AN UNBALANCED AC SOURCE THREE-PHASE CONVERTER POWER CONTROLLABILITY USING FUZZY CONTROLLER

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ABSTRACT: *At present scenario, renewable energy sources become an alternative source of energy for future energy demand and to mitigate environment pollution problems. Grid connected renewable energy source like wind energy system uses power electronics converters as an interfacing device between wind energy system and utility grid. These converters are commonly based on a voltage source inverter (VSI) connected to the supply network, operated to achieve objectives such as power flow regulation with unity power factor operation. However, intermittent nature of wind energy must be controlled to meet the grid requirements. The grid requirements include independent control of active & reactive power, improved power quality, grid synchronization and Good transient response during fault conditions etc. Usually voltage oriented control (VOC) of grid side converter in the synchronous reference frame was universally adapted for independent control of active and reactive power of the grid. However, the dynamic response during abnormal condition of grid is sluggish and poor power quality. In order to design controller for robust performance and to know the control characteristics, VSI needs to be accurately modelled. This project has taken an attempt to derive the small signal model of a single phase inverter in isolated mode and its performance with different controllers. Further, the work is extended to modelling of three phase grid connected VSI and its relevant transfer functions have been deduced from the model so as to analyse the system performance for designing a controller through wellknown bode plots. The studied system is modelled and simulated in the MATLAB-Simulink environment.*

1. Introduction

Due to exponential growth of future energy demand and depletion of fossil fuels, renewable energy sources are playing a pivotal role in the today power scenario. Renewable energy sources include wind power, PV system, bio mass, wave energy and small hydro etc. Among all renewable energy sources, wind energy system is most promising source of energy due to economic viability [1]. Distributed generation (DG) based on renewable energy sources are basically small scale power generation units (typically ranges from 20 kW to 20 MW) and they are located at the end user without long distance transmission line. As a result, it reduces the transportation cost of generation and consumption points are close to each other. It is feasible to implement interfaces having ability to operate in grid connected as well as in isolated mode without grid connection which is called micro grids [2]. The ultimate aim of this study is to meet the following objectives: ¬ To derive a small signal modelling of 1-Φ inverter and its transfer functions for designing controller. ¬ To extend small signal modelling to 3-Φ grid connected inverter. ¬ To derive transfer functions of modelled grid connected inverter and observe the effect of resonance from the bode plots. ¬ To design a controller for three phase grid connected inverter based on derived small signal model.

2 Literature Review

Grid connected inverter system employes different control algorithm in order to improve the over all system perfomance and the relevent control strategies are extensively studied in the available literature[1]-[18]. Average current control (ACC) has been widely used for controlling DC/DC as well as single-phase power factor correction (PFC) converters. Compared to peak current control ACC has following advantages[5]. ¬ Error is minimized as a high gain current error amplifier is used.

- Large noise margin.
- No need of external compensation ramp.
- Easy current limit implementation.
- Good tracking performance of Average current mode control.

In order to design an average current control for an inverter, small signal modelling needs to be done which is based on average switched modelling [5]. In this technique manipulations are performed on the circuit rather than on its equations. The converter switches are replaced with voltage and current sources to obtain a time invariant circuit. Then the converter wave forms are averaged over one switching period to remove the undesired switching harmonics. Any non-linear elements present in the averaged circuit model can then be perturbed and linearized to represent small signal model [6]. In order to implement average current controller small signal modelling of inverter is required. This can be achieved by circuit averaging and as well as state space averaging. In [7] a state space averaging method is employed so as to get a small signal model. In [8] an average current mode controller is used to get equal current distribution in case of a resonant DC to DC converter. In average model of three phases inverter is proposed so as to reduce the current distributions in multi module Resonant dc to dc converter. However, in case of three phase grid connected inverter voltages and currents are usually transferred to rotating d-q reference frame for making design of controller easier because the current space vector in the rotating d-q reference frame is fixed, the PI controllers operate on dc, rather than sinusoidal signals.

3. LIMITS OF A TYPICAL THREEWIRE CONVERTER SYSTEM

To examine the controllability and the execution of the power hardware converter under an antagonistic air conditioning source, as each uneven air conditioning voltage is first characterized as a contextual investigation in this venture. As appeared in Fig. 3, the phasor chart of the three stage mutilated air conditioning voltage are demonstrated, it is accepted that the sort B blame occurs with the noteworthy voltage plunge on stage An of the air conditioner source. Additionally, there are numerous different sorts of voltage flaws which have been characterized as sort A–F. As indicated by [2] and [9], any twisted three-stage voltage can be communicated by the total of parts in the positive succession, negative grouping, and zero arrangement. For effortlessness of investigation, just the segments with the major recurrence are considered in this venture, be that as it may, it is likewise conceivable to extend the examination to higher request music. The misshaped three-stage air conditioning source voltage in Fig. 1 can be spoken to by Where $V+$,$V-$, and $V0$ are the voltage amplitude in the positive, negative, and zero sequence, respectively. And $\phi+$, $\phi-$, and$\phi 0$ represent the initial phase angles in the positive sequence,negative sequence, and zero sequence, respectively. The predefined voltage dip as indicated in Fig. 3 should contain voltage components in all the three sequences [2], [9] .

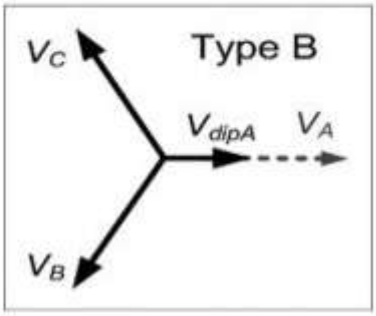


Fig. 1.Phasor diagram definitions for the voltage dips in the ac source

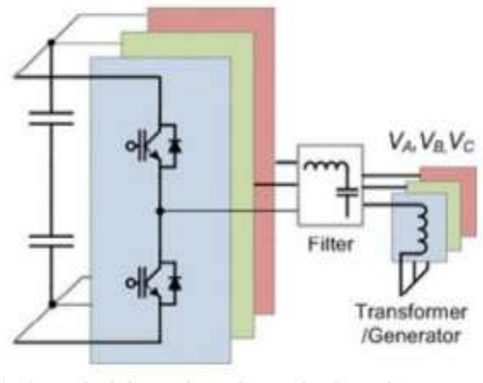


Fig. 2. Typical three-phase three-wire 2L-voltage source converter

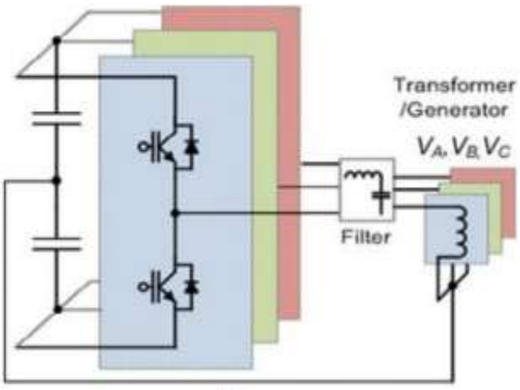
A typically used three-phase three-wire two-level voltage source dc–ac converter is chosen and basically designed, as shown in Fig. 2, where the converter configuration and the parameters are indicated, respectively. It is noted that the three-phase ac source is represented here by three winding switch a common neutral point, which can be the windings of an electric machine or a transformer Because there are only three wires and a common neutral point in the windings of the ac source, the currents flowing in the three phases do not contain zero-sequence components.

Elimination of the Negative-Sequence Current

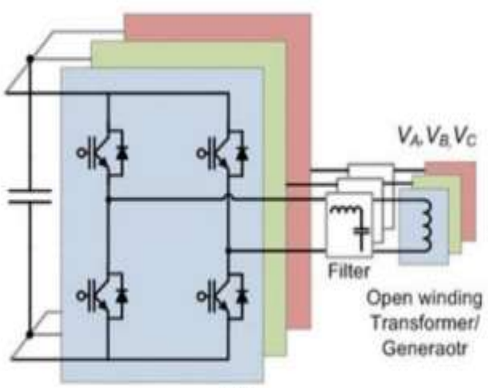
In the greater part of the matrix coordination applications, there are strict network codes to direct the conduct of the framework associated converters. The negative-grouping current which dependably brings about the uneven load current might be unsatisfactory from the point perspective of a TSO.

4.CONVERTER SYSTEM WITH THE ZERO- SEQUENCECURRENT PATH

As can be finished up, in the run of the mill three-stage three-wire converter structure, four control flexibilities for the heap current appear to be insufficient to accomplish palatable exhibitions under the unequal air conditioning source. (Regardless of what blends of control targets are utilized, either huge power wavering or over- burden/twisted current will be introduced.) Therefore, more present control flexibilities are required with a specific end goal to enhance the control execution under the lopsided air conditioning source conditions. Another arrangement of the converter structure are appeared as demonstrated as the four-wire framework in Fig. 3(a) and the six-wire framework in Fig. 3(b). Contrasted with the three-wire converter structure, these sorts of converters present the zero-grouping current way , which may empower additional present control flexibilities to accomplish better power control exhibitions. It is noticed that in the matrix associated application, the zero-succession current is not infused into the lattice but rather caught in the ordinarily utilized d-Y transformer.



(a)



(b)

Fig. 5.Converter structure with the zero-sequence current path. (a) Four-wire system. (b) Six-wire system.

A potential control structure is proposed in Fig. 10, in which an extra control loop is introduced to enable the controllability of the zero-sequence current. After introducing the regulated zero-sequence current, the three- phase current generated by the converter can be written By operating the voltage of the ac source (1) and the current controlled by the power converter (14), the instantaneous generated real power p, the imaginary power q in the αβ coordinate,and the real power p0 in the zero coordinate can be calculated as

$$\overline{P} = \frac{3}{2}(v_d^+ \cdot i_d^+ + v_q^+ \cdot i_q^+ + v_d^- \cdot i_d^- + v_q^- \cdot i_q^-)$$

$$P_{c2} = \frac{3}{2}(v_d^- \cdot i_d^+ + v_q^- \cdot i_q^+ + v_d^+ \cdot i_d^- + v_q^+ \cdot i_q^-)$$

$$P_{s2} = \frac{3}{2}(v_q^- \cdot i_d^+ - v_d^- \cdot i_q^+ - v_q^+ \cdot i_d^- + v_d^+ \cdot i_q^-) \quad (17)$$

$$\overline{Q} = \frac{3}{2}(v_q^+ \cdot i_d^+ - v_d^+ \cdot i_q^+ + v_q^- \cdot i_d^- - v_d^- \cdot i_q^-)$$

$$Q_{c2} = \frac{3}{2}(v_q^- \cdot i_d^+ - v_d^- \cdot i_q^+ + v_q^+ \cdot i_d^- - v_d^+ \cdot i_q^-)$$

$$Q_{s2} = \frac{3}{2}(-v_d^- \cdot i_d^+ - v_q^- \cdot i_q^+ + v_d^+ \cdot i_d^- + v_q^+ \cdot i_q^-)$$

$$\begin{bmatrix} \overline{P} + \overline{P_0} \\ P_{c2} + P_{0c2} \\ P_{s2} + P_{0s2} \\ \overline{Q} \\ Q_{c2} \\ Q_{s2} \end{bmatrix} = \frac{3}{2} \begin{bmatrix} v_d^+ & v_q^+ & v_d^- & v_q^- & v_{\mathrm{Re}}^0 & v_{\mathrm{Im}}^0 \\ v_d^- & v_q^- & v_d^+ & v_q^+ & v_{\mathrm{Re}}^0 & -v_{\mathrm{Im}}^0 \\ v_q^- & -v_d^- & -v_q^+ & v_d^+ & -v_{\mathrm{Im}}^0 & -v_{\mathrm{Re}}^0 \\ v_q^+ & -v_d^+ & v_q^- & -v_d^- & 0 & 0 \\ v_q^- & -v_d^- & v_q^+ & -v_d^+ & 0 & 0 \\ -v_d^- & -v_q^- & v_d^+ & v_q^+ & 0 & 0 \end{bmatrix} \begin{bmatrix} i_d^+ \\ i_q^+ \\ i_d^- \\ i_q^- \\ i_{\mathrm{Re}}^0 \\ i_{\mathrm{Im}}^0 \end{bmatrix}$$

It is noted that unlike the traditional approach in which the zero sequence components are normally minimized, the zero sequence voltage and the current here look like single-phase AC components running at the same fundamental frequency. As a result, the zero-sequence voltage/current can be represented by vectors. It can be seen from (22) that if the three-phase ac source voltage is decided, then the converter has six controllable freedoms (i+d,i+q, i−d , i−q , i0Re, and i0Im) to regulate the current flowing in the ac source. That means: six control targets/functions can be established by the converter having the zero-sequence current path. Similarly, the three-phase average active and reactive power delivered by the converter are two basic requirements for a given application, then, two control functions need to be first settled.

Elimination of Both the Active and Reactive Power Oscillation: Because of more current control freedoms, the power converter with the zero-sequence current path can not only eliminate the oscillation in the active power, but also cancel the oscillation in the reactive power at the same time. The power oscillation caused by the zero-sequence currentP0c2 and P0s2 are used to compensate the power oscillation caused by the positive- and negative-sequence currents Pc2 andPs2. When combing (26), (30), and (31), each of the current components controlled by converter. In order to facilitate the analytical solution, assuming that the d-axis or the real axis in the synchronous reference frame is allied with the voltage vectors in each of the sequence (positive, negative, and zero), then all of the controllable current components with the zero-sequence current path can be solved.

SIMULINK MODELLING AND RESULTS

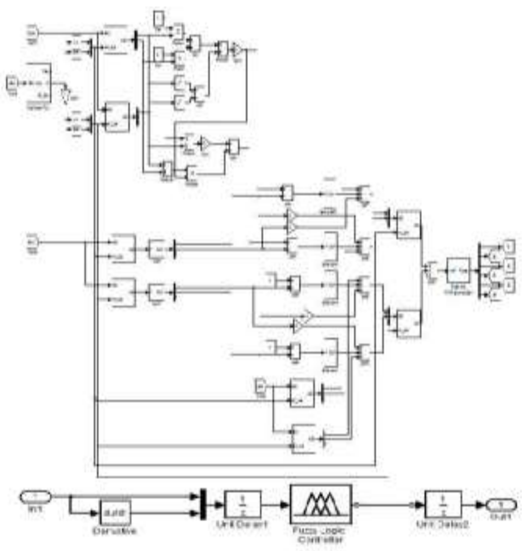


Fig 5.1 Simulink modeling diagrams:

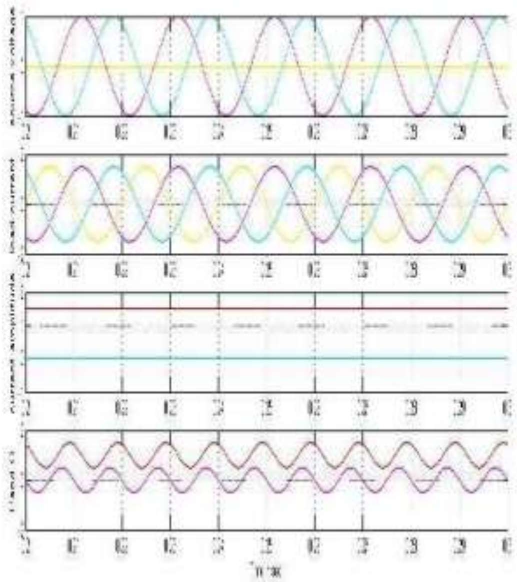


Fig.5.2. Simulation of the converter with no negative- sequence current control (three-phase three-wire converter, Pref = 1 p.u., Qref = 0 p.u.,Id− = 0 p.u., Iq− =0 p.u., VA = 0 p.u., I+, I−, and I0 means the amplitude of the current in the positive negative, and zero sequences, respectively.

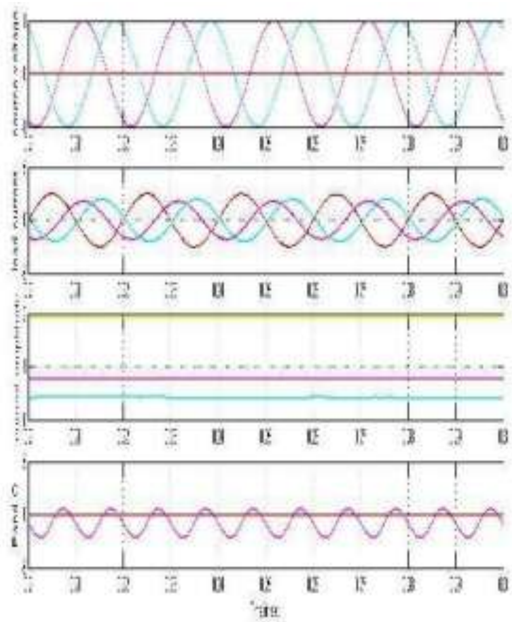


Fig.5.3 Simulation of the converter control with no active power oscillation

CONCLUSION

In a typical three-phase three-wire converter structure, there are four current control freedoms, and it may be not enough to achieve satisfactory performances under the unbalanced ac source, because either significantly the oscillated power or the overloaded current will be presented. In the three-phase converter structure with the zero sequence current path, there are six current control freedoms. The extra two control freedoms coming from the zero sequence current can be utilized to extend the controllability of the converter and improve the control performance under the unbalanced ac source. By the proposed control strategies, it is possible to totally cancel the oscillation in both the active and the reactive power, reduced the oscillation amplitude in the reactive power. Meanwhile, the current amplitude of the faulty phase is significantly relieved without further increasing the current amplitude in the normal phases. The advantage and features of the proposed controls can be still maintained under various conditions when delivering the reactive power. The analysis and proposed control methods are well agreed by simulation validations.

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