Space Vector Controlled Bipolar LVDC Micro Grid Analysis with DC Symmetrical Component Technique

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Abstract- The DC symmetrical component technique is introduced for the analysis and control of bipolar DC distribution systems under asymmetrical operation. This technique 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. Here Generally DC symmetrical Component theory approaches the power distribution network will be changed towards the future Smart Grid due to increased number of installed renewable power generation units to fulfill the tightened environmental regulation. The Control of the future Smart Grid will be challenging due to increased number of renewable power Generation units, which are variable in nature, and at the same time, the customers are highly dependent on uninterruptable, high quality power supply. So For that 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.

Index Terms- Active damping, bipolar dc distribution, common mode, differential mode, symmetrical component, SVPWM.

I. INTRODUCTION

DC power delivery is restoration quality recently when it was briefly defeated by its ac opponent a century ago. The foremost important development was found in high

Voltage DC (HVDC) transmission systems, because of its advantage in power capability and controllability over ac transmission lines. Currently the trend of dc is increasing to all-time low a part of the electrical provide chains, from transmission to Distribution systems. It's predicted that dc distribution might facilitate to accommodate higher penetration of renewable distributed generators (DGs), increase power capability and quality, and supply larger resilience against power surge and irregular load fluctuations .The exploration of dc distribution technologies begins at the lowest voltage level. The key reason is that the relative maturity of low-tension dc (LVDC) electrical equipment, as well as power electronic converters and dc circuit breakers. Primary dc distribution systems are initially deployed for communication power provides, with a rated voltage of solely forty eight Volts. This is often followed by transportation power systems, like those in additional electrical aircrafts and ships. Correspondingly, the dc voltage level is scaled up to many hundred volts to handle the extended power vary. The most recent dc distribution initiatives are reaching

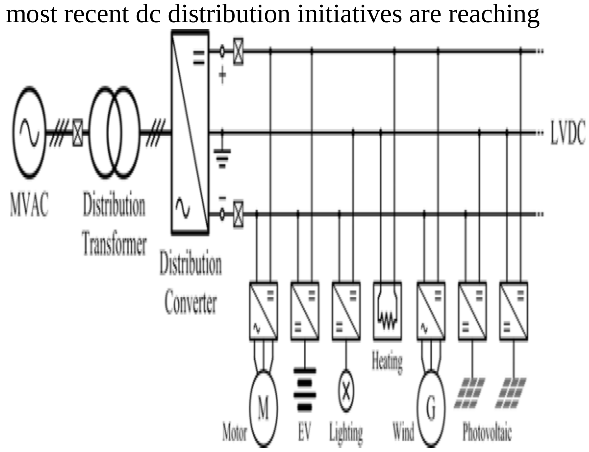

Fig.1: Bipolar LVDC DISTRIBUTION SYSTEM

For residential applications in inexperienced buildings and electrical vehicle charging stations a typical LVDC grid is shown in Fig. 1.

A distribution converter combined with a distribution transformer acts because the interface between the voltage AC (MVAC) lines and LVDC grid. Just like the three-phase structure in ac power systems, a bipolar configuration is adopted for the dc grid to produce 2 various voltage levels for DGs and hundreds with totally different voltage or power scales. The voltage between the positive and negative poles is comparable to the line-line voltage in three-phaseSystems, whereas every pole is analogous to one section to produce a lower voltage for smaller instrumentation.

One of the most important challenges for a bipolar dc grid is that the asymmetricaloperation caused by the uneven power distribution in the two poles. Such imbalance could cause voltage unbalance, and deteriorate power quality and voltage stability. To cope with this downside, a comprehensive investigation is required in each the device topology and therefore the operation management strategy.

Thispaper discussing about the dc symmetrical element methodology is introduced for analysis and management of bipolar dc distribution systems. This approach uses an analogous technology and provides an analogous benefit to it of the classical ac symmetrical elementtheory. The

Asymmetrical Voltage and Current of Each Pole Are Decomposed Into Symmetrical Components In CommonMode 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 associate application of the introduced technology, associate increased common-mode voltage regulation theme is developed fora LVDC distribution system. It provides effective damping of the attainable common-mode voltage oscillation and offers tight voltage balance management by reducing the common-mode Impedance.

The projected technique is additionally appropriate for additional refined bipolar dc distribution systems with multiple sources and complex grid structures. Moreover, the in depth analysis works at the start targeted on a unipolar dc distribution grid is readily migrated to a bipolar grid, taking advantage of the symmetricalcomponent decomposition and decoupling. As shown in below figure.

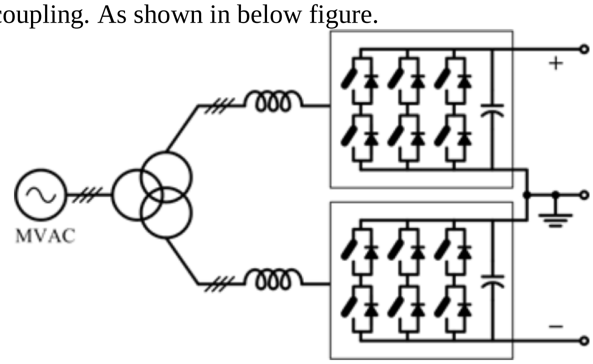

Fig.2: Bipolar LVDC distribution converter with two cascaded VSCs.

II. BIPOLAR LVDC DISTRIBUTION CONVERTER

The distribution device is that the facility hub of the entire LVDC grid. Throughout this section, the device topologies suitable for bipolar LVDC distribution unit in brief summarized. They're the physical basis for the theoretical derivation in succeeding sections. The foremost simple approach to making a device with bipolar dc output is to use a pair of cascaded voltage provide converters (VSCs), as shown in Fig2. This topology primarily contains a pair of freelance voltage sources and therefore permits freelance operation of the positive and negative poles. However, a pair of separated converters unit needed in such a configuration, at the side of a pair of isolated windings among the distribution electrical device. This might result in raised size and

Cost. Bipolar dc voltage is also no transmissible by one VSC with some modifications. As an example, the neutral line of the electrical device is going to be connected to the mid-point of the dc output capacitors, as delineated in Fig3 as shown.

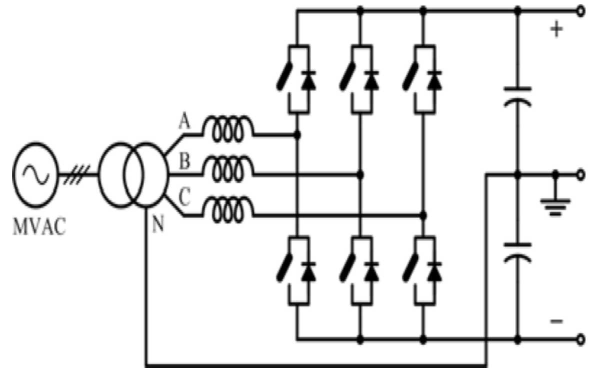

Fig.3: VSC with neutral line connected to dc mid-point

This among the neutral line is going to be regulated to balance the dc side voltage. Sadly, the neutral line current would possibly contain Necessary dc half during this case that got to be strictly restricted to forestall transformer saturation. Therefore on forestall the neutral line DC current, an extra bridge are going to be used, that is dedicated to voltage effort by actively redistributing the currents as shown in the figure 4 below.

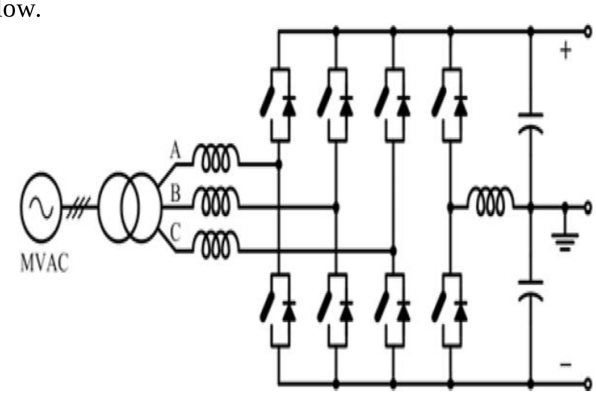

Fig.4: VSC with extra voltage balancing half bridge.

III. DC SYMMETRICAL COMPONENT TECHNIQUE

In three-phase ac installation theories, the symmetrical component technique provides a useful gizmo for analyzing asymmetrical phenomena. This approach may be extended to bipolar systems. The symmetrical transformation in three-phase ac systems is defined by The symmetrical transformation in three-phase ac systems isdefined by

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

Where

$\alpha = e^{j2\pi/3}$, $[x_a \quad x_b \quad x_c]$ Are the phase variables, and $[x_0 \quad x_1 \quad x_2]$ are the symmetrical components in each sequence

Essentially, a bipolar dc system is viewed as a two-phase ACsystem with zero frequency. Therefore, the same transformationCan be derived from (1) by changing***a***to $e^{j\pi}$ and reducingthe dimension to 2. The resulted expression is

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

---2

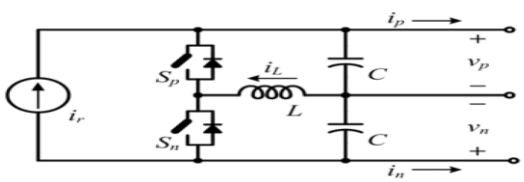

Fig.5: Simplified two-stage circuit for the converter in Fig 4

In which $[x_p \; x_n]$ are the values within the positive and negative poles respectively, whereas $[x_0 \; x_1]$ are the corresponding symmetrical components. The inverse transformation of (2) is

$$\begin{bmatrix} x_p \\ x_n \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \begin{bmatrix} x_0 \\ x_1 \end{bmatrix}$$

……..3

It is attention-grabbing to look at that are basically the common-mode and differential-mode parts in analog electronics. They're named dc symmetrical parts during thispaper to spotlight its relationship with the ac counterpart. TheDC symmetrical parts have several valuable properties. For examples, there's an influence conservation relationship within the transformation.

$$v_p \cdot i_p + v_n \cdot i_n = 2(v_1 \cdot i_1 + v_0 \cdot i_0)$$

......4

If the voltages are balanced, and. During this case

$$v_p \cdot i_p + v_n \cdot i_n = 2 v_1 \cdot i_1$$

…5

This implies that the differential-mode part represents the collective power transfer of the 2 poles, while thecommon-mode part describes the inter-pole interactioncaused by unbalanced operation. More significantly, decoupled equivalent circuits are often derived for each mode. This allows simplified analysis of thetwo modes severally, and provides a perceptive read of the static and dynamic behaviors of bipolar dc systems. Detailed procedures for getting the mode circuits for every phase ofa bipolar LVDC grid, together with the distribution device, lines and loads, are mentioned below.

The LVDC system thought responds to the present challenge within the field of distribution of electricity. The LVDC gear mechanism has higher transmission capability than a conventional 400V AC system ensuing from the voltage distinction between the systems. The transmission capability may be over sixteen times at the dip limit and over four times at thermal limit compared to tradition 400V AC system. The transmission capability on the used DC voltage level is way over that of its AC counterpart, therefore resulting in either smaller cross-sectional of cables or higher power delivery capability. The quantity of various quite variations will gift in LVDC topologies, that area unit as follows:

A.Monopole: AC/DC conversion is usually situated close to medium voltage (MV) or high voltage (HV) line. The DC/AC and/or DC/DC conversion will instead be situated at completely different location.

- HVDC link sort resolution, wherever the link between AC/DC and DC/AC or DC/DC is high voltage link (HV) that is then stepped down and distributed among numerous fashion designer. It constructs of 1 DC link between 2 separate AC network and AC-DC network. Customers area unit connected to a standard 3-phase AC or common DC link.
- Wide LVDC distribution district, wherever DC/AC or DC/DC conversion is created at each individual client finish. The network consists of variety of branches adequate to the quantity of consumers.

B. Bipolar: In bipolar system 2 unipolar systems area unit connected asynchronous. Multiple ways in which may be achieved exploitation bipolar system.

1. Between a positive pole and customary.
2. Between a negative pole and customary.
3. Between a positive and a negative pole.
4. between a positive and a negative pole with common association.

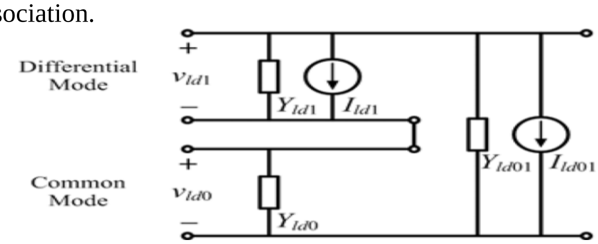

Fig.6: Summary of load mode circuits

IV. ENHANCED COMMON-MODE VOLTAGE CONTROL

A major benefit of the dc symmetrical component method is that it allows for independent analysis and control of the two

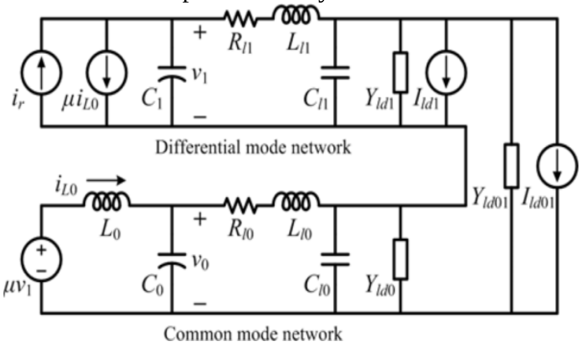

Fig.7: Combined mode model for bipolar LVDC system.

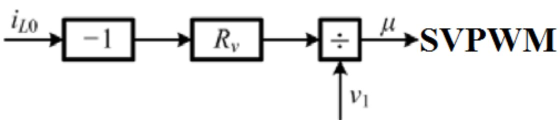

Fig.8: Summary of load mode circuits

As would be clear from the discussions within the on top of sections, the SVPWM is bothered with the management of inverter output voltages during a unified manner. It doesn't control the individual section voltages individually. The instantaneous magnitude and direction of the specified resultant voltage vector is set as per the frequency and magnitude of inverter's basic output voltage. The SVPWM is best realized with the assistance of a digital information processing system, like microchip or digital signal processor. The algorithmic rule to be dead is outlined below:

Is an algorithmic rule for the management of pulse dimension modulation (PWM). within which the reference signal is sampled regularly; when every sample, non-zero active switch vectors adjacent to the reference vector and one or additional of the zero switch vectors area unit selected for the acceptable fraction of the sampling amount so as to synthesize the reference signal because the average of the used vectors. the topology of a three-leg voltage supply electrical converter is due to the constraint that the input lines mustn't ever be shorted and also the output current should be continuous a voltage supply electrical converter will assume solely eight distinct topologies. Six out of those eight topologies turn out a nonzero output voltage and area unit referred to as non-zero switch states and also the remaining 2 topologies turn out zero output voltage and area unit referred to as zero switch states. It's used for the creation of electrical energy (AC) waveforms; there are a unit variation of SVPWM that end in totally different quality and procedure necessities. One active space of development is within the reduction of total harmonic distortion (THD) created by the speedy switch inherent to those algorithms. Pulse-width modulation (PWM) uses an oblong pulse wave whose pulse dimension is modulated leading to the variation of the typical worth of the undulation. The only thanks to generate a PWM signal is that the interceptive methodology, which needs solely a saw tooth or a triangle modulation (easily generated employing a easy oscillator) and a square wave. Once the worth of the reference signal is quite the modulation undulation, the PWM signal is within the high state, otherwise it's within the low state. The electrical converter output voltage is decided within the following:

- When $V_{control}>V_{tri}$, $V_{A0} = V_{dc/2}$
- When $V_{control}<V_{tri}$, $V_{A0} = -V_{dc/2}$

Ex: Considering an electrical drive system as shown in Figure one, the controller generates a reference voltage, us, depicted with voltage house vector, as equation.

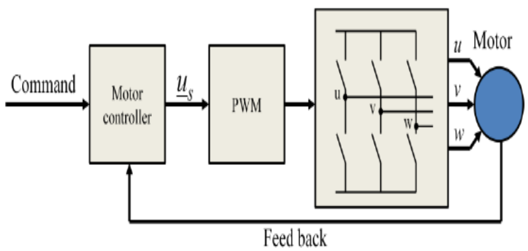

Fig.9: Structure of an electric drive system

In order to use this voltage on the motor, it's needed to convert this reference voltage to the switch signals for the electrical converter. To do this, many PWM methods are a unit out there. Within the sub-oscillation strategies, the 3 section voltages area unit first calculated and that they area unit compared with a high frequency carrier signal to come up with the pulses to regulate the electrical converter switches. Besides such strategies, it's potential to come up with the switch signals directly exploitation the house vector of the reference voltage, while not having to convert the house vector to the 3 section values initially. This methodology is termed house vector modulation (SVM).

V. PRINCIPLE

It is famed that the 3 switch arms within the device have eight base states as shown in Figure a pair of. Six vectors of them have non-zero magnitudes, whereas the opposite 2 area unit zeros length vectors. Referring to Figure a pair of, suppose a reference voltage North American country is to be applied to the motor. If it's not similar to one amongst the bottom vectors, it should be approximated exploitation these eight vectors. Within the case shown in Figure a pair of, North American country is approximated supported timely switch among u_{100}, u_{110} and also the 2 zero vectors. In this case, vector u100 ought to be applied for an extended time than u_{110}

since North American country is nearer to u_{100}; and a time of zero vectors ought to even be applied so as to scale back the magnitude

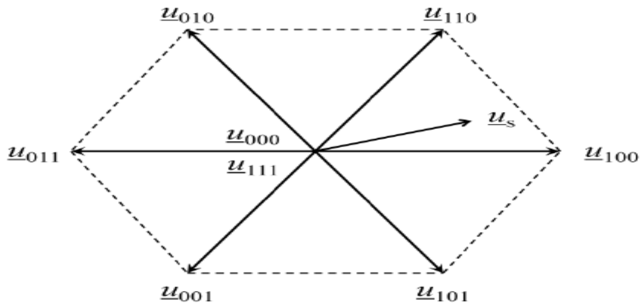

Fig.10: Voltage space vectors available using a three phase inverter

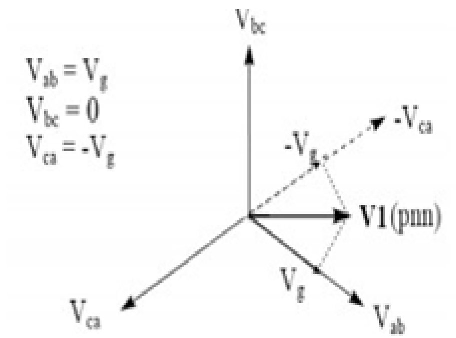

Fig.11: Topology 1-V1 (P_{nn}) of a Voltage Source Inverter

This technique is incredibly the same as dc machine's independent excitation wherever flux is that operateof field current and force is in proportion with flux and rotor current. The most downside of vector management method is flux axis angle calculation wherever is finished by measuring the flux in 2 points with ninety degrees displacement then angles square measure calculated exploitation the resulted fluxes or estimating in reference to rotor speed.

VI. SIMULATION WORK:

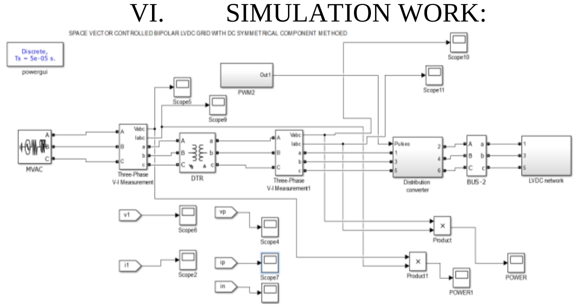

Fig.12: Space Vector Controlled Bi Polar LVDC Grid Simulink Model

Subsystems:

Distribution converter:

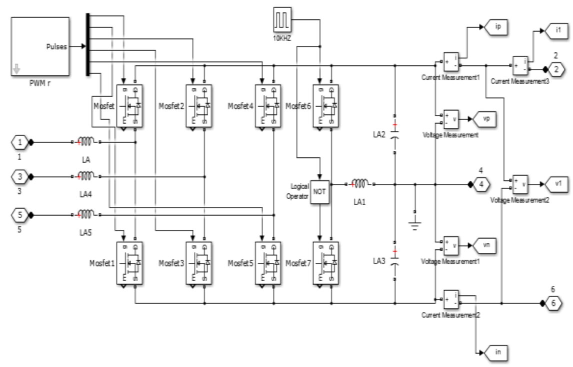

Fig.13: Distribution converter simulink model

LVDC Network:

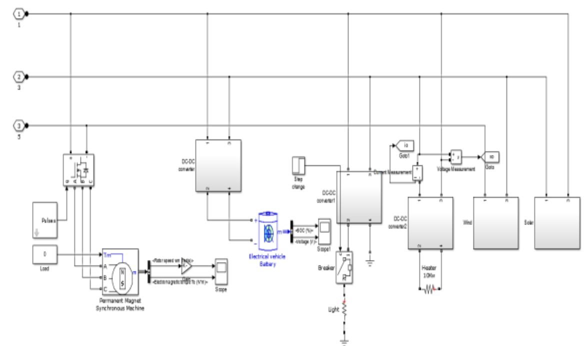

Fig.14: LVDC grid simulink model

Solar:

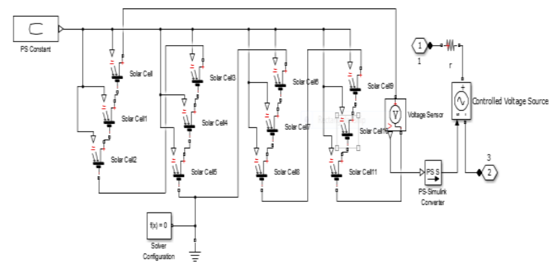

Fig.15: Solar panelsimulink model

Wind:

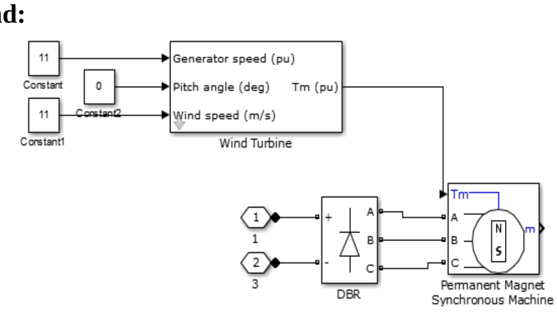

Fig.16: Wind power simulink model

VII. RESULTS& DISCUSSIONS

Input voltage:

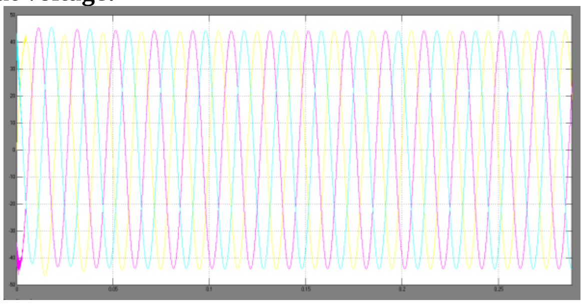

Fig.17: Input voltage wave form

Inputcurrent:

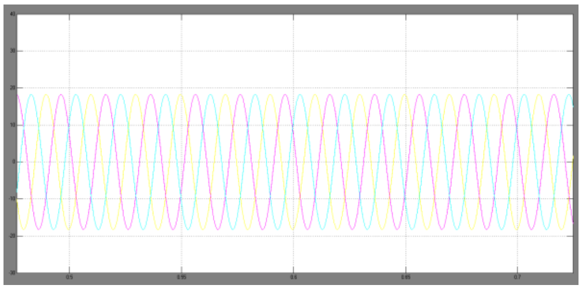

Fig.18: Input current wave form

Output voltages:

Fig.19: DTR Output Voltage

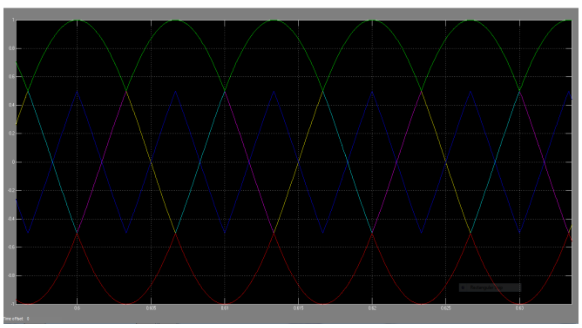

Fig.20: SVPWM Modulation Index output

THD for existing & extension model:

Voltage for existing:

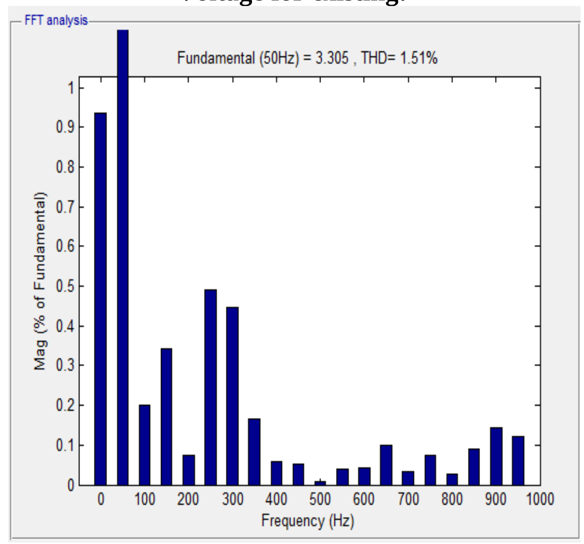

Fig.21: Output voltage THD for existing

Voltage for extension:

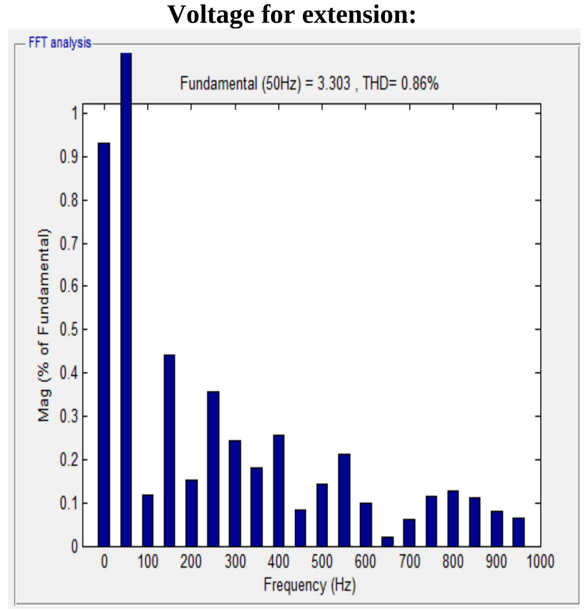

Fig.22: Output voltage THD for Extension

THD ANALYSIS TABLE:

SNO	MODEL	THD %
1	EXISTING	1.51%
2	EXTENSION	0.86%

VIII. CONCLUSION

The dc symmetrical element technique provides a useful tool for the analysis and management of bipolar LVDC distribution systems. It decomposes a bipolar dc grid into decoupled differential- mode and common-mode networks, thereby facultative separated and simplified investigation of every mode. Supported this technique, the enhanced common-mode voltage regulation theme shows advantageous performances in damping the common-mode LC resonance to enhance power quality and voltage stability.

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