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.NEURAL NETWORK BASED DUAL VOLTAGE SOURCE INVERTER FOR POWER QUALITY IMPROVEMENT

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ABSTRACT:
The power system networks are in the need of power quality compensation due to larger population as well as power demand. This proposed work is addressing the technique for above mentioned issue by implementing the dual voltage source inverter topology. This topology actively injecting the real power at needy time from the distributed energy resources like Photovoltaic panel and also compensating the reactive power by incorporating the capacitor bank. Two separate inverters are participating in these control strategies. The control algorithm is fully based on Instantaneous Symmetrical component Theory. The Back Propagation Neural Network is a well-known controller for reducing the error in the system. This proposed system introducing a back propagation neural network controller for switching the two inverters in this topology. The accurate switching of inverter may lead to acute control of real and reactive power compensations. The proposed system is simulated on MATLAB/Sim power system toolbox for various load levels.

I – INTRODUCTION

Technological progress and environmental concerns drive the power system to a paradigm shift with more renewable energy sources integrated to the network by means of distributed generation (DG). These DG units with coordinated control of local generation and storage facilities form a microgrid. In a microgrid, power from different renewable energy sources such as fuel cells, photovoltaic (PV) systems, and wind energy systems are interfaced to grid and loads using power electronic converters. A grid interactive inverter plays an important role in exchanging power from the microgrid to the grid and the connected load. This microgrid inverter can either work in a grid sharing mode while supplying a part of local load or in grid injecting mode, by injecting power to the main grid.

Maintaining power quality is another important aspect which has to be addressed while the microgrid system is connected to the main grid. The proliferation of power electronics devices and electrical loads with unbalanced nonlinear currents has degraded the power quality in the power distribution network.

Moreover, if there is a considerable amount of feeder impedance in the distribution systems, the propagation of these harmonic currents distorts the voltage at the point of common coupling (PCC). At the same instant, industry automation has reached to a very high level of sophistication, where plants like automobile manufacturing units, chemical factories, and semiconductor industries require clean power. For these applications, it is essential to compensate nonlinear and unbalanced load currents. Load compensation and power injection using grid interactive inverters in microgrid have been presented in the literature. A single inverter system with power quality enhancement is discussed in. The main focus of this work is to realize dual functionalities in an inverter that would provide the active power injection from a solar PV system and also works as an active power filter, compensating unbalances and the reactive power required by other loads connected to the system. In, a voltage regulation and power flow control scheme for a wind energy system (WES) is proposed. A distribution static compensator (DSTATCOM) is utilized for voltage regulation and also for active power injection. The control scheme maintains the power balance at the grid terminal during the wind variations using sliding mode control. A multifunctional power electronic converter for the DG power system is described in [9]. This scheme has the capability to inject power generated by WES and also to perform as a harmonic compensator. Most of the reported literature in this area discuss the topologies and control algorithms to provide load compensation capability in the same inverter in addition to their active power injection. When a grid-connected inverter is used for active power injection as well as for load compensation, the inverter capacity that can be utilized for achieving the second objective is decided by the available instantaneous microgrid real power. Considering the case of a grid-connected PV inverter, the available capacity of the inverter to supply the reactive power becomes less during the maximum solar insolation periods [11]. At the same instant, the reactive power to regulate the PCC voltage is very much needed during this period. It indicates that providing multi functionalities in a single inverter degrades either the real power injection or the load compensation capabilities.

II – RELATED WORK

M. Hamid et al., presented a study on a scheme to reduce the current harmonics from a photovoltaic (PV) plant. The scheme uses a power conditioner unit, which is placed parallel with the plant and works in feed-forward mode, and behaves to compensate the PV plant's output current distortion, so that the total current flows to the grid is sinusoidal.Y. Tang et al., investigated the inherent damping characteristic of LCL-filters for three-phase grid-connected voltage source inverters (VSIs). Specifically, it is found that there is an inherent damping term embedded in the feedback loop when converter current is used for implementing closed-loop control. This additional damping term can indeed neutralize the resonance introduced by LCL-filters, and thus giving rise to a more stable system than that of grid current feedback control. P. Rodriguez et al., presented a new grid synchronization method for three-phase three-wire networks, namely dual second-order generalized integrator (SOGI) frequency-locked loop. The method is based on two adaptive filters, implemented by using a SOGI on the stationary αβ reference frame, and it is able to perform an excellent estimation of the instantaneous symmetrical components of the grid voltage under unbalanced and distorted grid conditions.X. Yu et al., derived mathematical models to quantitatively evaluate the reliability of parallel inverters under different topologies and control strategies. A framework to determine the number of inverters in parallel in terms of reliability and cost optimization is proposed.N. R. Tummuru et al., proposes a control scheme to control the microgrid side voltage-source converter (μG-VSC) using instantaneous symmetrical components theory. The μ G-VSC with proposed control can be utilized as a bidirectional power sharing converter to control the power flow from the dc side to the ac side and vice versa, based on renewable power available at the dc link.

This proposed work is addressing the technique for above mentioned issue by implementing the dual voltage source inverter topology. This topology actively injecting the real power at needy time from the distributed energy resources like Photovoltaic panel and also compensating the reactive power by incorporating the capacitor bank. Two separate inverters are participating in these control strategies. The control algorithm is fully based on Instantaneous Symmetrical component Theory. The Back Propagation Neural Network is a well-known controller for reducing the error in the system. This proposed system introducing a back propagation neural network controller for switching the two inverters in this topology.

III – PROPOSED SYSTEM

This section demonstrates a BPNN based dual voltage source inverter (DVSI) scheme, in which the power generated by the microgrid is injected as real power by the main voltage source inverter (MVSI) and the reactive, harmonic, and unbalanced load compensation is performed by auxiliary voltage source inverter (AVSI). This has an advantage that the rated capacity of MVSI can always be used to inject real power to the grid, if sufficient renewable power is available at the dc link. In the DVSI scheme, as total load power is supplied by two inverters, power losses across the semiconductor switches of each inverter are reduced. This increases its reliability as compared to a single inverter with multifunctional capabilities. Also, smaller size modular inverters can operate at high switching frequencies with a reduced size of interfacing inductor, the filter cost gets reduced. Moreover, as the main inverter is supplying real power, the inverter has to track the fundamental positive sequence of current. The following figure 1

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represents the circuit topology of the proposed DVSI scheme.

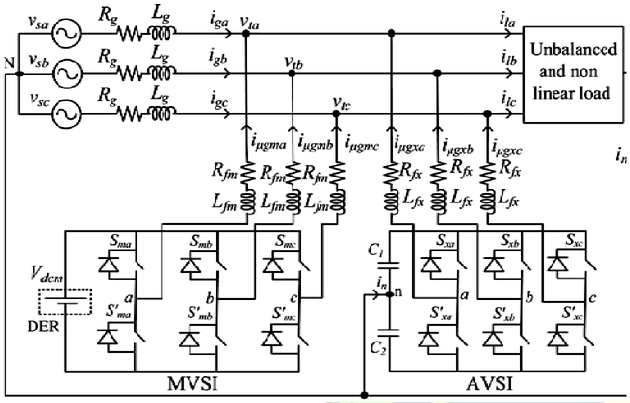

Fig. 1. Topology of proposed DVSI scheme.

The proposed topology consists of a neutral point clamped (NPC) inverter to realize AVSI and a three-leg inverter for MVSI [18]. These are connected to grid at the PCC and supplying a nonlinear and unbalanced load. The function of the AVSI is to compensate the reactive, harmonics, and unbalance components in load currents. Here, load currents in three phases are represented by ila, ilb, and ilc, respectively. Also, ig(abc), iμgm(abc), and iμgx(abc) show grid currents, MVSI currents, and AVSI currents in three phases, respectively.

The dc link of the AVSI utilizes a split capacitor topology, with two capacitors C1 and C2. The MVSI delivers the available power at distributed energy resource (DER) to grid. The DER can be a dc source or an ac source with rectifier coupled to dc link. Usually, renewable energy sources like fuel cell and PV generate power at variable low dc voltage, while the variable speed wind turbines generate power at variable ac voltage. Therefore, the power generated from these sources use a power conditioning stage before it is connected to the input of MVSI. In this study, DER is being represented as a dc source. An inductor filter is used to eliminate the high-frequency switching components generated due to the switching of power electronic switches in the inverters. The system considered in this study is assumed to have some amount of feeder resistance Rg and inductance Lg. Due to the presence of this feeder impedance, PCC voltage is affected with harmonics.

A. Instantaneous Symmetrical Component Theory:

ISCT was developed primarily for unbalanced and nonlinear load compensations by active power filters. The system topology shown in Fig. 3 is used for realizing the reference current for the compensator [15]. The ISCT for load compensation is derived based on the following three conditions.

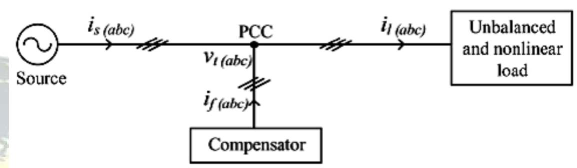

Figure 2. Schematic of an unbalanced and nonlinear load compensation scheme.

1) The source neutral current must be zero. Therefore

$$i_{sa} + i_{sb} + i_{sc} = 0.$$

2) The phase angle between the fundamental positive sequence voltage ($v+ta1$) and source current (isa) is φ

$$\angle v_{ta1}^{+} = \angle i_{sa} + \phi.$$

3) The average real power of the load (Pl) should be supplied by the source

$$v_{ta1}^{+}\, i_{sa} + v_{tb1}^{+}\, i_{sb} + v_{tc1}^{+}\, i_{sc} = P_l.$$

Solving the above three equations, the reference source currents can be obtained as

$$i_{sa}^{*} = \left(\frac{v_{ta1}^{+} + \beta(v_{tb1}^{+} - v_{tc1}^{+})}{\sum_{j=a,b,c} {v_{tj}^{+}}^{2}}\right) P_l$$

$$i_{sb}^{*} = \left(\frac{v_{tb1}^{+} + \beta(v_{tc1}^{+} - v_{ta1}^{+})}{\sum_{j=a,b,c} {v_{tj}^{+}}^{2}}\right) P_l$$

$$i_{sc}^{*} = \left(\frac{v_{tc1}^{+} + \beta(v_{ta1}^{+} - v_{tb1}^{+})}{\sum_{j=a,b,c} {v_{tj}^{+}}^{2}}\right) P_l$$

where$\beta = \tan \varphi / \sqrt{3}$ The term$\varphi$is the desired phase angle between the fundamental positive sequence of PCC voltage and source current. To achieve unity power factor for source current, substitute $\beta = 0$in. Thus, the reference source currents for three phases are given by,

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$$i^*_{s(abc)} = \left(\frac{v^+_{t(abc)1}}{\sum_{j=a,b,c} v^{+2}_{tj}} \right) P_l$$

Where $i*sa$, $i*sb$, and $i*sc$are fundamental positive sequence of load currents drawn from the source, when it is supplying an average load power *Pl*. The power *Pl* can be computed using a moving average filter with a window of one-cycle data points as given below

$$P_l = \frac{1}{T} \int_{t_1-T}^{t_1} (v^+_{ta1}\, i_{la} + v^+_{tb1}\, i_{lb} + v^+_{tc1}\, i_{lc}) dt$$

Where *t*1 is any arbitrary time instant. Finally, the reference currents for the compensator can be generated as follows:

$$i^*_{f\,(abc)} = i_{l\,(abc)} - i^*_{s\,(abc)}$$

Equation (12) can be used to generate the reference filter currents using ISCT, when the entire load active power, *Pl* is supplied by the source and load compensation is performed by a single inverter. A modification in the control algorithm is required, when it is used for DVSI scheme. The following section discusses the formulation of control algorithm for DVSI scheme. The source currents, *is*(*abc*) and filter currents *if*(*abc*) will be equivalently represented as grid currents *ig*(*abc*) and AVSI currents *iμgx*(*abc*), respectively, in further sections.

B. Control Scheme for DVSI

Control strategy of DVSI is developed in such a way that grid and MVSI together share the active load power, and AVSI supplies rest of the power components demanded by the load. The functional block diagram is shown in figure 3.

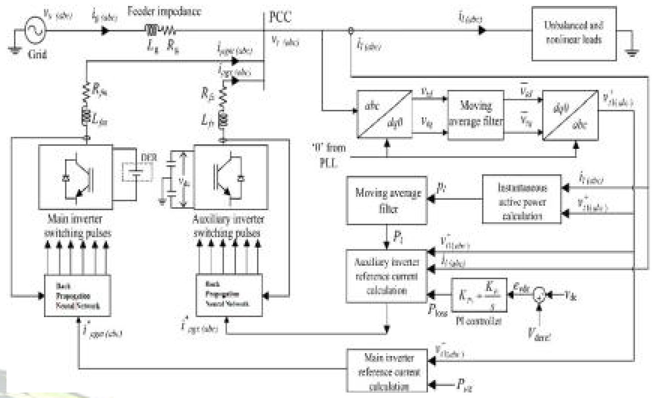

Figure 3. Functional Block Diagram of BPNN - DVSI

1) Reference Current Generation for Auxiliary Inverter:

The dc-link voltage of the AVSI should be maintained constant for proper operation of the auxiliary inverter. DC-link voltage variation occurs in auxiliary inverter due to its switching and ohmic losses. These losses termed as *P*loss should also be supplied by the grid. An expression for *P*loss is derived on the condition that average dc capacitor current is zero to maintain a constant capacitor voltage. The deviation of average capacitor current from zero will reflect as a change in capacitor voltage from a steady state value. A PI controller is used to generate *P*loss term as given by

$$P_{\text{loss}} = K_{Pv}\, e_{v\text{dc}} + K_{Iv} \int e_{v\text{dc}} dt$$

Where *ev*dc = *V*dcref− *v*dc, *v*dc represents the actual voltage sensed and updated once in a cycle. In the above equation, *KPv*and *KIv*represent the proportional and integral gains of dc-link PI controller, respectively. The *P*loss term thus obtained should be supplied by the grid, and therefore AVSI reference currents can be obtained as given in. Here, the dc-link voltage PI controller gains are selected so as to ensure stability and better dynamic response during load change

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$$i^*_{\mu gxa} = i_{la} - \left(\frac{v^+_{ta1}}{\sum_{j=a,b,c} v^{+2}_{tj}}\right)(P_l + P_{\text{loss}})$$

$$i^*_{\mu gxb} = i_{lb} - \left(\frac{v^+_{tb1}}{\sum_{j=a,b,c} v^{+2}_{tj}}\right)(P_l + P_{\text{loss}})$$

$$i^*_{\mu gxc} = i_{lc} - \left(\frac{v^+_{tc1}}{\sum_{j=a,b,c} v^{+2}_{tj}}\right)(P_l + P_{\text{loss}})$$

2) Reference Current Generation for Main Inverter:

The MVSI supplies balanced sinusoidal currents based on the available renewable power at DER. If MVSI losses are neglected, the power injected to grid will be equal to that available at DER ($P\mu g$). The following equation, which is derived from ISCT can be used to generate MVSI reference currents for three phases (*a*, *b*, and *c*)

$$i^*_{\mu gm(abc)} = \left(\frac{v^+_{t(abc)1}}{\sum_{j=a,b,c} v^{+2}_{tj}}\right) P_{\mu g}$$

Where $P\mu g$is the available power at the dc link of MVSI. The reference currents obtained from (14) to (15) are tracked by using hysteresis band current controller (HBCC). HBCC schemes are based on a feedback loop, usually with a two-levelcomparator. This controller has the advantage of peak current limiting capacity, good dynamic response, and simplicity in implementation.

3) Back Propagation Neural Network controller:

The reference current and the actual current from the inverter circuit is compared with each other the error is given into the neural network controller. The controller is responsible to create the gate pulses for the both inverters.

A back-propagation neural network is only practical in certain situations. Following are some guidelines on when you should use another approach:

- A large amount of input/output data is available, but you're not sure how to relate it to the output.
- The problem appears to have overwhelming complexity, but there is clearly a solution.
- It is easy to create a number of examples of the correct behavior.
- The solution to the problem may change over time, within the bounds of the given input and output parameters (i.e., today 2+2=4, but in the future we may find that 2+2=3.8).
- Outputs can be "fuzzy", or non-numeric.

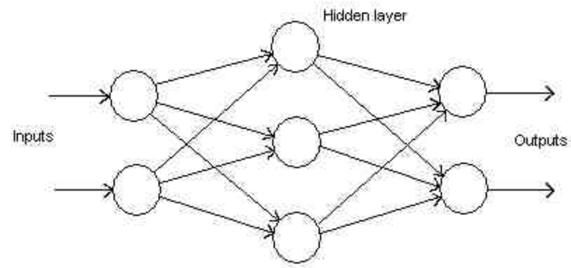

Figure 4. Structure of BPNN

IV – SIMULATION RESULTS

The proposed work is completed on MATLAB software on the version of R2013a. The designed circuits were drawn and simulated using MATLAB Simulink and Sim power system toolboxes. The following figure depicts the overall MATLAB simulink model for the proposed system. The parameter for the DVSI simulation model is tabulated on the table 1.

The proposed system is designed with the 5kW dc source as a DG in this work. This resembles an ideal solar power plant system as a DG. The capacitance supplies reactive power to the AVSI circuit and the DG system that supplies real power to the MVSI circuit. The functional control blocks that includes Back propagation neural network is highlighted in this following diagram.

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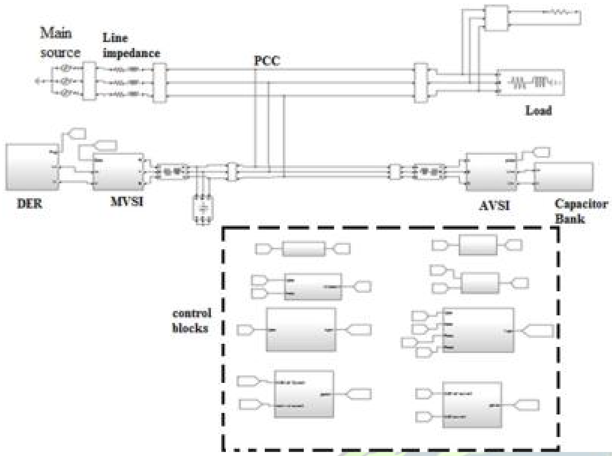

Figure 5. Overall Simulink model

Table 1. Parameter specification

Source voltage	230V
Fundamental frequency	50Hz
Sampling time	50 μs
Load real power	5kW
Load reactive power	1kVAR
Line impedances	10+j0.025Ω
DC link capacitance	2000μF
DG – Solar generated power	5kW
Derivative controller (K_p)	0.15
Integral Controller (K_I)	0.001

The Neural network controller needs some training data and after training with the valid data, the controller will be provided by the simulink. The BPPN simulink model can be trained and designed with the help of Neural Net time series Application on the MATLAB R2013a.

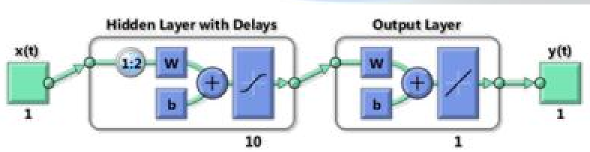

Figure 6. Back Propagation neural network structure

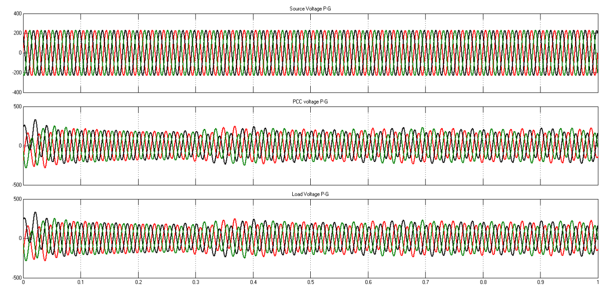

Figure 7. Voltage waveforms: Top – source voltage; Middle – PCC voltage; Bottom – Load voltage

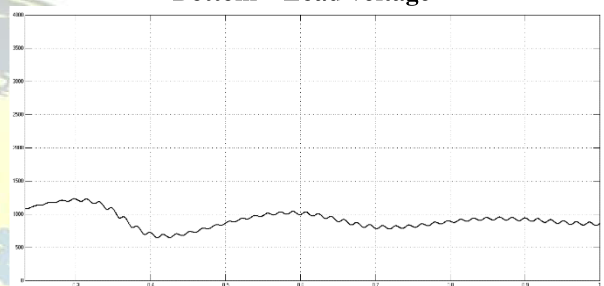

Figure 8. DC link voltage response

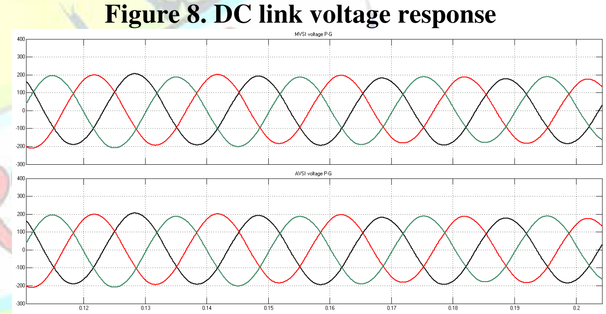

Figure 9. VSI voltage responses: Top – MVSI; Bottom– AVSI

The real and reactive power responses of the source, load, MVSI and AVSI side are depicted below. The waveforms clearly demonstrates the operation of the proposed DVSI. The real power is supplied by then MVSI and the reactive power is only supplied by the AVSI circuit.

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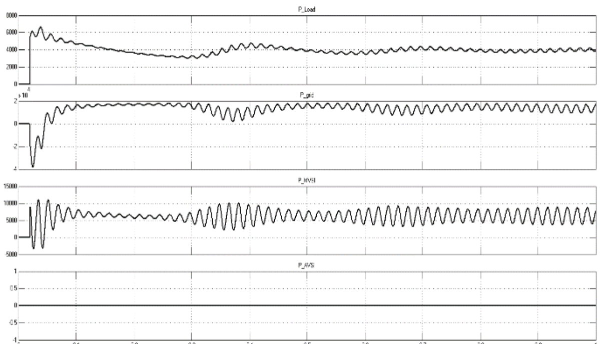

Figure 10. Real power responses: 1) Source side 2) Load side 3) MVSI side 4) AVSI side

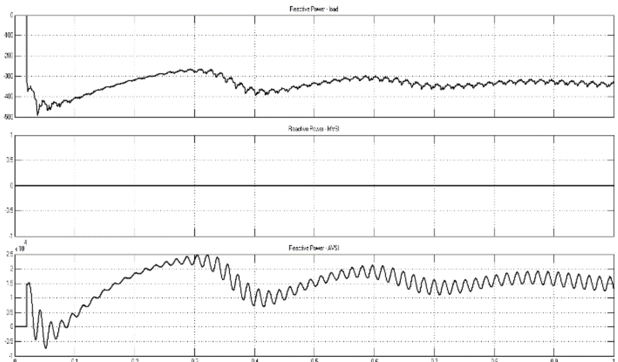

Figure 11. Reactive power responses: 1) load side 2) MVSI side 3) AVSI side

V – CONCLUSION

A BPNN based DVSI scheme is proposed for microgrid systems with enhanced power quality. Control algorithms are developed to generate reference currents for DVSI using ISCT. The proposed scheme has the capability to exchange power from distributed generators (DGs) and also to compensate the local unbalanced and nonlinear load. The performance of the proposed scheme has been validated through simulation and experimentalstudies. As compared to a single inverter with multifunctional capabilities, a BPNN- DVSI has many advantages such as, increased reliability, lower cost due to the reduction in filter size, and more utilization of inverter capacity to inject real power from DGs to microgrid. Moreover, the use of three-phase, three wire topology for the main inverter reduces the dc-link voltage requirement. Thus, a BPNN-DVSI scheme is a suitable interfacing option for microgrid supplying sensitive loads.

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