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"Single Phase Inverter Based Load Unbalanced Compensator for Standalone Micro-Grid"

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Abstract

In this project, a control strategy is proposed for voltage-source inverters in micro grids. The main objective of the proposed controller is to inject a clean sinusoidal power to the grid, even in the presence of nonlinear/unbalanced loads and/or grid-voltage distortions. The repetitive control technique is adopted because it can deal with a very large number of harmonics simultaneously. The proposed controller consists of an internal model and a stabilizing compensator, which is designed by using the H∞ control theory. It turns out that the stabilizing compensator may be simply an inductor. This leads to a very low total harmonic distortion (THD) and improved tracking performance. In order to demonstrate the improvement of performance, the proposed controller is compared with the traditional proportional–resonant, proportional–integral, and predictive deadbeat controllers. The control strategies are evaluated in the grid-connected mode with experiments under different scenarios: steady-state and transient responses without local loads, and steady-state responses with unbalanced resistive and nonlinear local loads. The proposed controller significantly outperforms the other control schemes in terms of the THD level, with the price of slightly slower dynamic responses.

Keywords— LUC, voltage source inverter, DSTATCOM, Power quality.

I - INTRODUCTION

Micro-grids are emerging as a consequence of rapidly growing distributed power generation systems (DPGS). Compared to a single DPGS, micro-grids have more capacity and control flexibilities to fulfill system reliability and power quality requirements. A micro-grid is normally operated in the grid-connected mode, but it is also expected to provide sufficient generation capacity, controls, and operational strategies to supply at least a part of the load after being disconnected from the public grid and to remain operational as a stand-alone system. As nonlinear and/or unbalanced loads can represent a high proportion of the total load in small-scale systems, the problem with power quality is a particular concern in micro-grids.

The power quality assessment is mainly based on total harmonic distortion (THD) in voltages and currents. For both wind turbines and photovoltaic arrays connected to the utility grid, the maximum voltage and current THD allowed is 5%. Traditionally, inverters used in micro-grids behave as current sources when they are connected to the grid, and as voltage sources when they work autonomously.

Current-controlled inverters have the advantages of the high-accuracy control of an instantaneous current, peak-current protection, overload rejection, and very good dynamics.

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The performance of the VSI depends on the quality of the applied current-control strategy and, in order to meet power quality requirements, inverters in micro-grids should have very good capability in harmonic rejection. Different strategies, e.g., proportional–integral (PI), proportional– resonant (PR), predictive deadbeat (DB), or hysteresis controllers have been proposed.

The PI control scheme in the synchronously rotating (d,q) reference frame is commonly used and can work well with balanced systems, but it cannot cope with unbalanced disturbance currents, which are common in micro-grids. The PR control scheme in the stationary (α,β) reference frame is popular due to the capability of eliminating the steady-state error, while regulating sinusoidal signals, and the possible extension to compensate multiple harmonics. DB predictive control is widely used for current-error compensation and offers high performance for current-controlled VSIs.

However, it is quite complicated and sensitive to system parameters. Hysteresis control is simple and brings fast responses, but it results in high and variable sampling frequencies, which leads to high current ripples, poor current quality, and difficulties in the output filter design. In order to obtain a fixed switching frequency, the complexity of the controller will be increased, if an adaptive band hysteresis controller is used.

It is able to eliminate periodic errors in dynamic systems, according to the internal model principle, as it introduces high gains at the fundamental and all harmonic frequencies of interest. The internal model is infinite dimensional and can be obtained by connecting a delay line into a feedback loop. Such a closed-loop system can deal with a very large number of harmonics simultaneously. It has been successfully applied to constant-voltage constant-

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frequency pulse PWM inverters, grid-connected inverters and active filters. However, these are mainly used in the form of voltage controllers except the one.

II. CIRCUIT DIAGRAM

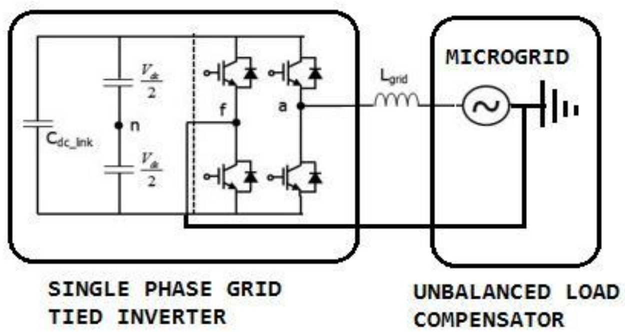

Fig.1. single phase inverter based LUC As far as high power and medium voltage applications are concerned, two level voltage source inverter is not so effective to be realized in comparison with the multilevel inverters. In distribution systems, where load harmonics effect the ac source, presence of multilevel inverter in place of a 2 level inverter nullifies the effect and make the source balanced. So, in this thesis among various topologies of multilevel inverter, cascaded H-bridge multilevel inverter in asymmetrical arrangement of dc voltages is implemented. Various levels of asymmetrical cascaded H-bridge inverters are first realized with different algorithms of dc source voltage arrangement and then a comparative analysis is done on the basis of harmonic contents, sinusoidal waveforms,

switching devices. Out of these different levels, one level is implemented with DSTATCOM for the enrichment of power quality in distribution network by reducing THD. in the source current and making it balanced.

A grid interactive inverter 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 has 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.

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. 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 micro grid 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 isolation periods. 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.

The square wave type is the simplest method to produce AC from DC; however, it suffers from low frequency harmonics which causes difficulty in filtering out the noise to prevent these harmonics to return back to the primary side of the transformer. The PWM inverter, on the other hand, forces the harmonics to be way up higher than the fundamental (line) frequency; thus, easing up the filtering requirement of the inverter. However, the major drawback of the PWM inverter is the increased switching losses due to the frequent switching actions of the electronic switches within the inverter. This project proposes an improved version of the square-wave inverter by increasing the number of steps per one period of the desired frequency with the use of additional electronic switches. With the conventional square wave inverter, there are only two pulses generated by the controller to mimic an AC output.

This is in fact what is causing the low harmonic distortion of the inverter. To lessen these low harmonic distortions in square wave technique, the approach is then to increase the number of steps per period. This is the approach taken by the proposed inverter by adding the number of steps to seven; hence, the name seven-level H-bridge interconnected inverter.

In essence, the seven-step AC output voltage generated by the inverter will push the low harmonic to above seven times the line frequency. For a 60-Hz AC system, this means the harmonic content of the inverter output will be at 420 Hz and above. This is a significant improvement over 180 Hz and above offered by the conventional square wave technology.As previously mentioned, the purpose of an inverter is to convert DC power to AC power.Inverters are an integral part of many technologies including uninterruptable power

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supplies, induction heating, high-voltage direct current power transmission, variable frequency drives, electric vehicle drives, and multiple renewable energy applications.

There are many varieties of inverter designs. The most common topology uses what is referred to as the H-bridge topology. This topology is used in conjunction with either the square wave, or pulse width modulation (PWM) switching schemes.The square-wave switching scheme is a method for controlling the switches (labelled S1through S4) in order to achieve a square wave AC output signal. The AC output is achieved by using a control signal with a 50% duty cycle wired to S1 and S4. An inverted copy of the same signal is also wired to S2 and S3. This switching scheme ensures that S1 and S4 are always on when S2 and S3 are off. It should be easily seen how such a switching scheme creates the square wave output shown in Figure. The advantage of using an H-bridge inverter is that only a single, simple control signal is required to control four transistors. The disadvantage, however, is that the square wave output is a low quality AC signal that injects many harmonics into any loads to which it is powering.

As mentioned previously, PWM control signals can be used with the same H-bridge topography. The disadvantage of the PWM switching scheme is that it is more complicated than the square-wave switching scheme. Multiple, relatively complex control signals are needed to control the transistors of the PWM inverter. The advantage, however, of the PWM switching scheme is that it is able to generate a more perfect sinusoidal AC output, which some loads prefer.

This project presents a proposed new single-phase interconnected H-bridge inverter (or multistep inverter). One advantage of a multistep inverter is that it provides a more sinusoidal output voltage than an inverter with basic square-wave switching scheme. Another

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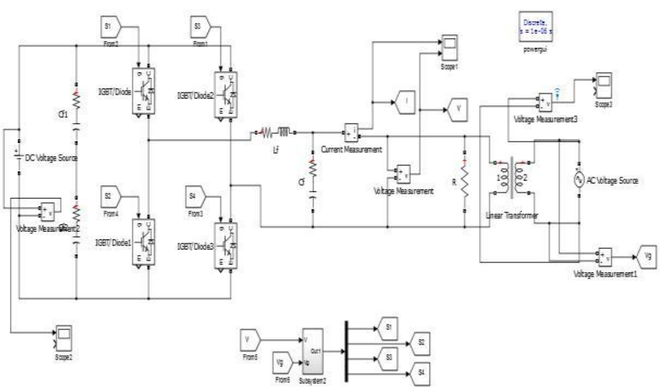
advantage is that its control signals are less complicated than that of the PWM inverter. However, the multistep inverter does not generate as high of quality of sinusoidal output voltage as that of the PWM switching scheme inverter.

III. DSTATCOM TECHNIQUE

D-STATCOM (Distribution Static Compensator), which is schematically depicted, consists of a two-level Voltage Source Converter (VSC), a dc energy storage device, a coupling transformer connected in shunt to the distribution network through a coupling transformer. The VSC converts the dc voltage across the storage device into a set of three-phase ac output voltages. These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the D-STATCOM output voltages allows effective control of active and reactive power exchanges between the DSTATCOM and the ac system. Such configuration allows the device to absorb or generate controllable active and reactive power.The VSC connected in shunt with the ac system provides a multifunctional topology which can be used for up to three quite distinct purposes:

1. Voltage regulation and compensation of reactive power
2. Correction of power factor; and
3. Elimination of current harmonics.

IV. SIMULATION RESULTS



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Hardware Block Diagram

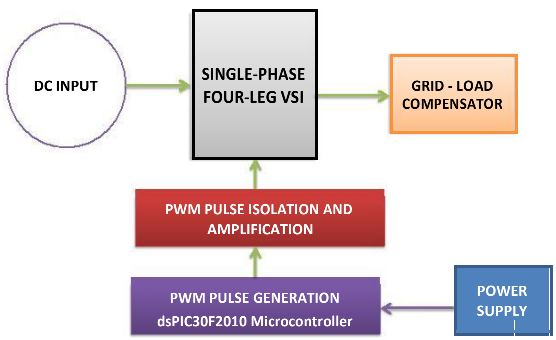

Fig.2. Hardware block diagram

SIMULATION RESULTS OF INVERTER :

TABLE 1
PARAMETERS TO DESIGN

Parameters name	symbols	Value
Input voltage	VI	300 DC volts
Grid frequency	Fn	50Hz
Control period	Ts	50e-6 s
Filter inductance	L_1	3.2mH
Capacitance	C	5e-6 F
Filter resistance	Fs	22 Ω
Load resistance	R	100Ω
Grid vol	Vg	300 Volts

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V. WAVE FORM RESULTS

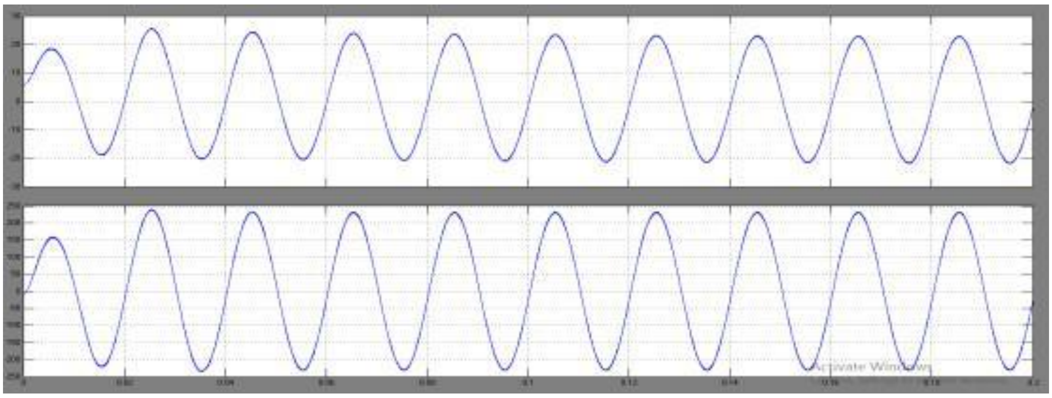

Fig.4.Output AC voltage

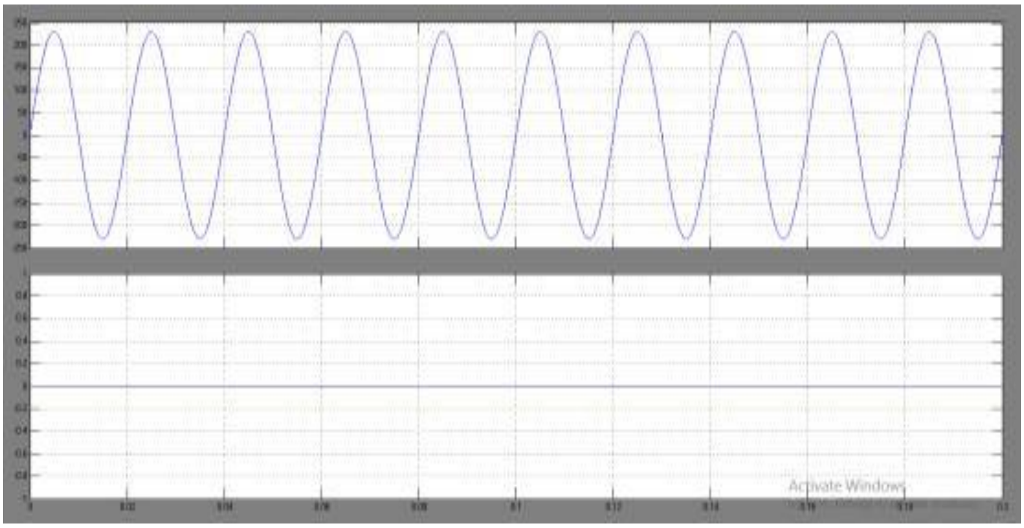

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Fig.3. simulink diagram of single phase unbalanced load compensator

Fig.5.Output DC voltage

VI. CONCLUSION

A DVSI scheme 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 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 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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