A REVIEW PAPER ON THE PROTECTION SCHEMES OF THE LOW VOLTAGE DC NETWORKS

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ABSTRACT

Low voltage DC (LVDC) applications find their applications in many field including telecom data centre, vehicle power system, etc. In this paper the LVDC system and their configurations are reviewed first. Four types of Architecture of DC Micro grid are discussed. Further the types of the fault that occurs in the DC microgrid is reviewed further. The existing DC protection schemes and four previous done protection methods are reviewed in detail.

Keywords: LVDC, Protection Schemes, Microgrid.

I. INTRODUCTION

Climate change and carbon emission are today's major concern. EU's plan for 2050 has moved the researches to focus more toward non-renewable source of energy [1,2]. EU's framework has plans to cut the carbon emission to 80 to 95% by the year 2050 and at least 27% usage by 2030. Major challenges faced by the researchers is in the integration of several non-renewable sources. This problem results the development of smart grids. In [3], it has been shown that the integration will result in the reduction of usage of fossil fuels and also CO₂ emission. Several energy sources connected together forms Distributed Energy Sources (DES). Integration of several DES is termed as microgrid [4]. Further, the microgrids can be classified as the AC microgrid and the DC microgrid. Most of the devices runs on the DC. To prevent the unnecessary power conversion, DC microgrid is proposed for a distribution system. Focus on the usage of renewable sources and the Electric vehicle gave the concept of distributing the power at the lower voltage level and this is commonly known as Low Voltage DC (LVDC).

Low and Medium voltage DC were already in use in the applications [5,6] like telecom data center, vehicle power systems, railway traction system, etc. The development of protection scheme is still the focused research area and it needs to be explore more [7].

II. ARCHITECTURE OF DC MICROGRID

Many DC microgrid architecture have been proposed considering specific design and the applications [8-11]. DC microgrids can be classified into following four categories.

a) Single bus configuration
b) Multi-bus configuration
c) Ring configuration
d) Interconnected configuration

Single bus configuration: Figure shows the single line diagram of the single bus configuration [12-13]. Single bus topology is used in the telecom sector to supply 48VDC [14,15]
Multibus configuration: Multibus topology makes the system more flexible by providing different amplitude DC voltages to the different buses. This also improves the power supply reliability [16]. DC Bipolar multibus configuration is shown in the figure.

Ring Configuration: In ring configuration, there are multiple paths present between the source and the load as shown in the figure. Ring topology are generally suggested to urban and industrial applications [17].
Interconnected configuration: In interconnected configuration, several DC microgrids are connected to the existing AC Network as shown in the figure. Powerflow can be the birectional according to the requirements. This configuration is mainly used in the applications where the power reliability need is more for example unmanned aerial vehicle, shipboards and aircraft [18].

Figure 4: Interconnected configuration

III. PROTECTION IN LVDC SYSTEM

For the system reliability, protection in the LVDC system is very much critical. Whenever a fault occurs, there must be a protection scheme for the protected the connected devices from this fault [19,20]. Following types of fault may occur in the LVDC systems:

a) Overvoltage fault
b) Under voltage fault
c) Short circuit fault
Short circuit fault is further classified into two types of fault.

a) Line to Line fault
b) Line to Ground fault

In [21], paper addresses the problem of over and under voltage as well as short circuit in Low Voltage DC (LVDC) system. Disturbance caused by these faults can result in damage of components, loss of energy and can heavily effect the operation of delicate medical and industrial equipment. This paper describes the protection schemes, fault calculations and circuit modeling against over and under voltage as well as short circuit in LVDC system. Solid state switches are used as breaker in circuit model. Finally, validity of the calculations and results are verified by using MATLAB/Simulink software.

In [22], the protection scheme for the LVDC distribution system is presented. The possible fault cases and protection requirements are also presented. The future challenge is the integration of protection functions to the power electronic devices to reduce system costs and to decrease protection system complexity.

IV. EXISTING PROTECTION SCHEME

Mehdi Monadi [23], proposed a centralized protection scheme for MVDC (Medium Voltage DC) type microgrids. The proposed scheme has a communication assisted mechanism for fault detection, along with a centralized coordinator for the protection. It also has a fault isolation technique that uses the minimum number of DC circuit breakers. The proposed scheme not only has fault detection and fault isolation techniques but also a backup protection is there. A backup protection gets activated when the communication falls. The main components of the proposed scheme are following

1. For fault detection and location, differential based relay is used.
2. To protect the VSC connected to the host network and DG (Distributed Generator), overcurrent relay was being used.
3. For the supervision of the adaptive devices and making them adaptive to the operating conditions, a centralized protection unit is implemented.
4. Combination of DCCB and the isolators are there for the Practical Computation of d i /d t for High-Speed Protection of DC Microgrids he fast fault interruption.

The above mentioned technique have been HIL simulated, and the result obtained found to be optimally fast for the safety of the VSCs. The time required to restore the network is found to be with 100ms to 300ms.

Chunpeng Li et al [24] in the paper shows that the major challenge that the DC systems has in the short circuited faults. This problem can be addressed by isolating the faulty networks just before the discharge of the DC side capacitors. A new method has been proposed to get the new high speed distance protection schemes using the rate of change of current. In this method, two techniques are presented that optimizes the rate of change of fault current transients using the MATLAB model of DC microgrid with injected measurement noise.

1. The first method derives the optimized selection of the sampling frequency of the current measurement signal and at the same time minimizing the noise pickups. In this method the effect of noise is constrained. Computational step is M times the sampling period ∆T, the equation of computation is represented as equation 1

\[
\frac{d \ln}{dt} = \frac{\ln - \ln - M}{M \Delta T} \quad \text{equation 1}
\]

M * ∆T have been set of 25, 100 and 400 micro sec. to test the sensitivity of the approach. As shown in the figure. the effect of noise is reduced as the sampling time increases.
The larger time steps are good for the noise suppression but not for the accuracy. It gave rise to the tradeoff between noise suppression and accuracy. An optimum sampling time is to be used. A method to get the optimum time step is also discussed in the paper. According to the discussed method the optimum sampling interval was found to be just greater than the 19.6 micro second.

2. The second method uses the Finite Impulse Response filter, for conditioning of the signal just before the di/dt computation. The RLC current and voltage response is given below

\[ i_L(t) \approx \frac{v_{CF}}{L} e^{-\alpha t} \sin(\omega_d t) \] ........................ (2)

\( \alpha \) is the damping factor, \( \omega_d \) is the damped resonant frequency. \( v_{CF} \) is the voltage across the capacitor. Applying a fourier transform on the above mentioned equation will give rise to the frequency distribution of the fault current signal.

\[ I(\omega) \approx \frac{v_{CF}(0)}{L} \frac{1}{\omega_d^2 + (\omega + j\omega)^2} \] ........................ (3)

The obtained result in the paper shows that the main frequency content is found to be in lower band. While designing a low pass filter the cut-off frequency is found to be

\[ f_c \gg f_0 = \frac{1}{2\pi \sqrt{L C_F}} \] ........................ (4)

The designed FIR filter gives the following frequency response.
Further the paper shows that the derivative based over current protection is found to be faster than the threshold based over current protection.

Khaled et al. [25] uses the travelling wave approach for the fault detection and location finding. In this paper a travelling wave is studied that used to be generated from the different types of fault in the MVDC circuits. The proposed method analyses the frequency of the generated travelling wave rather than the arrival time. The microgrid has been modelled in the PSCAD/EMTDC. The underground cables has been modelled as the distributed parameters that depends on the frequency. The telegrapher’s equation has been used to describe current and voltage travelling wave in the frequency domain

\[
\frac{dV_{tw}(\omega)}{dx} = -Z_d(\omega)V_{tw}(\omega)
\]

......... (5)

\[
\frac{dI_{tw}(\omega)}{dx} = -Y_i(\omega)V_{tw}(\omega)
\]

............... (6)

\(V_{tw}\) and \(I_{tw}\) are the functions of the frequency \(\omega\). These are the Fourier transform of the voltage and currents respectively. Solution of \(V_{tw}\) and \(I_{tw}\) are given in following equation

\[
V_{tw}(\omega, \chi) = V_i e^{-\gamma(\omega) \chi} + V_r e^{\gamma(\omega) \chi}
\]

............ (7)

\[
I_{tw}(\omega, \chi) = I_i e^{-\gamma(\omega) \chi} + I_r e^{\gamma(\omega) \chi}
\]

............ (8)

\(V_i, V_r, I_i\) and \(I_r\) are the incident and reflective voltages and currents respectively. \(\chi\) is the distance travelled by the wave. \(\gamma\) is the propagation constant. The proposed scheme based on the frequency analysis of the fault generated travelling wave detects the fault within 128 micro second. The proposed scheme does not uses any communication systems and only the local measurements has been taken, this process avoid any issues that may arise due to the communication systems. In this paper a comparison has been done with the previous methods and the proposed method has been found to be better in terms of selectivity, sensitivity and the accuracy.

Dong Wang et al. [26] proposes a method based on the both voltage change and the current change. The main focus of the proposed method is to reduce the level of the fault current within the distribution network. The result of the multiplication of the both, current change and voltage change is used as a coordination for the protection on the different relays. The model is implemented in PSCAD/EMTDC simulator. The used distribution network is shown in the figure.
Limiting the fault current level also give the more time to the overcurrent based protection schemes to operate. This limited level also support the system to withstand the thermal impact. Flow chart of the proposed scheme is shown in the figure.

![Flow chart of the proposed scheme](image)

**Figure 8:** Flow chart of the proposed scheme

The paper also gave the future scope of the current limiting techniques to be widely used.

**V. CONCLUSION**

The application of Low Voltage DC networks are vast and it is the main component of the modern day microgrid. Different type of fault may occur inside such networks. This review paper highlighted the basic architecture of the DC network. Faults in the DC networks were also reviewed. Over-voltage, under voltage and short circuit fault were reviewed. Result of previous protection scheme for DC network were done. In future, more advance controllers can be design to cate the faults present in the LVDC Networks.

**VI. REFERENCES**


