Fault Analysis and Protection of DC Microgrid

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***Abstract*—In this paper, a ring-type DC microgrid is considered, and its features such as current and voltages are specified. The Fault in the system/grid and schemes that need to be addressed in modern power system involving DC Microgrid are studied. This study analyses and presents a comprehensive review of the DC microgrids protection. Additionally, the open-circuit fault in the system is overcome by implementing a ring configuration circuit for protecting the DC Microgrid circuit. In each part, a brief review has been carried out. Finally, future Scopes of the DC Microgrid protection and usage of the different circuit breaker in the future has been discussed. The DC Microgrid having ring configuration and its protection schemes using circuit breaker are simulated using MATLAB/Simulink platform and the results of the simulation will be analyzed. The results obtained from the output graph shows that the proposed method is effective in protecting the DC Microgrid. Even for high fault resistance values, different configuration methods can be used.**

Keywords—DC Microgrid; DC Fault Analysis; Protection Challenges; Circuit Breakers; DC Ring Microgrid

I. INTRODUCTION

DC Microgrid Protection is an important part of the power system studies. One of the major objectives of DC Microgrids is improving the overall reliability of the system. This is a complex challenge in DC Microgrid, but to overcome this complex challenge, and protection to it, requires various circuits with complicated designs to be added to the grid. The basic thing which is required for protection is to get to know are where it should be provided, which component to be used, what parameter shouldn't be altered while designing the circuit so that the DC Microgrid works as per the expectation.

DC Microgrid has numerous advantages compared to AC Microgrid, so designing an appropriate protection circuit for the DC microgrids remains to be a significant challenge. 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 paper, we have used a normal Circuit Breakers which are available in MATLAB Simulink, and by using the Power electronic devices like GTO we can increase the Switching time. Both active and passive methods are used in determining the fault location and it is even more demanding issue in DC microgrids because it's reactance and dc line resistance are presumably lower than that of the AC systems. When designing an appropriate fault detection strategy, the parameter which should be evaluated effectively are cost, computation, and performance. 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 micrgrids, 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 related to protection issues. Therefore, reliable protection scheme should be developed for the DC Microgrid acting in both grid and islanded mode of operation.

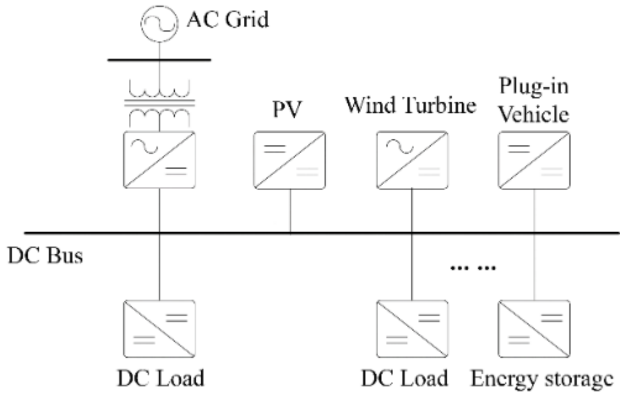

Fig.1: Diagram of a DC Microgrid [2]

DC microgrids provide advantages over AC Microgrids in terms such as efficiency, reliability, resilience and flexibility. And also, the advantages of the DC Microgrid are:

1. The overall residential loads that we are using are DC, or it can also operate with DC voltage.
2. DC Microgrid requires two current leads in comparison to the six current lead required by the AC Microgrid and hence losses are reduced in DC Microgrid. It lowers the need for refrigeration and it's cost-effective.
3. Cable losses are reduced by 15% as an absence of skin effect in DC Cable.
4. DC systems are safer than the AC systems.
5. Power transfer capability is more.
6. Less redundant stages for converters, hence reduces the losses and heat, as loads and resources are considered to be DC [2].
7. Power flow is more robust because multiple resources can connect to a bus.

This paper deals with 3 sections, the first section discusses the system under consideration, the second section describes Simulation results and analysis, the third section will be the conclusion.

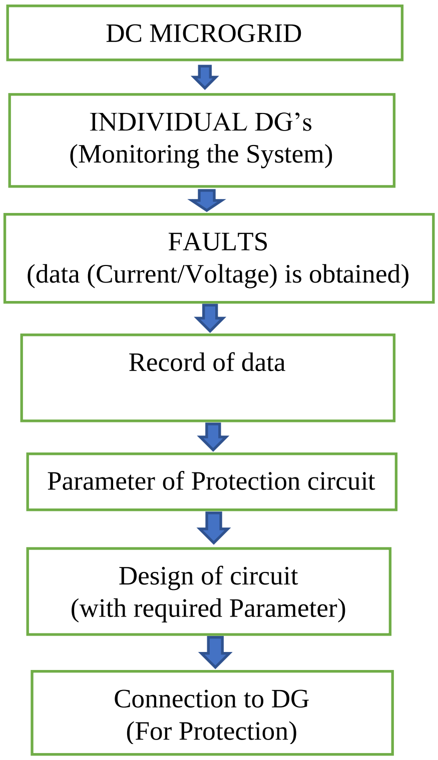

Fig2.Flowchart proposed for the Protection scheme

Faults are the abnormal conditions in the circuit, it can also lead to variation in fault voltage and current and this data we require to process and correct the circuit. That we need to monitor the fault current and voltages, and these currents and voltages will be used for setting the protection circuit. These conditions may vary with time, hence at every second the data get changed and should be recorded well, to design suitable protection scheme for the DC Microgrid. Thus, after monitoring and collecting the relevant data the protection schemes and protection devices can be selected because the newly developed circuit may cause new fault occurrence while previous are compensated. So, the cycle continues until it is favourable to the system load. Thus, to design a protection scheme for a grid system (especially for dc microgrid) is very difficult, the component used in the DC microgrid are power electronic devices, sensors, different distributed generations etc. Lot of work has been done in the area of DC Microgrid but less attention has been paid to the DC Microgrid protection area. DC system consists of many Distributed Energy Resource (DER) systems which involve photovoltaic, fuel cells and energy storage batteries and also load such as EVs, Light Emitting Diode which are natively powered by DC source. The DC systems have an additional advantage in power quality which impacts to the public utility grids. Power flow and frequency regulation are managed by cost-effective methods. "DC microgrids have a convenient mechanism for integrating Distributed Energy Resources with local loads into a fully integrated system. It has an interface to the AC electrical through a bidirectional AC to DC converter" [2].

II Simulation Results

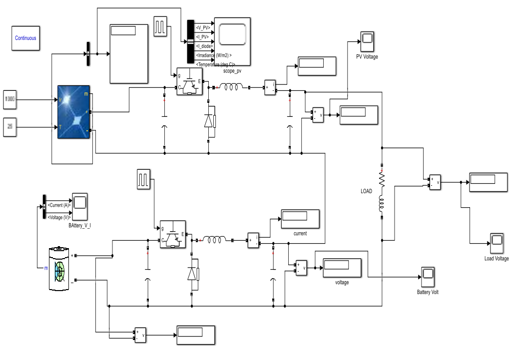

Fig3.Ring Configuration

The Simulation model in Fig3 shows a ring Configuration circuit and consist of a PV system, Battery and DC load. As shown PV-Array is provided with 1000 W/m^2(irradiance) at a constant temperature of here respective power of 210-350 watt is produced [18]. PV system is connected to DC load, to supply the power required by it and also battery if any unnecessary faults occur to the main distributed generated source, then backup power can be provided by it. Here the load is maintained by both PV System and Battery. Output Results are shown in Fig 4,5,6,7,8.

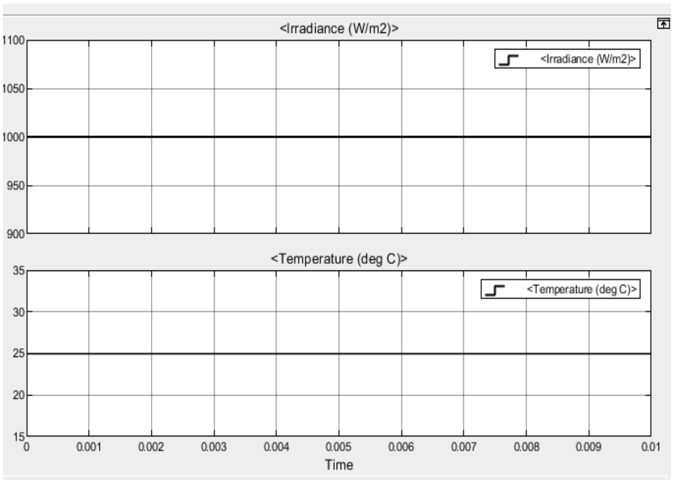

Fig4: Temperature and irradiance of PV Panel

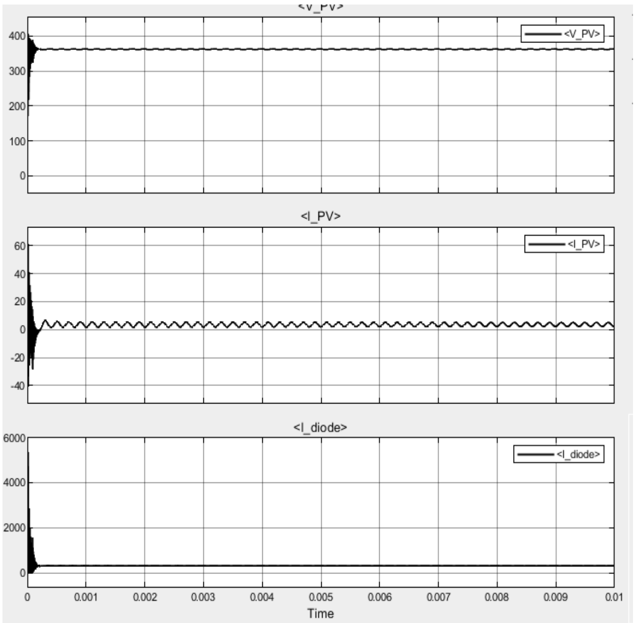

Fig 5: Voltage and Current variations in the PV Panel

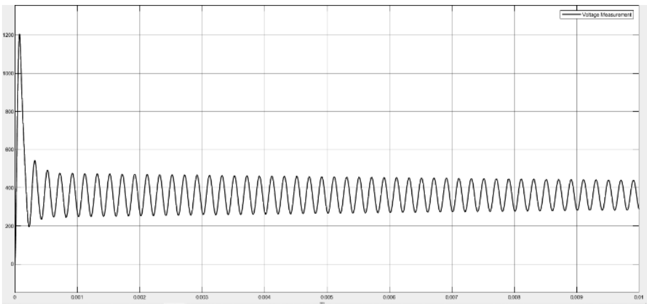

Fig6: Output Voltage of the PV System

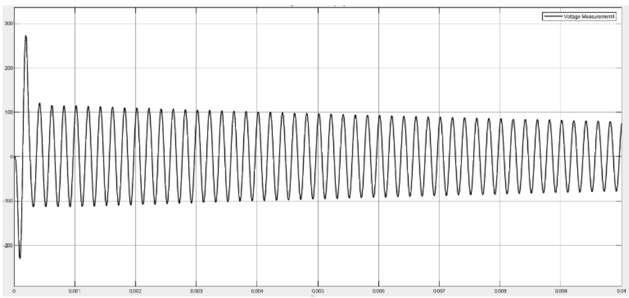

Fig7: Output Voltage of the Battery

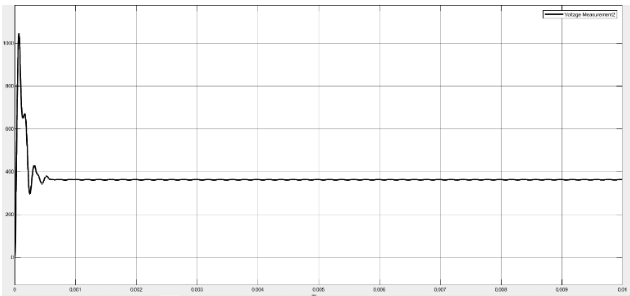

Fig8: Load Output Voltage

Fig (4,5,6,7,8), shows how a DG (PV Array) and energy storage device (Battery) provides the power to the DC Load and also the load voltage curve of the load, so we can observe the load operate at a certain voltage range.

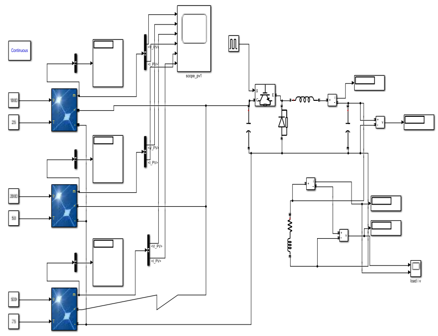

Fig9.Fault Circuit without using the Circuit Breaker

Simulation Model in Fig.9 shows a power dc load with three PV Systems having different power output at a given time.

PV Array	Irradiance (w/m^2)	Temperature (Celsius)
PV Array 1	1000	25
PV Array 2	2000	50
PV Array 3	500	75

All the PV System provide power to DC Load in parallel Connections which connects through a Boost converter. The load requirement is power /voltage to be maintained around 300V-400V, by all the systems connected to load through boost Converter, initially voltage peaks to a larger value (such as 1000) and a gradual decrease in it, hence initially there are certain changes for the system to be faulted at load end because of excess voltage supplied. Here we design a fault-less system to maintain the required voltage gradient at load. The Faulted graph for the system is shown in Fig10.

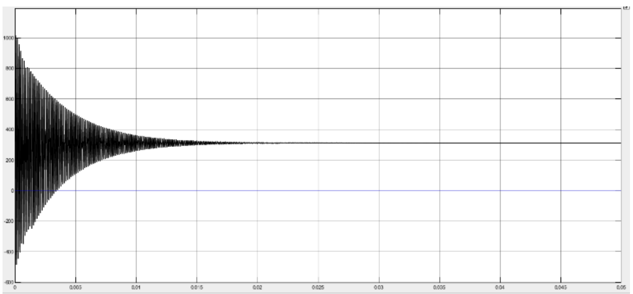

Fig10.The output obtained for the Fault Circuit

Fig 10 shows the output of the circuit designed by the three PV System and it provides power to the load so that it can be operated as required. Initially, certain Voltage spikes can be observed, which may lead to a fault at load side due to overvoltage. Thus, protection is required and it is designed and observed in Fig.11 by using the circuit breakers.

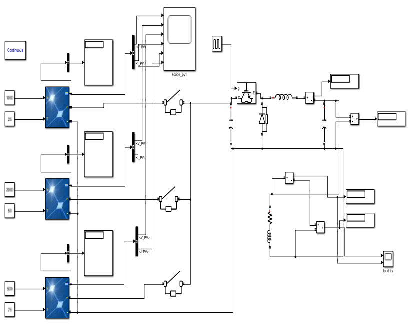

Fig11: Protection circuit by using the Circuit Breaker

As mentioned in the fault circuit (Fig 9) to avoid the voltage spikes causing fault across loads, we use Circuit Breakers (Breakers) (Fig.11) in the transfer of power to the boost Converter and finally to the load. In this, the breakers act at the respective period when the voltage spikes are larger and could cause damage to the system, as they break the circuit so the excessive voltage not required by the load can be driven out of the system and protects the system from the fault occurrence, So the breakers are used timely (for a brief period of time) and protect the overall system, the output results are shown in Fig 12.

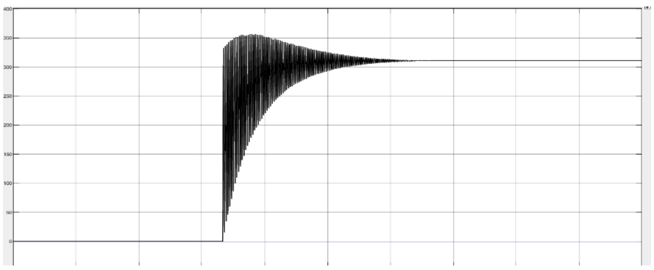

Fig12: The output of the Protection circuit using the circuit Breaker

The graph (Fig12) provides information about the voltage curve of the load, which is supplied with power by PV systems. In this, the initial voltage drop across it is zero for a certain time (i.e. Time until spikes are produced). Later the voltage settles at the range voltage required by the load. Thus, making it work smoothly.

III.CONCLUSION

This paper shows the Modelling and Simulation results for the protection of DC Microgrid. The specific requirements for their protection during fault occurrence was discussed. The stated methods provide essential knowledge for the proper design of the protective devices/protection circuit. It specifies that it can be modified to protects the DC microgrids. The simulations of the model and its output results signify the protection of DC Microgrid. In this paper, we have used a normal Circuit Breakers which are available in MATLAB/ Simulink, and by using the Power electronic devices like GTO we can increase the Switching time. In the future works, we can use Z Source CB, MCCB and vacuum CB for the protection of the DC Microgrid. As DC system protection lacks its standard and also guidance for its maintenance, hence these systems should be studied by further researchers. The below-mentioned topics should undergo development in future works:

- In DC Microgrid Current-based relays cannot be implemented directly hence, its types must be developed.
- Based on the nature of the DC faults in the systems protection method must be designed. AC Circuit Breakers and protection methods cannot be implemented in DC microgrids.
- A fault detection method in DC Microgrid should be developed and it should be independent of their fault impedance.
- Accuracy of the model can be increased by the dynamic behaviour of renewable energy.
- A smart Protection schemes should be provided such that it adopts the fault protection algorithm and can solve the protection problems due to variation in topologies

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