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Solar PV Based Grid Connected System with Hybrid Control Scheme

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ABSTRACT

In this paper, a cascaded current voltage control strategy is proposed for inverters to simultaneously improve the power quality of the inverter local load voltage and the current exchanged with the grid. It also enables seamless transfer of the operation mode from stand-alone to grid-connected or vice versa. The control scheme includes an inner voltage loop and an outer current loop, with both controllers designed using the fuzzy logic control and H∞repetitive control strategy. This leads to a very low total harmonic distortion in both the inverter local load voltage and the current exchanged with the grid at the same time. The Photo Voltaic (PV) energy system, used in this project, is a very new concept in use, which is gaining immense popularity due to increasing importance to research on alternative sources of energy over depletion of the conventional fossil fuels all around the world. The systems which are being developed extract energy from the sun in the most efficient manner and suit them to the available loads without affecting their performance.

The proposed control strategy can be used to single-phase inverters and three-phase four-wire inverters. It enables grid connected inverters to inject balanced clean currents to the grid even when the local loads (if any) are unbalanced and/or nonlinear. Simulation under different scenarios, with comparisons made to the current repetitive controller replaced with a current proportional–resonant controller, is presented to demonstrate the excellent performance of the proposed strategy.

KEYWORDS: ***solar pv, grid connected system.***

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I.INTRODUCTION

THE application of distributed power generation has been increasing rapidly in the past decades. Compared to the conventional centralized power generation, distributed generation (DG) units deliver clean and renewable power close to the customer's end [1]. Therefore, it can alleviate the stress of many conventional transmission and distribution infrastructures. As most of the DG units are interfaced to the grid using power electronics converters, unbalanced utility grid voltages and voltage sags, which are they have the opportunity to realize enhanced power generation through a flexible digital control of the power converters. On the other hand, high penetration of power electronics based DG units also introduces a few issues, such as system resonance, protection interference, etc. In order to overcome these problems, the micro grid concept has been proposed, which is realized through the control of multiple DG units. Compared to a single DG unit, the micro grid can achieve superior power management within its distribution networks. In addition, the islanding operation of micro grid offers high reliability power supply to the critical loads. Therefore, micro grid is considered to pave the way to the future smart grid [1].

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It is advantageous to operate inverters as voltage sources because there is no need to change the controller when the operation mode is changed. A parallel control structure consisting of an output voltage controller and agrid current controller was proposed in [8] to achieve seamless transfer via changing the references to the controller without changing the controller. Another important aspect for grid connected inverters or micro gridsis the active and reactive power control; see, e.g., [9] and[10] for more details. As nonlinear and/or unbalanced loadscan represent a high proportion of the total load in smallscalesystems, the problem with power quality is a particularconcern in micro grids [11].Moreover, unbalanced utilitygrid voltages and utility voltage sags, which are two mostcommon utility voltage quality problems, can affect microgrid power quality [12], [13].

The inverter controller should be able to cope withstressing that the cascaded current–voltage controlwithin the range given by the waveform qualityrequirements of the local loads and/or micro grids. When critical loads are connected to an inverter, severe unbalanced voltages are not generally acceptable, and the invertershould be disconnected from the utility grid. Only when thevoltage imbalance is not so serious or the local load is notvery sensitive to it can the inverter remain connected. Sincethe controllers designed in the *dq* or *αβ* frames under unbalanced situations become noticeably complex [14], it isadvantageous to design the controller in the natural referenceframe.

Another power quality problem in micro grids isthe total harmonic distortion (THD) of the inverter local loadvoltage and the current exchanged with the grid (referred toas the grid current in this paper), which needs to bemaintained low according to industrial regulations. It hasbeen known that it is not a problem to obtain low THDeither for the inverter local load voltage [15], [16] or for thegrid current [17], [18].However, no strategy has beenreported in the literature to obtain low THD for both the inverter local load voltage and the grid current simultaneously.

This may even have been believed impossiblebecause there may be nonlinear local loads. In this paper, acascaded control structure consisting of an inner-loopvoltage controller and an outer-loop current controller isproposed to achieve this, after spotting that the inverter *LCL* filter can be split into two separate parts (whichis, of course,obvious but nobody has taken advantage of it).The *LC* part can be used to design the voltage controller, and the gridinterface inductor can be used to design the currentcontroller.

The voltage controller is responsible for thepower quality of the inverter local load voltage and powerdistribution and synchronization with the grid, and thecurrent controller is responsible for the power quality of thegrid current, the power exchanged with the grid, and theover current protection. With the help of the *H*∞ repetitive able to maintain low THD in both the inverter local loadvoltage and the grid current at the same time. When theinverter is connected to the grid, both controllers are active;when the inverter is not connected to the grid, the currentcontroller is working under zero current reference.

Hence, no extra effort is needed when changing the operation modeof the inverter, which considerably facilitates the seamlessmode transfer for grid-connected inverters. For three-phaseinverters, the same individual controller can be used for eachphase in the natural frame when the system is implementedwith a neutral point controller, e.g., the one proposed in[19]. As a result, the inverter can cope with unbalanced localloads for three-phase applications.

In other words, harmonic currents and unbalanced local load currents are all contained locally and do noaffect the grid.

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II.PROPOSED SYSTEM

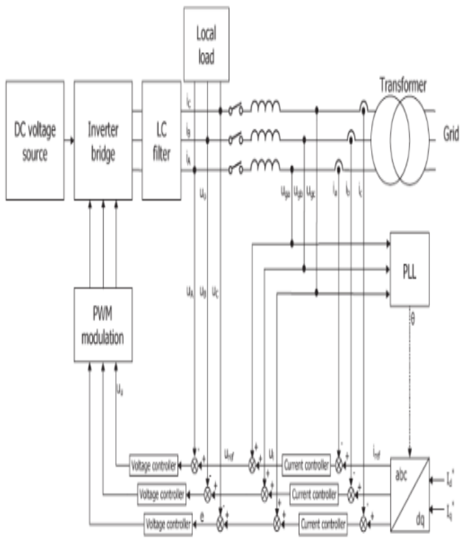

Fig.1 grid-connected three-phase inverter using the proposed strategy.

A three-phase *LC* filter, a three-phase grid interface inductor, a board consisting of voltage and current sensors, a step-up wye-wye transformer (12 V/230 V/50 Hz), in MATLAB Simulink software package. The inverterboard consists of two independent three-phase inverters and has the capability to generate PWM voltagesfrom a constant 42-V dc voltage source. One inverter was used to generate a stable neutral line for the three-phase inverter. The generated three-phase voltage was connected to the grid via a controlled circuit breaker and a step-up transformer. The PWM switching frequency was 12 kHz. A Yokogawa power analyzer WT1600was used to measure the THD. The Three sets of identical controllers were used for the three phases because there was a stable neutralline available. The control structure for the three-phase system is designed.A traditional *dq* PLL was used to providethe phase information needed to generate the three-phase grid current references via a *dq/abc* transformation from the current references I_d^* and I_q^* . The internal model was implemented according to [16], with the capability to adapt to the frequency change in the grid.

It is worth noting that it is quite a challenge to work with low-voltage inverters to improve the voltage THD, because, in general, the higher the voltage, the bigger the value of the fundamental component. Moreover, the impact of noises and disturbances is more severe for low-voltage systems than for high-voltage ones. Hence, it should be easy to apply the strategy proposed in this paper to inverters at higher voltage and higher power ratings.

Solar Pv Based Grid Connected System

A grid-connected photovoltaic power system, or grid-connected PV system is an electricity generating solar PV system that is connected to the utility grid. A grid-connected PV system consist of solar panels, one or several inverters, a power conditioning unit and grid connection equipment. They range from small residential and commercial rooftop systems to large utility-scale solar power stations. Unlike stand-alone power systems, a grid-connected system rarely includes an integrated battery solution, as they are still very expensive. When conditions are right, the grid-connected PV system supplies the excess power, beyond consumption by the connected load, to the utility grid.

Operation

Fig.2 Photovoltaic power station,.

Connection of the photovoltaic power system can be done only through an interconnection agreement between the consumer and the utility company. The agreement details the various safety standards to be followed during the connection.[4]

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Advantages

1.A grid-connected photovoltaic power system will reduce the power bill as it is possible to sell surplus electricity produced to the local electricity supplier.

2.Grid-connected PV systems are comparatively easier to install as they do not require a battery system.[1][6]

3.Grid interconnection of photovoltaic (PV) power generation systems has the advantage of effective utilization of generated power because there are no storage losses involved.[7]

4.A photovoltaic power system is carbon negative over its lifespan, as any energy produced over and above that to build the panel initially offsets the need for burning fossil fuels. Even though the sun doesn't always shine, any installation gives a reasonably predictable average reduction in carbon consumption.

III. CONTROL AND OPERATING STRATEGY OF THE HYBRID SYSTEM

It consists of an inverter bridge, an *LC* filter,and a grid interface inductor connected with a circuit breaker. Itis worth noting that the local loads are connected in parallelwith the filter capacitor. The current *i*1 flowing through thefilter inductor is called the filter inductor current in this paper,and the current *i*2 flowing through the grid interface inductor iscalled the grid current in this paper. The control objective is tomaintain low THD for the inverter local load voltage *uo* and,simultaneously, for the grid current *i*2. As a matter of fact, thesystem can be regarded as two parts, as shown in,cascaded together. Hence, a cascaded controller can be adoptedand designed. The proposed controller, as shown in Fig. 4,consists of two loops: an inner voltage loop to regulate theinverter local load voltage *uo* and an outer current loop to

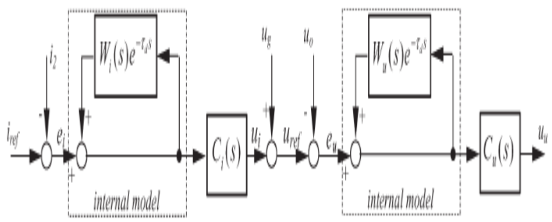

Fig.3 Proposed cascaded current–voltage controller for inverters, where both controllers adopt the *H*∞ repetitive strategy.

regulate the grid current *i*2. According to the basic principlesof control theory about cascaded control, if the dynamics ofthe outer loop is designed to be slower than that of the innerloop, then the two loops can be designed separately. As a result,the outer-loop controller can be designed under the assumptionthat the inner loop is already in the steady state, i.e., *uo* = *u*ref .It is also worth stressing that the current controller is in theouter loop and the voltage controller is in the inner loop. This iscontrary to what is normally done. In this paper, both controllersare designed using the *H*∞ repetitive control strategy becauseof its excellent performance in reducing THD.

The main functions of the voltage controller are the following:to deal with power quality issues of the inverter localload voltage even under unbalanced and/or nonlinear localloads, to generate and dispatch power to the local load, andto synchronize the inverter with the grid. When the inverter issynchronized and connected with the grid, the voltage and thefrequency are determined by the grid.The main function of the outer-loop current controller is toexchange a clean current with the grid even in the presence ofgrid voltage distortion and/or nonlinear (and/or unbalanced forthree-phase applications) local loads connected to the inverter.The current controller can be used for overcurrent protection,but normally, it is included in the drive circuits of the inverterbridge. A phase-locked loop (PLL) can be used to providethe phase information of the grid voltage, which is neededto

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generate the current reference *i*ref (see Section V for anexample). As the control structure described here uses just oneinverter connected to the system and the inverter is assumed tobe powered by a constant dc voltage source, no controller is
needed to regulate the dc-link voltage (otherwise, a controllercan be introduced to regulate the dc-link voltage).
Another important feature is that the grid voltage *ug* is fed forward and added to the output of the current controller. Thisis used as a synchronization mechanism, and it does not affectthe design of the controller, as will be seen later.

III.SIMULATION RESULTS

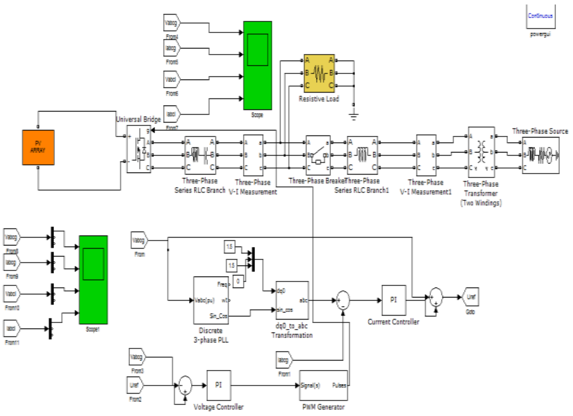

Fig.4 Cascaded voltage current control extension(Solar PV & Mppt)

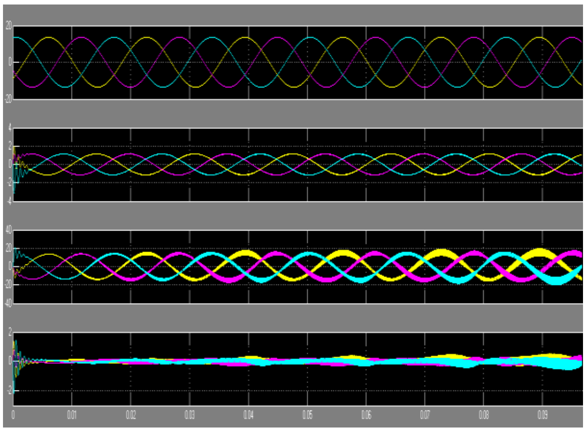

Fig 5 .Resistive Load Circuit Vgrid,Igrid,VL,IL

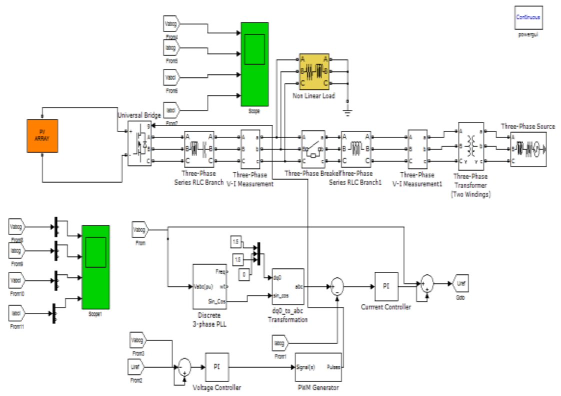

Fig .6 Non-Linear Load

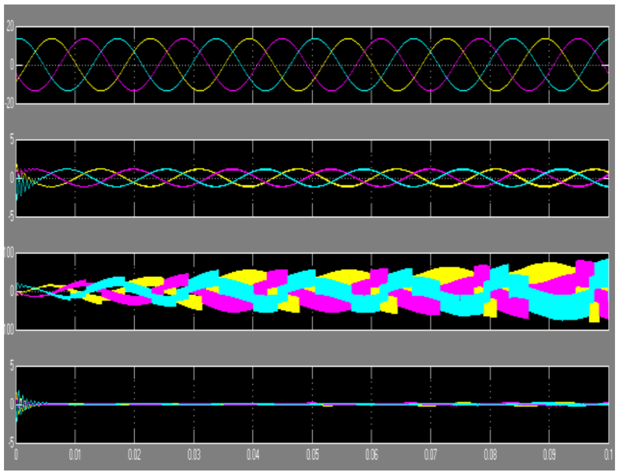

Fig.7 Vgrid,Igrid,VL,IL

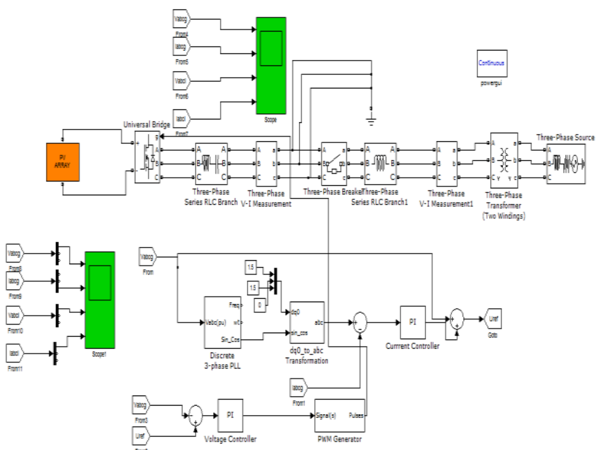

Fig .8No Load Circuit

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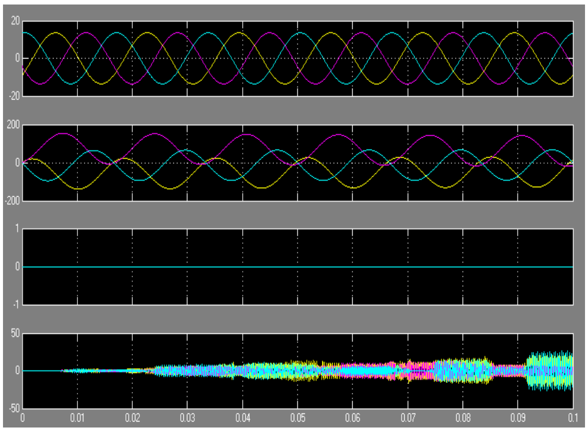

Fig .9 Vgrid,Igrid,VL,IL

V.CONCLUSION

The cascaded current–voltage control strategy has been proposedfor inverters in microgrids. It consists of an inner voltageloop and an outer current loop and offers excellent performance in terms of THD for both the inverter local load voltage and thegrid current. In particular, when nonlinear and/or unbalancedloads are connected to the inverter in the grid-connected mode,the proposed strategy significantly improves the THD of theinverter local load voltage and the grid current at the same time.The controllers are designed using the $H\infty$ repetitive control inthis paper but can be designed using other approaches as well.The proposed strategy also achieves seamless transfer betweenthe stand-alone and the grid-connected modes. The strategy canbe used for single-phase systems or three-phase systems. As aresult, the nonlinear harmonic currents and unbalanced local load currents are all contained locally and do not affect thegrid.

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