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Control Of three Phase Inverter in Distributed Generation using PI and Fuzzy Controller

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Abstract-— **This paper presents the effective control strategy for the control of three phase PWM inverter connected to the distributed generation. This inverter is used to convert the DG output to the alternating quantity as required by the load and also to interface the DG unit to the grid. The proposed scheme uses a single controller to control the inverter in both the islanded and grid connected mode of operation. In the propose scheme the output power of the inverter is controlled in the transition stages of the given system. For that it uses the synchronous reference frame for controlling the inverter. Also the advantage of proposed strategy is that it does not require any islanding detection scheme. Finally the effectiveness of the proposes control scheme is validated in MATLAB simulation.**

Index Terms— Distributed Generation, Fuzzy controller, PI controller, PLL, SRF

I. INTRODUCTION:

DISTRIBUTED generation (DG) is emerging as a viable alternative when renewable or nonconventional energy resources are available, such as wind turbines, photovoltaic arrays, fuel cells, micro turbines. Most of these resources connected to the utility through power electronic interfacing converters, i.e., three-phase inverter. Therefore Inverter-based distributed power generation systems (DPGSs) have received much attention recently due to flexible power-controlling capability. Usually, the inverter with the grid-following control is used to accomplish power conversion between the grid and DPGSs. However, this method may suffer from voltage stability, frequency variation, voltage harmonics, and cannot work in the islanding situation. Instead of the grid-following control, the grid-forming inverter is preferred because it is able to provide many ancillary services defined in IEEE Std. 1547[5], such as load regulation, reactive power compensation, and power quality improvement.

Distributed generation offers many advantages such as

a) peak shaving to reduce the overall cost of power by generating during peak load hours when the cost of electricity is high and

b) standby generation to provide power during system outages until service can be restored. Both of the above advantages can be effectively utilized if the distributed generation system is utility-interactive.

In the grid-tied operation, DG deliveries power to the utility and the local critical load. Upon the occurrence of utility outage, the islanding is formed. Under this circumstance, the DG must be tripped and cease to energize the portion of utility as soon as possible according to IEEE Standard 929-2000[7]. However, in order to improve the power reliability of some local critical load, the DG should disconnect to the utility and continue to feed the local critical load . The load voltage is key issue of these two operation modes, because it is fixed by the utility in the grid-tied operation, and formed by the DG in the islanded mode, respectively. Therefore, upon the happening of islanding, DG must take over the load voltage as soon as possible, in order to reduce the transient in the load voltage. And this issue brings a challenge for the operation of DG.

This paper presents a control strategy for three phase inverter. In this method of control the reference current generation module is developed by using two types of controllers i.e. the PI controller and the Fuzzy controller. Also the comparison is done between the conventional hybrid method and proposed method of inverter control.

The remaining paper is structured as follows. Firstly, the schematic diagram of the propose control strategy is presented in Section II. A detailed description of method used to control is discussed in III. Section IV shows the simulation and results. The paper is concluded in Section V.

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II. PROPOSED CONTROL SRATEGY

The schematic diagram of proposed control strategy is as shown in the fig. 1.

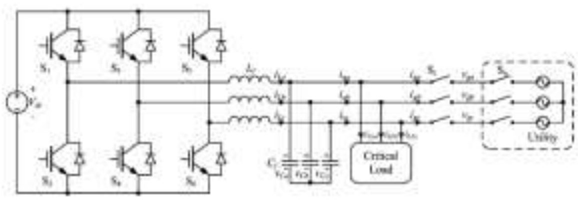

Fig. 1 Schematic diagram of proposed control strategy.

The schematic diagram of the DG based on the proposed control strategy is shown by Fig. 1. The DG is equipped with a three-phase interface inverter terminated with a LC filter. The input dc source to the inverter is represented by the dc voltage source Vdc in Fig.1.In the ac side of inverter, the local critical load is connected directly. It should be noted that there are two switches, denoted by Su and Si, respectively, in Fig. 1, and

their functions are different. The inverter transfer switch Si is controlled by the DG, and the utility protection switch Su is governed by the utility. When the utility is normal, both switches Si and Su are ON, and the DG in the grid-tied mode injects power to the utility. When the utility is in fault, the switch Su is tripped by the utility instantly, and then the islanding is formed. After the islanding has been confirmed the switch Si is disconnected, and the DG is transferred from the grid-tied mode to the islanded mode. When the utility is restored, the DG should be resynchronized with the utility first, and then the switch Si is turned ON to connect the DG with the grid.

III. METHODOLOGY

A. Control Diagram of the proposed scheme

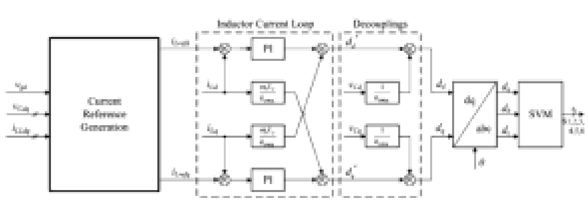

Fig. 2 Control Diagram of the Proposed Scheme

Fig. 2 describes the overall control diagram for the proposed control strategy, where the inductor current iLabc, the utility voltage vgabc, the load voltage vCabc, and the load current iLLabc are sensed. And the three-phase inverter is controlled in the SRF, in which, three phase variable will be represented by dc quantity. The control diagram is mainly composed by the inductor current loop, the PLL, and the current reference generation module.

In the inductor current loop, the PI compensator is employed in both D- and Q-axes, and a decoupling of the cross coupling denotedbyω0Lf/kPWM is implemented in order to mitigate the couplings due to the inductor. The output of the inner current loop ddq , together with the decoupling of the capacitor voltage denoted by 1/kPWM, sets the reference for the standard space vector modulation that controls the switches of the three-phase inverter. It should be noted that kPWM denotes the voltage gain of the inverter, which equals to half of the dc voltage in this paper.

B. Current reference generation module

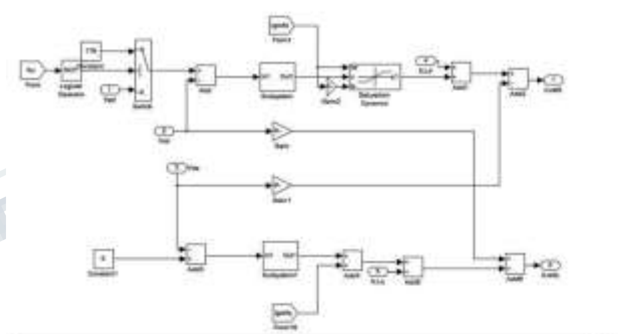

Fig. 3 Current reference generation module

The basic idea of this paper is to control the output power of the inverter so as to improve the dynamic response of the system as well as the load voltage waveform quality

hence to minimize the deviation of load voltage and frequency from its rated value during the transition process.

So for this , the current reference generation module is shown in Fig.3, which regulates the current reference to guarantee the power match between the DG and the local load and enables the DG to operate in the islanded mode. Moreover, the unified load current feedforward, to deal with the nonlinear local load, is also implemented in this module. The current reference generation module provides the current reference for the inner current loop in both grid-tied and islanded modes. In this module, it can be found that an unsymmetrical structure is used in D- and Q-axes. The PI compensator is adopted in D-axes, while the P compensator is employed in Q-axis. Besides, an extra limiter is added in the D-axis. Moreover, the load current feed forward is implemented by adding the load current iLLdq to the final inductor current reference iLrefdq.

The contribution of this module is in two aspects. First, by introducing PI compensator and P compensator in D-axis and Q-axis respectively, the voltage controller is inactivated in the grid-tied mode and can be automatically activated upon occurrence of islanding. Therefore, there is no need for switching different controllers or critical islanding detection, and the quality of the load voltage during the transition from the grid-tied mode to the islanded mode can be improved. The second contribution of this module is to present the load current feed forward to deal with the issue caused by the nonlinear local load, with which, not only the waveform of the grid current in grid-tied is improved, but also the quality of the load voltage in the islanded mode is enhanced.

C. PI Controller

PI Controller is a feedback controller which drives the plant to be controlled with a weighted sum of the error and the integral of that value. The proportional response can be adjusted by multiplying the error by constant KP, called proportional gain. The contribution from integral term is proportional to both the magnitude of error and duration of error. The error is first multiplied by the integral Gain, Ki and then was integrated to give an accumulated offset that has been corrected previously.

D. Fuzzy Logic Controller

Fuzzy logic (FL) controller is one of the most successful operations of fuzzy set theory, its major features are the use of linguistic variables rather than numerical variables. This control technique relies on human capability to understand the behavior of the system and is based on quality control rules [9]. Fuzzy Logic provides a simple way to arrive at a definite conclusion based upon vague, ambiguous, imprecise, noisy, or missing input information. The basic functions of PLC are listed in following four steps.

- A Fuzzyfication interface which converts input data into suitable linguistic values.
- A Knowledge Base which consists of a database with the necessary linguistic definitions and control rule set.
- A Decision Making Logic which, simulating a human decision process, infers the fuzzy control action from the knowledge of the control rules and the linguistic variable definitions and
- A De-fuzzyfication interface which yields a non-fuzzy control action from an inferred fuzzy control action.

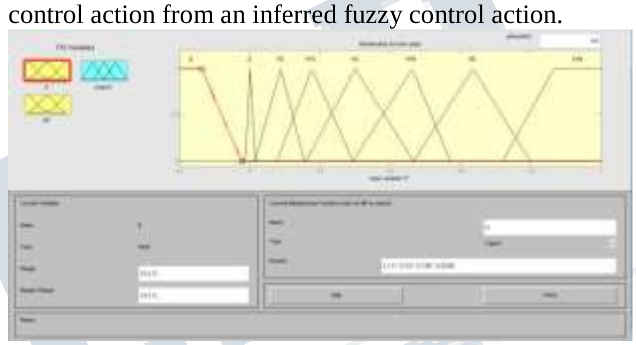

Fig. 4 Membership function of input variable E

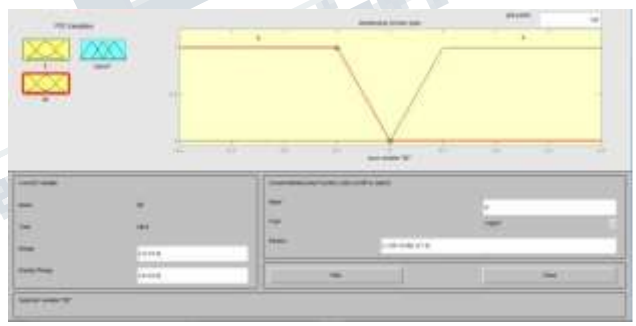

Fig. 5 Membership function of input variable DE

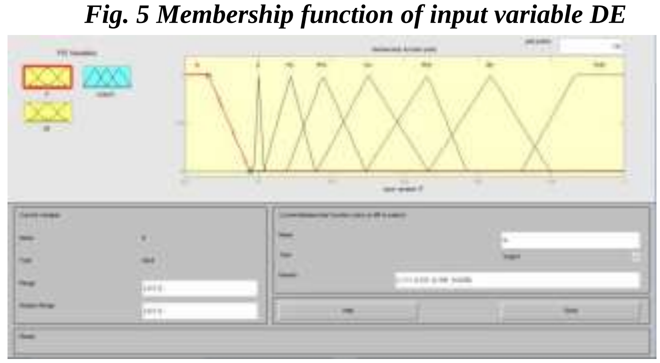

Fig. 6 Membership function of output

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DE\E	N	Z	PS	PFS	PA	PFB	PB	PVB
N	N	Z	PS1	PFS1	PA1	PFB1	PB1	PVB
P	N	Z	PS2	PFS2	PA2	PFB2	PB2	

Table I. Rule base for fuzzy

In the proposed control system the fuzzy controller is use in the current reference generation module. Error and Change in Error are the inputs to the fuzzy controller. The membership function for the inputs and outputs are given in the Fig. 4 to Fig. 6 .

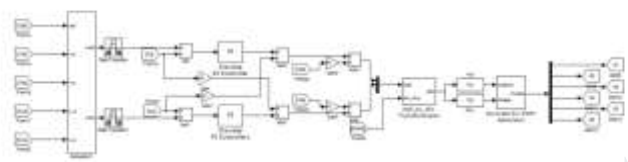
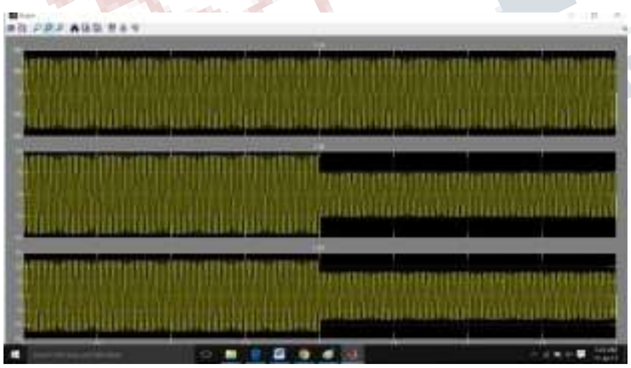


Fig. 7. Simulation of proposed control scheme

IV. SIMULATION RESULTS AND DISCUSSIONS

For that in the grid tied mode the grid current is stepped down from 9A to 5A to check the dynamic response of the system. And from the fig 8 it can be seen that the time require for the



control system to follow the change in the input condition is very less.

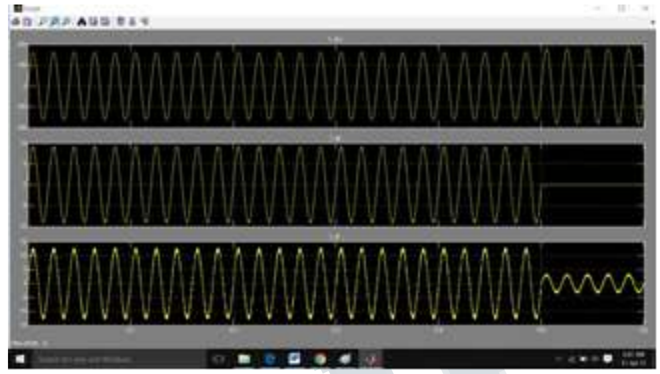


Fig. 9 Simulation Results for Transition mode.

From fig. 9 it can be seen that using the propose strategy the waveform quality of the load voltage is improved with this strategy during the transition mode as the %THD value of the load voltage waveform is zero.

CONCLUSION

In this paper the control strategy is proposed for the three phase inverter in the distribution generation. The control strategy consists of the current reference generation module, inner control loop and the outer voltage loop. All the control is done in the SRF. A load current feed forward is used which improves the quality of the load voltage waveform during the transition state. Because of the use of current reference generation module there is no need for switching different controllers or critical islanding detection upon the utility outage. Hence the proposed control strategy more effective for the control of thee phase grid connected inverter. The use of Fuzzy controller for the proposed strategy simplifies the designing part of the CRG module.

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