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Analysis of Effective Control Strategy for Three-Phase Inverter in Distributed Generation

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ABSTRACT: The proposed control strategy comprises of an inner inductor current loop, and a novel voltage loop in the synchronous reference frame. The inverter is regulated as a current source just by the inner inductor current loop in grid-tied operation, and the voltage controller is inevitably activated to regulate the load voltage upon the occurrence of islanding. Furthermore, the waveforms of the grid current in the grid-tied mode and the load voltage in the islanding mode are distorted under nonlinear local load with the conventional strategy. And this issue is addressed by proposing a unified load current feed-forward in this paper. Finally, the effectiveness of the proposed control strategy is validated by the simulation results.

KEYWORDS-Distributed generation (DG), islanding, load current, seamless transfer, three-phase inverter.

I. INTRODUCTION

Renewable energy resources are being widely used now adays for power generation. Three phase inverterimplemented in the unified control strategy is effective andgives the better inductor current [1]. Distributed generation(DG) is emerging as a viable alternative when renewable ornonconventional energy resources are available, such as windturbines, photovoltaic arrays, fuel cells, micro turbines [2], [4].Most of these resources are connected to the utility throughpower electronic interfacing converters, i.e., three-phaseinverter. Moreover, DG is a suitable form to offer high reliableelectrical power supply, as it is able to operate either in thegrid-tied mode or in the islanded mode [3]. In the grid-tiedoperation, DG deliveries power to the utility and the localcritical load. Upon the occurrence of utility outage, theislanding is formed. Under this circumstance, the DG must betripped and cease to energize the portion of utility as soon aspossible according to IEEE Standard 929-2000 [5]. However,in order to improve the power reliability of some local criticalload, the DG should disconnect to the utility and continue tofeed the local critical. Distributed generation is not a new concept since traditional diesel generator asbackup power source for critical load has been used for decades. However, due to itslow efficiency, high cost, and noise and exhaust, diesel generator would be objectionable in any applications but emergency and fieldwork and it has never become a truedistributed generation source on today’s basis. What endows new meaning to thisold concept is technology.

Environmental friendly renewable energy sources, such as photovoltaic devices andwind electric generators, clean and efficient fossil-fuel technologies, such as micro gasturbines, and hydrogen electric devices-fuel cells, have provided great opportunitiesfor the development in distributed generation.Gas fired micro-turbines in the 25-100kW range can be mass produced at low costwhich use air bearing and recuperation to achieve reasonable efficiency at 40% withelectricity output only and 90% for electricity and heat micro-cogeneration.Fuel cells have the virtue of zero emission, high efficiency, and reliability andtherefore have the potential to truly revolutionize power generation. The hydrogencan be either directly supplied or reformed from natural gas or liquid fuels such asalcohols or gasoline.

A Distributed generation (DG) is emerging as a viable alternative when renewable or nonconventional energyresources are available, such as wind turbines, photovoltaic arrays, fuel cells, microturbines [1], [3]. Most of these resourcesare connected to the utility through power electronic interfacingconverters, i.e., three-phase inverter. Moreover, DG is a suitableform to offer high reliable electrical power supply, as it is able tooperate either in the grid-tied mode or in the islanded mode [2].In the grid-tiedoperation, DG deliveries power to the utility and thelocal critical load. Upon the occurrence of utilityoutage, the islanding is formed. Under thiscircumstance, the DG must be tripped and cease toenergize the portion of utility.However, in order to improve the powerreliability of some local critical.

A fuel cell converts chemical energy of afuel directly into electrical energy. It consists of twoelectrodes and an electrolyte, retained in a matrix. Theoperation is similar to that of a storage battery exceptthat the reactant and products are not stored, but arecontinuously fed to the cell. During operation thehydrogen rich fuel and oxidant are separately suppliedto the electrodes.

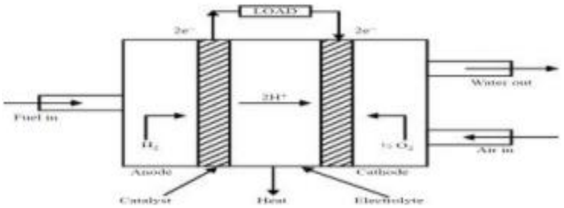


Fig 1: Basic Construction of a Fuel Cell

Fuel is fed to the anode and oxidant to the cathode,and the two streams are separated by an electrodeelectrolyte system. Electrochemical oxidation andreduction takes place at the electrodes to produceelectricity. Heat and water are produced as byproducts. Fig 1 shows the basic construction of a fuelcell. The Flows and reactions in a Fuel Cell are shownin Fig 2.

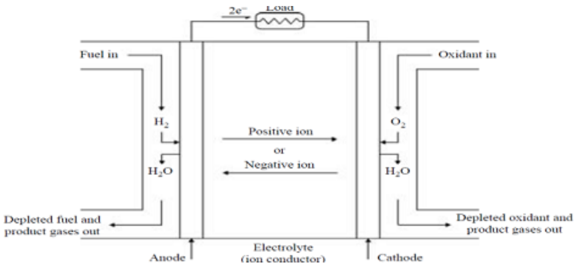


Fig 2: Flows and reactions in a fuel cell

This paper proposes a unified control strategy thatavoids the aforementioned shortcomings. First, thetraditional inductor current loop is employed tocontrol the three-phase inverter in DG to act as acurrent source with a given reference in thesynchronous reference frame (SRF). Second, a novelvoltage controller is presented to supply reference forthe inner inductor current loop, where a proportionalplus-integral (PI) compensator and a proportional (P)compensator are employed in D-axis and Q-axis,respectively.

II. PROPOSEDCONTROL STRATEGY

This paper presents a unified control strategy for athree-phase inverter in DG to operate in both islandedand grid-tied modes. The schematic diagram of theDG based on the proposed control strategy is shownby Fig. 3. The DG is equipped with a three-phaseinterface inverter terminated with a LC filter. Theprimary energy is converted to the electrical energy,which is then converted to dc by the front-end powerconverter, and the output dc voltage is regulated by it.Therefore, they can be represented by the dc voltagesource V_{dc} in Fig. 3. In the ac side of inverter, the localcritical load is connected directly.

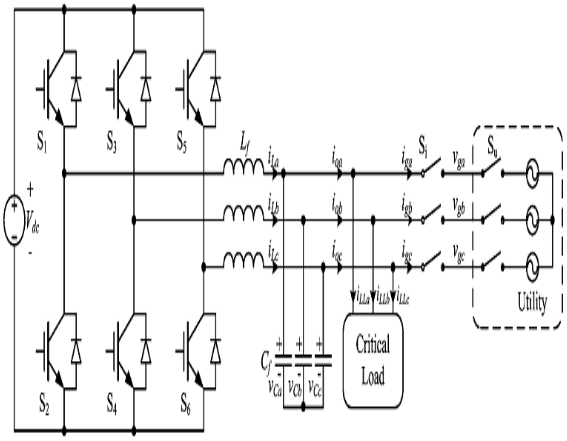


Fig. 3. Schematic diagram of the DG based on the proposed control strategy

Basic idea

With hybrid voltage and current mode control, theinverter is controlled as a current source to generate the reference power PDG+jQDG in the grid-tiedmode. And its output power PDG+jQDG should besum of the power injected to the grid Pg+jQg and theload demand Pload+jQload,which can be expressedfollowed by as assuming that the load is representedas a parallel RL circuit.

$$P_{load} = \frac{3}{2} \cdot \frac{V_m^2}{R} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$Q_{load} = \frac{3}{2} V_m^2 \cdot \left(\frac{1}{\omega L} - \omega C \right) \ldots \ldots \ldots \ldots \ldots .. (2) .$$

In (1) and (2), Vm and ωrepresent the amplitudeand frequency of the load voltage, respectively. Whenthe nonlinear local load is fed, it can still beequivalent to the parallel RLC circuit by just takingaccount of the fundamental component.

Fig. 4 describes the overall block diagram for theproposed unified control strategy, where the inductorcurrent iLabc , the utility voltage $v_{g\ abc}$, the load voltagev_{Cabc} , and the load current are sensed. And the threephase inverter is controlled in the SRF, in which, threephase variable will be represented by dc quantity. Thecontrol diagram is mainly composed by the inductorcurrent loop, the PLL, and the current referencegeneration module. In the inductor current loop, the PIcompensator is employed in both D- and Q-axes, anda decoupling of the cross coupling denoted by $\omega_0 L_f / k_{PWM}$ is implemented in order to mitigate thecouplings due to the inductor.

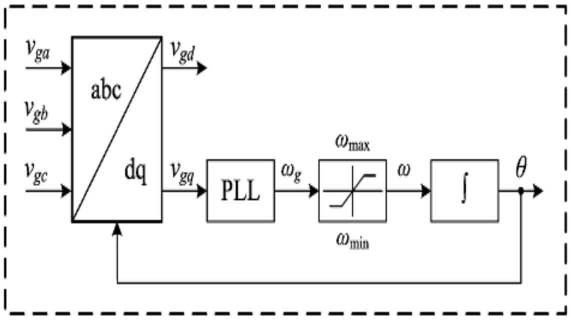


Fig. 4. Overall block diagram of the proposed unified control strategy.

The output of the innercurrent loop ddq together with the decoupling of thecapacitor voltage denoted by 1/kPWM , sets thereference for the standard space vector modulationthat controls the switches of the three-phase inverter.It should be noted that kPW M denotes the voltage gainof the inverter, which equals to half of the dc voltagein this paper.

III. OPERATION PRINCIPLE OF DG

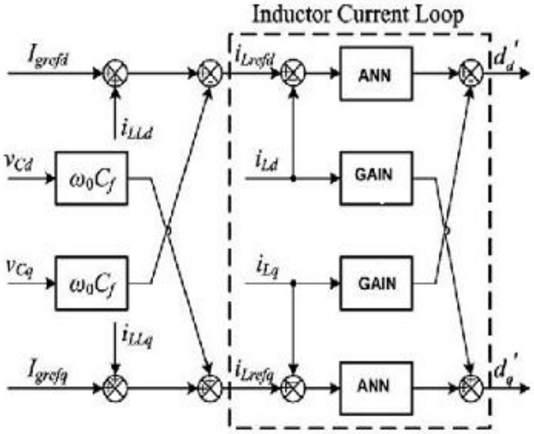
The operation principle of DG with the proposedcontrol strategy will be illustrated in detail in thissection, and there are in total two states for the DG,including the grid-tied mode, the islanded mode.

A. Grid-Tied Mode

When the utility is normal, the DG is controlledas a current source to supply given active andreactive power by the inductor current loop, and theactive and reactive power can be given by thecurrent reference of D- and Q-axis independently.

Second, the filter inductor current, which hasbeen trans-formed into SRF by the Parktransformation, is fed back and compared with theinductor current reference iLr efdq , and the inductorcurrent is regulated to track the reference i_{Lrefdq} bythe PI compensator G_I The reference of the inductorcurrent loop $i_{L\ r\ efdq}$ seems complex and it isexplained as below.

The control diagram of the inverter can be simplified asFig. 5 in the grid-tied mode, and the inverter is controlled asa current source by the inductor current loop with theinductor current reference being determined by the currentreference $I_{gref\ dq}$ and the load current i_{LLdq} . In otherwords, the inductor current tracks the current reference andthe load current. If the steady state error is zero, Igref dqrepresents the grid current.



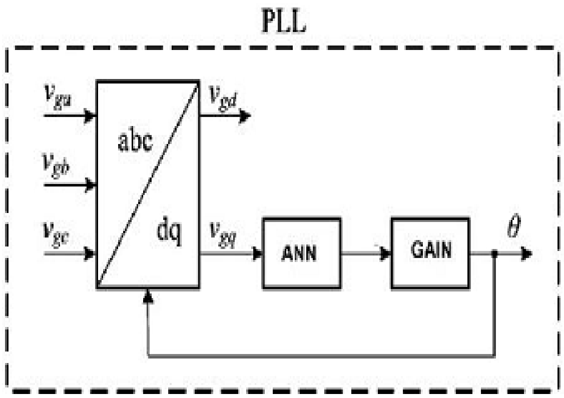


Fig. 5. Simplified block diagram of the unified controlstrategy when DG operates in the grid-tied mode.

B. Transition From the Grid-Tied Mode to the Islanded Mode

When the utility switch Su opens, the islanding happens,and the amplitude and frequency of the load voltage willdrift due to the active and reactive power mismatch betweenthe DG and the load demand. The transition, shown in Fig.6, can be divided into two time interval. The first timeinterval is from the instant of turning off Su to the instant ofturning off Si when islanding is confirmed. The second timeinterval begins from the instant of turning off inverterswitch Si .

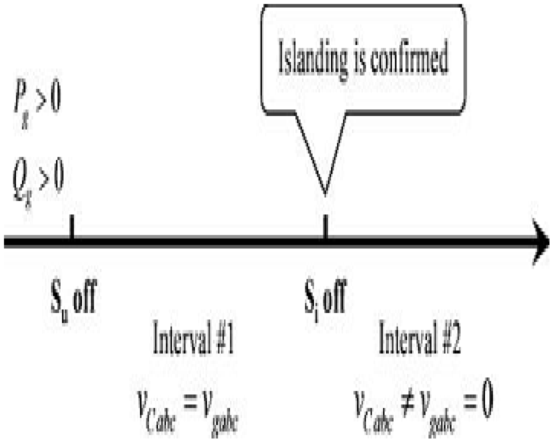


Fig.6. Operation sequence during the transition from the grid-tied mode to the islanded mode.

C. Islanded Mode

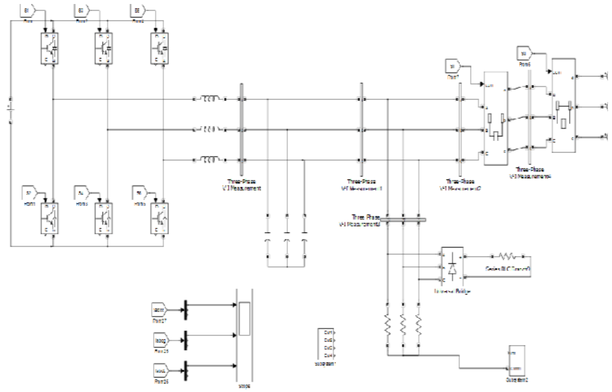
In the islanded mode, switching Si and Su are both inOFF state. The PLL cannot track the utility voltagenormally, and the angle frequency is fixed. In this situation,the DG is controlled as a voltage source, because voltagecompensator GV D and GV Q can regulate the load voltagevCdq . The voltage references in D and Q-axis are Vmax andzero, respectively.

D. Transition From the Islanded Mode to the Grid-Tied Mode

If the utility is restored and the utility switch Su is ON,the DG should be connected with utility by turning onswitch Si . However, several preparation steps should beperformed before turning on switch Si . First, as soon asutility voltage is restored, the PLL will track the phase of theutility voltage. As a result, the phase angle of the loadvoltage vCabc will follow the grid voltage vgabc. If the loadvoltage vCabc is in phase with the utility voltage, vgd willequal the magnitude of the utility voltage according to (5).Second, as the magnitude of the load voltage Vmax is largerthan the utility voltage magnitude V_g , the voltage referenceV_{ref} will be changed to V_g by toggling the selector S fromterminals 1 to 2. As a result, the load voltage will equal tothe utility voltage in both phase and magnitude. Third, theswitch S_i is turned on, and the selector S is reset to terminal1.

IV. SIMULATION AND EXPERIMENTAL RESULTS

To investigate the feasible of the proposed efficientcontrol strategy, the simulation has been done inSIMULINK. The power rating of a three-phase inverter is3kWin the simulation. In the grid-tied mode, the dynamicperformance of the conventional voltage mode control andthe proposed control strategy is compared by stepping downthe grid current reference. The simulation results can beseen that the dynamic performance of the proposed controlstrategy is better than the conventional voltage modecontrol. During the transition from the grid-tied mode to theislanded mode, the proposed control strategy is comparedwith the hybrid voltage and current mode control. TheSIMULINK model for the proposed control strategy is shown in the Fig. 6.



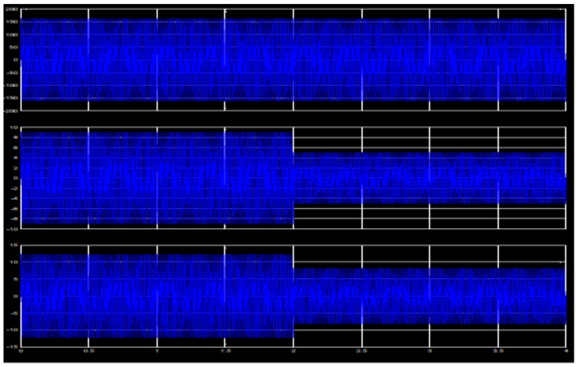


Fig. Grid Connected Mode

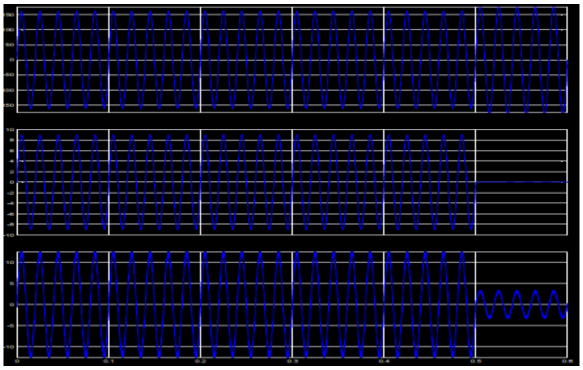


Fig. Islanding Mode

V. CONCLUSION

An efficient control strategy was proposed for threephase inverter in DG using Artificial neural networks tooperate in both islanded and grid-tied modes, with no needfor switching between two different control architectures orcritical islanding detection. The voltage controller isinactivated in the grid-tied mode, and the DG operates as acurrent source with fast dynamic performance. Upon theutility outage, the voltage controller can automatically beactivated to regulate the load voltage. Moreover, the loadcurrent feedforward can improve the waveform quality ofboth the grid current in the grid-tied mode and the loadvoltage in the islanded mode.

REFERENCES

[1] R. C. Dugan and T. E. McDermott, “Distributed generation,” IEEE Ind. Appl. Mag., vol. 8, no. 2, pp. 19–25, Mar./Apr. 2002.

[2] R. H. Lasseter, “Microgrids and distributed generation,” J. Energy Eng., vol. 133, no. 3, pp. 144–149, Sep. 2007.

[3] C. Mozina, “Impact of green power distributed generation,” IEEE Ind. Appl. Mag., vol. 16, no. 4, pp. 55–62, Jul./Aug. 2010.

[4] IEEE Recommended Practice for Utility Interface of Photovoltaic(PV) Systems, IEEE Standard 929-2000, 2000.

[5] IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems, IEEE Standard 1547-2003, 2003.

[6]IEEE Standard for Interconnecting DistributedResources with Electric Power Systems, IEEEStandard 1547-2003, 2003.

[7]J. Stevens, R. Bonn, J. Ginn, and S. Gonzalez,Development and Testingof an Approach toAnti-Islanding in Utility-InterconnectedPhotovoltaic Systems. Livermore, CA, USA:Sandia National Laboratories, 2000.

[8]A. M. Massoud, K. H. Ahmed, S. J. Finney, andB. W. Williams, “Har-monic distortion-basedisland detection technique for inverter-baseddistributed generation,” IET RenewablePower Gener., vol. 3, no. 4, pp. 493– 507,Dec. 2009.

[9] T. Thacker, R. Burgos, F. Wang, and D.Boroyevich, “Single-phase is-landingdetection based on phase-locked loopstability,” in Proc. 1st IEEEEnergyConvers.Congr.Expo., San Jose, CA, USA,2009, pp. 3371–3377.

[10]S.-K. Kim, J.-H.Jeon, J.-B.Ahn, B. Lee,and S.-H.Kwon, “Frequency-shift accelerationcontrol for anti-islanding of a distributedgeneration inverter,”

IEEE Trans. Ind.Electron., vol. 57, no. 2, pp. 494–504, Feb.2010.

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