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Stability Analysis of Bipolar LVDC Grid

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Abstract: The study and regulation of bipolar DC structures covered by asymmetrical action, the DC symmetric part approach is implemented. This approach expands the standard principle of symmetrical components in three-phase AC-controlled networks. The asymmetrical voltage and current in the positive and negative poles are separated into symmetric segments in typical and differential modes. An analogous circuit is imitative for each mode, producing decoupled case circuits. Consequently, it provides autonomous recommendations of each situation and offers an informative mode of a bipolar DC power system's static and dynamic behavior. A common methodology relevant to numerous device scheme cases is the DC symmetrical portion process. An improved common-mode voltage control scheme is defined as an example. By incorporating active damping regulation, it suppresses common mode LC resonance and decreases common-mode impedance to enhance power efficiency and stability of voltage. Matlab/Simulink effects validate the main theoretical assumptions.

Keywords: LVDC Grid, Stability Analysis, DC Distribution, Symmetrical components

1. Introduction

The voltage transformation equipment is the most critical factor for DC or AC grids. The transformers may quickly adapt the voltage for energy transportation to a higher degree or reduce it to satisfy load requirements in an AC device [1]. The traditional networks High Voltage, Medium Voltage and Low Voltage interface with several low-frequency electromagnetic transformers.

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The voltage conversion for DC is still not easy and involves the use of power electronics, often known as electric or DC transformers. In general, the performance of the standard transformer is above 98 percent.

The DC transformer can produce at least the same efficiency to equal the quality of an AC system. DC distribution technology exploration starts at the lowest voltage stage [2]. This is primarily because of the relative sophistication of electrical equipment with Low Voltage DC (LVDC), which consists of circuit barkers and power switching converters. Initially, main DC distribution networks along a standard voltage of 48 V are added to the contact power supply, followed by transport power systems in higher electric ships and aircraft. The DC voltage standard is correspondingly extended to more volts to accommodate the expanded power spectrum. The new delivery projects are now being introduced for domestic utilization in green apartments and charging points for electric vehicles. Modern grid codes worldwide enable Wind Energy Conversion Systems (WECS) to be linked to the grid during voltage sales. Besides, certain grid codes specify reactive current feed in voltage sessions to lead to the reliability of the power system [3-4]. The Ride-Through Fault Curve (RTFC) required by the Brazilian grid code shows the magnitude and time characteristics of the voltage drop that cannot be disconnected from the grid. There are numerous WECS topologies. Nowadays the Dual-Fed Induction Generator (DFIG) is the main wind turbine on the market [5]. The advantages of DFIG technology is the usage of partial converters, lowering device costs, but it does have two significant drawbacks: the use of gearboxes that reflect a vulnerable point in the mechanism at high maintenance costs, and due to the direct relation of the stator to the grid, grid disruptions have a major effect on this technology.

Low voltage is a relative concept, in low voltage electrical power systems primarily the user level voltage used for lighting applies to. The IEC describes low voltage supply grid within 120-1500V DC. Since the battle of currents, the local grid has come a long way. The Light Emitting Diodes (LED) also replaced Elision's light bulb, which is monochromatic, efficient and reliable. After Fukoshimo's event in Japan, the panel demand for panels in Europe has exploded, thus growing the involvement of DC in the distribution stage (low/medium voltage). LVDC may be mounted at the distribution stage, removing the AC (MVAC) medium voltage row. The need for undistributed resources is rising as society largely depends on energy. This raises the probability of failure, which adversely impacts consumers and results in a rise in maintenance costs. Therefore, upgrading to a more stable network is important relative to conventional 3-phase MVAC.

Research has found that every year an LVAC machine (office buildings, homes, etc.) wastes approximately 13% of its energy merely by transmitting and transforming power from the service meter to a degree that it can power it. The degree of failure for automatic, optimized networks is much higher (compared to comparable DC systems).The LVDC device principle tackles this problem in the field of electricity delivery. The LVDC is more efficient than the conventional 400V AC system, owing to the increase in voltage between the devices. The transmission capability can be more than 16 times at the drop voltage limit and more than 4 times at the thermal limit compared with conventional 400V AC device [6]. At the used DC voltage standard, the transmitting capability is much greater than its AC level, resulting in either a narrower transverse cross section of cables or a higher power supply. In LVDC topologies, the number of distinct forms of variants may be as follows:

Monopoly: Conversion of AC/DC is often situated along the medium or high voltage lines. The conversion DC/AC and/or DC/DC should instead be found elsewhere.

a) HVDC connection style solution where high voltage connection (HV) is formed between the AC/DC and DC/AC or DC/DC, which is then spread to different consumers. It establishes a single DC link between two distinct AC networks or AC-DC networks. A typical 3-phase AC or a standard DC connection links consumers.
b) Big LVDC Delivery District, where the DC/AC or DC/DC is converted at the end of each client. The network comprises many divisions proportional to the number of clients.

Bipolar: Two unipolar systems are linked in sequence in the bipolar system. Bipolar method can accomplish several forms.

- Between a positive and a common pole.
- Between a traditional and negative pole.
- Between a pleasant and a bad pole.
- A positive pole to a negative pole with a standard relation.

2. Bi polar LVDC system

Fig.1 indicates a standard LVDC grid. The connection between the Middle Voltage AC (MVAC) and the LVDC Grid is a distribution converter in conjunction with the distribution transformer. Like the three-phase arrangement of AC networks, a bipolar design for the AC grid may be used to provide two alternate degrees of voltage for DG and loads of various voltage or power scales. The voltage among the negative and positive pole is equivalent to the voltage of a three phase line, although every pole has a lower voltage for smaller equipment in a single phase. The asymmetrical activity induced by the unequal energy delivery of the two poles is one of the main difficulties for a bipolar DC system [7]. Such asymmetry may cause voltage imbalance and affect power quality and voltage stability. The controlling networks and strong operational strategies need a thorough review to resolve this issue. This article presents the DC symmetrical signals approach for studying and managing bipolar DC structures.

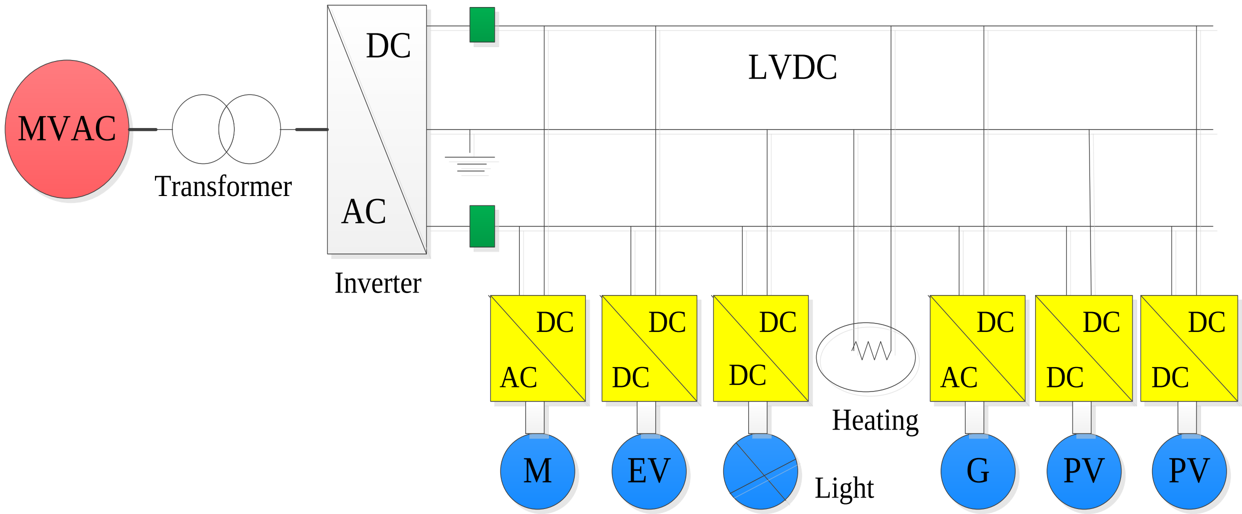

Fig. 1: Schematic of bipolar LVDC network

This method utilizes a framework close to that of the general AC symmetrical approach. Each poles' asymmetric current and voltage in common cases and variable cases are decomposed into symmetric components. Then the corresponding circuit can be extracted for each mode, which is disassociated. It offers an overview of the constant and variable performance of bipolar DC power networks and promotes organizational research and design. An improved common-mode voltage control system is built being LVDC distribution networks as an application of the implemented process. It efficiently controls the potential common mode voltage changes and provides close voltage balancing by decreasing impedance in common operations [8].

The suggested methodology is sufficient for highly advanced multi source and distribution grid networks. Detailed studies on a unipolar DC distribution system can be changed conveniently into a bipolar utility, gaining from symmetrical decomposition and disassociation. The control hub for the whole LVDC utility is the delivery converter. The converter structures considering bipolar LVDC delivery are outlined shortly in this portion. These are the natural foundations for the academic discussion in the subsequent sections. The simplest way to provide a controller with bipolar DC production is to operate two VSC converters, as seen in Fig. 2.

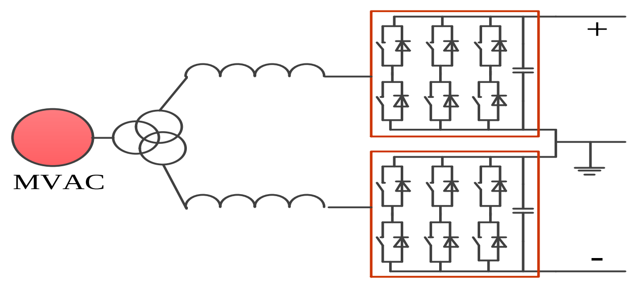

Fig. 2. Two cascaded converters based LVDC distribution system

This topology comprises two different voltage origins and thus enables the positive and negative poles to work separately. In such a design, however, two separate converters and two isolated windings in the distribution transformer are required, which might contribute to higher size and expense. One VSC with few recommendations may also gain bipolar dc voltage [9]. For eg, the transformer neutral wire can be attached to the midpoint of the DC output condensers, as shown in Fig. 3.

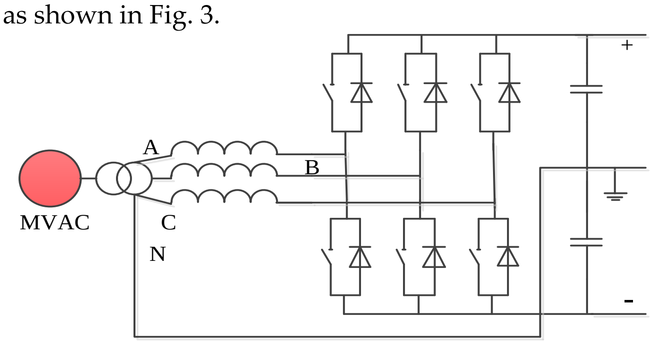

Fig. 3. Neutral wire connected VSC to DC middle point.

The neutral wire current in the converter can be balanced for the DC portion voltage equilibrium. In this case, the current in the neutral line may sadly include a major DC portion which should be restricted strictly to avoid saturation of the transformer [10]. An extra half bridge may be used to avoid the neutral line DC, which is devoted to voltage balance by effectively giving away the current signals as depicted in Fig. 4.

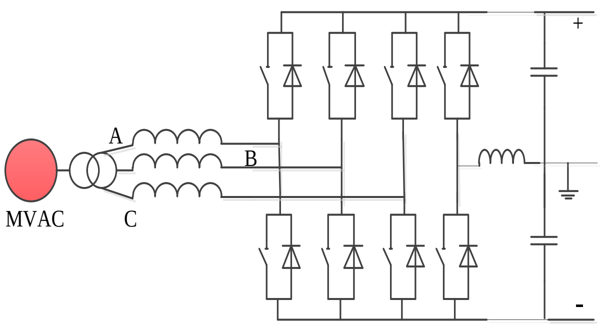

Fig. 4: Extra voltage balancing half bridge VSC.

This variation in unbalanced load currents is greater. This also has a simplified Fig structure as in Fig.2. Therefore the distributor to control the bipolar LVDC grid is approved in this article. In Fig. 4, the positive and negative poles are not separate, but contact between the poles can be caused. The potential inter-pole interference in bipolar DC systems is precisely modeled by a method. The symmetrical part approach offers a valuable technique to examine asymmetrical patterns in three-phase ac power system theories. It can be generalized to bipolar DC networks.

3. Proposed method

The symmetrical components are described in three-phase ac networks as in equation (1). The dependents are the phase variables and the independent variables are the symmetrical components. The symmetrical components are used in three-phase system for solving the asymmetrical components. The same concept is applied here to solve the bipolar LVDC systems.

$$\begin{bmatrix} x_0 \\ x_1 \\ x_2 \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \end{bmatrix}\begin{bmatrix} x_a \\ x_b \\ x_c \end{bmatrix} \tag{1}$$

From the known way, the bipolar LVDC can be viewed as a two phase AC system with zero frequency. The equation (1) can be modified as (2)

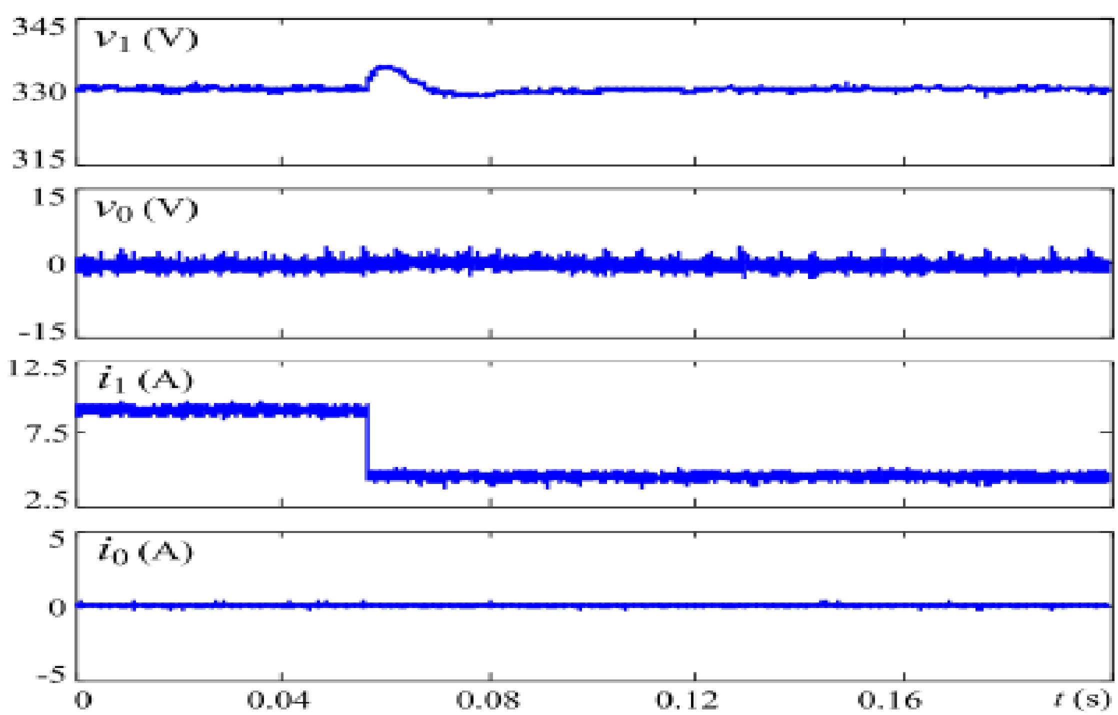

Fig. 5: Mode voltage and current for changes in step load

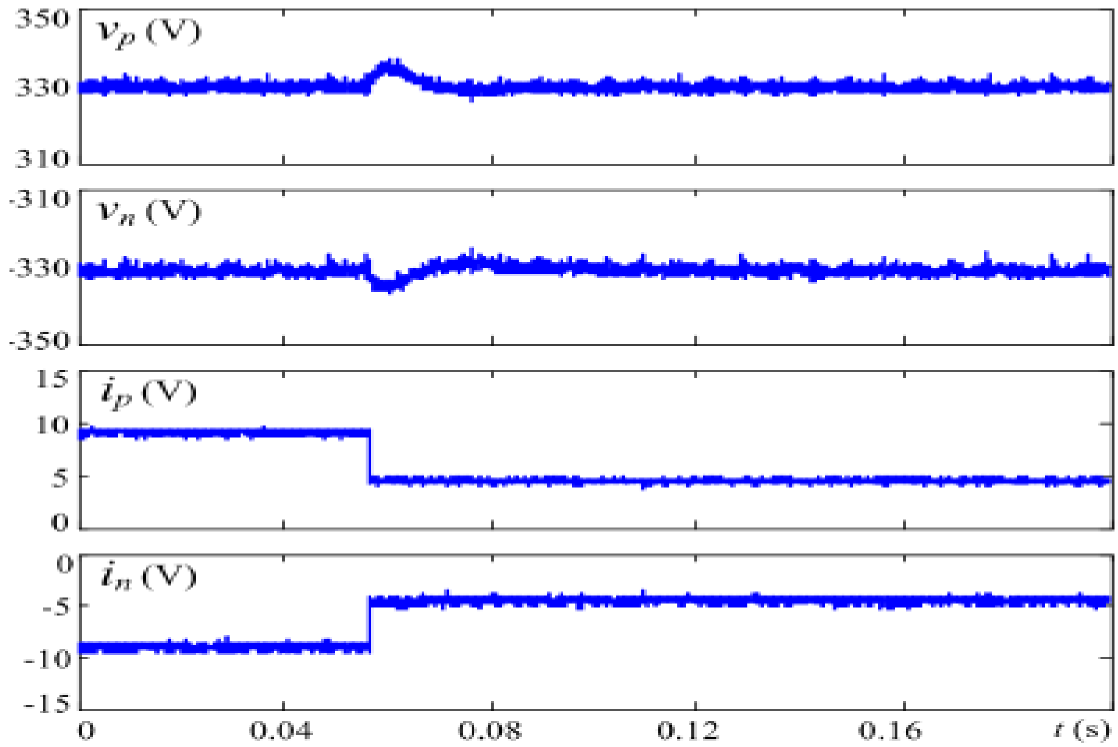

Fig. 6: Pole voltage and current for step load changes

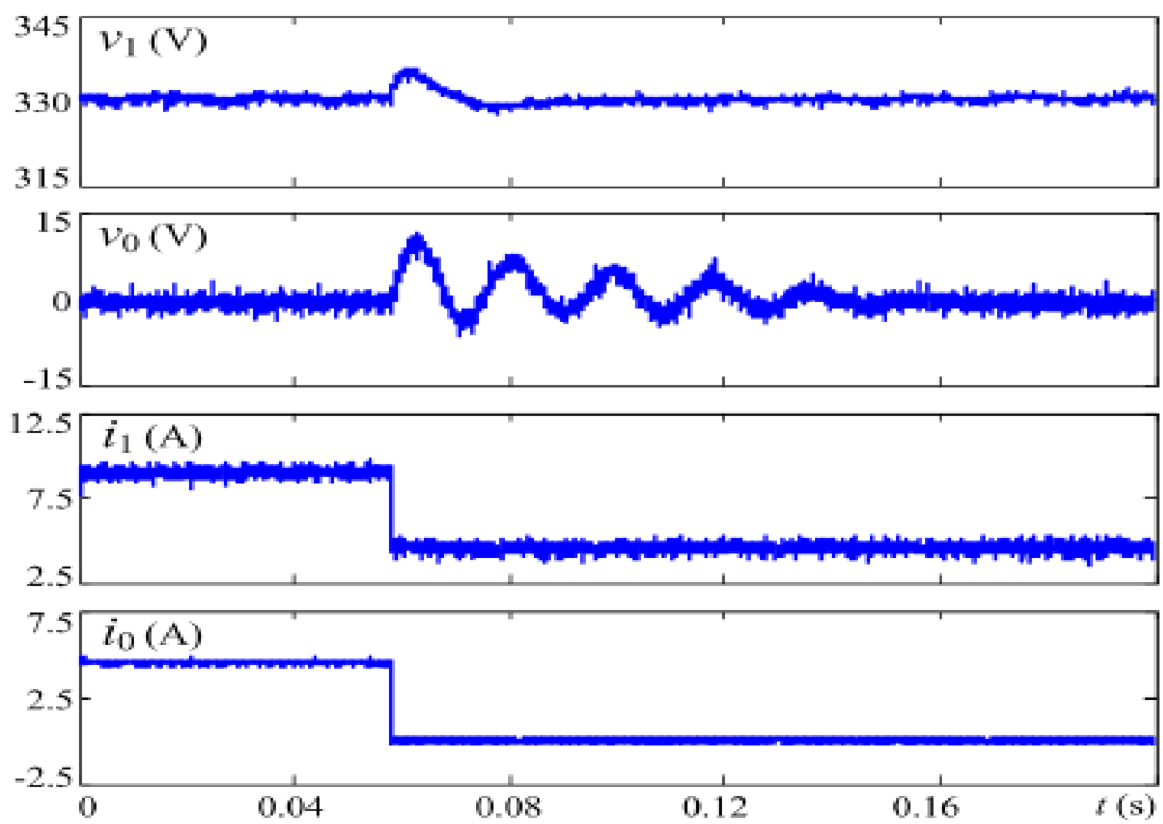

Fig. 7: Mode voltage and current for unsymmetrical load changes

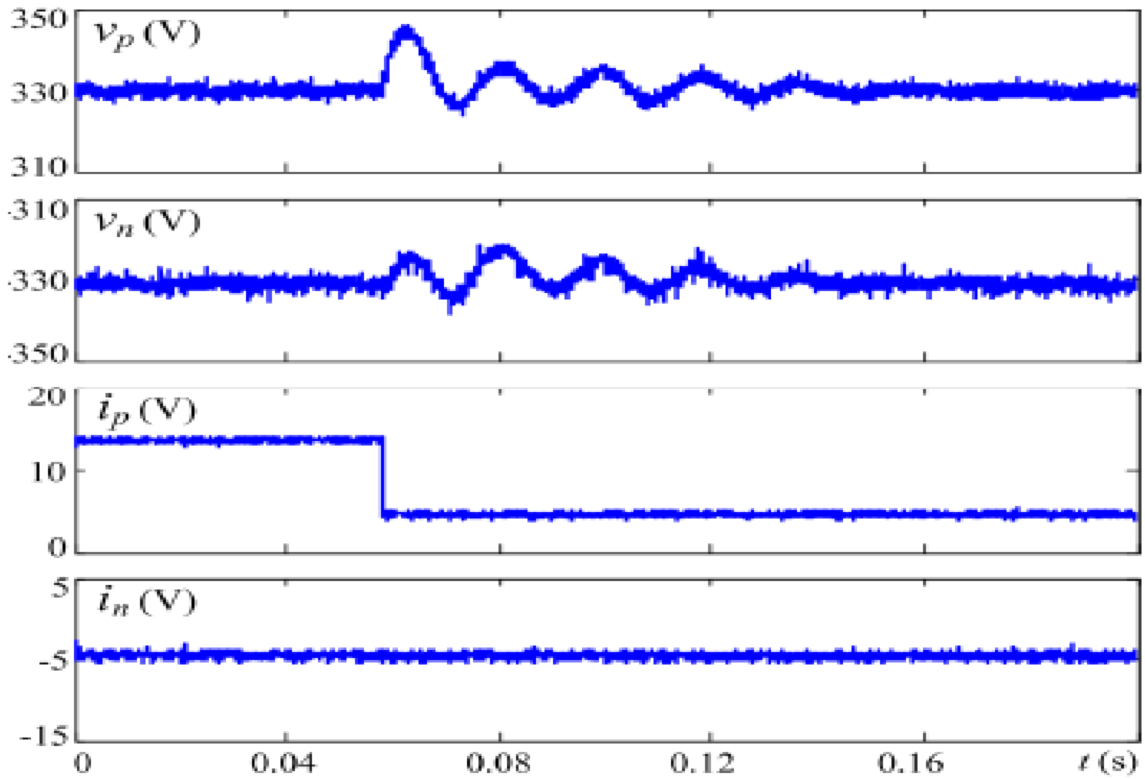

Fig. 8: Pole voltage and current for unsymmetrical step load changes

$$\begin{bmatrix} x_0 \\ x_1 \end{bmatrix} = \frac{1}{2}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}\begin{bmatrix} x_p \\ x_n \end{bmatrix} \quad (2)$$

In this equation (2) the dependent variables are the positive and negative poles, whereas the independent variables are the symmetrical components. These symmetrical components are the DC counterparts to the AC system, and the changes in these components are used to describe the unbalanced operation in the LVDC system.

4. Simulation results

A bipolar LVDC distribution test system is built to verify the theoretical analysis in the preceding sections. The distribution converter networks in Fig. 4 are used. The simulation results for mode voltage and current changes for step load and unsymmetrical load are depicted in Fig. 5 and Fig. 7. The pole voltage and current for step and unsymmetrical load changes are depicted in Fig. 6 and Fig. 8 respectively.

5. Conclusion

A valuable technique for evaluating and controlling bipolar LVDC delivery systems is the dc symmetrical portion approach. A bipolar LVDC utility is broken down into decoupled variable mode and common mode systems, making a separate and simpler analysis of each fashion. The improved common mode tension control device demonstrates favorable efficiency in damping standard mode LC resonance to increase the consistency of power and voltage stability.

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Conflict of Interest

The authors declare that they do not have any conflict of interest.

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