New Scheme for Protection of DC Micro grid

Ganesh Patil [1], M. F. A. R. Satarkar[2], Gorakshanath Abande [3]

[1]Department of Electrical Engineering, Dr. B. A. T. University, Lonere, Maharashtra, India
[2]Department of Electrical Engineering, Dr. B. A. T. University, Lonere, Maharashtra, India
[3]Department of Electrical Engineering, Dr. B. A. T. University, Lonere, Maharashtra, India

ABSTRACT— The AC distribution system is adopted because of simple and easy protection scheme. In contrast, the protection of DC grid is difficult because of no current zero crossing. The main advantage of DC microgrid is reduced losses so higher efficiency than AC. Conventional protection techniques in DC microgrid completely de-energies the DC link. A new protection scheme for DC micro-grid against line to line fault is presented in this paper. The scheme isolates only faulty section from the DC grid. Healthy sections are operated without any disturbance and supply continuity is maintained in a loop type system. The current sensor placed at both ends of transmission line continuously monitors the current. Because of fault, current difference occurs in two ends of line. Controller detects this current difference and opens the power switches. To meet the requirement of fast interrupting time and high short-circuit current withstanding capability, IGBTs used as power switches. MATLAB-Simulink results for said scheme are presented in this paper. This scheme is most suitable for distributed power generation and distribution of power in isolated areas.

KEYWORDS— DC distribution, Distributed generation, DC bus micro-grid, Fault protection, Current extinction.

I. INTRODUCTION

The ever increasing demand of power causes the imbalance between supply and demand. The gap between supply and demand is increasing. At the same time, there is large scarcity of non-renewable sources. Because of this imbalance the community in isolated areas lives without electricity. The electrified area also faces problem of power cuts. To fulfill this increasing demand, there is a need to increase the penetration of renewable energy resources like solar energy systems, wind energy conversion systems, hydro energy system and other distributed energy sources [1], [2]. In isolated areas, there is more scope for development of DC microgrid instead of AC systems where distributed generation has more advantages.

The microgrid is a distribution level network of generators and loads, it can exchange power with other networks [3]-[5]. Microgrid may be grid connected orstandalone so connection to central grid are reduced. The microgrid can be 1) AC bus or 2) DC bus systems [6], [7]. The DC distribution system faces problems regarding protection like interruption of dc arc, less protection equipment, standards and guidelines, location of fault [8]. Apart from this DC microgrid having less losses can deliver 1.41 times more power than AC system for same cross sectional area of conductor. In DC system skin effect is almost negligible while AC system faces problems like reactive power control, proximity effect, skin effect, and more power loss. But there is a large development in AC system protection technology. Also AC system is simple and easy to control [7], [9]. The diagram of DC bus micro-grid is shown in Fig. 1.
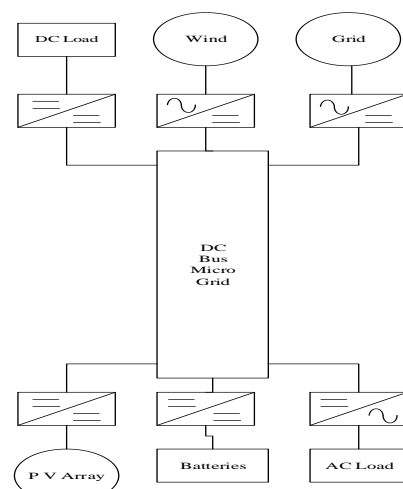

Fig. 1. DC bus microgrid.

II. DC MICROGRID

Low voltage DC (LVDC) grid is emerging concept in distribution system. Offices with computer load or isolated power system and rural power system are well suited for LVDC [8]. When load connected to AC bus power electronics converters are required for power conversion. If load connected to DC bus is DC such as TV, computers, fluorescent lamps; DC bus requires less power conversion stages [3], [8]. Since power conversion stages are less, losses in conversion also gets reduced.

III. FAULTS IN DC SYSTEM

DC grid may be unipolar with ground as return path or bipolar with positive and negative terminal. Fig. 2(a) and 2(b) depicts unipolar and bipolar grid respectively.
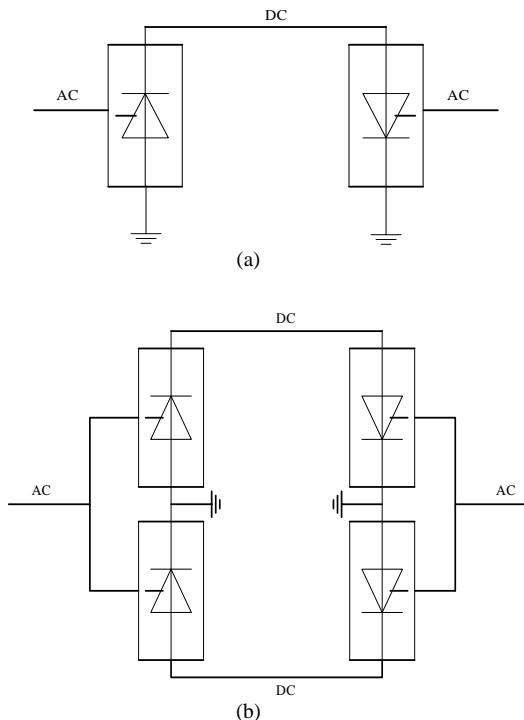

(a)

(b)

Fig. 2. DC grids (a) Unipolar. (b) Bipolar

A. *Single line to ground fault*

A single-line to ground fault is shown in Fig. 3. This is most common type of fault. This fault reduces the reliability and continuity of supply. When lightning strikes on transmission line one of the conductor may break either positive or negative and fall on the earth. This causes the line to ground fault. And the line is out of operation till fault is unclear. It may also occur when objects falling on line and providing ground path for current [10].
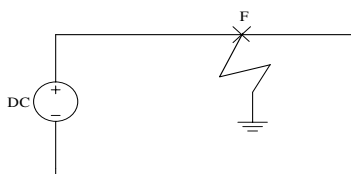

Fig. 3. Single line to ground fault.

B. *Line to line fault*

This is most harmful fault for the system than single line to ground fault. This fault rarely occurs in the system. In overhead transmission a double line fault occurs when objects falling across the positive and negative line and shorted them. In underground cables this fault causes because of insulation failure [10]. Line to line fault between positive and negative line is shown in Fig. 4.
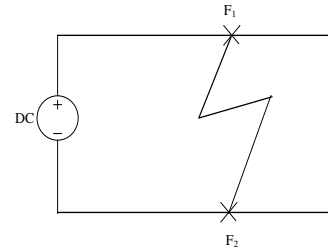

Fig. 4. Line to line Fault.

C. *Fault isolation schemes*

i) Conventional fault isolation scheme

Protection is provided on AC side where AC and DC grid is connected. During fault, AC circuit breaker operates and completely de-energies the DC link. The part of the system which is under normal condition also goes out of operation. This causes the unnecessary outages in the healthy system. [11], [12].

ii) New fault isolation scheme

The new protection scheme isolates only faulty section instead of isolating complete DC link. This scheme uses IGBT as circuit breaker because of fast switching operation and high current withstand capability against short circuit currents [13], [14]. This is explained in section IV.

IV. NEW FAULT ISOLATION SCHEME

The proposed protection scheme is shown in Fig. 5. This scheme isolates only the faulty section of DC microgrid. The other buses continue to provide power to load. This results in maintaining the supply continuity to the load. To achieve this, a loop type bus system is suggested. When the distribution system is not so long the loop type system has good efficiency [15].

In proposed scheme current sensor continuously senses and monitors the current from the two ends of line and provides information to the controller. In normal operating condition the current at the two ends of line is nearly same. The current difference occurs when any fault occurs on the line. Under fault condition the controller operates and gives command to the IGBTs to isolate faulty section from healthy section.
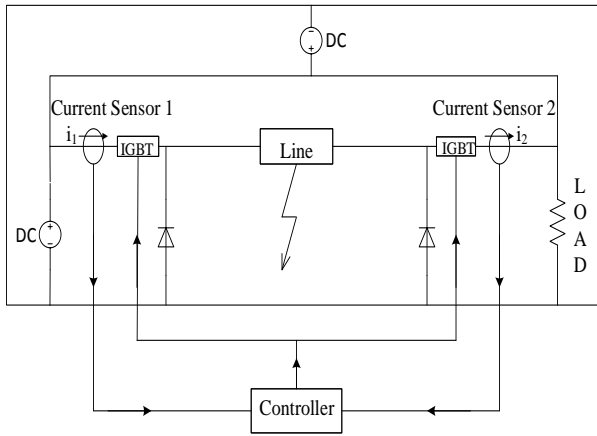
Fig. 5. Proposed protection scheme.

Fig. 5 depicts only one bus protection. The controller operates when two currents are different

$$i_{operation} = i_1 - i_2 \qquad (1)$$

Where i_1 is the sending end current and i_2 is the receiving end current. Depending on controller action, IGBTs are opened and isolates the faulty section and supply continuity is maintained through other buses with loop type system [6]. When faulty section is isolated using switches (SW), the fault current in this section is extinguished through the freewheeling resistors (R) and diode (D). Fault current path and freewheeling current path for single line to ground fault and line to line fault is shown in Fig. 6.

Fault current extinction depends on the freewheeling path resistance. When the freewheeling path resistance is large, fault current can be extinguished quickly [6].
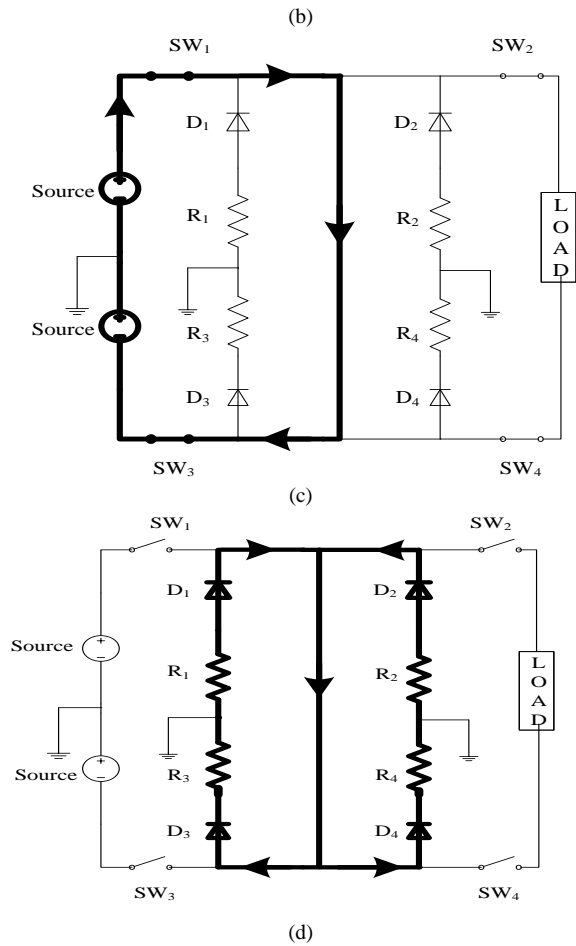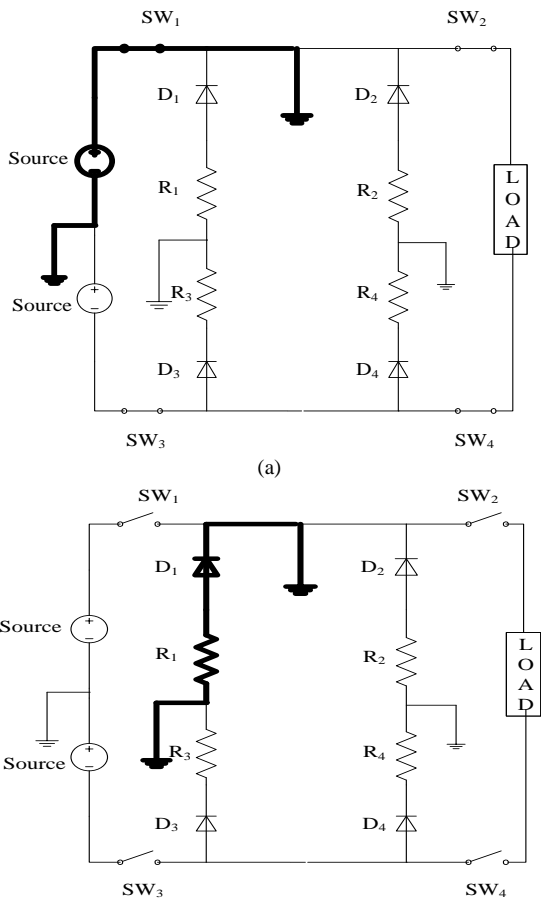

(b)

(c)

(d)

Fig. 6. Fault current path and its extinction in proposed scheme. (a) Single line to ground fault. (b) Fault current extinction in single line to ground Fault. (c) Line to line fault. (d)Fault current extinction in line to line fault.

V. RESULTS

MATLAB-Simulink model for a bipolar DC bus with constant 240 V supply between two terminals is created. The two sources are connected to feed a common load. A line to line fault is created in the middle of the bus 1. It is assumed that the controller will operate IGBTs in 0.025 second considering controller and switching devices are fast [6]. Simulation results are shown in Fig. 7 for line to line fault. Line parameters of system are given in Table 1.

(a)

TABLE 1: LINE PARAMETERS

Parameter	Specification
Load	10 KW
Freewheeling resistance	50 Ω
Line resistance	121mΩ/km
Line capacitance	12.1nF/km
Line inductance	0.97mH/km
Bus voltage	240V

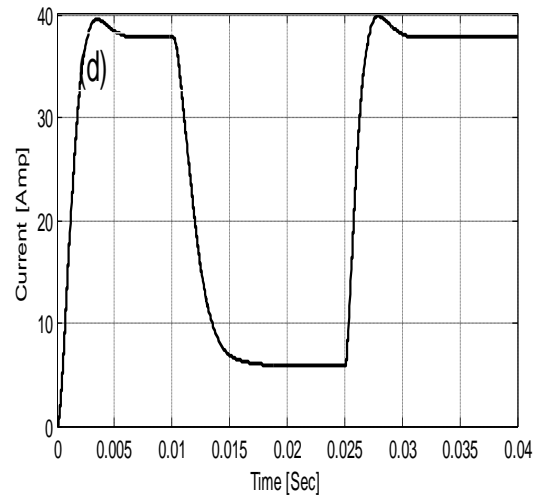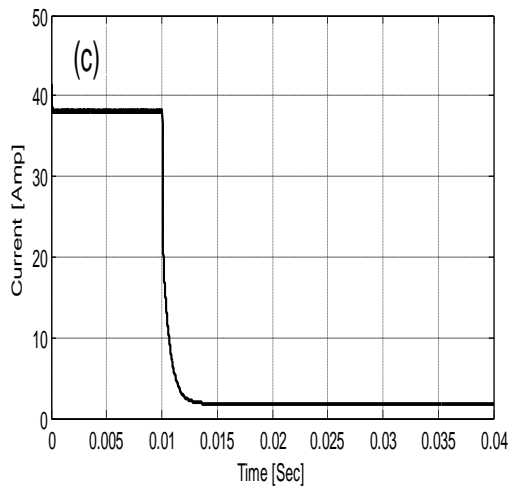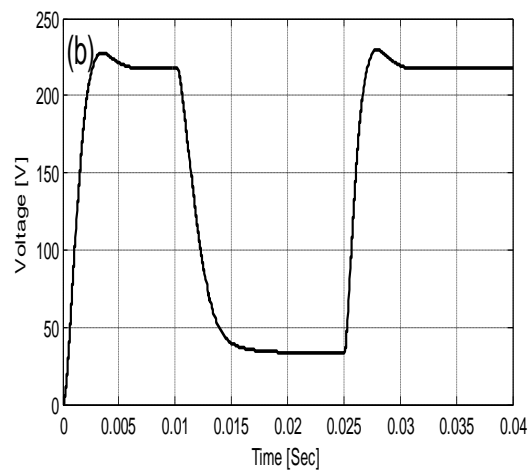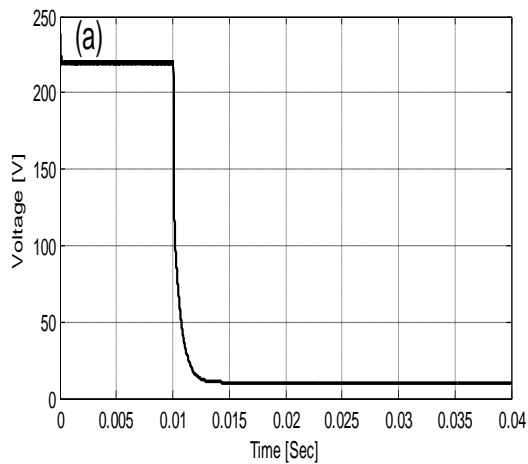| Bus length	500m

(a)

(d)

Fig. 7. Load voltage and current; without protection and with protection.
(a) Load voltage without protection. (b) Load voltage with Protection.
(c) Load current without protection. (d) Load current with Protection.

Load voltage and load current with and without protection is shown in Fig. 7. Without protection load voltage drop down after fault is shown in Fig. 7(a), when the protection is used the voltage is restore quickly after the clearance of fault. From Fig. 7(b) it is seen that fault is cleared within 0.025 sec. This provides the system reliability and continuity. Changes of current in faulted bus is shown in Fig. 8.

As the IGBTs opened fault current freewheel and extinguished through resistors is shown in Fig. 9.

Fig. 10 depicts the fault bus current which is high during faulty condition and goes to zero after isolating this bus. The protection devices in other bus are not shown here.
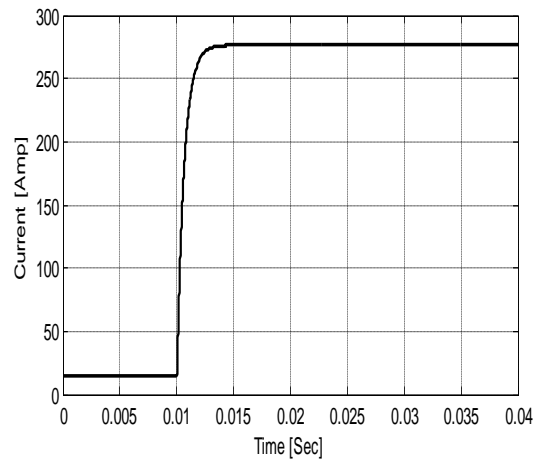

(b)

(c)

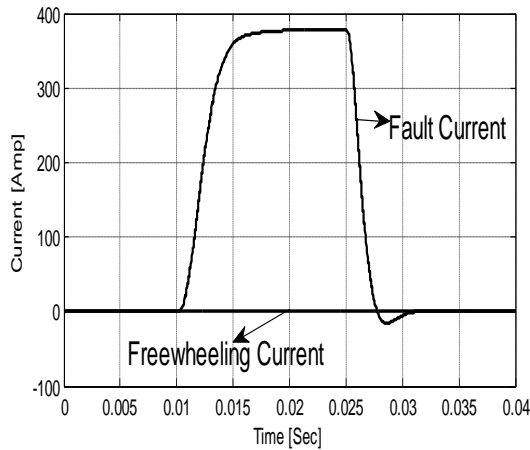Fig. 8. Fault bus current without protection.

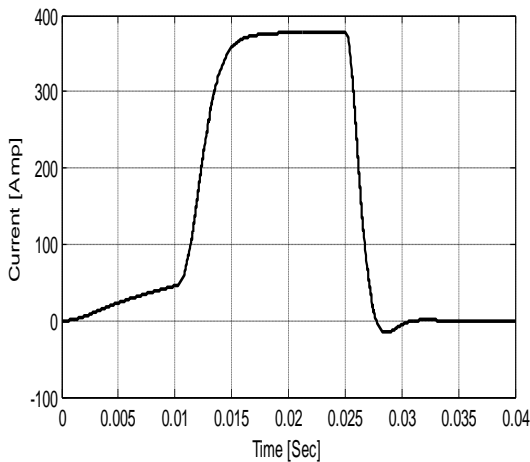Fig. 9. Fault path current and freewheeling current.

Fig. 10. Fault bus current.

VI. CONCLUSIONS

The proposed protection scheme for DC microgrid avoids complete shut-down of DC link and isolates only faulty section. The loop type system is presented and suggested, supply continuity is maintained through the other buses. Fault current in the faulty section is extinguished through freewheeling path provided by resistors and diodes. This provides additional protection to the convertors. This scheme is useful for the isolated area supplied through distributed generation and also, where the AC and DC grids are connected.

REFERENCES

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

[2] F. Blaabjerg, R. Teodorescu, M. Liserre, and A. Timbus, "Overview of control and grid synchronization for distributed power generation systems," *IEEE Trans. Ind. Electron.*, vol. 53, no. 5, pp. 1398–1407, Oct. 2006.

[3] R. Cuzner and G. Venkataramanan, "The status of DC micro-grid protection," in *Proc. IEEE Ind. Appl. Soc. Annu. Meeting*, Oct. 2008, pp. 1–8.

[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] 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.

[7] 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.

[8] . 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.

[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] 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.

[11] 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.

[12] 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.

[13] Y. Ito, Y. Zhongqing, and H. Akagi, "DC micro grid based distribution power generation system," presented at the 4th Int. Conf. Power Electron. Motion Control, Xi'an, China, Aug. 2004.

[14] R. Schmerda, S. Krstic, E. Wellner, and A. Bendre, "IGCTs vs. IGBTs for circuit breakers in advanced ship electrical systems," in *Proc. IEEEElectric Ship Technol. Symp.*, Apr. 2009, pp. 400–405.

[15] 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.

[16] J. Das and R. Osman, "Grounding of AC and DC low-voltage and medium-voltage drive systems," *IEEE Trans. Ind. Appl.*, vol. 34, no. 1, pp. 205–216, Jan./Feb. 1998.