Faults Detection and Isolation in Demand Side of Direct Current Microgrid

[1]Vilas Bugade, [2]Ganesh Patil, [3]Pradeep K. Katti
[1,3]*Department of Electrical Engineering, Dr. Babasaheb Ambedkar Technological University, Lonere (Raigad), Maharashtra, India*
[2]*Dr.D.Y.Patil Institute of Technology, Pimpri, Pune, Maharashtra, India*

Abstract: **In conventional protection schemes of D.C. grid, the protection only is provided on A.C. side of the link using A.C. circuit breaker where A.C. and DC grids are interconnected, there were no any protection percolated on D.C. side. When fault occurs in D.C. system A.C .breakers sense and isolate whole D.C. link, causing completely de-energizing the D.C. link. Also, the current power electronic devices cannot survive or sustain high magnitude faults. Converters will shut down to protect themselves under faulted conditions. This causes unnecessary outage in the system. Also fault current is not extinguished quickly which is harmful for the converters. The objective of this innovation which presented in this paper is to detect and isolate only faulty section of the system and maintain supply continuity. This avoids the complete shutdown of whole system. Fault current in the isolated section is extinguished quickly through the diodes and resistors. It minimizes damage to the system. So healthy sections are operated without any disturbance and supply continuity is maintained through other buses.**

***Keywords—LVDC*, Microgrid, RES, MOSFET**

I. INTRODUCTION

The growing for the demand of electricity power increases complexity on generation and distribution system. This increase in demand causes imbalance, gap between supply and demand of power and creates large scarcity of non-conventional energy sources. To bridge the gap between supply and demand the renewable energy resources (RES) theaters vigorous role e.g. Solar PV, wind energy etc. This can serve by making it as Distributed Generation (DG) with RES are likely to become wide spreading in demand side management, due to environmental aspects as well as commercial benefits of DG. Increased penetration of DG in distribution networks also poses challenges and these will depend on a variety of factors, such as the generation technology, the voltage level the DG. Also it is associated with, the size of the producing plant and on the type of network (e.g. rural or urban).

A few cases of the challenges posed to distribution networks by DG include: i) DG changes current flows and shape of load cycle at their connection. This could make thermal ratings be surpassed. ii) DG can make framework voltage ascend beyond the acceptable limits. Iii) DG can add to fault level, which can raise the fault level over the rating of system hardware. iv) DG could bring about switch reverse power flows. v) DG could add to harmonics, and raise them.vi) Quick change of output brings voltage change or flicker.

In future with modern smartgrid technologies for theDGwill resolve balance between supply and demand through optimal power techniques [17]. Due to the power gap there is load shedding in many segments and this segment goes into dark, likewise numbers of individuals in segregated range live without power. Power generate from DG, is exchanged through the A.C. or D.C. network. At the point when this power is provided to the segregated zone, there is huge extension for D.C. small scale framework rather than A.C. framework [1].

Low voltage DC framework (LVDC) is emerging idea in distribution system. The micro grid framework is a little scale appropriated control framework comprising of distributed energy sources and loads, and it can be promptly coordinated with the renewable energy sources [4]–[6]. Because of the distributed nature of the micro- grid approach, the association with the central dispatch can be evacuated or limited, It can be operated in the network associated mode, operation in the autonomous (islanded) mode, and ride-through between the two modes [7],[8]. There is straightforward and simple control and huge improvement in protection technology of A.C. framework when contrasted with D.C. framework. Be that as it may, it confronts the issue like skin impact, proximity impact, and reactive power control; additionally losses are more in A.C. matrix. Then again D.C. smaller scale matrix having less loses, and D.C. framework can deliver 1.41 times more power when contrasted with AC framework with a similar cable cross segment [8], [9].

II. LITERATURE REVIEW

The first step in this innovation was an extensive study of up-to-date relevant literature and background material. This was necessary in order to deepen for understanding of the topic and highlight any new interesting or useful facts. For the purpose of this topology, mainly available literature on low voltage dc (LVDC) grid, Protection of LVDC grid, current protection methods, status of D.C. micro-grid protection and fault detection and isolation techniques were read and consulted.

Out of the vast literature survey that has been referred, few important ones are noted below which are worth in my dissertation. Paper gives the information about the importance of distributed generation. [1] It focuses on how distributed generation reduces pressure on distribution and transmission line and comparison of A.C. and D.C. grids with their advantages and disadvantages. Information about different components of D.C. grids is given in [2] which relate the micro-grid, for interconnection of distributed generation and utility. It describes micro-grid efficiency, advantages and its control, micro-grid constructed and tested. Information on the energy storage system and the power electronic interface included in micro sources of the CERTS[4]micro grid. This shows necessity of energy storage to micro sources. Details of the energy storage module, the power electronic interface and the corresponding controls are described**. T**he protection of LVDC grid [5] LVDC micro-grid, faults in D.C. grid, current fault isolation techniques are explained. The classification of D.C. grid according to voltage level and their benefits Different layouts for the D.C. grids and the associated technical issues are highlighted.[7] The related components of micro-grid, design of micro-grid, protective devices, different faults given in [8]. Theprotections of D.C. grid and fault current limiting methods are proposed [10] and further from this literature the topology is described in next sections for protection with simulation model of it.

III. LOW VOLTAGE DC (LVDC) MICROGRID

The schematic chart of a LVDC micro-grid is shown in Fig. 1. As the figure demonstrates, A.C. loads are interfaced to the lattice through power converters. All DER require control converters. General D.C. loads may require control converters if the voltage rating is not the same as the rated grid voltage. Control converters are utilized for altering generator and load voltages to the standard grid voltage, if required [7].

The LVDC is appropriate for the system, for example, workplaces with PC loads or rural power system [10].A D.C. micro-grid is also suited for integrate a range of DER units, such as internal combustion engines, gas turbines, micro-turbines, photovoltaic panels, fuel cells, and wind-power.

A large portion of these sources are not appropriate to work with fixed frequency, or fixed D.C. voltage, so they require power converters to interface with either D.C. or A.C. electrical distribution systems. The LVDC have many focal points when contrasted with A.C. distribution framework. Control gadgets converters are utilized for association of load to either A.C. or D.C. transport for power conversion. At the point when load associated with transport is D.C., for example, PCs, fluorescent light, TV sets; D.C. transport requires fever power conversion stages [10][11]. Since power conversion stages is less, losses in transformation likewise lessened. The greater part of the resistive load can be associated with either A.C. or D.C. bus.

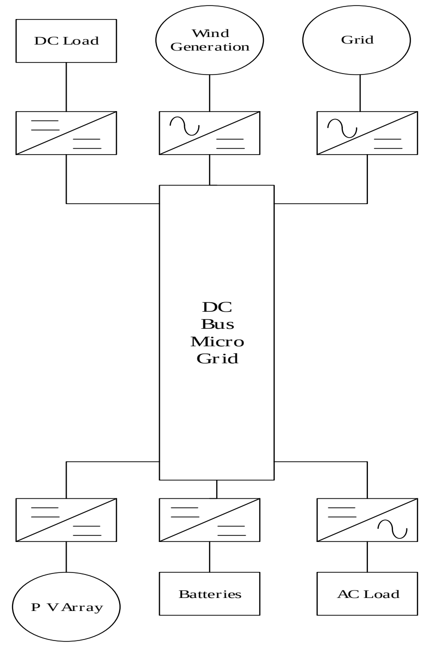

Fig. 1: D.C. Bus Microgrid

In any case, the A.C. stack can't interface directly to D.C. micro-grid [8].

Now the power system should tries to shift and decentralization of the grid is beginning to gain attention. This would mean that traditional loads would install local generation often called independent power producers (IPP).The local generation can be used to supply the local loads, thus decreasing the transmission losses. When the IPP produces more electricity than the load consumes it can sell the power back to the utility, and when production falls short the grid is there to make up the difference. It is in this application that LVDC has started to gain attention. Although, the electric grid is primarily A.C. many of the loads in our homes and businesses are D.C. This means that each of these devices requires a small A.C.-to-D.C. converter,which increases losses. If local IPP's produce D.C. power that the loads are able to use directly it would decrease these conversion losses. This is especially advantageous for data centers where almost all of the equipment is D.C. [10].

IV. POSSIBLE FAULTS IN DC GRIDS

4.1 Line to Ground fault

A line to ground fault (ground fault) occurs when the positive or negative line is shorted to ground. In overhead lines faults may occur when lightning strikes the line. This may cause the line to break, fall to the ground and create fault. In this situation the fault is always permanent and the line must be isolated for repair. Ground faults may also occur by objects falling onto the line, such as trees, providing a path to ground. If the fault persists the line would have to be taken out of service until the fault path can be cleared.

Underground cable is almost completely immune to line-to-line faults, as insulation, conduit and the earth separate the cables. However, they can still occur. The insulation of the cable can fail due to improper installation, excessive voltage/current, and exposure to the environment (water, soil, etc) or cable aging.This cause for imbalance of D.C. link voltage between the positive and negative poles, as the voltage of the fault line begins to fall and high currents flows.

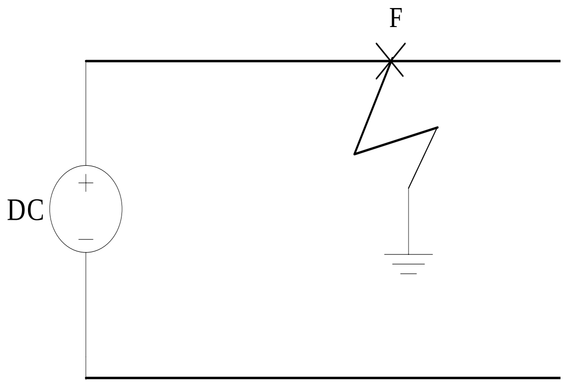

Fig. 2: Single Line to ground fault.

These high currents may damage the converter [12]. A single line to ground fault on positive terminal of line is shown in Fig.2.

4.2 Double line fault (Line to line fault)

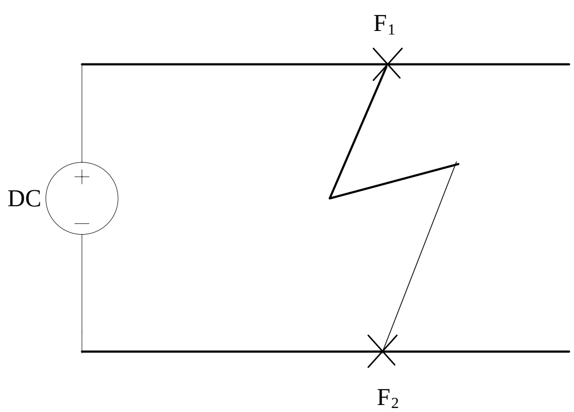

Fig. 3: Line to line fault.

A line to line faulton a cable-connected system is less likely to occur on the cable. In an overhead system, line-to-line faults can be caused by an object falling across the positive and negative line, they may also occur in the event of the failure of a switching device causing the lines to short. A switching fault, which is independent of how the converter stations are connected together, causes the positive bus short to the negative bus inside the converter [12]. Fig. 3 depicts the line to line faultbetween positive and negative line.

4.3 Overcurrent

While overcurrent protection is important during line-to-line and line-to ground faults, it must also operate when the system is being overloaded. Overload conditions may occur in two-terminal systems when the load increases past the rating of the converter or as a result of a fault on another part of the system. For example, if three VSC's are feeding a common load and one VSC is dropped due to a permanent fault, the remaining two must supply the load. This will result in elevated currents that may overload the converters. In this situation the overcurrent protection would need to operate. Another option to avoid a wide spread blackout would be to shed non-critical loads [12].

4.4 Fault Isolation Scheme

Considering problem of conventional protection circuits instead of shutting down the whole system or limiting the bus current, the presented scheme detects the fault and separates the faulted section so that the rest of the system keeps operating. The loop-type D.C. bus is suggested for the presented scheme to make the system robust under faulted conditions. It has also been reported that the loop-type bus has a good system efficiency especially when the distribution line is not long [16].

V. PROTECTION SCHEME

Here MOSFETs used as a circuit breaker/ power switch. An MOSFET circuit breaker (MOSFET-CB) utilizes the blocking capability of the solid-state device. For two-terminal systems, MOSFET-CBs can be placed at each converter station, one on the positive line and one on the negative line. Fast acting D.C. switches are used in conjunction with the MOSFET-C.B., which is used to isolate the line once the fault current has been cleared. It should be noted that the switch cannot break current and may only be opened once the fault has been extinguished. As with A.C., the D.C. current of each line and the D.C. voltage of each capacitor will be sensed. Once the control system senses a fault on the line, an appropriate MOSFET-C.B. will receive a gate signal to block the current. Once the fault current has been extinguished the fast acting D.C. switches will open, isolating the line. The advantage of using an MOSFET-C.B. is that the entire converter is not shutdown in the case of a ground fault or line to line fault. This allows the faulted line to be isolated and have the system continue to run monopolar. The MOSFE-C.B. also opens faster than A.C. counter parts [15].

In this scheme current sensors placed at the sending end and receiving end of D.C. micro grid. These current sensors continuously sense the line current and give information to the controller. In healthy operating condition the current at the two end of line is approximately same. But when single line to ground or the line to line fault occurs in the bus, there is a current difference between the two ends of the line is occurs. When this current difference exceeds the threshold value, controller will operate and gives command to the power switches. The MATLAB-simulink model for proposed scheme is shown in Fig. 4.1 and depicts only one bus protection

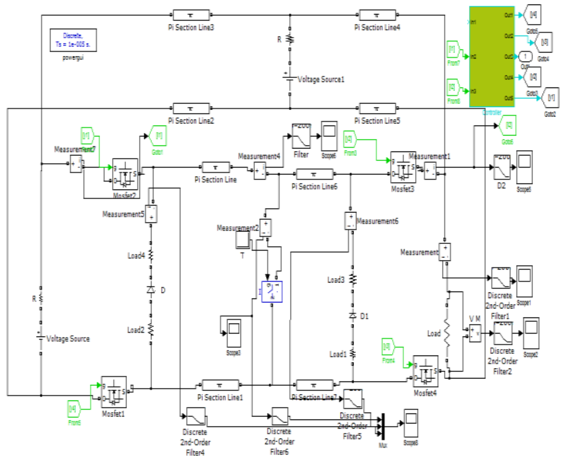

Fig. 4: MATLAB-simulink model

The proposed scheme comprising, current sensors placed at two ends of bus and near to power switches/circuit breaker as shown in fig.5. The controller operates when currents different between two ends exceeds a set value.

$$i_{operation} = i_1 - i_2$$

Where, i_1 and i_2 is the line current at each end of the bus segment. When fault occurs in the system, current difference exceeds the threshold value. Then the controller sends the appropriate commands to power switches/circuit breaker, so that the faulted segment can be separated from the system. The system uses the differential relaying principle for monitoring only the relative difference of input and output current of a segment, it can detect the fault on the bus regardless of fault current amplitude or power supply's delivering capacity. Once the faulted segment has been isolated, the load voltage will be restored and remainder of the system can continue to operate on the loop-type bus. Even with multiple faulted segments, the system can operate partially if the segments from some power sources to loads are intact. The possibility of the fault around the device connection point can be minimized, if the sensors are installed as close to the connection point as possible.

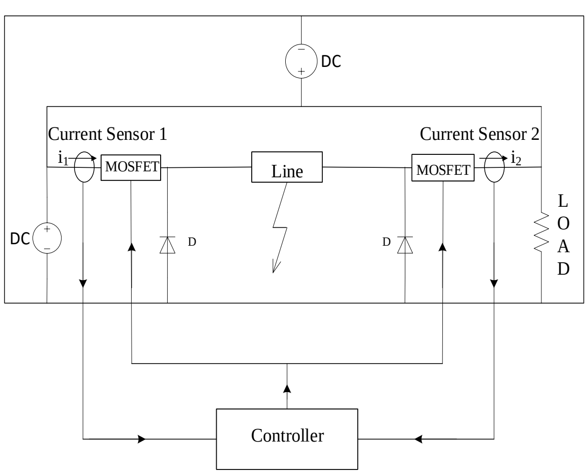

Fig. 5: Placement of current sensorand power switches.

When faulty section is isolated using switches (SW), the fault current in this section is extinguished through the freewheeling resistors (R), and diode (D) is used for the freewheeling path fig.5. In healthy operating condition freewheeling diodes are in blocking mode, and there is no current passing through the freewheeling path. But when circuit breaker opens and isolates the faulted bus, diodes comes into conduction mode. Fault current freewheel through diode, resistors and extinguished. How the fault current flows in the system and how this current extinguished through freewheeling path for single line to ground fault and line to line fault are shown in Fig. 6 and 7 respectively.Fault current extinction rate depends on resistance of freewheeling path. If the freewheeling resistance is large, current dissipates largely and fault current is extinguished quickly.

Advantages of autonomous scheme:

i) Automatically sense the fault current.

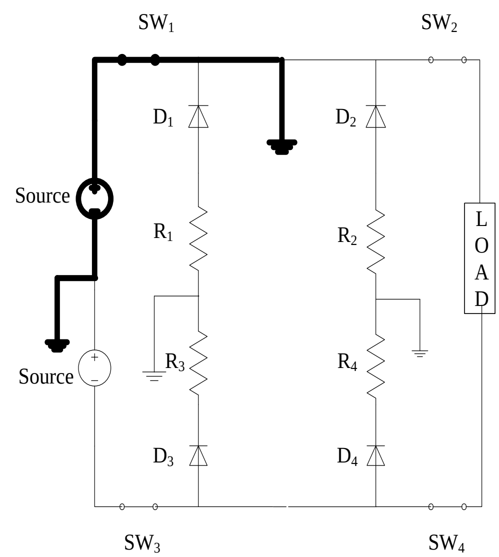

Fig. 6. Fault current path in single line to ground fault

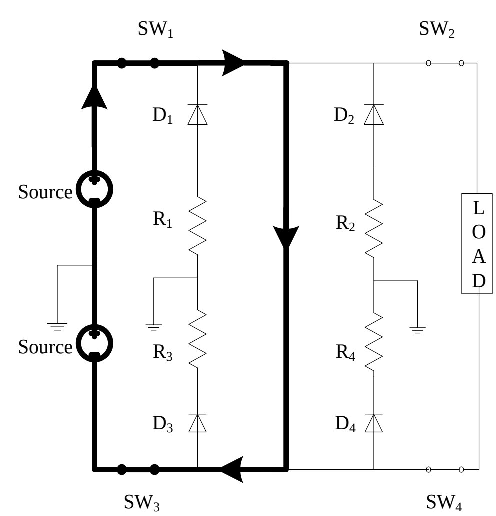

Fig.: 7 Fault current extinction in line to line fault.

ii) No need of person for fault isolation

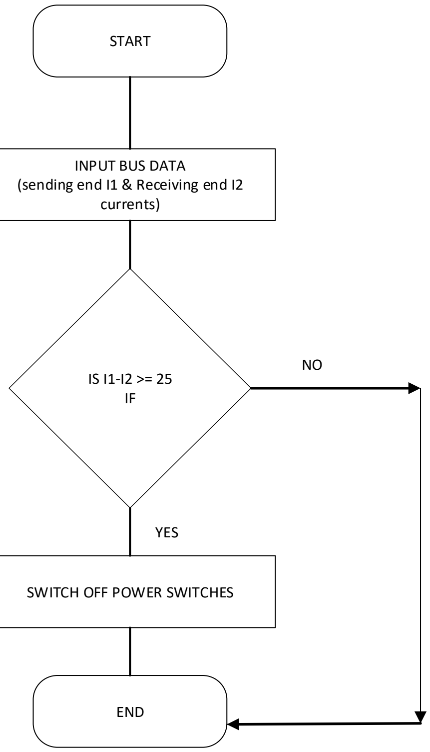

Fig.8. shows a flow chart of proposed protection scheme

iii) Fast operation iv) Quick extinction of fault current, suitable for converters. v) Quick restoration of the system.

VI. PRACTICAL RESULTS

Table 1 Observation Table

Normal operating condition		
Source 1		**Source 2**
0.180 A		0.100 A
Sending End(CS 1)	Receiving End (CS 2)	
0.180 A	0.180A	

Fault Condition		
Source 1		**Source 2**
0.500A		0.500 A
Sending End(CS 1)	Receiving End (CS 2)	
0.500 A	0 A	

After Protection Scheme Operation		
Source 1		**Source 2**
0.00 A		0.50 A
Sending End(CS 1)	Receiving End (CS 2)	
0.00 A	0.00 A	

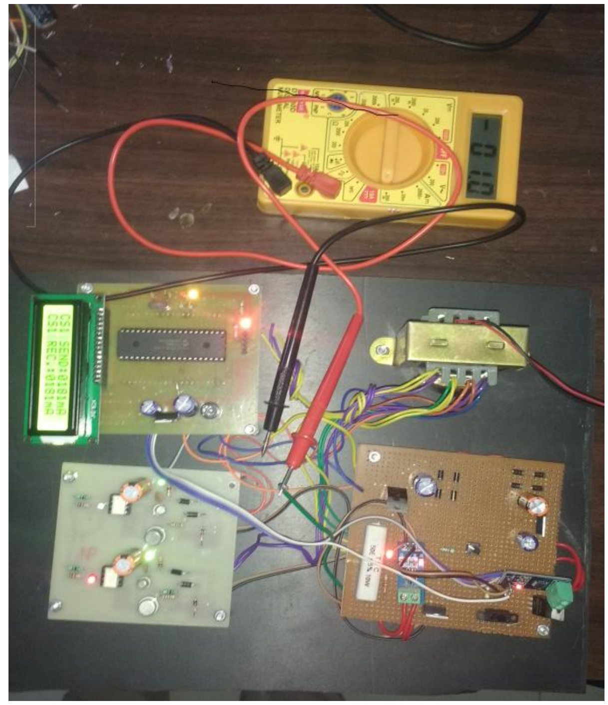

Fig.9. Implementation Diagram

6.1 Advantages

i) Losses are less.

ii) Reduction in conductor size.

iii) Faulty section is isolated.

iv) DC link not completely de-energizes.

v) Continuity of supply is maintained by other buses.

vi) Fault current is extinguishes quickly.

vii) Protection of converters.

viii) System restore quickly.

6.2 Disadvantages:

Increases cost of the line, if loop systemis used.

6.3 Applications:

This scheme is useful for the isolated area which is supplied through the distributed generation.Also it is suitable for the A.C. and D.C. micro grid interconnections.

VII. CONCLUSION

The smart grid and distributed generation micro-grids are recently become an integral part of our electric power grid. DC micro-grids have proven to be a sustainablechallenger to AC micro-grids. Protection of the DC bus is an integral part to the DC micro-grid, and must be able to isolate faults with minimal impact to the overall system. It can be seen that the conventional techniques require a complete shutdown of the DC bus. This is not suitable for critical loads.

Fault detection and isolation scheme for low-voltage DC-bus micro-grid system is presented in this paper. The loop-type bus allows multiple paths for power to flow when a section has been isolated. Successful fault detection and isolation was shown using MATLAB simulations and hardware results. Though the fault detection and isolation proves the scheme is successful for suppressing fault current, locating the faulty and isolating the zone for line-to-line fault.Also, when a fault occurs and a source is removed from the micro-grid, the remainder of the sources must accommodate the load. This will improve stability in the grid and maximize efficiency from all of the sources.

REFERENCES

[1]. R. Dugan, T. McDermott, “Distributed generation,” IEEE Ind. Appl. Mag., vol. 8, no. 2, pp. 19-25, Mar./Apr. 2002.

[2]. “Comparison of Costs and Benefits for AC and DC Transmission” OAK RIDGE NATIONAL LABORATORY.

[3]. Roberto Rudervall, J.P. Charpentier, Raghuveer Sharma “High Voltage Direct Current (HVDC)Transmission Systems Technology Review Paper” Presented at Energy Week 2000, Washington, D.C, USA, March 7-8, 2000.

[4]. R. Lasseter and P. Paigi, “Microgrid: A conceptual solution,” in Proc. 35th Annu. IEEE Power Electron. Specialists Conf., 2004, pp. 4285–4290.

[5]. H. Nikkhajoei and R. Lasseter, “Distributed generation interface to the CERTS microgrid,” IEEE Trans. Power Del., vol. 24, no. 3, pp. 1598–1608, Jul. 2009.

[6]. F. Katiraei, R. Iravani, N. Hatziargyriou, and A. Dimeas, “Microgrids management,” IEEE Power EnergyMag., vol. 6, no. 3, pp. 54–65, May/ Jun. 2008.

[7]. J. Park, J. Candelaria, ”Fault detection and isolation in low voltage DC-Bus microgrid system” IEEE Trans. Power Del., vol. 28, no. 2, pp. 779-787, Apr. 2013.

[8]. M. Saeedifard, M. Graovac, R. Dias, and R. Iravani, “DC power systems: Challenges and opportunities,” in Proc. IEEE Power Energy Soc. Gen. Meeting, July 2010, pp. 1–7

[9]. P. Salonen, P. Nuutinen, P. Peltoniemi, and J. Partanen, “LVDC distribution system protection: Solutions, implementation and measurements,” in Proc. 13th Eur. Conf. Power Electron. Appl., 2009, pp. 1–10.

[10]. D. Salomonsson, L. Soder, and A. Sannino, “Protection of low-voltage DC microgrids,” IEEE Trans. Power Del., vol. 24, no. 3, pp. 1045–1053, Jul. 2009.

[11]. R. Cuzner and G. Venkataravmanan, “The status of DC micro-grid protection,” in Proc. IEEE Ind. Appl. Soc. Annu. Meeting, Oct. 2008, pp. 1–8.

[12]. J. Candelaria and J.-D. Park, “VSC-HVDC system protection: A review of current methods,” in Proc. IEEE/Power Energy Soc. Power Syst. Conf. Expo., Mar. 2011, pp. 1–7.

[13]. P. Cairoli, R. Dougal, U. Ghisla, and I. Kondratiev, “Power sequencing approach to fault isolation in dc systems: Influence of system parameters,” in Proc. IEEE Energy Convers. Congr. Expo., 2010, pp. 72–78.

[14]. L. Tang and B. Ooi, “Locating and isolating DC faults in multi-terminal DC systems,” IEEE Trans. Power Del., vol. 22, no. 3, pp. 1877–1884, Jul. 2007.

[15]. R. Schmerda, S. Krstic, E. Wellner, and A. Bendre, “IGCTs vs. IGBTs for circuit breakers in advanced ship electrical systems,” in Proc. IEEE Electric Ship Technol. Symp., Apr. 2009, pp. 400–405.

[16]. M. Saisho, T. Ise, and K. Tsuji, “Configuration of DC loop type quality control center,” in Proc. Power Convers. Conf.,2002, vol. 2, pp. 434–439.

[17]. Vilas Bugade, Pradeepkatti“Optimal Power Flow Approach for Cognitive and Reliable Operation of Distributed Generation as Smart Grid” SGRE, Scientific Research Publications, 2017, Vol.8, 87-98.