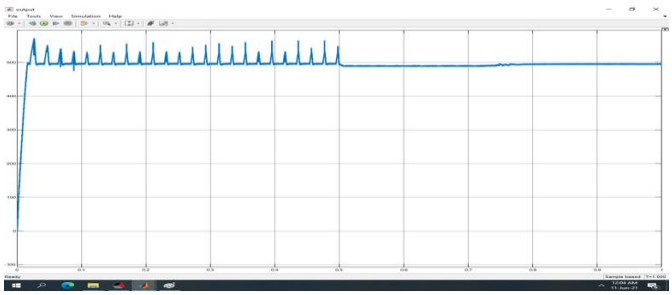


Figure 12. Output voltage

Similarly, Output Voltage is Constant.

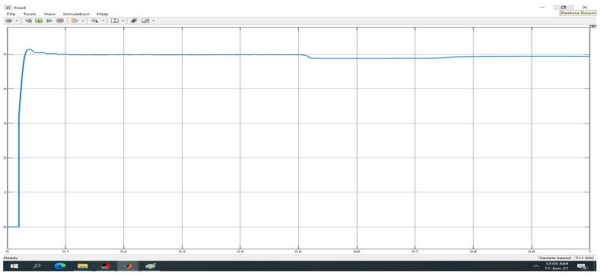


Figure 13. Load current

Similarly, load current is constant during faulty and normal condition as fuel cell and battery continues to supply power to load. Therefore, maintaining the reliability of DC microgrid system.

MATLAB/Simulink is used to design and simulate the individual components of the DC microgrid. In this DC microgrid system for short circuit fault detection and protection, as shown in fig.1.4 two generating sources are taken which are solar PV and fuel cell with battery 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 Maximum Power Point Tracker (MPPT) in order to extract maximum power from solar array during unfavorable condition. Solar PV is also connected with fault current limiter (FCL) to limit the fault current without complete disconnection. Solar PV and Fuel Cell connected to boost converter in orderto 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 furtheror damage any equipment.

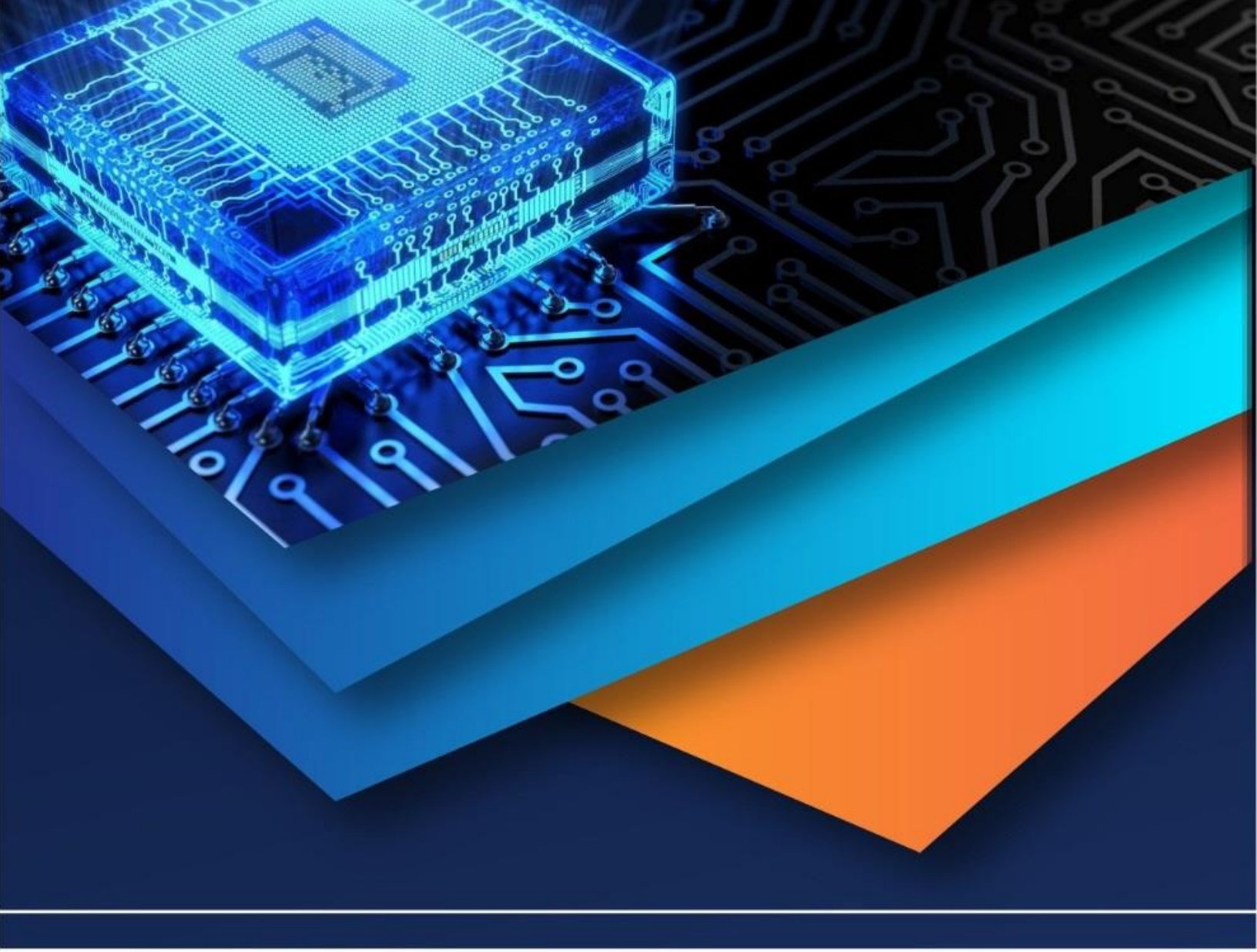
VII. CONCLUSION

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 DCmicrogrid 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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