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Implementation of Inverter with Flexible Voltage Control for A DC Line in a System

M. Mohanraj*, R. Lalitha**
*(Department of Electrical and Electronics Engineering, Kumaraguru College of Technology, Coimbatore-46)
** (Department of Electrical and Electronics Engineering, Kumaraguru College of Technology, Coimbatore-46)

ABSTRACT
Due to raising demands in electric power it becomes more important to use the available energy sources efficiently and along with them the distributed generation comes into picture which means collection of energy from many small sources say RES. For distribute generation (DG) systems a challenging issue is to smartly integrate renewable-energy sources into the grid as it leads to power quality problems under fault conditions. Another approach for meeting the power demand is to implement TEP .This work proposes an method which uses a control algorithm for inverters for providing a flexible voltage control using reference current generation under grid faults. The controlled inverter designed is used for inversion processes at the receiving end in a HVDC line. A system with three sources is considered, their performances if the three lines connecting three sources are AC lines and if one line is replaced with a DC line is studied.
Keywords – Distributed Generation, High Voltage DC Transmission, Renewable energy sources, Transmission Expansion Planning.

I. Introduction

The Transmission expansion planning exercise aims for improving the security and reliability of power systems without taking economics as primary concern. Network expansions can be carried out by AC as well as DC model each having their merits and demerits. Compared to ac transmission the high voltage DC transmission (HVDC) has certain advantages which are stated as minimized power losses for long transmission lines, capability of delivering bulk power etc. It is considerable that the DC transmission system is most suitable for delivering the non-conventional energy sources from sites to load centre.

A DC transmission system consists of two and more converters. One end converters will be used as rectifiers and another converter will be used as inveter.The inverter used here will be provided with a control scheme which will provide different voltage support strategies for different voltage sags under grid fault conditions. A control algorithm for flexible voltage control using reference current generation under grid fault condition is discussed in this work. Nowadays DG penetration into the grid sources is rapidly increasing and so the control schemes with high performances are required. This ensures the proper operation of DG systems especially under grid fault conditions. The proposed work here gives an idea of using current mode three phase inverters to support the grid voltage, whereas the behaviour of inverter is commanded by a controller unit. These type converters finds applications in HVDC lines for implementing the DC model TEP.A comparison will transmitted power and the voltage sag compensation in an AC and DC lines will be made here. The work here is done by considering a simple three bus system with all the three buses connected by AC lines and also another three bus system where any one line is replaced by DC line which uses controlled invereter.The voltage sag compensation is studied using simulation and also comparison between the transferred power of two models is done here.

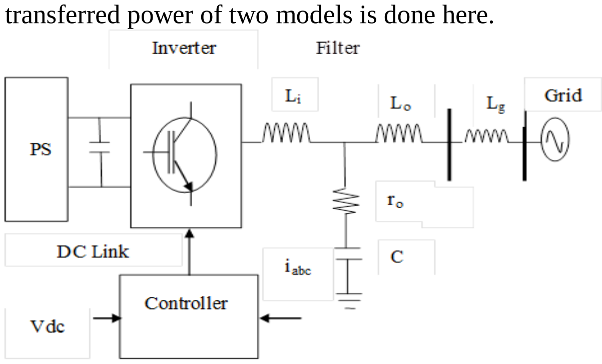

FIG.1.Block diagram of Flexible voltage control

II. Flexible voltage control

For DG system to be smartly integrated into the grid, a very important issue is to provide voltage support flexibly according to various voltage sags that occurs under various grid fault conditions. If the grid is suffered from a balanced three phase fault, the inverter will be injecting reactive power to raise the voltage levels in all three phases. If the fault occurred is unbalanced (i.e.) if one or two phase fault occurs, the inverter here will be in concern of equalizing the voltage by reducing the negative sequence and also helps to clear the phase jump. Current mode three-phase inverter to smartly support the grid voltage is discussed here.The inverter whose operation is commanded by controller unit helps in fulfilling the following requirements:

1. Voltage ride through
2. active power control
3. reactive current injection
4. high power quality

When grid is in fault, voltage support control can mitigate voltage sag effects by injecting additional reactive current to ride through the voltage sag problems and support the grid voltage.

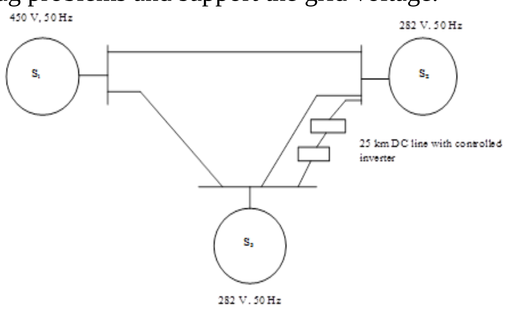

FIG.2.Implementation of inverter in transmission line.

III. Control Algorithm

The control algorithm proposed here will be providing a balance of positive and negative sequence components by using reference current generation. The reference current will be generated based on the requirements. Whenever the voltage sag occurs the reactive current component will get added along with the real current component and will be supporting the grid voltage levels.

For generating the reactive current references he formulae used are

$$i^*_{\alpha(q)} = 2/3Q^* \frac{k^+ v_\beta^+ + k^- v_\beta^-}{k^+\left[(v_\alpha^+)^2+(v_\beta^+)^2\right]+k^-[(v_\alpha^-)^2+(v_\beta^-)^2]} \quad (1)$$

$$i^*_{\beta(q)} = 2/3Q^* \frac{-K^+ V_\alpha^+ - K^- V_\alpha^-}{K^+[(V_\alpha^+)^2+\left(V_\beta^+\right)^2]+K^-[(V_\alpha^-)^2+(V_\beta^-)^2]} \quad (2)$$

For generating the active current references the formulae used are

$$i^*_{\alpha(p)} = \frac{2}{3} P^* \frac{v_\alpha^+}{(v_\alpha^+)^2+(v_\beta^+)^2} \quad (3)$$

$$i^*_{\beta(p)} = \frac{2}{3} P^* \frac{v_\beta^+}{(v_\alpha^+)^2+(v_\beta^+)^2} \quad (4)$$

Here k^+ and k^- are control parameters which are used for balancing the positive and negative sequences. For normalizing these parameters we use

$K^- = 1-K^+$

Various control strategies can be attained by setting different control parameters values. For achieving desired voltage proper tuning of control parameters are required.

Thus total reference current generated is given as

$$i^*_\alpha = i^*_{\alpha(p)} + i^*_{\alpha(q)} \quad (5)$$

$$i^*_\beta = i^*_{\beta(p)} + i^*_{\beta(q)} \quad (6)$$

The proposed control scheme ensures the following :

- By proper tuning of one single control parameter k^+,the voltage at the inverter side can be raised when k^+ value tends to one and also can be equalized when k^+ value tends to zero or a flexible combination of both ($0<k^+<1$).
- No harmonic distortion appears in the references generated.

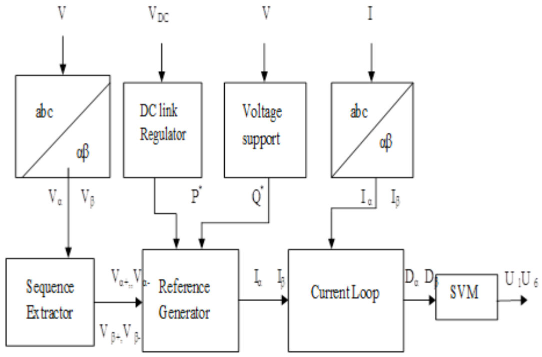

FIG.3. Control Block

The reference current generated will be compared with actual current in current loop. The output of current loop will be the duty cycle values d_α and d_β and they are processed by space vector modulator to control the inverter switches. The voltage support block used will first detect the sag by computing the root mean square value of voltage for all phases. The voltage support block will be activated if one or more rms values reduce below threshold value.

IV. Implementation Of Controlled Inverter In Transmission Network

The controlled inverter designed for voltage support of the grid under fault is implemented for the DC line on the receiving end (inverting side).Considering a system having three interconnected sources, among those three sources, two sources will be connected through AC line and third line will be a DC line. The DC line has a converter and the controlled inverter designed using the reference current generation is implemented. A

25 kilometers DC line is used. The voltage from three bus bars is measured and the output waveforms are shown. The fault current and the occurrence of the voltage sag are shown in waveforms .The voltage outputs on all three ends will be compared with each other. The simulation block for implementation of inverter in a system consist of three sources and simulation block for design of inverter will be drawn in Mat Lab software. The results will be taken in form of waveforms with run time as 0.5 seconds. It is considered that the fault occurs after 0.3 seconds and the output waveforms for sag compensation are studied here. In Fig.4.

The simulation diagrams for system with AC lines and for system with one line replaced with a DC line are given separately as simulation blocks in following figure.

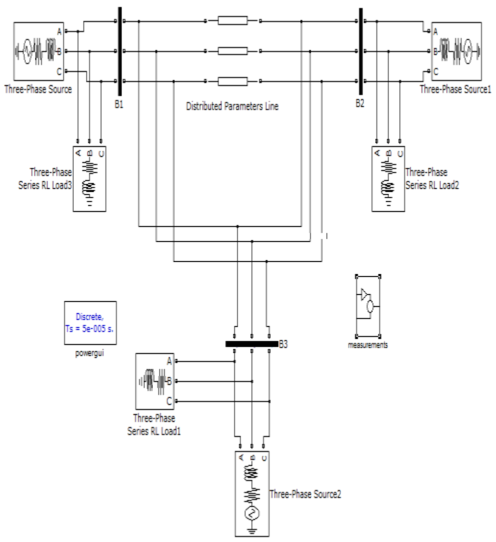

FIG.4. Simulation Block of a system With Three AC lines.

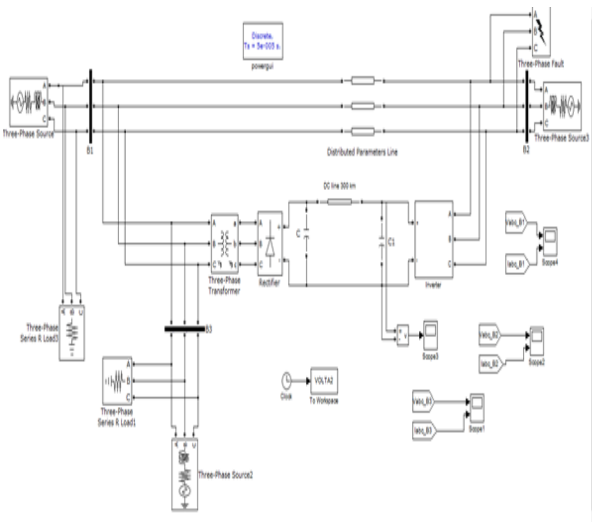

FIG.5. Simulation Block of a system With Controlled Inverter.

The simulation blocks for a system with three AC lines and a system with one AC line replaced by a DC line shown above. In Fig.5.

V. Simulation results

The simulation results will be discussed in this section. The bus bar one and three are operated under normal conditions and bus bar two is considered to be under fault (three phase fault).

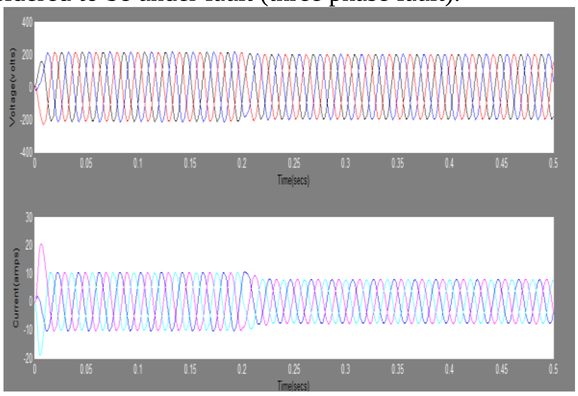

FIG.6. voltage and current waveforms of bus bar 2 & 3

The Bus bar 1 is taken to be operated under normal condition and the waveform for the voltage and current is shown,

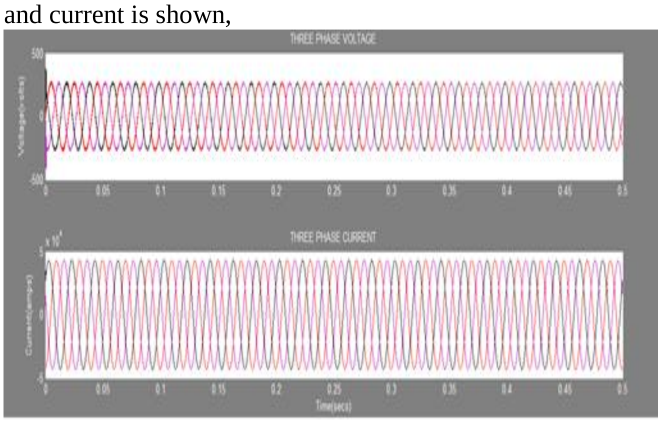

FIG.7. voltage and current waveforms of bus bar 1.

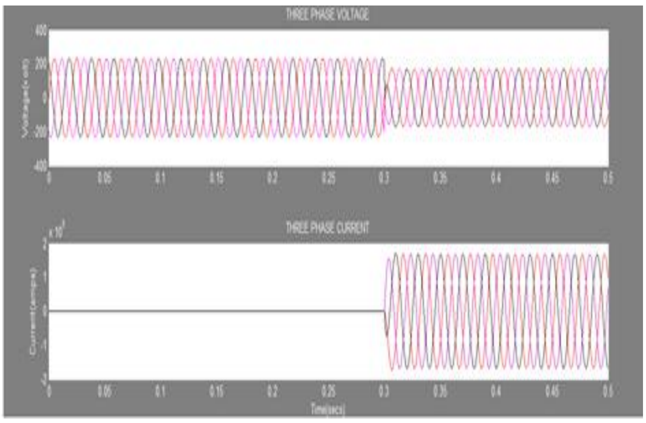

FIG.8.Sag and Fault current waveform

5.1. Phase voltage and current after fault clearance:

The controlled inverter designed for voltage support is used in the DC line that connects the bus bar 2 and 3.The sag compensation after 0.3 secs by the usage of the inverter is shown in the waveform,

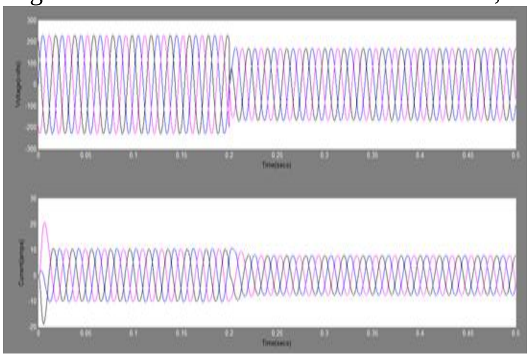

FIG.9.Sag compensation waveform

5.2. DC Line voltage:

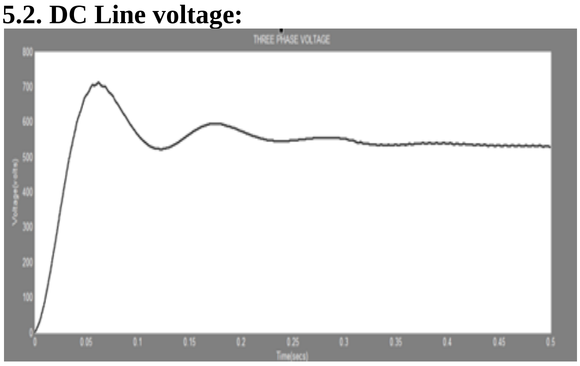

FIG.10. DC Voltage waveform

5.3. THD Values:

The total harmonic distortion values are obtained by using FFT analysis in Mat Lab. In fig 11, the THD value for the AC line without inverter is shown. The THD value is 80.3%.

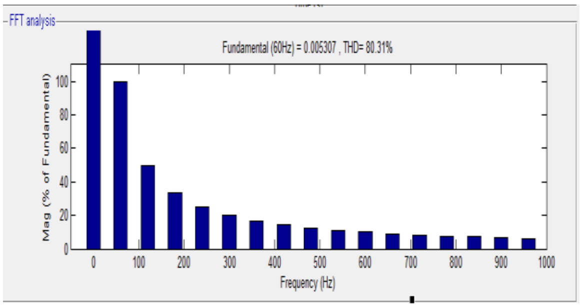

FIG.11. THD waveform for bus 2 without inverter.

The THD value for the AC line while using inverter is shown in fig.12.The value obtained is 24.90%.

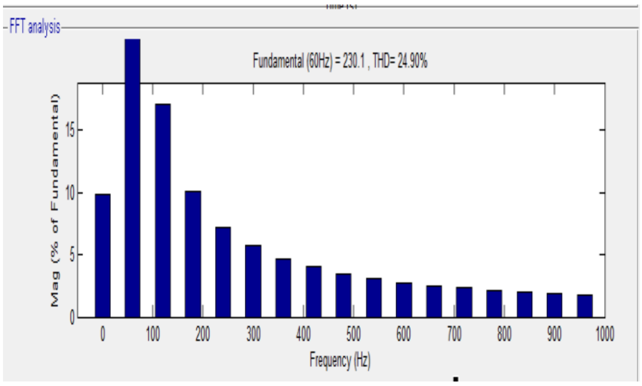

FIG. 12.THD waveform with inverter.

The THD value for the DC line is shown in fig.12.The value obtained is 77.15%.

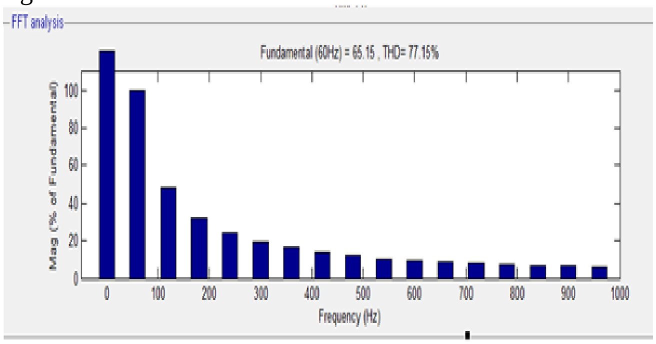

FIG13.THD waveform for DC line

VI. Conclusion

The paper proposes a three phase inverter that will provide a flexible voltage support when grid fault occurs. A simple system consisting of three AC sources is considered that are connected through AC lines. Among three AC lines one line will be replaced by DC line and a comparative study has been made for the occurrences voltage sag and the THD in AC and DC lines. The controlled inverter used here has the following advantages:

- flexibly support the line voltage
- clear the phase jump

In future this work can be extended for IEEE bus systems and for transmission network expansion.

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Authors Biography

M.Mohanraj, received B.E degree in Electrical and Electronics Engineering from Bharathiar University in the year 2001 and M.E (Power System) from Annamalai University in 2005.Currently he is pursuing Ph.D. research work under Anna University , Chennai. He is a senior Assistant Professor of EEE department in Kumaraguru College of Technology, Coimbatore. He is having one year of industrial and 12 years in teaching experience. He has published twelve papers in National conferences and six journals. He is a Life member in Indian Society for Technical Education (India). His research area includes Wind Energy Conversion, Solar Energy, Machines and Power Quality issues.

Rani Thottungal, obtained her B.E and M.E degrees from Andhra University and Doctorate from Bharathiar University. She is currently working as Professor and Head in EEE department, Kumaraguru College of Technology, Coimbatore. Her research interest includes Power System, Power Inverter and Power Quality Issues.

R.LALITHA completed her B.E in Hindusthan College of Engineering and Technology, Coimbatore and pursuing final year M.E. in Power Electronics and Drives in Kumaraguru College of Technology, Coimbatore.