Power Quality Improvement for Grid Connected Renewable Energy System using FLC

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ABSTRACT

Power management for a hybrid power system (solar and wind power) is done by fuzzy logic system using a seven level cascaded multilevel inverter. The implementation of the seven level cascaded inverter is to maintain the THD level of the power system within IEEE standard (5%). This system comprises one set of rectifier unit which is connected to the wind system. PV voltage and rectifier voltage is given as input to the seven level inverter. The proposed inverter reduces the switching loss complexity, size and cost. The PWM signals are originated by using FLC (Fuzzy Logic controller). MPPT algorithm is implemented for the improvement of voltage level in PV panel. The inverted three phase voltage is obtained by functioning the FL membership functions which helps in maintaining the harmonics level below 5%. The fuzzy logic technique has been expectant in the field of converter, electric drives and other intelligent controllers. This process has quick access and it is simpler to integrate. Mamdani model of FL has enhanced in this paper to give linear output when compared to Tsukeno model. Fuzzy logic controller was developed and verified for three phase systems using the simulink MATLAB 2009a in which the components are arranged according to the circuit required. In MATLAB based defuzzification centroid method of fuzzification is done to defuzzify.

Keywords: *Boost Converter, FLC (Fuzzy Logic controller), cascaded Multi-Level Inverter, MPPT.*

1. INTRODUCTION

The rapid growth in power electronic techniques makes the feasibility in hybrid scheme generation using wing and photovoltaic system. The renewable energy systems can be used to supply power either directly to utility grid or to an isolated load. The stand-alone systems find wider application as water-pumps, for village electrification, supply of power to isolated areas which are far away from the utility grid.

Generally, PV power and wind power are complementary since sunny days are usually calm and strong winds often occur on cloudy days or in night time. The hybrid PV-wind power system therefore has higher availability to deliver continuous power and results in a better utilization of power conversion and control equipment than the individual sources.

Further hybrid PV-wind scheme has environment benefits such as reduction of carbon emission due to use of renewable energy sources. In case of stand-alone wind power generation system with a self-excited induction generator, it is necessary to provide a dynamically variable reactive power to maintain constant output voltages. But in case of solar-wind hybrid scheme the necessary reactive power under varying rotor speed or load can be achieved by providing a three-phase fixed frequency pulse width modulation (PWM) inverter fed from the photovoltaic array. In this project fuzzy logic controller is designed to vary the duty-cycle of the DC-DC converter such that to maintain the load voltage constant under varying rotor speeds or loads.

2. BLOCK DIAGRAM

This paper proposes a new solar and wind power generation system. The proposed solar power generation system is composed of a dc/dc power converter and a seven-level inverter. The seven level inverter is configured using a capacitor selection circuit and a full-bridge converter connected in cascade. The seven-level inverter contains only six power electronic switches, which simplifies the circuit configuration. Since only one power electronic switch is switched at high frequency at any time to generate the seven-level output voltage, the switching power loss is reduced and the power efficiency is improved as shown in the figure. The inductance of the filter inductor is also reduced because there is a seven level output voltage. In this topology fuzzy logic controllers are used to produce pulse width modulated signals. Conventional PI controller has some disadvantage i.e large steady state error and more settling time. The general block diagram of the system is as shown in fig. 1.

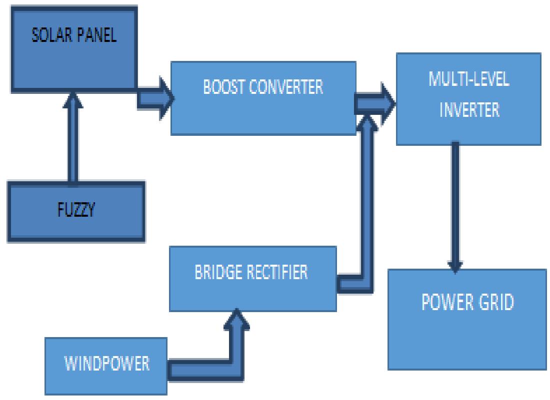


Fig:1 General Block Diagram

3. CIRCUIT CONFIGURATION

The proposed solar power generation system is composed of a solar cell array and wind turbine, a dc-dc power converter, rectifier, and a new seven level inverter. The solar cell array is connected to the dc-dc power converter and the dc-dc power converter is a boost converter that incorporates with a turn ratio of 2:1. The dc-dc power converter converts the output power of the solar cell array into two independent voltage source with multiples relationships, which are supplied to the seven-level inverter. The rectifier is also connected to seven-level inverter This new seven-level inverter is composed of a capacitor selection circuit and a full-bridge power converter, connected in a cascade. The power electronic switches of capacitor selection circuit determine the discharge of the two capacitors while the two capacitors are being discharged individually or in series. Because of the multiple relationships between the voltages of the dc capacitors, the capacitor selection circuit outputs a three-level dc voltage. The full-bridge power converter further converts this three-level dc voltage that is synchronized with the utility voltage. In this way the proposed solar and wind power generation system generates a sinusoidal output current that is in phase with the utility voltage and is fed into the utility, which produces a unity power factor. As can be seen this seven-level inverter contains only six power electronic switches, so the power circuit is simplified.

4. DC-DC POWER CONVERTER

The dc to dc power converter incorporates a boost converter and a current fed- forward converter. The boost converter is composed of an inductor L_D, a power electronic switch S_{D1}, and a diode D_{D3}. The boost converter charges capacitor C2 of the seven-level inverter. The current-fed forward converter is composed of an inductor L_D, power electronic switches S_{D1} and S_{D2}, a transformer, and diodes D_{D1} and D_{D2}. The current-fed forward conductor charges capacitor C1 of the seven- level inverter. The inductor L_D and the power electronic switch $S_{D1,}$ of the current fed converter are also used in the boost converter. The solar cell array supplies energy to the inductor L_D When S_{D1} is turned OFF and S_{D2} is turned ON. Accordingly, capacitor C1 is connected to capacitor C2 in parallel to the transformer, so the energy of the inductor L_D and the solar cell array charge capacitor C2 through D_{D3} and charge capacitor C1 through the transformer and D_{D1} during the OFF state of S_{D1}. Since capacitor C1 and C2 are charged in parallel by using the transformer, the voltage ratio of capacitor C1 and C2 is the same as turn ratio (2:1) of the transformer. Therefore the voltage of C1 and C2 have multiple relationships. The boost converter isoperated in the continuous conduction mode (CCM).

5. RECTIFIER

A rectifier is a circuit that converts AC supply into unidirectional DC supply. The rectifier ranges from few amperes to several hundred amperes. Mostly in bridge rectifier circuit semiconductor diode is used for converting AC since it allows the current low in one direction only (Unidirectional device). Bridge rectifier selection depends on load requirements and apart from this some more considerations are breakdown voltage, forward current rating, transient current rating, temperature ranges, mounting requirements etc., Majorly rectifiers are classified into single phase and three phase rectifiers uncontrolled, half controlled and full controlled rectifiers.

Single phase uncontrolled rectifier uses thee uncontrolled diode to rectify the input AC supply. At the output terminals power becomes constant, magnitude only changes. Half wave rectifier is the simples structure only one diode is placed at the secondary on the transformer. Full-Wave Centre - tapped rectifier uses two diodes and create a return path for the current by adding a tap at the centre of the secondary winding . This is so-called centre-tapped rectifier.its advantages are lower ripple factor and higher frequency. Single phase half wave rectifier uses two diodes and two thyristors which ae connected across the load. It contains continuous conduction mode in each leg. The load current always remains zero is termed as the continuous conduction mode in rectifying DC.

6. SEVEN LEVEL CASCADED INVERTER

Multilevel voltage source inverter is recognized as an important alternative to the normal two level Voltage Source Inverter especially in high voltage application. Using multilevel technique, the amplitude of the voltage is increased, stress in the switching devices is reduced and the overall harmonics profile is improved. Among the familiar topologies, the most popular one is cascaded multilevel inverter. The operation of the seven-level inverter in the positive cycle of the utility can be further divided into four modes

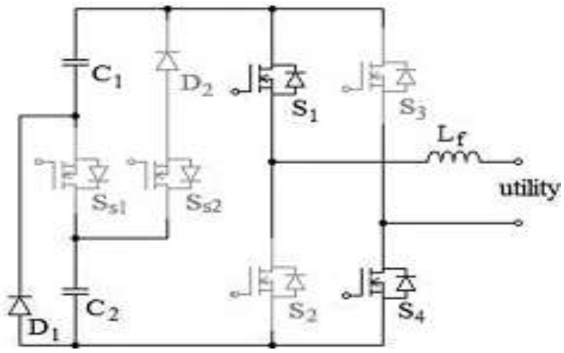
MODE 1: The operation of mode 1 as shown in figure. Both S_{S1} and S_{S2} of the capacitor are OFF, so C1 is discharged through D1 and the output voltage of the capacitor selection circuit is $V_{DC}/3$ S_1 and S_4 of the full-bridge power converters are ON. At this point, the output voltage of the seven-level inverter is directly equal to the output voltage of the capacitor selection circuit, which means the output voltage of the seven-level inverter is $V_{DC}/3$.

MODE 2: The operation of mode 2 as shown in figure. In the capacitor selection circuit S_{S1} is OFF and S_{S2} and D_2 and the output voltage of the capacitor selection circuit is $2V_{DC}/3$ S_{D1} and S_4 of the full- bridge power converter are ON. At this point, the output voltage of the seven-level inverter is $2V_{DC}/3$.

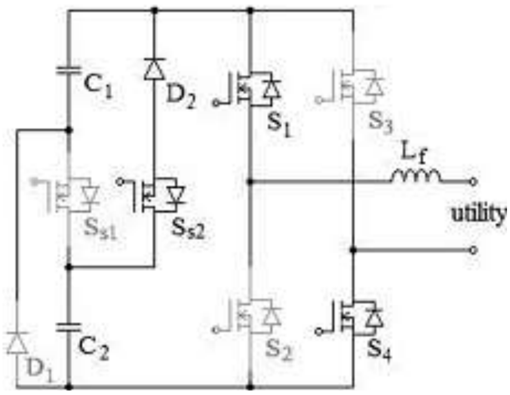
MODE 3: The operation of mode 3 is shown in figure. In the capacitor selection circuit, S_{S1} is ON. Since D_2 has a reverse bias when SS1 is ON, the state of S_{S2} cannot affect the current flow. Therefore S_{S2} may be ON or OFF, to avoiding switching of S_{S2}. Both C1 and C2 are discharged in series and the output voltage of the capacitor selection circuit is V_{DC}. S_1 and S4 of the full-bridge power converter are ON. At this point, the output voltage of the seven- level inverter is V_{DC}.

MODE 4: The operation of mode 4 as shown in figure. Both S_{S1} and S_{S2} of the capacitor selection circuit are OFF. The output voltage of the selection circuit is $V_{DC}/3$. Only S_4 of the full-bridge power converter is ON. Since the output current of the seven-level inverter is positive and passes through the filter inductor, it forces the anti parallel diode of S_2 to be switched ON for continuous conduction of the filter inductor current . At this point, the output voltage of the seven level inverter is zero. Therefore , in the positive half cycle, the output voltage of the seven-level inverter has four levels: $V_{DC}/3$, $2V_{DC}/3$, $V_{DC}/3$, 0.

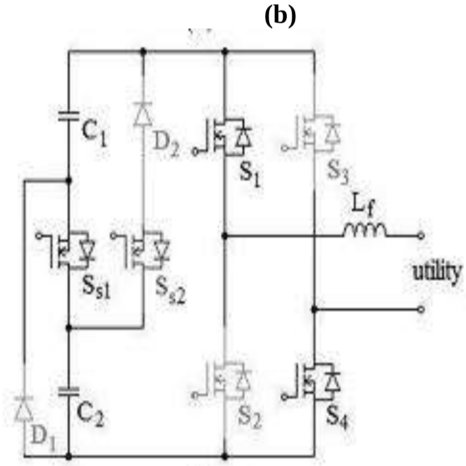
In the negative half cycle, the output current of the seven-level inverter is negative. The operation of the seven-level inverter can alsocircuit is inverted by the full-bridge power converter , so the output voltage of the seven be further divided into four modes, as shown in figure. A comparison with figure shows that the operation of the capacitor selection circuit in the negative half cycle is the same as that in positive half cycle . The difference is that S_2 and S_3 of the full-bridge power converter are ON during modes 5,6,7 and S2 is also ON during mode 8 of the negative half cycle. Accordingly, the output voltage of the capacitor selection level inverter also has four levels: $-V_{DC}$, $-2V_{DC}/3$,$V_{DC}/3$, 0. In summary, the output voltage of the seven-level inverter has the voltage levels: to $V_{dc,}2V_{DC}/3$, $V_{DC}/3$,0, $-V_{dC}/3$, $-2V_{DC}/3$, and $-V_{DC}$. The seven-level inverter is controlled by the current-mode control and pulse-width modulation (PWM) is use to generate the control signals for the power electronic switches. The output voltage of the seven-level inverter must be switched in two levels, according to the utility voltage. One level of the output voltage is higher than the utility voltage in order to increase the filter inductor current, and the other level of the output voltage is lower than the utility voltage, in order to decrease the filter inductor current. The operation of seven level inverter for different modes in positive half cycle is shown in fig.2.



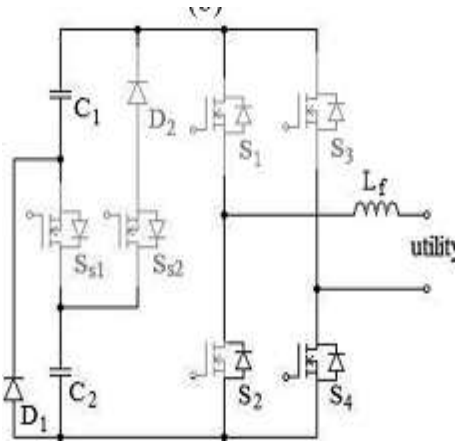
(a)



(b)



(c)



(d)

Fig.2. Operation of the seven-level inverter positive cycle (a) mode 1 (b) mode 2 (c) mode 3 (d) mode 4

The above diagrams shows the various functional modes of seven level cascaded inverter. The output levels has been obtained as V_{dc},$2V_{dc}$,$3V_{dc}$ for the positive half-cycle of the inverter. Like-wise the negative half-cycle will be obtained for the seven level cascaded inverter as $-V_{dc}$,$-2V_{dc}$,$-3V_{dc}$. The negative half-cycle also includes the modes from mode 1,2,3 and 4. Accordingly, the output voltage of the seven-level inverter must be changed in accordance with the utility voltage. In the positive half cycle, when the utility voltage is smaller than $V_{dc}/3$, the seven-level inverter must be switched between modes 1 and 4 to output a voltage of $V_{DC}/3$ or 0. Within this voltage range , S1 is switched in PWM. The duty ratio d of S1 can be represented as,

$$d = V_m / V_{tri}$$

Where V_m and V_{tri} are the modulation signal and the amplitude of carrier signal in the PWM circuit, respectively. The output voltage of the seven-level inverter can be written as,

$$V_0 = d \quad \& \quad V_{dc} = Kpwm\ Vm$$

Where k pwm is the gain of the inverter which can be return as,

$$K_{pwm} = V_{dc} / 3\, V_{tri}$$

The seven- level inverter the utility voltage is smaller than Vdc/3. The closed loop function can be derived as

$$,I_o = \frac{KpwmGc/Lf}{s+KiKpwmGc/Lf} I^*o - \frac{1/Lf}{s+KiKpwmGc/Lf} Vu$$

Where G_c is the current controller and Ki is the gain of the current detector. The seven-level inverter is switched between modes 2 and 1 in order to output a voltage of $2V_{dc}/3$ or $V_{dc}/3$ when the utility voltage is in the range ($V_{dc}/3$,$2V_{dc}/3$) . Within this voltage range, SS2 is switched in PWM.

$$V_o = d.V_{dc} + V_{dc} = K_{pwm} v_m + V_{dc.}$$

TABLE I: States of Power Electronic Switches for a Seven-Level Inverter

POSITIVE HALF CYCLE						
	S_{s1}	S_{s2}	S_1	S_2	S_3	S_4
$\lvert V_u\rvert < v_{dc}$	Off	Off	on	off	off	on
$2V_{dc} > \lvert V_u\rvert > V_{dc}$	Off	On	on	off	off	on
$\lvert V_u\rvert > 2v_{dc}$	On	On	on	off	off	on
NEGATIVE HALF CYCLE						
$\lvert V_u\rvert < v_{dc}$	Off	Off	off	on	on	off
$2v_{dc} > \lvert v_u\rvert > v_{dc}$	Off	On	off	on	on	off
$\lvert V_u\rvert > 2v_{dc}$	On	On	off	on	on	off

7. CONTROL BLOCK

Fuzzy logic controller is used to reduce the rise time, settling time to almost negligible and also try to remove the time delay and inverted response. It works with uncertain and imprecise knowledge. It provides an approximate but effective means of describing the behaviour of systems that are too complex, ill-defined or not easily analysed mathematically. Fuzzy variables are processed using a system called a Fuzzy logic controller . It involves Fuzzification , Fuzzy inference and de-fuzzification. The Fuzzification process converts a crisp input value to a fuzzy value. The fuzzy inference is responsible for a drawing conclusions from the knowledge base. The de-fuzzification process converts the fuzzy control action into a crisp control action. Membership function values are assigned to the linguistic variables using seven variable subsets: NB (NEGATIVE BIG), NS(NEGATIVE SMALL), ZE(ZERO), PB(POSITIVE BIG), PS(POSITIVE SMALL) So it is framed in the below table, the fuzzy logic controller controls the switches present in the dc/dc boost converter and a H-bridge converter. the linguistic variables using seven variable subsets: NB (NEGATIVE BIG), NS(NEGATIVE SMALL), ZE(ZERO), PB(POSITIVE BIG), PS(POSITIVE SMALL) . So it is framed in the below table, the fuzzy logic controller controls the switches present in the dc/dc boost converter and a H-bridge converter.

TABLE II: Rules Based Fuzzy Logic Controller

E\dE	NB	NM	NS	ZE	PB	PM	PS
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PB	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PS	ZE	PS	PM	PB	PB	PB	PB

8. MATLAB / SIMULINK OUTPUT

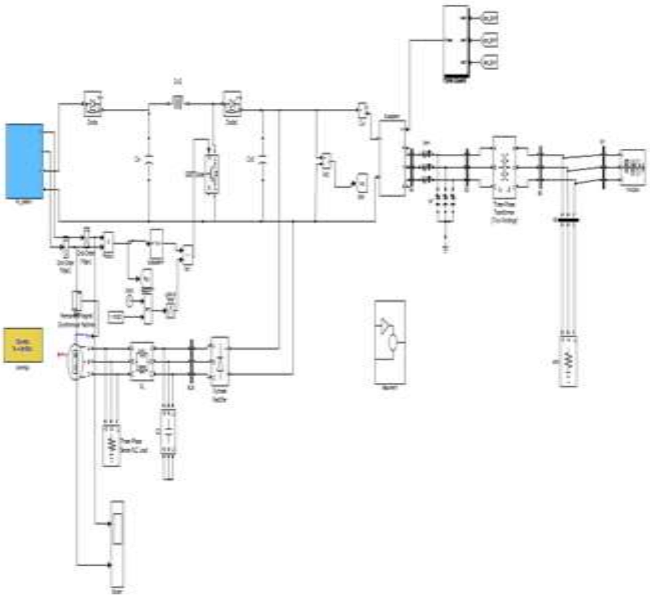


Fig.3.Simulation Diagram of Hybrid Scheme

Case (a) Seven Level Inverter for RES by using Fuzzy Controller

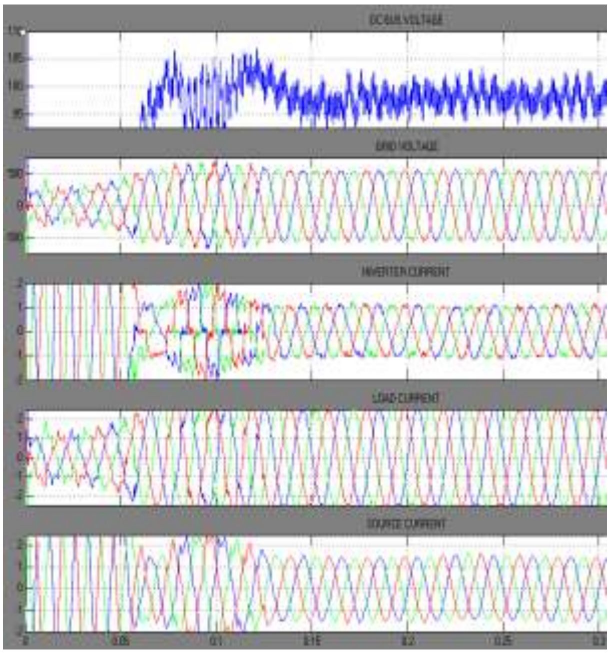


Fig.4. Simulation results for (a) DC Bus Voltage (b) Grid voltage (c) Inverter current (d) Load current (e) Source current

Case(b)

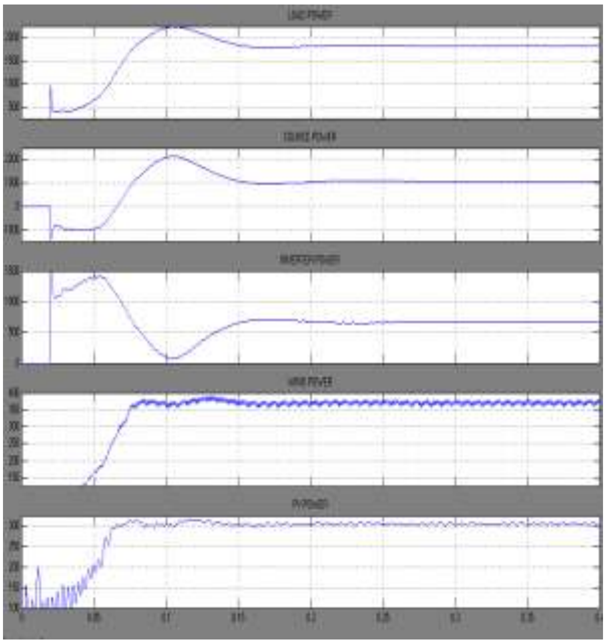


Fig.5. (a) Load power (b) Source power (c) Inerter power (d) Wind power (e) PV power

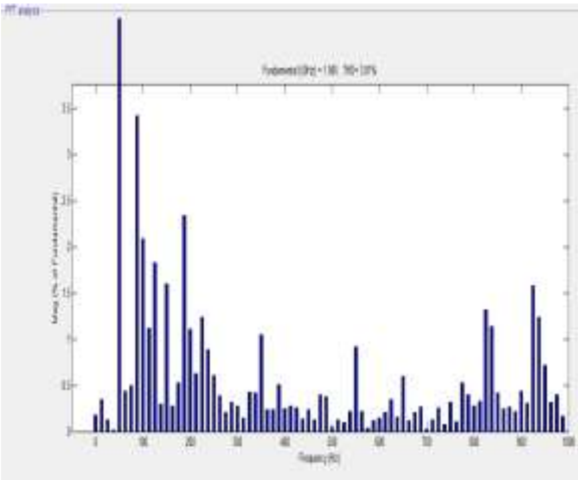


Fig.6. FFT analysis of inverter

9. CONCLUSION

In the present statistics of this scope the power of solar and wind system have been generated for the utility purpose and it is universally improved on the large scale. The hybrid energy used in this scenario is flexible for the generation during the time of demand. Significant improvement in frequency response and power generation response is achieved in terms of less settling time and oscillations. The position of Maximum Power Point Tracking (MPPT) is used to conserve the energy. A new approach for Fuzzy logic has been empowered for the purpose of regulation of frequency and generation power in the renewable energy system. The THD level of seven- level inverter is maintained within the IEEE standard (3.81%) by using the switching device MOSFET.

10. FUTURE SCOPE

In present work implementation of change of output can be attained by using seven-level inverter. In future change in output by using symmetrical inverter can be used to work in neural networks.

The hybrid system providing power to a grid is considered for investigation. It may be linked to grid via large HVDC lines in future

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