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A NEW CONTROL STRATEGY FOR A BIPOLAR DC DISTRIBUTION SYSTEM TO IMPROVE VOLTAGE STABILITY

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Abstract— **The dc symmetrical component method is introduced for the analysis and control of bipolar dc distribution systems under asymmetrical operation. This method is an extension of the classical symmetrical component theory in three-phase ac power systems. The asymmetrical voltage and current in the positive and negative poles are decomposed into symmetrical components in common and differential modes. The equivalent circuit for each mode is derived, which forms decoupled mode networks. Consequently, it allows for independent investigation of each mode, and provides an insightful view of the static and dynamic behavior of a bipolar dc power system. The dc symmetrical component method is a general approach which is applicable to different aspects of system design. As an example, an enhanced common-mode voltage regulation scheme is described. It suppresses common-mode *LC* resonance by adding active damping control, and reduces common-mode impedance to improve power quality and voltage stability. The major theoretical conclusions are verified by matlab/simulink results.**

I. INTRODUCTION

The crucial element to either DC or AC grids is the voltage transformation devices. In an AC system, the transformers can easily adapt the voltage to a higher level for energy transport or reduce it to meet the load requirements. Conventionally the High Voltage (HV), Medium Voltage (MV) and Low Voltage (LV) networks are interfaced with multiple low frequency electromagnetic transformers. Voltage conversion for DC is yet not so simple and requires the use of power electronics, also called power electronic or DC transformer. The efficiency of conventional distribution transformer is generally higher than 98%. In order to match the efficiency of an AC system, the DC transformer should obtain at least the same efficiency.

The exploration of dc distribution technologies begins at the lowest voltage level. The major reason is the relative maturity of low-voltage dc (LVDC) electric apparatus, including power electronic converters and dc circuit breakers. Primary dc distribution systems are first deployed for communication power supplies, with a rated voltage of only 48 V. This is followed by transportation power systems, such as those in more electric aircrafts and ships. Correspondingly, the dc voltage level is scaled up to several hundred volts to handle the extended power range. The latest dc distribution initiatives are also reaching for residential applications in green buildings and electric vehicle charging stations.

Modern grid codes around the world require that wind energy conversion systems (WECS) remain connected to the grid during voltage sags. Furthermore, some grid codes specify reactive current infeed during voltage sags in order to contribute to the power system stability. The ride-through fault capability curve (RTFC) required by the Brazilian grid code, where the hatched area denotes the voltage sag amplitude and time characteristics which the system is not allowed to be disconnected from the grid. There are several different topologies of WECS. Nowadays, the gear-drive doubly-fed induction generator (DFIG) based wind turbine is dominating the market. The DFIG technology has the advantage of using partial scale converters, decreasing the system costs, but it has two main drawbacks: the use of a gearbox, which is a weak point in the structure with high maintenance costs, and due to the direct stator connection to the grid, this technology is greatly affected by grid disturbances.

Low voltage is a relative term, in electrical power systems low voltage mostly refers to the costumer/- consumer level voltage as used by lighting. The International Electro technical Commission (IEC) defines supply system low voltage in the range 120-1500V DC. The local grid has come a long way since the war of currents. Elision's light bulb has been substituted by Light Emitting Diodes (LED), cause of being monochromatic, efficient and effective. Solar panels have been gaining a lot popularity, ever since Fukoshimo incident in Japan, PV panel market in Europe has exploded, thus increasing the presence of DC in the distribution level (Low/Medium Voltage). LVDC can be implemented at the distribution level, substituting the medium voltage AC (MVAC) lines. The demand for undistributed power supply is growing when society depends more and more on electricity. This increases the chances of outages, which affects the customers in a negative way and produces increase in the outage cost. Thus upgrade to a more reliable network compared to traditional 3-phase MVAC becomes a necessity. Studies have shown that a LVAC system (office building, apartments, etc.) lose about 13% of their electrical power every year simply by distributing and converting power from utility meter down to the point where it can power the equipment. The percentage of loss is even higher for automated and optimised system (compared to similar DC based system).The LVDC system concept responds to this challenge in the field of distribution of electricity.

The LVDC transmission system has higher transmission capacity than a traditional 400V AC system resulting from the voltage difference between the systems. The transmission capacity can be over 16 times at the voltage drop limit and over 4 times at thermal limit compared to tradition 400V AC system. The transmission capacity on the used DC voltage level is much higher than that of its AC counterpart, thus leading to either smaller cross-section of cables or higher power delivery capacity. The number of different kind of variations can present in LVDC topologies, which are as follows:

Monopole: AC/DC conversion is always located near medium voltage (MV) or high voltage (HV) line. The DC/AC and/or DC/DC conversion can instead be located at different location.

a) HVDC link type solution, where the link between AC/DC and DC/AC or DC/DC is high voltage link (HV) which is then stepped down and distributed among various costumer. It constructs of one DC link between two separate AC network or AC-DC network. Customers are connected to a common 3-phase AC or common DC link.

b) Wide LVDC distribution district, where DC/AC or DC/DC conversion is made at every individual customer end. The network consists of a number of branches equal to the number of customers.

Bipolar: In bipolar system two unipolar systems are connected in series. Multiple ways can be achieved using bipolar system.

1) Between a positive pole and common.
2) Between a negative pole and common.
3) Between a positive and a negative pole.
4) Between a positive and a negative pole with common connection.

II. SYSTEM MODELING

A typical LVDC grid is shown in Fig. 1. A distribution converter combined with a distribution transformer acts as the interface between the mid voltage ac (MVAC) and LVDC grid. Just like the three-phase structure in ac power systems, a bipolar configuration can be adopted for the dc grid to provide two alternative voltage levels for DGs and loads with different voltage or power scales. The voltage between the positive and negative poles is similar to the line-line voltage in three-phase systems, while each pole is analogous to a single phase to provide a lower voltage for smaller equipment. One of the major challenges for a bipolar dc grid is the asymmetrical operation caused by the uneven power distribution in the two poles. Such asymmetry may lead to voltage unbalance, and deteriorate power quality and voltage stability. To deal with this problem, a comprehensive investigation is needed in both the converter topology and the operation control strategy. In this paper, the dc symmetrical component method is introduced for analysis and control of bipolar dc distribution systems. This approach uses a similar methodology and provides a similar benefit to that of the classical ac symmetrical component theory.

The asymmetrical voltage and current of each pole are decomposed into symmetrical components in common mode and differential mode. Then the equivalent circuit for each mode can be derived, which turns out to be decoupled. Consequently, it provides an insightful view of the static and dynamic behavior of bipolar dc power systems, and simplifies the operation analysis and design. As an application of the introduced method, an enhanced common-mode voltage regulation scheme is developed for a LVDC distribution system. It provides effective damping of the possible common-mode voltage oscillation, and offers tight voltage balance control by reducing the common-mode impedance. The proposed technique is also suitable for more sophisticated bipolar dc distribution systems with multiple sources and complex grid structures. Moreover, the extensive research works initially targeted on a unipolar dc distribution grid can be readily migrated to a bipolar grid, taking advantage of the symmetrical component decomposition and decoupling.

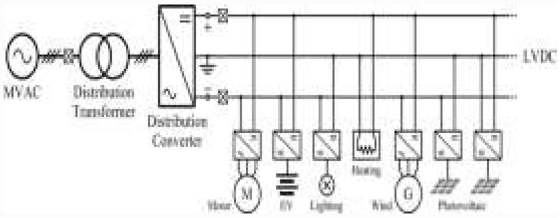

Fig. 1. Bipolar LVDC power distribution system.

The distribution converter is the power hub of the entire LVDC grid. In this section, the converter topologies suitable for bipolar LVDC distribution are briefly summarized. They are the physical bases for the theoretical derivation in succeeding sections. The most straightforward approach to build a converter with bipolar dc output is to use two cascaded voltage source converters (VSCs), as shown in Fig. 2.

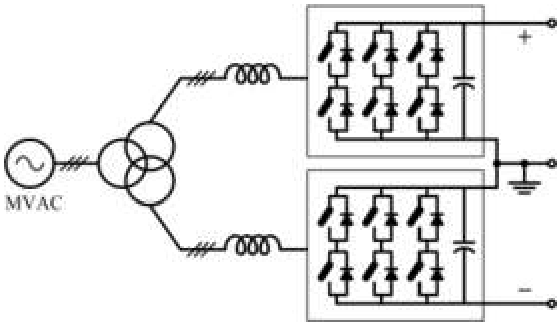

Fig. 2. Bipolar LVDC distribution converter with two cascaded VSCs.

This topology essentially contains two independent voltage sources, and therefore permits independent operation of the positive and negative poles. However, two separated converters are needed in such a configuration, along with two isolated windings in the distribution transformer. This may result in increased size and cost. Bipolar dc voltage can also be acquired by a single VSC with some modifications. For example, the neutral line of the transformer can be connected to the mid-point of the dc output capacitors, as depicted in Fig. 3.

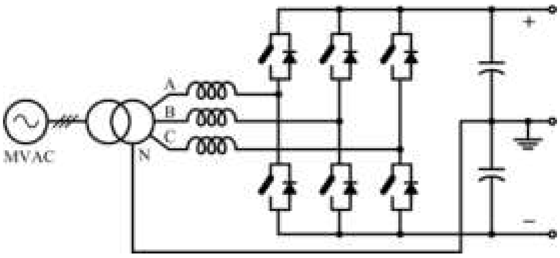

Fig. 3. VSC with neutral line connected to dc mid-point.

The current in the neutral line can be regulated to balance the dc side voltage. Unfortunately, the neutral line current may contain significant dc component in this case, which should be strictly limited to prevent transformer saturation. In order to prevent the neutral line dc current, an extra half bridge can be employed, which is dedicated to voltage balancing by actively redistributing the currents, as displayed in Fig. 4.

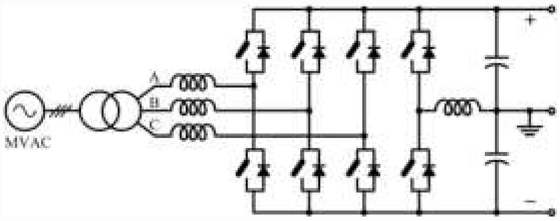

Fig. 4. VSC with extra voltage balancing half bridge.

This topology provides greater tolerance of unbalanced load currents than Fig. 3, and also has a simplified structure compared with Fig. 2. Therefore, it is adopted in this paper as the distribution converter to power the bipolar LVDC grid. In Fig. 4, the positive and negative poles are not independent, and therefore may induce the interaction between each pole. A method is needed to precisely model the possible inter-pole interference in bipolar dc systems. In three-phase ac power system theories, the symmetrical component method provides a useful tool for analyzing asymmetrical phenomena. This approach can be extended to bipolar dc systems. The symmetrical transformation in three-phase ac systems is defined by

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

III. SIMULATION RESULTS

A bipolar LVDC distribution test system is built to verify the theoretical analysis in preceding sections. The distribution converter topology in Fig. 4 is used.

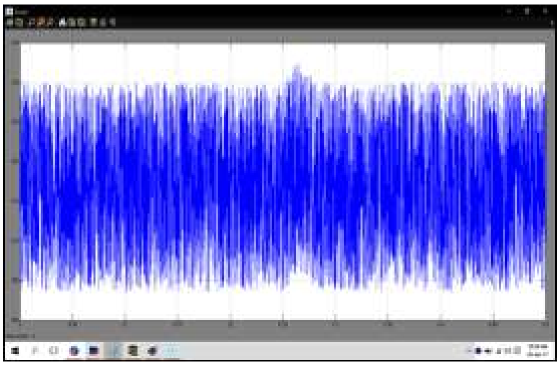

Fig.5.(a)

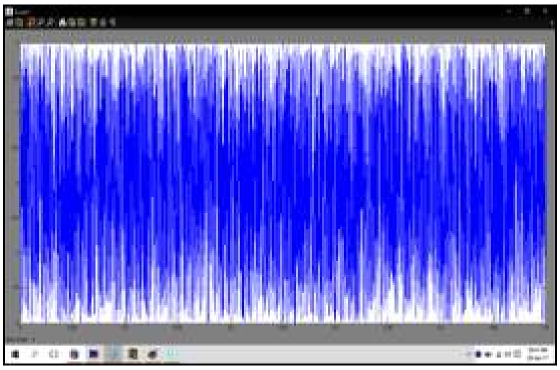

Fig.5(b)

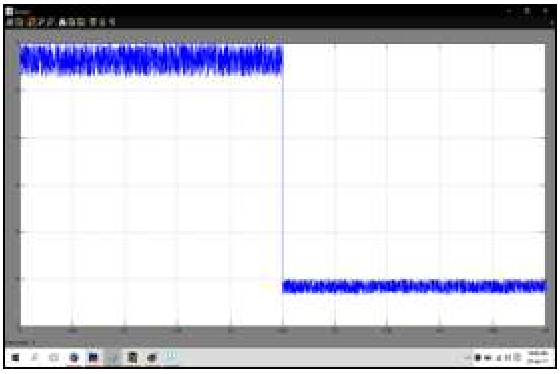

Fig.5(c)

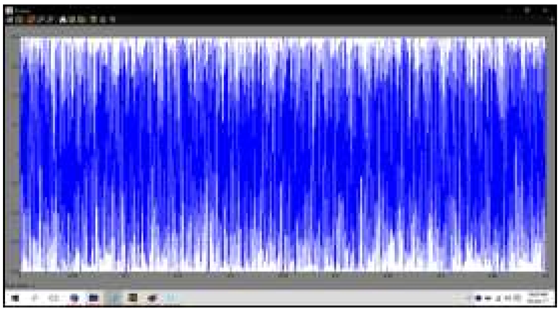

Fig.5(d)

Fig. 5(a), (b), (c), (d). System response under bipolar load step change of a Mode voltage and current.

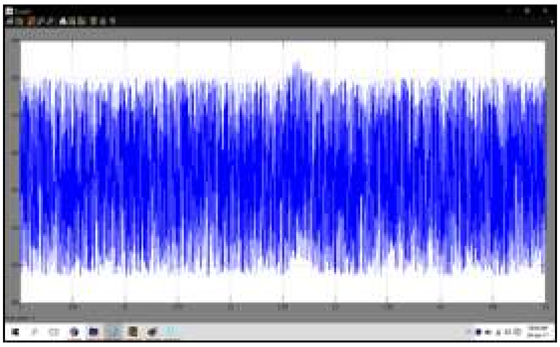

Fig.6(a)

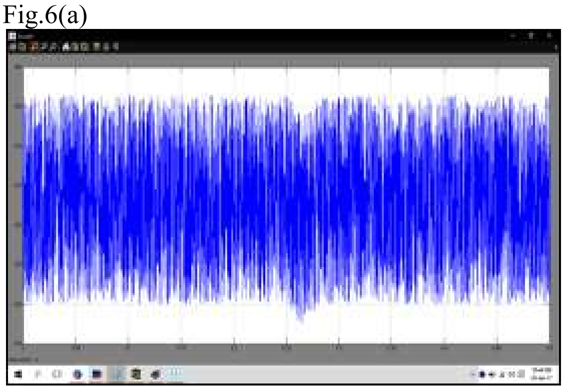

Fig.6(b)

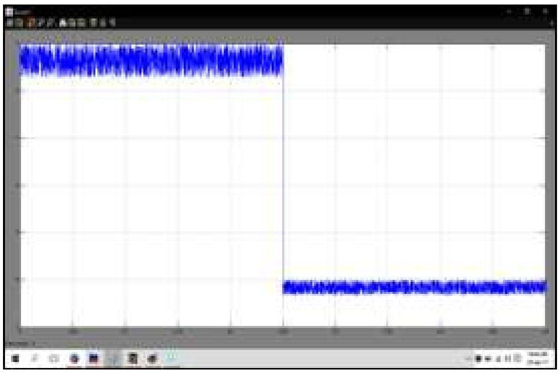

Fig.6(c)

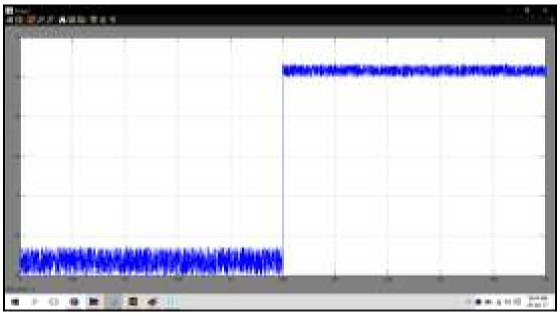

Fig.6(d)

Fig.6(a), (b), (c), (d). System response under bipolar load step change of a Pole voltage and current.

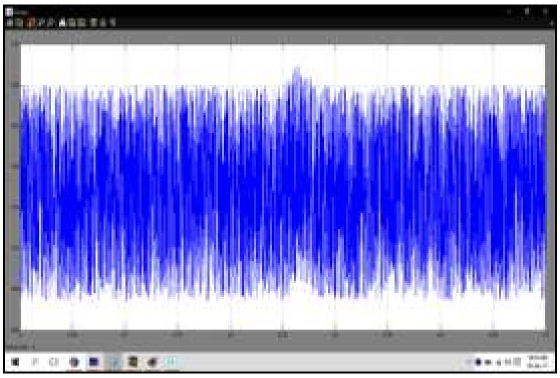

Fig.7(a)

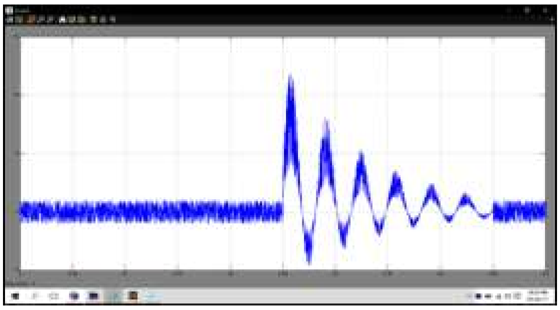

Fig.7(b)

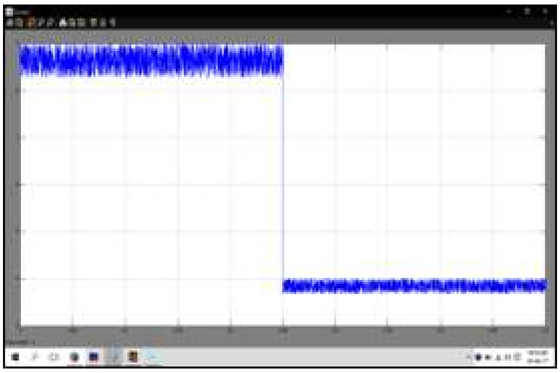

Fig.7(c)

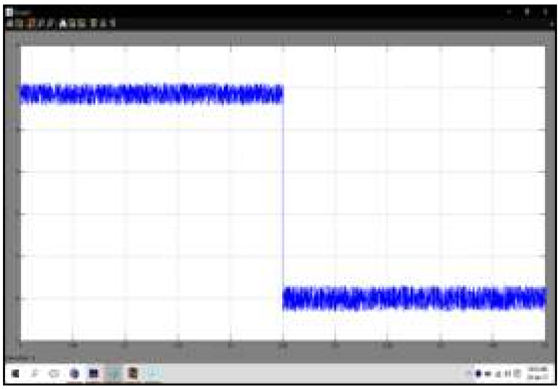

Fig.7(d)

Fig. 7(a), (b), (c), (d). System response under unipolar asymmetrical load step change of a Mode voltage and current.

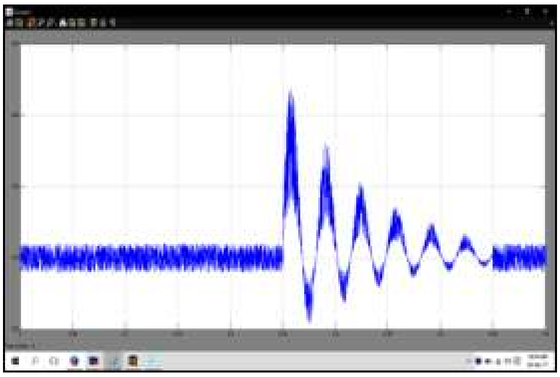

Fig.8(a)

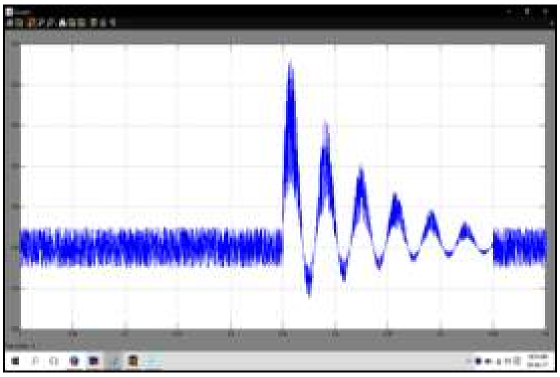

Fig.8(b)

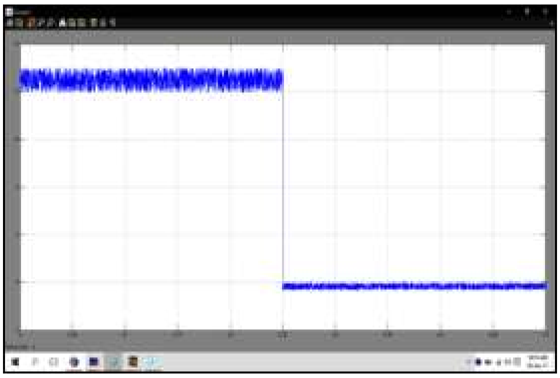

Fig.8(c)

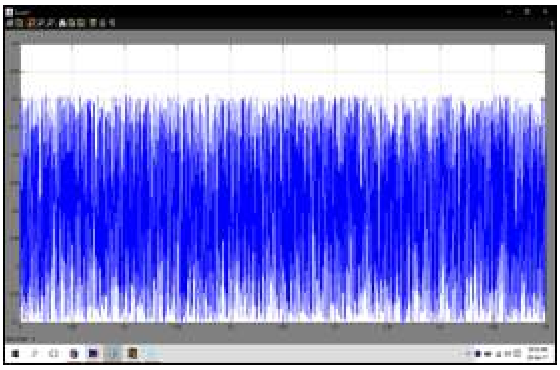

Fig.8(d)

Fig. 8(a), (b), (c), (d). System response under unipolar asymmetrical load step change of a pole voltage and current.

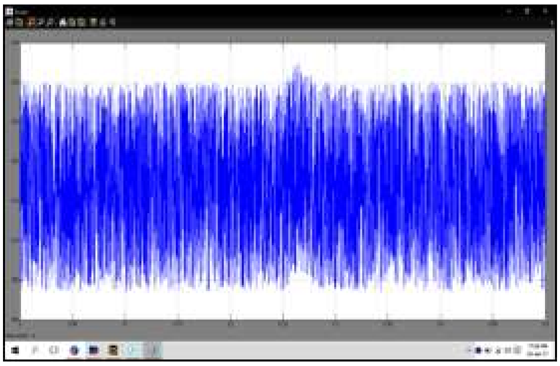

Fig.9(a)

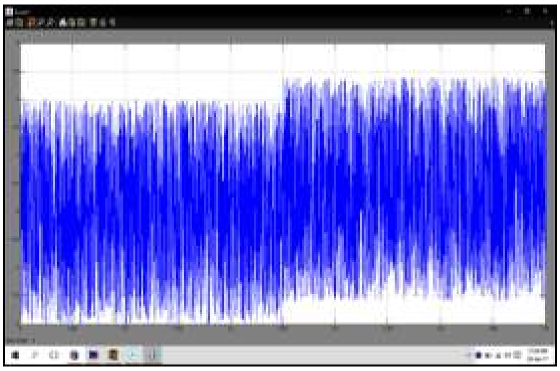

Fig.9(b)

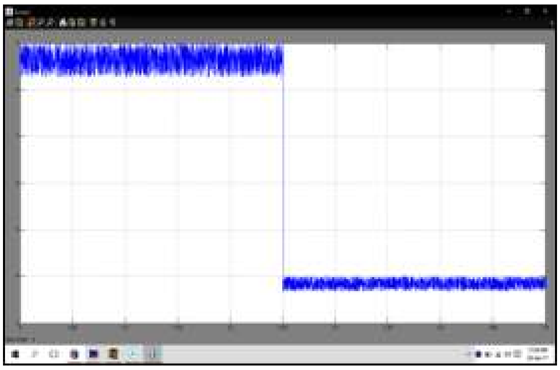

Fig.9(c)

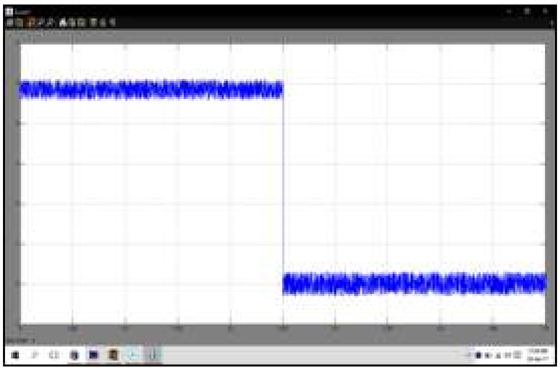

Fig.9(d)

Fig. 9(a), (b), (c), (d). System response under unipolar asymmetrical load step change with active damping control of a mode voltage and current.

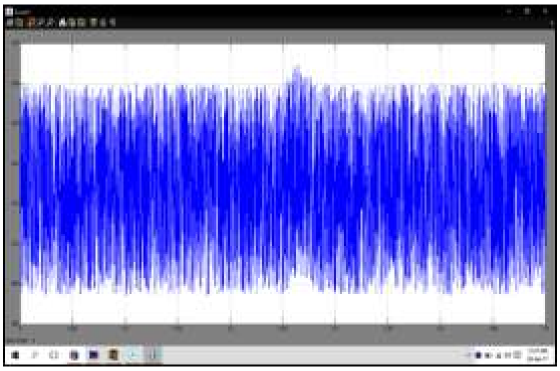

Fig.10(a)

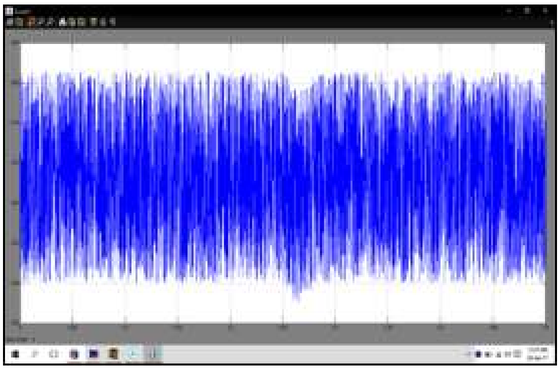

Fig.10(b)

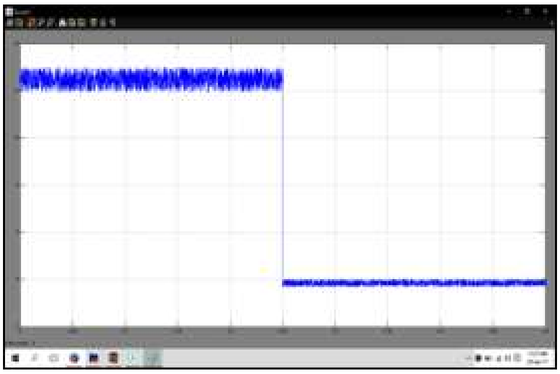

Fig.10(c)

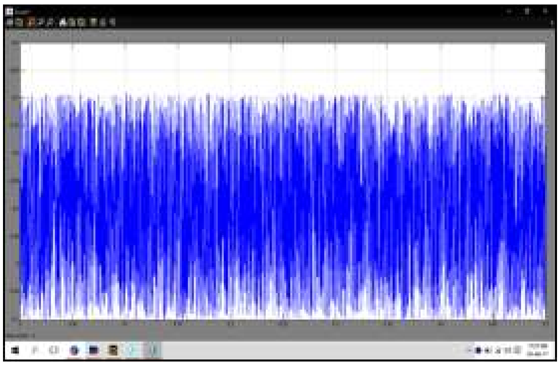

Fig.10(d)

Fig. 10(a), (b), (c), (d). System response under unipolar asymmetrical load step change with active damping control of a pole voltage and current.

IV. CONCLUSION

The dc symmetrical component method provides a useful tool for the analysis and control of bipolar LVDC distribution systems. It decomposes a bipolar dc grid into decoupled differential- mode and common-mode networks, thereby enabling separated and simplified investigation of each mode. Based on this method, the enhanced common-mode voltage regulation scheme shows advantageous performances in damping the common-mode *LC* resonance to improve power quality and voltage stability.

V. REFERENCES

[1] C. W. Taylor and S. Lefebvre, “HVDC controls for system dynamic performance,” *IEEE Trans. Power Syst.*, vol. 6, pp. 743–752, 1991.

[2] B. H. Bakken and H. H. Faanes, “Technical and economic aspects of using a long submarine HVDC connection for frequency control,” *IEEE Trans. Power Syst.*, vol. 12, pp. 1252–1258, 1997.

[3] L. Zhang, L. Harnefors, and H. P. Nee, “Modeling and control of VSCHVDC links connected to island systems,” *IEEE Trans. Power Syst.*, vol. 26, pp. 783–793, 2011.

[4] L. Zhang, L. Harnefors, and H. P. Nee, “Interconnection of two very weak AC systems by VSC-HVDC links using power-synchronization control,” *IEEE Trans. Power Syst.*, vol. 26, pp. 344–355, 2011.

[5] X. P. Zhang, “Multiterminal voltage-sourced converter-based HVDC models for power flow analysis,” *IEEE Trans. Power Syst.*, vol. 19, pp. 1877–1884, 2004.

[6] G. P. Adam, K. H. Ahmed, S. J. Finney, K. Bell, and B. W. Williams, “New breed of network fault-tolerant voltage-source-converter HVDC transmission system,” *IEEE Trans. Power Syst.*, vol. 28, pp. 335–346, 2013.

[7] D. Chen and L. Xu, “Autonomous DC voltage control of a DC microgrid with multiple slack terminals,” *IEEE Trans. Power Syst.*, vol. 27, pp. 1897–1905, 2012.

[8] Y. Gu, W. Li, and X. He, “Passivity-based control of DC microgrid for self-disciplined stabilization,” *IEEE Trans. Power Syst.*.

[9] Y. Gu, X. Xiang, W. Li, and X. He, “Mode-adaptive decentralized control for renewable DC microgrid with enhanced reliability and flexibility,” *IEEE Trans. Power Electron.*, vol. 29, pp. 5072–5080, 2014.

[10] Y. Gu, W. Li, and X. He, “Frequency-coordinating virtual impedance for autonomous power management of DC microgrid,” *IEEE Trans. Power Electron.*, vol. 30, pp. 2328–2337, 2015.