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Fault Protection of a Loop Type Low Voltage DC Bus Microgrid

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ABSTRACT: As the number of DC loads are increasing in our daily uses, the low voltage DC (LVDC) distribution system is becoming important. The conventional protection scheme for DC Bus Microgrid uses circuit breaker on AC side, on occurrence of fault AC circuit breaker opens and this cause's complete shutdown of DC link and introduces a forced outage in the system. A new protection scheme for DC Bus micro-grid against line to line fault is presented in this paper. It avoids the complete shutdown of the DC link and continuity of supply is maintained through other buses, as loop type distribution is considered. The current sensors placed at both end of transmission line continuously check the current at both side. When fault occur in line, current difference occurs at both end of line. Controller detects the current difference and opens the Solid state C.B. (IGBT's) which is placed at both ends. Hence the continuous supply is maintained through another line. The proposed scheme is verified through MATLAB Simulink.

KEYWORDS: DC bus micro-grid, Distributed generation (DG), IGBT's, Fault, Current Sensor (CS), Controller.

I. INTRODUCTION

Nowadays there is a large gap between supply and demand of power, and also there is large scarcity of non-renewable sources. To cope up with this, there is need to increase the generation from renewable energy resources like wind energy conversion systems and solar energy systems etc. Also distributed generation with renewable energy systems are likely to become wide spread in the future, due to environmental demands, as well as commercial benefits of DG.

Because of the power gap there is load shedding in many sections and this sections goes into dark, also number of people in isolated area are live without electricity. Power generate from distributed generation, is transferred through the AC or DC grid. When this power is supplied to the isolated area, there is large scope for DC micro-grid instead of AC system [1].

Conventionally AC line is used for transmission and distribution of power, because of easy protection scheme. In contrast, the protection of DC grid is difficult because of no current zero crossing. But the DC grid having number of advantages over AC line and it is desirable to use DC line. The main advantage of DC microgrid is reduced losses so higher efficiency than AC. Due to change in energy generation patterns from non-renewable to renewable it is convenient to use DC link, as most of them generate power in DC form.

II. LOW VOLTAGE DC (LVDC) MICROGRID

Low voltage DC grid (LVDC) is emerging concept in distribution system. The microgrid system is a small-scale distributed power system consisting of distributed energy sources and loads, and it can be readily integrated with the renewable energy sources [2]–[3]. Due to the distributed nature of the micro- grid approach, the connection to the central dispatch can be removed or minimized, It can be operated in the grid-connected mode, operation in the autonomous (islanded) mode, and ride-through between the two modes [4], [5]. There is simple and easy control and large development in the protection technology of AC system as compared to DC system. But it faces the problem like skin effect, proximity effect, and reactive power control; also losses are more in AC grid. On the other hand DC micro-grid having less loses, and DC system can deliver 1.41 times more power as compared to AC system with the same cable cross section [5], [6].

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The schematic diagrams of a LVDC micro-grid is shown on Fig. 1, As the figure indicates, AC loads are interfaced to the grid through power converters. All DER require power converters. General DC loads may require power converters if the voltage rating is not the same as the rated grid voltage. Power converters are used for adjusting generator and load voltages to the standard grid voltage, if required [4].

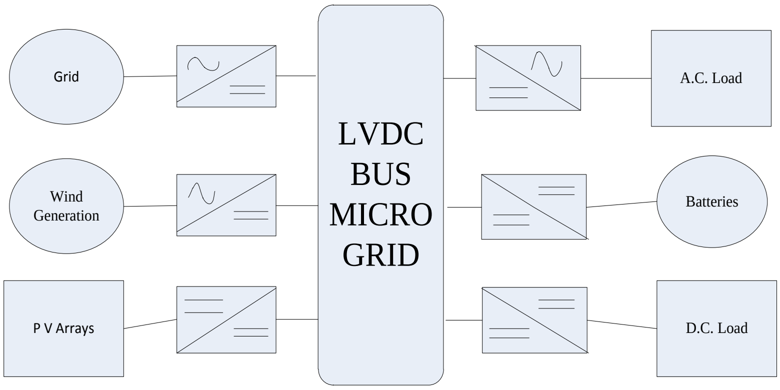

Fig.1 DC Bus Microgrid.

The LVDC is well suited for the system such as offices with computer loads or rural power system [7].A DC 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. Most of these sources are not well suited to operate with fixed frequency, or fixed DC voltage, so they require power converters to interface with either DC or AC electrical distribution systems. The LVDC have many advantages as compared to AC distribution system. Power electronics converters are used for connection of load to either AC or DC bus for power conversion. When load connected to bus is DC such as computers, fluorescent lamp, TV sets; DC bus requires fever power conversion stages [7]-[8]. Since power conversion stages is less, losses in conversion also reduced. Most of the resistive load can be connected to either AC or DC bus. But the AC load cannot connect directly to DC micro-grid [5].

III. CONFIGURATION OF LVDC MICROGRID

DC micro-grid may be unipolar type or bipolar type. The main components used in LVDC micro-grid are: sources, converters energy storage and loads.

A. Loads

The electrical appliances today are designed to operate with AC, but many of them can run on DC without modification. All resistive loads like heaters, incandescent lamps, stoves, operate with both AC and DC, and the output power is equal if the RMS values are the same. All electronic loads like computers, fluorescent lamps with electronic ballast, flat screen TV, battery charger, which all internally use DC, have a bridge rectifier to convert AC to DC. This rectification will introduce current harmonics, which have a negative effect on the power system, neutral conductors become overloaded and protections malfunction. All these electronic loads can directly be supplied with DC. Rotating loads driven by a universal machine, or frequency controlled machines can also be supplied with DC. Loads with inductive parts cannot be supplied with DC, since DC creates a constant increasing current through it. Also loads with mechanical breakers designed for AC voltage cannot be supplied with DC.

B. Source

The number of alternative generation sources connected to the distribution system increases. Some of them, like photovoltaic and fuel cells, produce DC, and they can easily be connected to a DC distribution system directly, or through a DC/DC converter. Micro turbines, generating high-frequency AC, which is very suitable to convert to DC due to the high frequency, is also easy to connect to a DC system. Connecting the generation to an AC system using converters generating a synchronized sinusoidal ac current is more complicated, regarding both design and control [7].
Both AC/DC and DC/DC converters are used in the LV micro- grid, where AC/DC converters are used to interconnect the AC micro-grid and the DC micro-grid. These converters need to generate sinusoidal ac voltages and currents, and be able to control the bidirectional power flow. Furthermore, the converters must have galvanic isolation, and be able to handle grid disturbances, such as voltage dips with unsymmetrical voltages. Finally, the converters should have high

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efficiency. Different DC/DC converters will be used to connect different sources and loads to the DC micro-grid. DC/DC converters can be built simpler compared with AC/DC converters, which results in lower cost and higher efficiency [7], [9].

C. Converters

Both AC/DC and DC/DC converters are used in the LV micro- grid, where AC/DC converters are used to interconnect the AC micro-grid and the DC micro-grid. These converters need to generate sinusoidal ac voltages and currents, and be able to control the bidirectional power flow. Furthermore, the converters must have galvanic isolation, and be able to handle grid disturbances, such as voltage dips with unsymmetrical voltages. Finally, the converters should have high efficiency. Different DC/DC converters will be used to connect different sources and loads to the DC micro-grid. DC/DC converters can be built simpler compared with AC/DC converters, which results in lower cost and higher efficiency [7], [9].

D. Energy Storage

For a critical loads reliability has become a hot issue. A power outage with a duration longer than a couple of hours has a great impact on our modern society, which is highly dependent on electric power. Most public services need computers and communication equipment to operate, but fail in case of a power outage. Some back-up systems are installed to feed the most critical loads but after a few hours they need maintenance to continue to operate. If the communication systems do not work it is difficult to arrange and perform the service. A distribution system which could be operated either connected to the large power grid utilizing all its advantages or in island in case of disturbances, would solve the above mentioned problem. In case of a disturbance of the supplying main grid, the distribution grid is disconnected from the main grid, and all sensitive loads are supplied with the local energy storage and the local generation [9].

IV. POSSIBLE FAULTS IN DC GRIDS

For DC system two types of faults exist, line-to-line and line-to-ground. A line-to-ground fault occurs when a path between the positive or negative pole and ground is created, Shown in fig (2). A line-to-line fault occurs when a path between the positive and negative line is created, shorting the two together, Shown in fig (3). A line-to-ground fault is the most common type of fault.

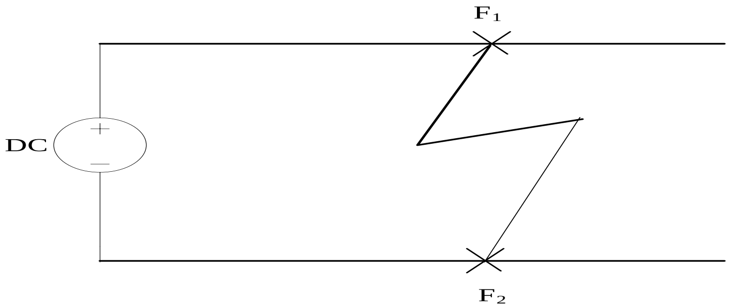

Fig.(2) Single Line to ground fault.

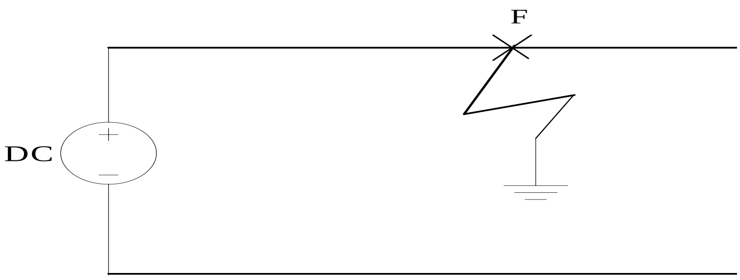

Fig.(3) Line to line fault.

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V. CONVENTIONAL FAULT ISOLATION TECHNIQUES

The common practice in DC power systems is not to install any protection on the DC side, and protection only provide on AC side using AC circuit breakers. Upon fault detection the AC CBs that link the AC and DC systems are opened, and disconnect DC link from AC grid. However, this method completely de-energizes the DC system until the fault is removed and the systems can be re-energized. It works for HVDC and medium-voltage DC (MVDC) transmission systems where the DC system is a conduit between the AC systems and loads. However, this method can create unnecessary out ages in LVDC micro-grids where multiple sources and loads are connected to a common bus [10], [11].Fuses also used for protection, but fuses have limitations and ac circuit breaker cannot use in DC systems [4].

VI. NEW FAULT ISOLATION TECHNIQUE

The new scheme detects the fault and separates the faulted section so that the rest of the system keeps operating. The loop-type DC 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 [12].

Here IGBTs used as a circuit breaker/ power switch. An IGBT circuit breaker (IGBT-CB) utilizes the blocking capability of the solid-state device. Fast acting DC switches are used in conjunction with the IGBT-CB, 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 AC, the DC current of each line and the DC voltage of each capacitor will be sensed. Once the control system senses a fault on the line, an appropriate IGBT-CB will receive a gate signal to block the current. Once the fault current has been extinguished the fast acting DC switches will open, isolating the line.

The Insulated Gate Bipolar Transistor (IGBT) uses the insulated gate (hence the first part of its name) technology of the MOSFET with the output performance characteristics of a conventional bipolar transistor, (hence the second part of its name).The advantage gained by the insulated gate bipolar transistor device over a BJT or MOSFET is that it offers greater power gain than the standard bipolar type transistor combined with the higher voltage operation and lower input losses of the MOSFET.

In this scheme current sensors placed at the sending end and receiving end of DC 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.

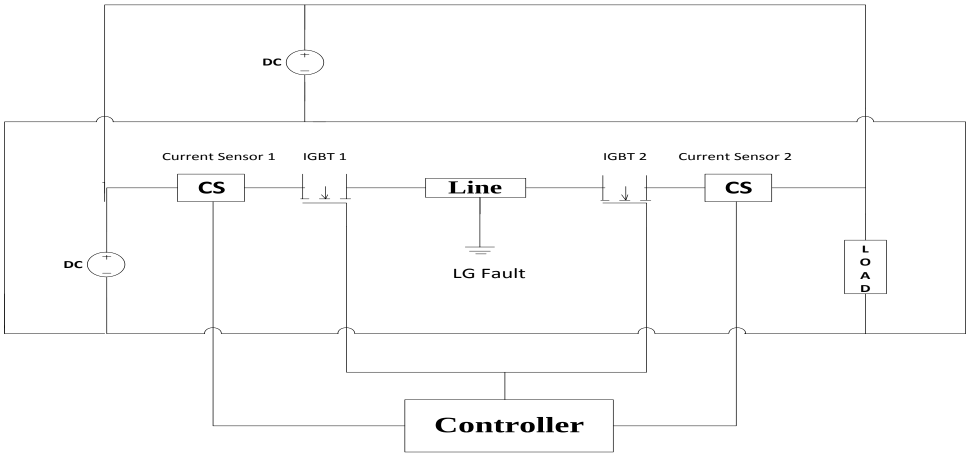

Fig.4 Placement of current sensor and power switches.

Fig.4 depicts only one bus protection. It is shown that, current sensors placed at two ends bus and near to power switches/circuit breaker (IGBT). The controller operates when currents different between two ends exceeds a set value.

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

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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. And the controller sends the appropriate commands to power switches/circuit breaker, so that the faulted segment can be separated from the system. Because this system uses the differential relaying principle 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 feeding 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. shows a flow chart of proposed protection scheme

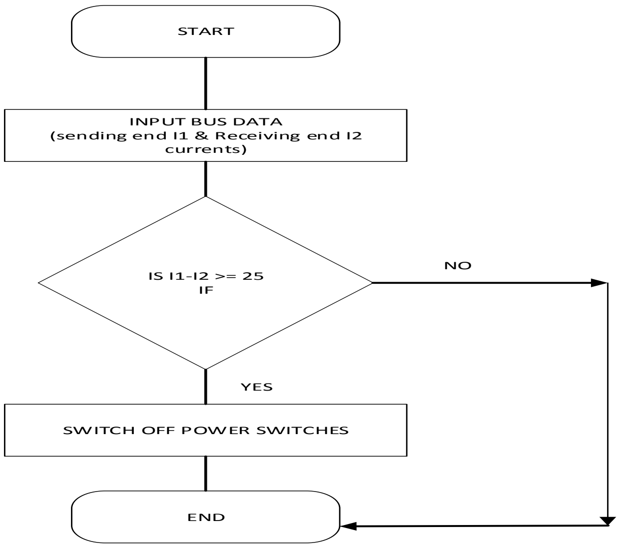

Fig.5 Proposed scheme flow chart.

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. 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 isolate the faulted bus, diodes comes into conduction mode. Fault current freewheel through diode, resistors and extinguished.

VII. SIMULATION RESULT AND DISCUSSION

MATLAB-Simulink model created for a 400 meter bipolar dc bus with constant 120 volt dc supply between two terminals. A line-to-line fault in the middle of the line is simulated at 0.02 sec. The fault current magnitude depends on the impedance of the fault path. The currents at each end of the segment which has been identical before fault. When fault occurs in the system current at the both ends of segment shows clear difference. On this current difference controller will operate and opens the power switches, considering speed of controller and switching devices is fast. The simulation parameters of system are given in Table 1.

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Parameter	Specification
Bus voltage	120V
Bus length	400m
Line resistance	121mΩ/km
Line capacitance	12.1nF/km
Line inductance	0.97mH/km
Freewheeling resistance	50 Ω
Load	2 KW

Table 1 Simulation Parameters.

The simulation results are shown in Fig.6 for line to line fault. Fig.6 (a) Shows that when there is no fault in the system i.e. in normal operating condition voltage across the load is constant, no disturbance in the system. When fault occurs at 0.02 second, voltage across the load is falls down rapidly. It is seen in the Fig 6 (b), when protection is applied to the system the controller will operate on current difference and opens the switches in 0.025 second. The voltage is immediately restore and the faulty section is isolated. The faulty bus is switched out from the operation and other buses will take care the load.

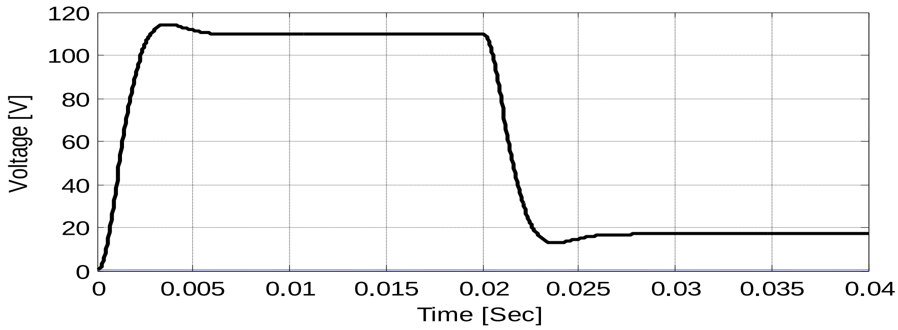
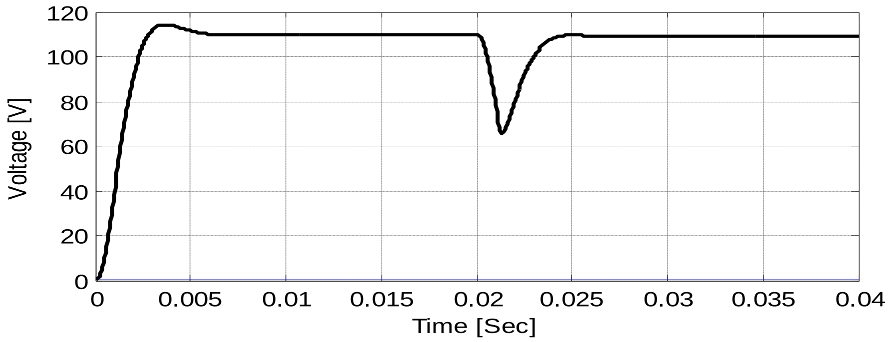


Fig. 6 (a) Load voltage without protection



. Fig. 6 (b) Load voltage with Protection.

Fig. 6 (c) depicts that before occurrence of fault load current is constant. But during faulty condition load current is falls down quickly and it remains as it is if protection is not used. When said scheme is applied, section under trouble is isolated and load current is again maintained through loop system, as shown in Fig. 6 (d).

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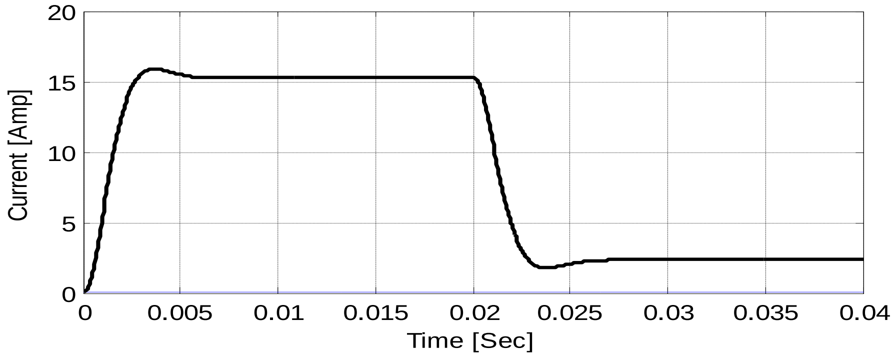
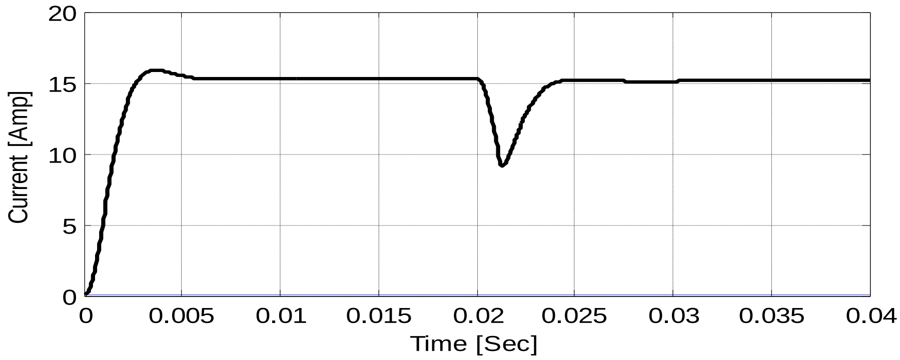


Fig. 6 (c) Load current without protection



. Fig. 6 (d) Load current with Protection.

Bus current is normal during healthy condition, it is very high on the occurrence of fault, and it remains high without protection is shown in Fig. 6 (e).

Fig.6 (f) depicts the fault path current and also the current in the freewheeling path. When there is no fault in the system, no current difference occurs at the two ends of line and there is no controller action. Therefore zero current flows through the freewheeling path. But when fault happen in the system current difference at the two ends of line is occurred. The current sensors sense the difference if, this difference exceeds a defined value the controller will operate and switches are opened. When switches are opened diodes starts conduction, freewheeling current flows through it and extinguished through resistors. Depending upon the value of resistors the rate of fault current extinction is determined. If high value resistors are used the fault current extinguish quickly.

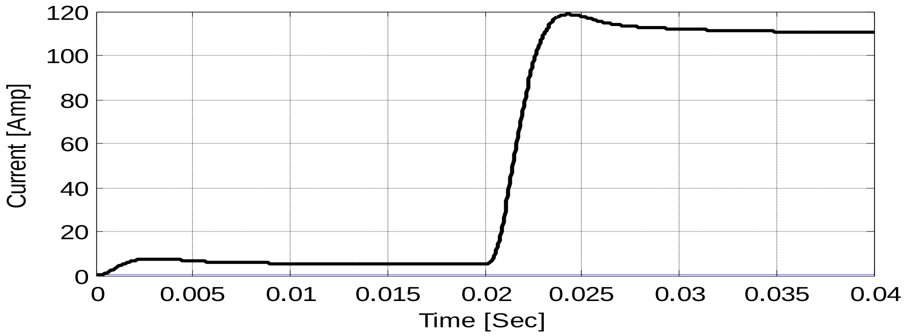


Fig. 6 (e) Fault bus current without protection.

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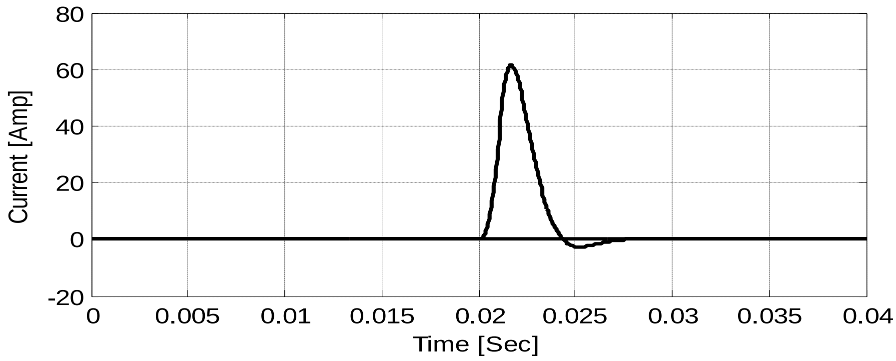

Fig. 6 (f). Fault path current.

VIII. CONCLUSION

With the new interest in green energy, the smart grid and distributed generation micro-grids may soon become an integral part of our electric grid. DC micro-grids have proven to be a viable competitor 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.

The new fault detection and isolation scheme for low-voltage DC-bus micro-grid system is shown here. 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. Though the fault detection and isolation proves successful for suppressing fault current, locating the faulted zone 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] R. Lasseter and P. Paigi, “Microgrid: A conceptual solution,” in Proc. 35th Annu. IEEE Power Electron. Specialists Conf., pp. 4285–4290, 2004.
[3] F. Katiraei, R. Iravani, N. Hatziargyriou, and A. Dimeas, “Microgrids management,” IEEE Power EnergyMag., vol. 6, no.3, pp. 54–65, May/ Jun. 2008.
[4] 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.
[5] M. Saeedifard, M. Graovac, R. Dias, and R. Iravani, “DC power systems: Challenges and opportunities,” in Proc. IEEE Power Energy Soc. Gen. Meeting, pp. 1–7, July 2010.
[6] 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., pp.1–10, 2009.
[7] 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.
[8] R. Cuzner and G. Venkataramanan, “The status of DC micro-grid protection,” in Proc. IEEE Ind. Appl. Soc. Annu. Meeting, pp. 1–8,Oct. 2008.
[9] 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., pp. 1–7, Mar. 2011.
[10] 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., pp. 72–78, 2010,
[11] 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.
[12] 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.