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Enhancement of Power Quality by using Renewable DG

[I]Homprakash Kollu, [II]Dr. Gowri Manohar.T
[I]PG Scholar, Dept. of EEE, SVUCE
[II]Associate Professor, Dept. of EEE, SVUCE

Abstract

A Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure or a malfunction of end user equipments. This paper presents a distribution grid consisting of different distributed generation (DG) units. The proposed design consists of a photovoltaic (PV) array [8] which functions as the primary generation unit of the grid and a proton-exchange membrane fuel cell [2] to supplement the variability in the power generated by the PV array. In addition to this we use wind power generation as secondary generation unit to the grid. A lithium-ion storage battery [15] is incorporated into the grid to mitigate peak demands during grid-connected operation and to compensate for any shortage in the generated power during islanding operation. The control design for the DG inverters employs a new inverter design which enhances power quality in the grid through reduction in THD, improving power factor and maintains better voltage profile.The salient features of the proposed seven-level inverter are that only six power electronic switches are used, and only one power electronic switch is switched at high frequency at any time.

Keywords

Distributed generation, distribution system, power quality enhancement, seven level inverter, power factor, Grid-connected.

Acronyms Used

DG = Distributed generation, PV = photovoltaic cell, THD = Total Harmonic Distortion, pf = power factor, BESS = Battery Energy Storage System, WECS = Wind Energy Conversion system

I. Introduction

In developing countries like India, even though installed apacity is more than the demanded load, due to its high transmission and distribution losses, the generation can't supply the targeted demand.

If we opted fossil fuel based power generation, then it results in enhancing global problem of green house emissions. Moreover, as the supplies of fossil fuels are getting depleted in future, they become expensive. Thus, solar energy is becoming more important since it produces less pollution and the cost is less. In particular, small-capacity distributed power generation systems using solar energy may be widely used in residential applications in the near future. It is not only eco friendly, It can helps us in reduction of power losses and reduces stability problems in the system.

But the problem with the solar energy is discontinuous and irregular power production and also management of power production with respect to load variations is difficult and hence It may cause power quality problem to the system.

Now a days, modern industrial devices are mostly based on the electronic devices such as programmable logic controllers and electronic drives. The electronic devices are very sensitive to disturbances and become less tolerant to power quality problems. The integration of renewable sources can supplement the generation from the distribution grid.

In this paper, a distribution grid consisting of a photovoltaic (PV) array, wind energy, a proton-exchange membrane fuel cell (PEMFC) [2], and a lithium-ion storage battery (SB) is proposed. The PEMFC is used as a backup generator unit to compensate for the power generated by the intermittent nature of the PV array. The SB is implemented for peak sharing [15] during grid-connected operation, and to supply power for any shortage in generated power during islanded operation and to maintain the stability of the distribution network.

In this paper we a new model of Inverter, which can't effect the power quality of the system, for which it is connected and with this model based distributed generation we can connect multiple sources like wind and solar. So the proposed model not only ensure good life span, less maintenance, less power losses. but also it enhances the good quality of power and maintains continuity in power generation regarding to their demand in the utility grid to which it is connected.

II. Photovoltaic Array Modelling [8]

Photovoltaic (PV) cells, or solar cells, take advantage of the photoelectric effect to produce electricity. The building blocks of all PV systems are PV cells because they are the devices that convert solar energy into electrical energy. Usually known as solar cells, individual PV cells are electricity-producing devices made of semiconductor materials. PV cells come in many sizes and shapes, from smaller than a postage stamp to several inches across. They are more often connected together to form PV modules that may be up to several feet long and a some feet wide. The solar cell arrays or PV arrays are usually constructed out of small identical building blocks of single solar cell units. They determine the rated output voltage and current that can be drawn for some given set of atmospheric data. The rated current is given by the number of parallel paths of solar cells and the rated voltage of the array is dependent on the number of solar cells connected in series in each of the parallel paths. A solar cell is basically a p-n junction fabricated in a thin substrate of semiconductor. When exposed to sunlight, some electron-hole pairs are created by photons that carry energy higher than the band-gap energy of the semiconductor. The Fig.1 shows the typical equivalent circuit of a PV cell

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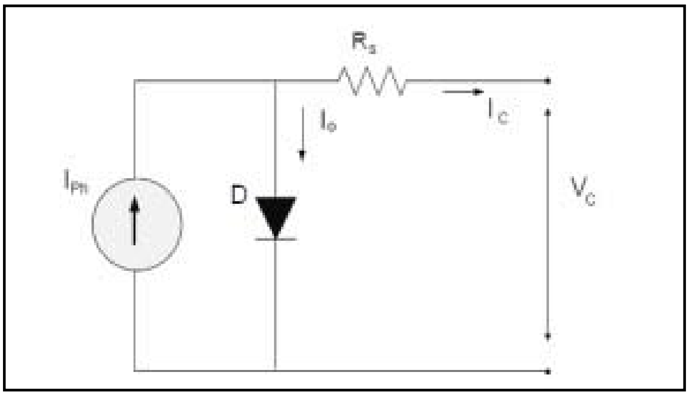

Fig. 1: PV equivalent circuit diagram.

The typical I-V output characteristics of a PV cell are shown by the following equations: Module Photo current (I_{ph}):
$I_{ph} = [Iscr + Ki\ (T - 298\ )]G/1000$
Module reverse saturation current (Irs):

$$I_{rs} = \frac{I_{scr}}{e^{\left(\frac{qV_{oc}}{N_s}KAT\right)}} - 1$$

Module saturation current (Io):

$$I_o = I_{rs} = \left[\frac{T}{T_r}\right] e^{\frac{qE_{gv}}{BK\left(\frac{1}{T_r}-\frac{1}{T}\right)}}$$

The current output of PV module (Ic):

$$I_c = N_p I_{ph} - NI_o\left[e^{\frac{q(V_c+I_{ph})}{NAKT}} - 1\right]$$

where
$V\ c$ is output voltage of PV module(V)
Tr is the reference temperature = 289K
T is the module operating temperature
A is an ideality factor = 1.6
K (Boltzmann constant)= 1.3805 * 10^{-23} J/K
q is electron charge
Rs is the series resistor of PV module
$Iscr$ PV array short circuit current = 1.1A
K is the short circuit current temperature coefficient= 0.0017A/C
G is the PV module illumination = 1000W/m2
Ego is the band gap for silicon = 1.1eV
$V\ o$ is the open circuit voltage = 18V

III. DC-DC Converter [1]

The dc–dc power converter is a boost converter that incorporates a transformer 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 sources with multiple relationships, which are supplied to the seven level inverter [1]. 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 C_2 of the seven-level inverter. An inductor L_D, power electronic switches S_{D1} and S_{D2}, a transformer, and diodes D_{D1} and D_{D2} charges capacitor C_1 of the seven-level inverter. When S_{D1} is turned ON , the PV array supplies energy to the inductor L_D .

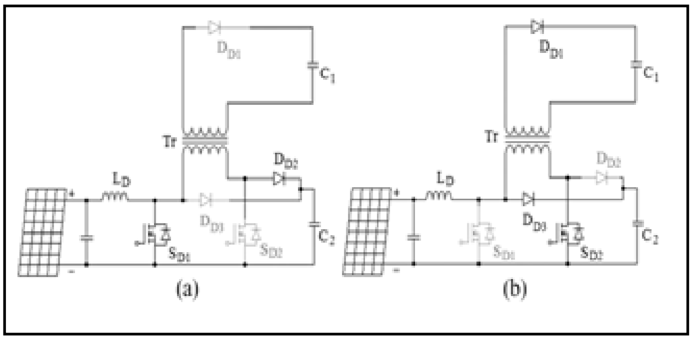

Fig. 2: Operation of dc–dc power converter:
(a) $SD1$ is on and (b) $SD2$ is off.

When S_{D1} is turned D_2 is turned ON, its operating circuit is shown in Fig.2 Accordingly, capacitor C_1 is connected to capacitor C_2 in parallel through the transformer, so the energy of inductor L_D and the solar cell array charge capacitor C_2 through D_{D3} and charge capacitor C_1 through the transformer and D_{D1} during the off state of S_{D1} . Since capacitors C_1 and C_2 are charged in parallel by using the transformer, the voltage ratio of capacitors C_1 and C_2 is the same as the turn ratio (2:1) of the transformer. Therefore, the voltages of C_1 and C_2 have multiple relationships. The boost converter is operated in the continuous conduction mode (CCM). The voltage of C_2 can be represented as

$$V_{c2} = \frac{1}{1-D}V_s$$

where V_s is the output voltage of solar cell array and D is the duty ratio of S_{D1}. The voltage of capacitor C_1 can be represented as

$$V_{c1} = \frac{1}{2(1-D)}V_s.$$

in the proposed dc–dc power converter, the energy stored in the magnetizing inductance is delivered to capacitor C_2 through D_{D2} and S_{D1} when S_{D2} is turned OFF. Since the energy stored in the magnetizing inductance is transferred forward to the output capacitor C_2 and not back to the dc source, the power efficiency is improved[11]. In addition, the power circuit is simplified because the charging circuits for capacitors C_1 and C_2 are integrated. Capacitors C_1 and C_2 are charged in parallel by using the transformer, so their voltages automatically have multiple relationships. The control circuit is also simplified.

IV. Seven level Inverter [1]

The seven-level inverter is composed of a capacitor selection circuit and a full-bridge power converter, which are connected in cascade. The operation of the seven level inverter can be divided into the positive half cycle and the negative half cycle of the utility

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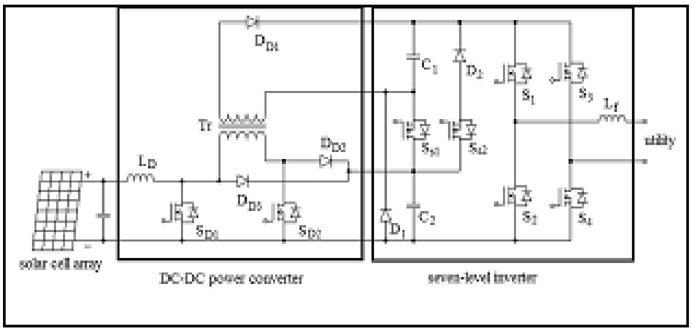


Fig. 3: seven level inverter

For ease of analysis, the power electronic switches and diodes are assumed to be ideal, while the voltages of both capacitors *C*1 and *C*2 in the capacitor selection circuit are constant and equal to *V*dc/3 and 2*V*dc/3, respectively. Since the output current of the solar power generation system will be controlled to be sinusoidal and in phase with the utility voltage, the output current of the seven-level inverter is also positive in the positive half cycle of the utility. The operation of the seven-level inverter in the positive half of the utility can be further divided into four modes.

Mode 1

The operation of mode 1 is shown in Fig. 4(a). Both *SS*1 and *SS*2 of the capacitor selection circuit are OFF, so *C*1 is discharged through *D*1 and the output voltage of the capacitor selection circuit is *V*dc/3. *S*1 and *S*4 of the full-bridge power converter 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 is shown in Fig. 4(b). In the capacitor selection circuit, *SS*1 is OFF and *SS*2 is ON, so *C*2 is discharged through *SS*2 and *D*2 and the output voltage of the capacitor selection circuit is 2*V*dc/3. *S*1 and *S*4 of the full-bridge power converter are ON. At this point, the output voltage of the seven-level inverter is 2*V*dc/3.

Mode 3

The operation of mode 3 is shown in Fig. 4(c). In the capacitor selection circuit, *SS*1 is ON. Since *D*2 has a reverse bias when *SS*1 is ON, the state of *SS*2 cannot affect the current flow. Therefore, *SS*2 may be ON or OFF, to avoiding switching of *SS*2. Both *C*1 and *C*2 are discharged in series and the output voltage of the capacitor selection circuit is *V*dc. *S*1 and *S*4 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 is shown in Fig. 4(d). Both *SS*1 and *SS*2 of the capacitor selection circuit are OFF. The output voltage of the capacitor 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 sevenlevel inverter is zero. Therefore, in the positive half cycle, the output voltage of the seven-level inverter has four levels: *V*dc, 2*V*dc/3, *V*dc/3, and 0.

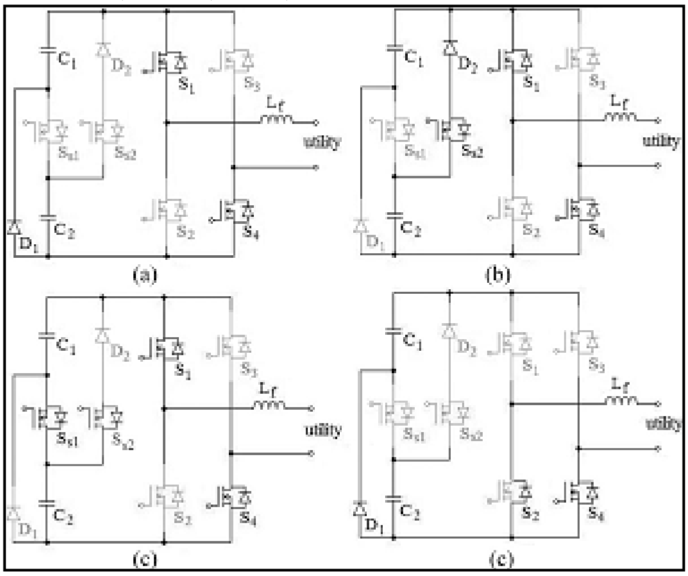


Fig.4 Operation of the seven-level inverter in the positive half cycle, (a) mode 1, (b) mode 2, (c) mode 3, and (d) mode 4.

In the negative half cycle, the output current of the seven-level inverter is negative. The operation of the seven-level inverter can also be further divided into four modes similar to the positive one. In summary, the output voltage of the seven-level inverter has the voltage levels: *V*dc, 2*V*dc/3, *V*dc/3, 0, −*V*dc/3, −2*V*dc/3, and −*V*dc. The seven-level inverter is controlled by the current-mode control, and pulse-width modulation (PWM) [12],[13] 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..

This is superior to the conventional multi-level inverter topologies [14], in which at least four semiconductor devices are conducting in series. Therefore, the conduction loss of the proposed seven-level inverter is also reduced slightly. The drawback of the proposed seven-level inverter is that the voltage rating of the full-bridge converter is higher than that of conventional multilevel inverter topologies.

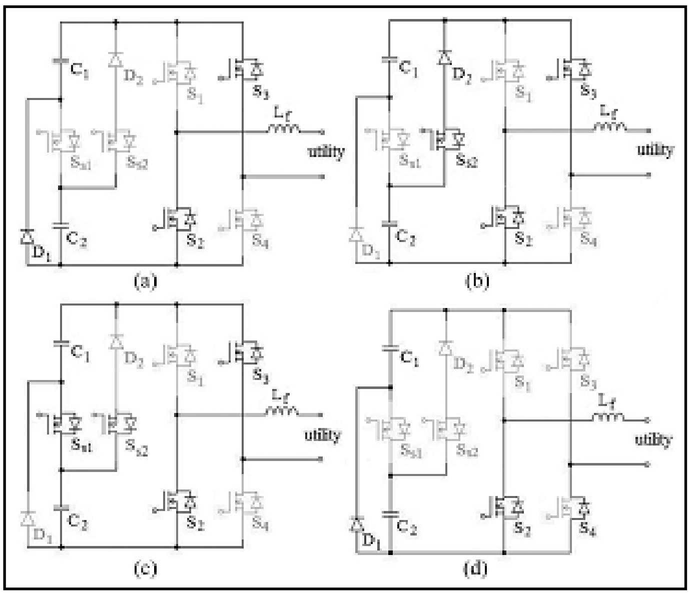


Fig. 5: Operation of the seven-level inverter in the negative half cycle (a) mode 5, (b) mode 6, (c) mode 7, and (d) mode 8.

V. Control Block

The proposed solar power generation system consists of a dc– dc power converter and a seven-level inverter. The seven-level inverter converts the dc power into high quality ac power and feeds it into the utility and regulates the voltages of capacitors $C1$ and $C2$. The dc–dc power converter supplies two independent voltage sources with multiple relationships and performs maximum power point tracking (MPPT) [3,6,7,9] in order to extract the maximum output power from the solar cell array.

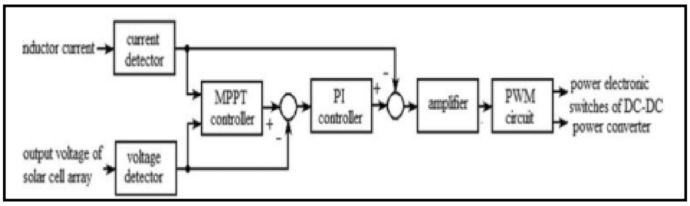


Fig. 6: control block of dc-dc converter.

The above figure shows the control block diagram for the dc–dc power converter. Dual control loops, an outer voltage control loop and an inner current control loop, are used to control the dc–dc power converter. The outer voltage control loop is used to regulate the output voltage of the PV array. The inner current control loop controls the inductor current so that it approaches a constant current and blocks the ripple voltages in $C1$ and $C2$. The 1ncremental conductance method is used to provide MPPT . The output voltage of the solar cell array and the inductor current are detected and sent to a MPPT controller to determine the desired output voltage for the solar cell array. The PWM circuit generates a set of complementary signals that control the power electronic switches of the dc–dc power converter.

Below Fig. (7) shows the control block diagram for the seven-level inverter. The utility voltage is detected by a voltage detector, and then sent to a phase-lock loop (PLL) circuit in order to generate a sinusoidal signal with unity amplitude. The voltage of capacitor $C2$ is detected and then compared with a setting voltage. The compared result is sent to a PI controller.

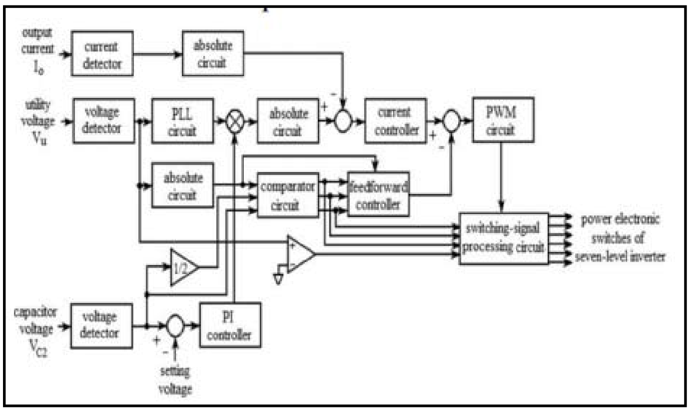


Fig. 7: Control block of seven level inverter

Then, the outputs of the PLL circuit and the PI controller are sent to a multiplier to produce the reference signal, while the output current of the seven-level inverter is detected by a current detector. The reference signal and the detected output current are sent to absolute circuits and then sent to a subtractor, and the output of the subtractor is sent to a current controller. The detected utility voltage is also sent to an absolute circuit and then sent to a comparator circuit, where the absolute utility voltage is compared with both half and whole of the detected voltage of capacitor $C2$, in order to determine the range of the operating voltage. The comparator circuit has three output signals, which correspond to the operation voltage ranges, (0, Vdc/3), (Vdc/3, 2Vdc/3), and (2Vdc/3, Vdc). The feed-forward control eliminates the disturbances of the utility voltage. The absolute value of the utility voltage and the outputs of the compared circuit are sent to a feed-forward controller to generate the feed-forward signal. Then, the output of the current controller and the feed-forward signal are summed and sent to a PWM circuit to produce the PWM signal. The detected utility voltage is also compared with zero, in order to obtain a square signal that is synchronized with the utility voltage. Finally, the PWM signal, the square signal, and the outputs of the compared circuit are sent to the switching signal processing circuit to generate the control signals for the power electronic switches of the seven-level inverter, according to Table I.

Table 1. States of Power Electronic Switches For a Seven-Level Inverter

	S_{S1}	S_{S2}	S_1	S_2	S_3	S_4
positive half cycle						
$\lvert v_u \rvert < V_{dc}/3$	off	off	PWM	off	off	on
$2V_{dc}/3 > \lvert v_u \rvert > V_{dc}/3$	off	PWM	on	off	off	on
$\lvert v_u \rvert > 2V_{dc}/3$	PWM	on	on	off	off	on
negative half cycle						
$\lvert v_u \rvert < V_{dc}/3$	off	off	off	on	PWM	off
$2V_{dc}/3 > \lvert v_u \rvert > V_{dc}/3$	off	PWM	off	on	on	off
$\lvert v_u \rvert > 2V_{dc}/3$	PWM	on	off	on	on	off

VI. Simulink

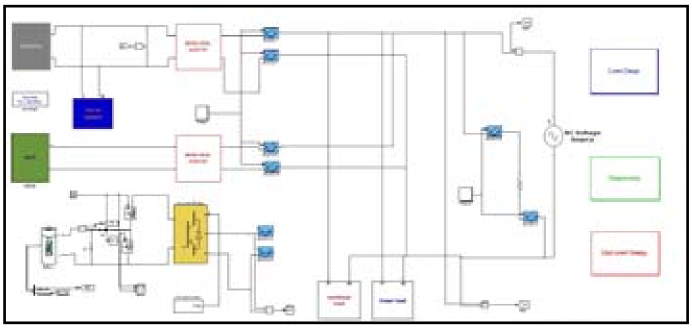
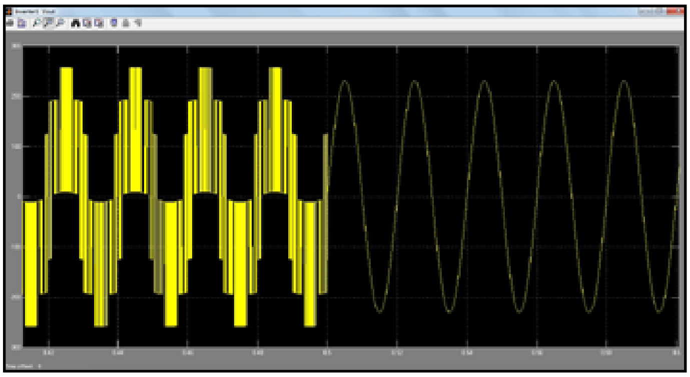


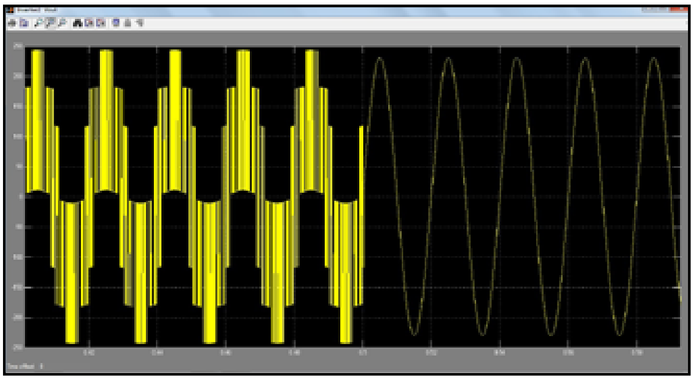
Fig. 8: Simulink Diagram

In order to overcome the problems due to discussed constraints we design an simulink model. In which we took two inverters solar array and fuel cell is given to one inverter and WECS[2] is given to another one, It can helps us in power supply continuity and here with the help of BESS[10],[15] we can reach the peak load demand for a short duration. The BESS is designed through Bi-directional Inverter. So that It can able charge the battery, when grid is having surplus power, at the same time at can supply power to grid, whenever grid does not have enough power wrt to demand. We can connect this DG grid to conventional grid at desired time or when ever it can have excess or deficient power. But here in our Simulink is designed such hat It gets connected ac grid at 0.5 simulated time. The Salient feature of the proposed 7-level inverter is it can control the harmonics in the system and thus It can't inject any more harmonics to the grid. The system is designed based on consideration of IEEE standard THD, EMI and power quality standards. The main important thing with the design is we can control the power in the dg grid wrt the load variations. Further Simulink results are evaluated as performance of Isolated grid[8] and after grid connection[7].

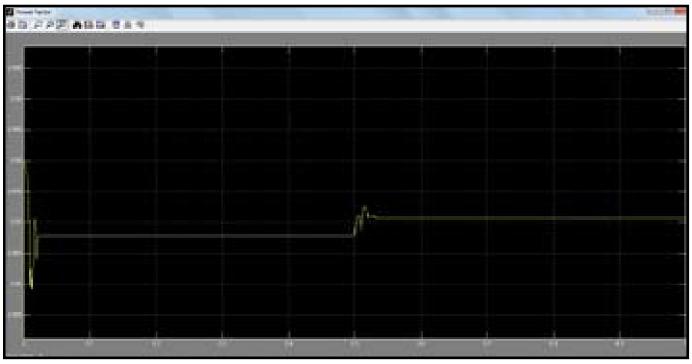
VII. Results



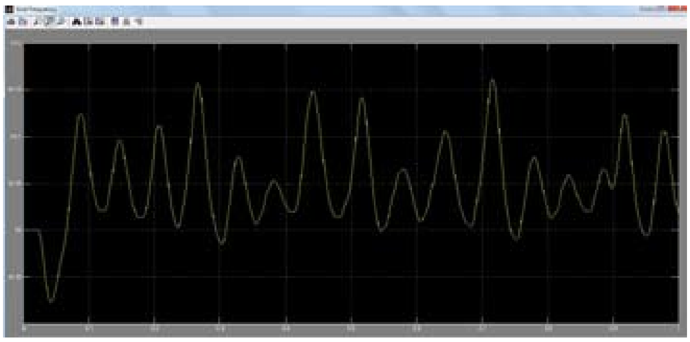
Inverter 1 output



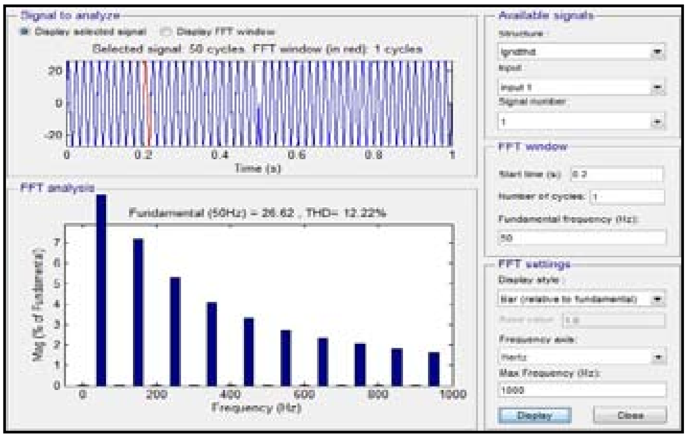
Inverter 2 output



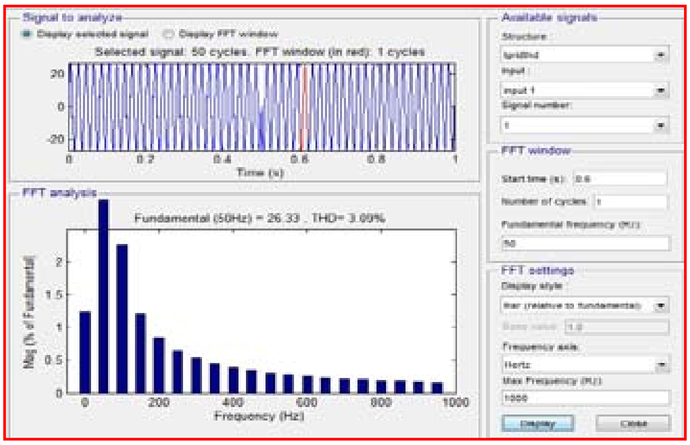
Improvement of Power factor in the grid



Frequency variations in the grid



Before grid connected THD at 0.2s



After grid connected THD at 0.6s

Table 2 : Summary of the Results

S.No	Parameter	With DG	DG and Grid
1.	Voltage	230	230
2.	Power factor	0.95	0.98
3.	Frequency	50	50
4.	THD	12.5%	3.09%

VIII. Conclusion

This paper proposes how power quality gets improved in Distribution system with implementation of novel design of seven level inverter [1],[4],[5] through renewable DG. In this paper we are Combination of solar and fuel cell as the primary generation unit of the grid to supplement the variability in the power generated by the PV array. In addition to this we use wind power generation as secondary generation unit to the grid. A lithium-ion storage battery is incorporated into the grid to mitigate peak demands during grid-connected operation and to compensate for any shortage in the generated power during islanded operation.

The paper overcome the problem with multiple dg integration and power quality issues. This proposed paper well suitable for micro grids, smart grids, smart house holds, Industries, and other commercial sectors. This design not only reduces the losses, cost of maintenance, economic losses but also helps to delivers good quality of power to the targeted demand through reduction in THD, improving power factor and maintains better voltage profile.

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References

[1] *Jinn-Chang Wu and Chia-Wei Chou "A Solar Power GenerationSystem With a Seven-Level Inverter," IEEE Trans. Power Electron., vol. 29, no. 7, pp. 3454–3462, Jul. 2014.*

[2] *S K. T. Tan, P. L. So, Y. C. Chu, and M. Z. Q. Chen, "Coordinated Control and of Distributed Generation Inverters in a Microgrid," IEEE Trans. Power Delivery, vol. 28, no. 2, pp. 704–713, Apr. 2013.*

[3] *S Bidyadhar Subudhi and Raseswari Pradhan," A Comparative Study on Maximum PowerPoint Tracking Techniques for Photovoltaic Power Systems," IEEE Trans. Sustain. Energy, vol. 4, no. 1, pp. 89–98, Jan. 2013..*

[4] *N. A. Rahim, K. Chaniago, and J. Selvaraj, "Single-phase seven-level grid-connected inverter for photovoltaic system," IEEE Trans. Ind. Electr., vol. 58, no. 6, pp. 2435–2443, Jun. 2011*

[5] *B. Kjaer, J. K. Pedersen, and F. Blaabjerg,"A review of single-phase grid for photovoltaic modules," IEEE Trans. Ind. Applvol. 41, no. 5, pp. 1292–1306, Sep./Oct. 2005*

[6]. *S.Mekhilef, "Performance of grid inverter maximum power point tracker and powerfactorcontrol," International Journal of Power Electronics, vol.1,pp.49-62,2008*

[7]. *N. Femia, G. Petrone, G. Spagnuolo, and M. Vitelli, "Optimization of perturb and observe maximum power point tracking method," IEEE Trans.Power Electron., vol. 20, no. 4, pp. 963–973, Jul. 2005.*

[8]. *K. T. Tan, P. L. So, Y. C. Chu, and K. H. Kwan, "Modeling, control and simulation of a photovoltaic power system for grid-connected and stand-alone applications," in Proc. Int. Power Energy Conf., 2010, vol. 56, pp. 608–613.*

[9]. *R. A. Mastromauro, M. Liserre, and A. Dell'Aquila, "Control issues in single-stage photovoltaic systems: MPPT, current and voltage control," IEEE Trans. Ind. Informat., vol. 8, no. 2, pp. 241–254, May. 2012.*

[10]. *Z. Zhao, M. Xu, Q. Chen, J. S. Jason Lai, and Y. H. Cho, "Derivation, analysis, and implementation of a boost–buck converter-based high-efficiency pv inverter," IEEE Trans. Power Electron., vol. 27, no. 3, pp. 1304–1313, Mar. 2012.*

[11]. *J.-M. Shen, H. L. Jou, and J. C. Wu, "Novel transformer-less gridconnected power converter with negative grounding for photovoltaic generation system," IEEE Trans. Power Electron., vol. 27, no. 4, pp. 1818– 1829, Apr. 2012.*

[12]. *A. K. Sadigh, S. H. Hosseini, M. Sabahi, and G. B. Gharehpetian, "Double flying capacitor multicell converter based on modifiedphase-shifted pulsewidth modulation," IEEE Trans. Power Electron., vol. 25, no. 6, pp. 1517–1526, Jun.2010.*

[13]. *S. Thielemans, A. Ruderman, B. Reznikov, and J. Melkebeek, "Improved natural balancing with modified phase-shifted PWM for single-leg fivelevel flying-capacitor converters," IEEE Trans. Power Electron., vol. 27, no. 4, pp. 1658–1667, Apr. 2012.*

[14]. *S. Choi and M. Saeedifard, "Capacitor voltage balancing of flying capacitor multilevel converters by space vector PWM," IEEE Trans. Power Delivery, vol. 27, no. 3, pp. 1154–1161, Jul. 2012.*

[15]. *L. Maharjan, T. Yamagishi, and H. Akagi, "Active-power control of individual converter cells for a battery energy storage system based on a multilevel cascade pwm converter," IEEE Trans. Power Electron., vol. 27, no. 3, pp. 1099–1107, Mar. 2012.*