Renewable Energy Hybrid Power System with Improvement of Power Quality in Grid by using DVSI

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Abstract - *This paper presents a dual voltage source inverter (DVSI) scheme to enhance the power quality and reliability of the microgrid system. The proposed scheme is comprised of two inverters, which enables the microgrid to exchange power generated by the Renewable energy resources (RESs) and also to compensate the local unbalanced and nonlinear load. The control algorithms are developed based on instantaneous symmetrical component theory (ISCT) to operate DVSI in grid sharing and grid injecting modes. The proposed scheme has increased reliability, lower bandwidth requirement of the main inverter, lower cost due to reduction in filter size, and better utilization of microgrid power while using reduced dc-link voltage rating for the main inverter. These features make the DVSI scheme a promising option for microgrid supplying sensitive loads. The topology and control algorithm are validated through extensive simulation and experimental results.*

Key Words: *DISTRIBUTED GENERATOR(DG), Point of COMMON COUPLING (PCC), DUAL VOLTAGE SOURCE INVERTER (DVSI), MAIN VOLTAGE SOURCE INVERTER (MVSI), WIND ENERGY SYSTEM (WES), INSTANTENEOUS SYMETRICAL COMPONENT THEORY (ISCT).*

1. 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 micro grid. In a micro grid, 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[1] plays an important role in exchanging power from the micro grid to the grid and the connected load. This micro grid 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 as to be addressed while the micro grid 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 micro grid [2]–[5] 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 [20] and also works as an active power filter, compensating unbalances and the reactive power required by other loads connected to the system [6]. In a voltage regulation and power flow control scheme for a wind energy system (WES) is proposed. A distribution static compensator (DSTATCOM) [8] is utilized for voltage regulation and also for active power injection[18].

This paper demonstrates a dual voltage source inverter (DVSI) scheme, in which the power generated by the micro grid 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).

2. POWER QUALITY

Power quality disturbance show in this paper organized into seven categories. They are

1. Transients.
2. Interruptions
3. Sag/Under Voltage
4. Swell/Over Voltage
5. Wave form distortion
6. Voltage fluctuation
7. Frequency variations

2.1. Solutions to Power Quality Problems

There are two approaches to the mitigation of power quality problems. The solution to the power quality can be done from customer side or from utility side. First approach is called load conditioning, which ensures that the equipment is less sensitive to power disturbances, allowing the operation even under significant voltage distortion [9].

A. Energy Storage Systems:

Batteries, superconducting magnet energy storage (SMES), storage capacitors or even fly wheels driving DC generators. The output of these devices can be supplied to the system through an inverter on a momentary basis by a fast-acting electronic switch

B. Electronic tap changing transformer:

A voltage-regulating transformer with an electronic load tap changer can be used with a single line from the utility. It can regulate the voltage drops up to 50% and requires a stiff system (short circuit power to load ratio of 10:1 or better). It can have the provision of coarse or smooth steps intended for occasional voltage variations.

C. Harmonic Filters:

Filters are used in some instances to effectively reduce or eliminate certain harmonics. If possible, it is always preferable to use a 12-pluse or higher transformer connection, rather than a filter. Tuned harmonic filters should be used with caution and avoided when possible. Usually, multiple filters are needed, each tuned to a separate harmonic. Each filter causes a parallel resonance as well as a series resonance, and each filter slightly changes the resonances of other filters.

Constant-Voltage Transformers:

For many power quality studies, it is possible to greatly improve the sag and momentary interruption tolerance of a facility by protecting control circuits. Constant voltage transformer (CVTs) can be used on control circuits to provide constant voltage with three cycle ride through, or relays and ac contactors can be provided with electronic coil hold-in devices to prevent mis-operation from either low or high.

3. INVERTER

The main objective of static power converters is to produce an ac output waveform from a dc power supply. These are the types of waveforms required in adjustable speed drives (ASDs), uninterruptible power supplies (UPS), static VAR compensators, active filters, flexible ac transmission systems (FACTS), and voltage compensators, which are only a few applications. For sinusoidal ac outputs, the magnitude, frequency, and phase should be controllable [13]. According to the type of ac output waveform, these topologies can be considered as voltage source inverters (VSIs), where the independently controlled ac output is a voltage waveform. Mainly used dual voltage source Inverter (DVSI)

These structures are the most widely used because they naturally behave as voltage sources as required by many industrial applications, such as adjustable speed drives (ASDs), which are the most popular application of inverters; Similarly, these topologies can be found as current source inverters (CSIs), where the independently controlled ac output is a current waveform. These structures are still widely used in medium-voltage industrial applications, where high-quality voltage

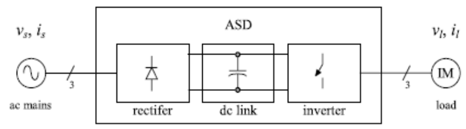

Fig 1. A schematic Diagram of Inverter

4. RENEWABLE ENERGY SYSTEM

4.1. SOLAR ENERGY

Solar energy is the most readily available source of energy. It is free. It is also the most important of the non-conventional sources of energy because it is non-polluting. Fuel cells, magneto hydrodynamic systems, and devices based on thermoelectric, thermo ionic and solar-electric conversion are all potentially useful nonconventional electricity sources [12] . Each of these sources has its advocates for further development, but none more so than solar energy which capitalizes, perhaps, on the deep-rooted associations between man and sun to foster an image of bountiful power from a no dependable, non-polluting and benign source [10].

4.2. FUEL CELLS

Hydrogen today is produced from natural gas from limited markets but it can be produced from renewable sources and promises substantial contributions to the global energy supplies in the long term. Hydrogen is most abundant element in the universe, the simplest chemical fuel (essentially a hydrocarbon without the carbon) that makes a highly efficient clean burning energy carrier. It has the potential to fuel transportation vehicle with zero emissions, provide process heat for industrial process, supply domestic heat through co-generation, help produce electricity from (centralized or distributed power systems and provide a storage medium for electricity from renewable sources.

5. PROPOSED SYSTEMS

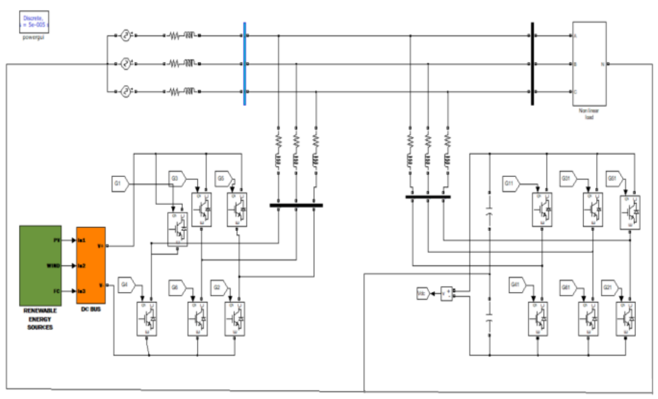

Fig 2: Simulation diagram

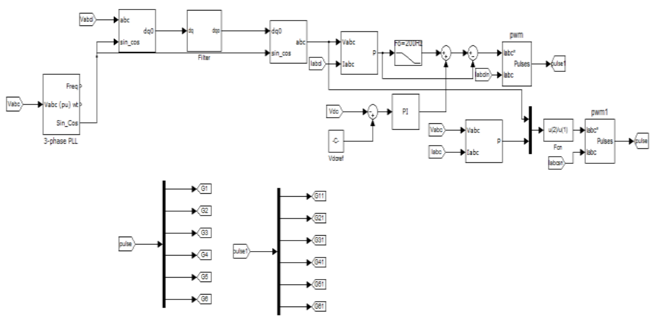

Fig.3 Controller SUB SYSTEM.

A. System Topology

The proposed DVSI topology is shown in Fig. It consists of a neutral point clamped (NPC) inverter to realize AVSI and a three-leg inverter for MVSI [18]. These are connected to grid [11] at the PCC and supplying a nonlinear and unbalanced load [14]-[15]. 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 *C*1 and *C*2. 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 at variable ac voltage [19]. 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.

Minimum to maximum, i.e., from 0 to *5* KVA. AVSI needs to exchange real power during transient to maintain the load power demand. This transfer of real power during the transient will results in deviation of capacitor voltage from its reference value. Assume that the voltage controller takes *n* cycles, i.e., *nT* seconds to act, where *T* is the system time period. Hence, maximum energy exchange by AVSI during transient will be *nST*. This energy will be equal to change in the capacitor stored energy. Therefore

$$\frac{1}{2}C_1(V_{\rm dcr}^2 - V_{\rm dc1}^2) = nST$$

Where *V*dcr and *V*dc1 are the reference dc voltage and maximum permissible dc voltage across *C*1 during transient, respectively. Here, *S* =5 kVA, *V*dcr = 520 V, *V*dc1 = 0.8 ∗ *V*dcr or 1.2 ∗ *V*dcr, *n* = 1, and *T* = 0.02 s. Substituting these values in (1), the dc link capacitance (*C*1) is calculated to be 2000 μF. Same value of capacitance is selected for *C*2.The interfacing inductance is given by

$$L_{fx} = \frac{1.6\,V_m}{4\,h_x f_{\max}}.$$

Assuming a maximum switching frequency (*f*max) of 10 kHz and hysteresis band (*hx*) as 5%of load current (0.5 A), the value of *Lfx* is calculated to be 26 mH.

B. MVSI:

The MVSI uses a three-leg inverter topology. Its dc-link voltage is obtained as 1.15 **Vml*, where *Vml* is the peak value of line voltage. This is calculated to be 648 V. Also, MVSI supplies a balanced sinusoidal current at unity power factor. So, zero sequence switching harmonics will be absent in the output current of MVSI. This reduces the filter requirement for MVSI as compared to AVSI . In this analysis, a filter inductance (*Lfm*) of 5 mH is used.

5.2. CONTROL STRATEGY FOR DVSI SCHEME

A. Fundamental Voltage Extraction

The control algorithm for reference current generation using ISCT requires balanced sinusoidal PCC voltages. Because of the presence of feeder impedance, PCC voltages are distorted. Therefore, the fundamental positive sequence components of the PCC voltages are extracted for the reference current generation. To convert the distorted PCC voltages to balanced sinusoidal voltages, *dq*0 transformation is used [7]. The PCC voltages in natural reference frame (*vta*, *vtb*, and *vtc*) are first transformed into *dq*0 reference frame as given by

$$\begin{bmatrix} v_{td} \\ v_{tq} \\ v_{t0} \end{bmatrix} = C \begin{bmatrix} v_{ta} \\ v_{tb} \\ v_{tc} \end{bmatrix}$$

where

$$C = \sqrt{\frac{2}{3}} \begin{bmatrix} \sin\theta & \sin(\theta - \frac{2\pi}{3}) & \sin(\theta + \frac{2\pi}{3}) \\ \cos\theta & \cos(\theta - \frac{2\pi}{3}) & \cos(\theta + \frac{2\pi}{3}) \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix}.$$

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In order to get θ, a modified synchronous reference frame (SRF) phase locked loop (PLL) [23] is used. The schematic diagram of this PLL is shown in Fig. It mainly consists of a proportional integral (PI) controller and an integrator. In this PLL, the SRF terminal voltage in q-axis (vtq) is compared with 0 V and the error voltage thus obtained is given to the PI controller. The frequency deviation $\Delta\omega$ is then added to the reference frequency $\omega 0$ and finally given to the integrator to get θ. It can be proved that, when, $\theta = \omega 0\, t$ and by using the Park's transformation matrix (C), q-axis voltage in $dq0$ frame becomes zero and hence the PLL will be locked to the reference frequency ($\omega 0$). As PCC voltages are distorted, the transformed voltages in $dq0$ frame (vtd and vtq) contain average and oscillating components of voltages

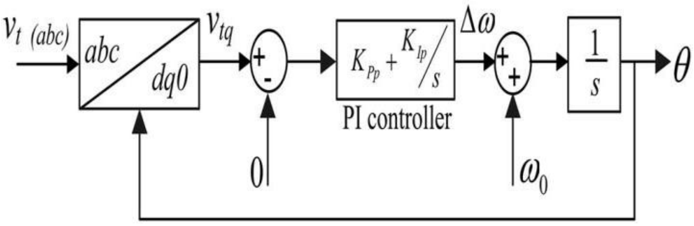


Fig.4 Schematic diagram of PLL.

B. Instantaneous Symmetrical Component Theory

ISCT was developed primarily for unbalanced and nonlinear load compensations by active power filters. The system topology shown in Fig is used for realizing the reference current for the compensator [1]. The ISCT for load compensation [16] is derived based on the following three conditions

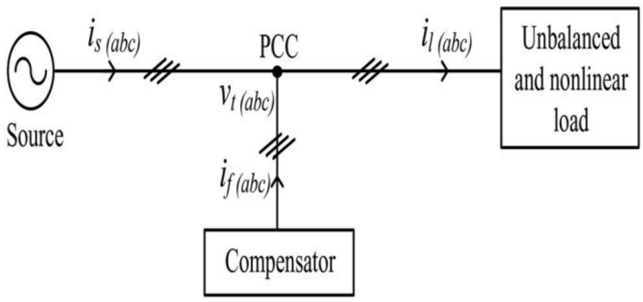


Fig.5 Schematic of an unbalanced and nonlinear load compensation scheme.

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

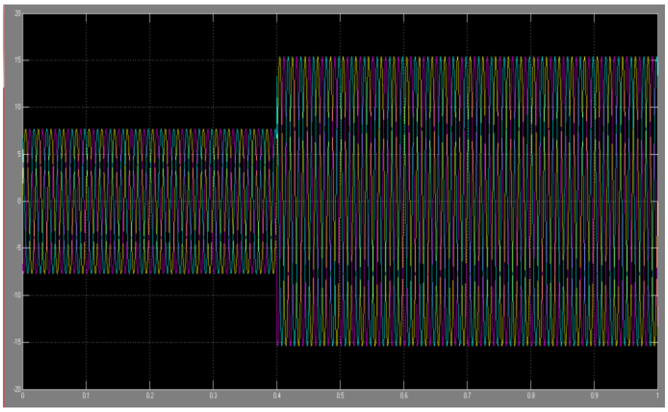
$$\angle v_{ta1}^{+} = \angle i_{sa} + \phi.$$

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

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

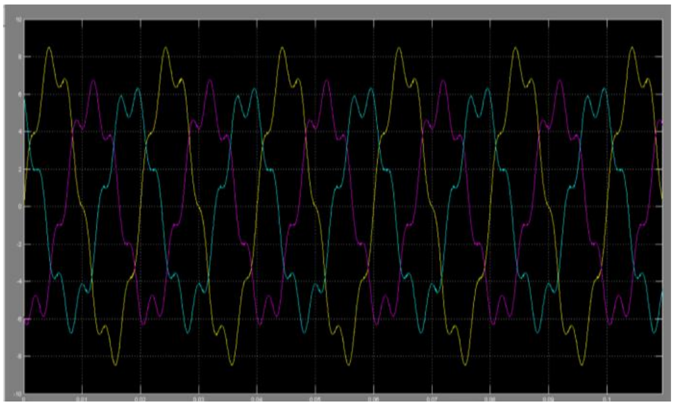
Solving the above three equations, the reference source currents can be obtained as

6. SIMULATION RESULTS



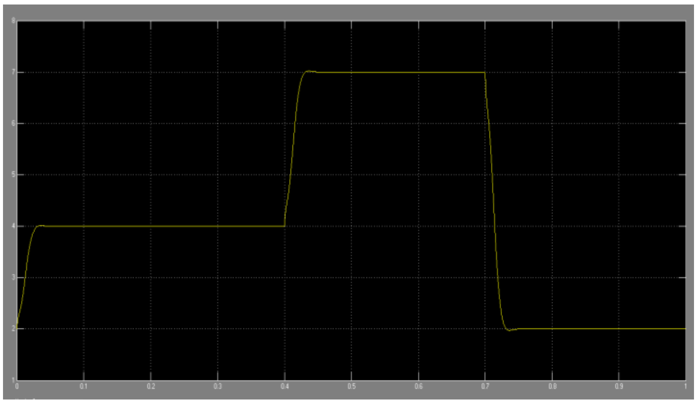
Time(S)

Fig.6 MVSI Current waveforms



TIME(S)

Fig.7 AVSI current waveforms



Time(s)

Fig9: ACTIVE POWER SUPPLIED BY MVSI

7. CONCLUSION

A DVSI scheme with Renewable energy sources is proposed for micro grid 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 Solar, Wind, Fuel cells and also to the performance of the proposed scheme has been validated through simulation and experimental studies. As compared to a single inverter with multifunctional capabilities, a 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 micro grid. Moreover, the use of three-phase, three wire topology for the main inverter reduces the dc-link voltage requirement. Thus, a DVSI scheme is a suitable interfacing option for micro grid supplying sensitive loads.

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