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Line Commutated Twelve Pulse Converter For Grid Interfacing of Solar Photovoltaic Panels

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***Abstract*—On account of continuously increasing energy demand, if the dependence is on fossil fuels only then it may lead to energy crises in future. To avoid energy crises, best practical solution is to move towards renewable green energy sources. Solar energy is one way to bridge energy gap. Synchronization of voltage source inverter with grid is crucial issue in interfacing. In the proposed scheme line commutated twelve pulse converter is used to interface solar photovoltaic panels and an ac grid and it does not require any synchronizing circuits.**

Keywords—line commutated twelve pulse converter; photovoltaic panels; grid; commutation; synchronization.

I. INTRODUCTION

The objective of this paper is to come out with a simulated model of line commutated twelve pulse converter and analyse its operation. Nowadays, environmental issues are more of a concern. Renewable green energy is one of the options in reducing pollution and various environmental problems. Also, natural resources used for producing power are dwindling and becoming more and more expensive. So one of the best possible way is to use photovoltaic panels. Photovoltaic cell converts solar energy into electrical energy in the form of dc. The price of photovoltaic modules are expensive for electricity generation, but in recent years, their price has been slowly dropping, and the payback period also reduces, as the technology is developed. For overall efficiency of photovoltaic, losses in the power converter plays a vital role. Grid connected systems use a photovoltaic array to generate electricity, which is then fed to the main grid via a grid interactive power converter [1]. India gets solar energy almost throughout the years, which makes it more convenient to utilize in India [2]. The solar energy cannot be directly interfaced with the utility grid due to some economical issues. Therefore a power electronic interface is developed to interface the solar systems to the utility grid. For high efficiency purpose line commutated converter are used. Main drawback of this is that it produces square wave current output containing harmonics but it can be filtered out by using filters [3]. A power converter technology which uses SCR provides flexibility in interconnection of panels and an ac grid [4]. Photovoltaic is reliable, renewable, clean and inexhaustible technology. Mainly the most important equipment in converting dc of panels into ac is inverter technology [5]. Voltage Source Inverter (VSI) are also used to interface these photovoltaic panels and ac grid [6]. VSI including PWM technique has some limitation of switching frequency to reduce the losses when high power is required [7].

SPWM technique has also its limitations [8]. For the transfer of bulk electricity over long distances to minimize the conduction losses of the transmission lines or connecting electrical networks of different frequencies, High Voltage DC transmission (HVDC) has been increasingly used. One converter is operated in rectifier mode and other is operated in an inverter mode [9].

As compared to any other higher pulse converters, the twelve pulse converter has less complexity in the control and it results in comparable power quality indices if used with an optimally designed passive filter [10]. Solar insolation is the energy radiated for the sun to the surface of the earth measured in J/�^{2}in hourly or daily basis as recommended by World Meteorological Organization. However, in photovoltaic power generation system, solar irradiance is preferred over solar insolation because it is measured in W/�^{2} [11]. In any system, the converters are usually a small component of a overall power system. Twelve pulse converter is significant part of power electronics [12].

In this paper, line commutated twelve pulse converter is used to interface dc of photovoltaic panels and an ac grid and the firing angle is made greater than 90° and without commutation failure it goes to 176°.There is photovoltaic panels on dc side of suitable polarity, and power flow is reversed. The configuration of line commutated twelve pulse converter is shown in Fig. 1.

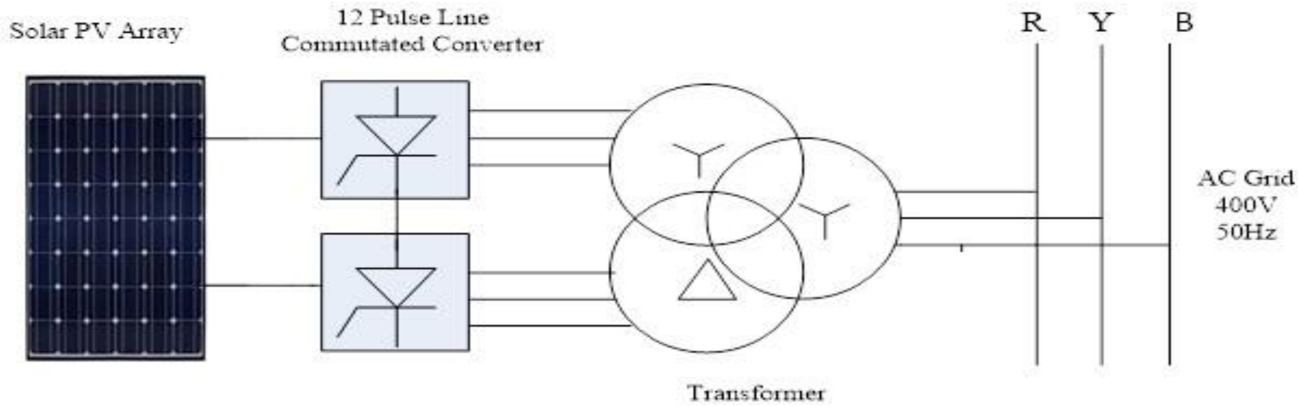

Fig. 1. Configuration of line commutated twelve pulse converter for grid interfacing of solar photovoltaic panels.

II. PROPOSED SCHEME

Circuit for twelve pulse line commutated converter is shown in Fig. 2. This scheme is for delivering 1MW of power to an ac grid.

It consist of two converters. Both the converters are magnetically coupled with one primary and two secondaries. Both converters are six pulse converters. A line commutated twelve pulse converter can be operated in rectification mode for firing angle (α<90°) or an inverter mode for firing angle (α>90°). In the proposed scheme, it is working in an inverter mode for firing angle α=176° and the power flow is reversed as there exists photovoltaic panels in the dc side.

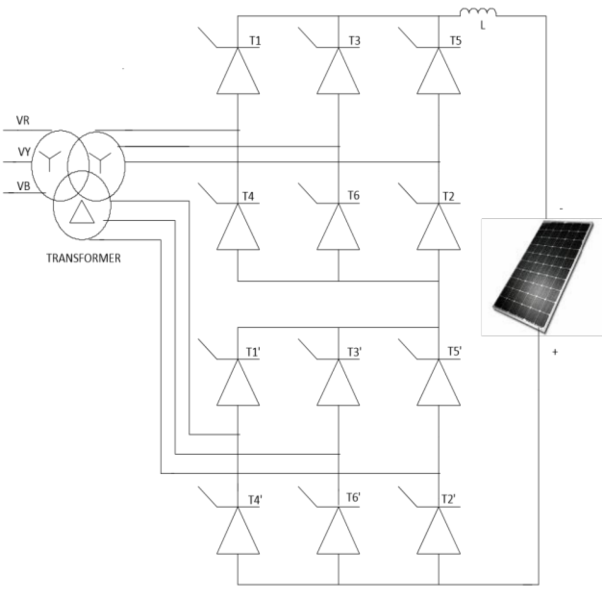

Fig. 2. Line Commutated Twelve Pulse Converter

If dc current Id is assume as constant for both positive half cycle as well as for negative half cycle, the current equation can be written as equation (1). In case of three phase, conduction period of each thyristor is 120°, the current waveform in line as well as secondary of transformer is same (transformer is connected in star) and the equation for this waveform is shown in equation (2). The current flowing through star connected primary of transformer is I_r. The current flowing through two secondaries are I_{r1} and I_{r2}. Here I_{r1} and I_{r2} are in phase but magnitudewise they are different. This current when referred to primary side as I_{r2}' and its magnitude will increase by $\sqrt{3}$ times. I_{r2} referred to primary side can be written by equation (3).

$$i(wt) = \frac{4}{\pi} Id\ [\sin wt+\frac{1}{3}\sin 3wt+\frac{1}{5}\sin 5wt+\frac{1}{7}\sin 7wt+\frac{1}{9}\sin 9wt+\frac{1}{11}\sin 11wt+\frac{1}{13}\sin 13wt+\frac{1}{15}\sin 15wt+\frac{1}{17}\sin 17wt+\frac{1}{19}\sin 19wt+\ldots] \quad (1)$$

$$I_{r1}=\frac{2\sqrt{3}}{\pi} Id[\sin wt-\frac{1}{5}\sin 5wt-\frac{1}{7}\sin 7wt+\frac{1}{11}\sin 11wt+\frac{1}{13}\sin 13wt-\frac{1}{17}\sin 17wt-\frac{1}{19}\sin 19wt+\frac{1}{23}\sin 23wt+\frac{1}{25}\sin 25wt+\ldots] \quad (2)$$

$$I_{r2}=\frac{2\sqrt{3}}{\pi} Id[\sin wt+\frac{1}{5}\sin 5wt+\frac{1}{7}\sin 7wt+\frac{1}{11}\sin 11wt+\frac{1}{13}\sin 13wt+\frac{1}{17}\sin 17wt+\frac{1}{19}\sin 19wt+\frac{1}{23}\sin 23wt+\frac{1}{25}\sin 25wt+\ldots] \quad (3)$$

$$I_r=I_{r1}+I_{r2}$$

$$I_r=\frac{4\sqrt{3}}{\pi} Id\ [\sin(wt)+\frac{1}{11}\sin 11wt+\frac{1}{13}\sin 13wt+\frac{1}{23}\sin 23wt+\frac{1}{25}\sin 25wt-\frac{1}{35}\sin 35wt+\frac{1}{37}\sin 37wt+\ldots] \quad (4)$$

From the above equation, the polarity of 5th , 7th , 17th , 19th, 29th and 31st will get cancelled. The equation for Ir is given by equation (4).

The harmonics which appear in twelve pulse converter is given by h=12q±1 where q=1,2,3….and the dc voltage of upper converter is

$$V = \frac{3\sqrt{2}}{\pi} V_L \cos\alpha_1 \quad (5)$$

The dc voltage of lower converter is

$$V = \frac{3\sqrt{2}}{\pi} V_L \cos \quad (6)$$

For delivering, 1MW power to an ac grid, the number of panels required to be connected are calculated. The Table I shows the standard parameters of solar panels which are used in this paper for panels calculation.

A. Solar Photovoltaic Array

The I-V characteristics of solar panel SPR-435NE-WHT-D is given in Fig. 3. Without commutation failure, the proposed topology operates when firing angle is 176°.

The atmospheric temperature is assumed to be 45°C and panel temperature to be 75°C. The maximum system voltage is not considered for panels calculation. On the basis of this assumption and paramerters of Table I, 141 panels are required to be connected in parallel and 19 panels are required to be connected in series to transfer 1MW of power to grid.

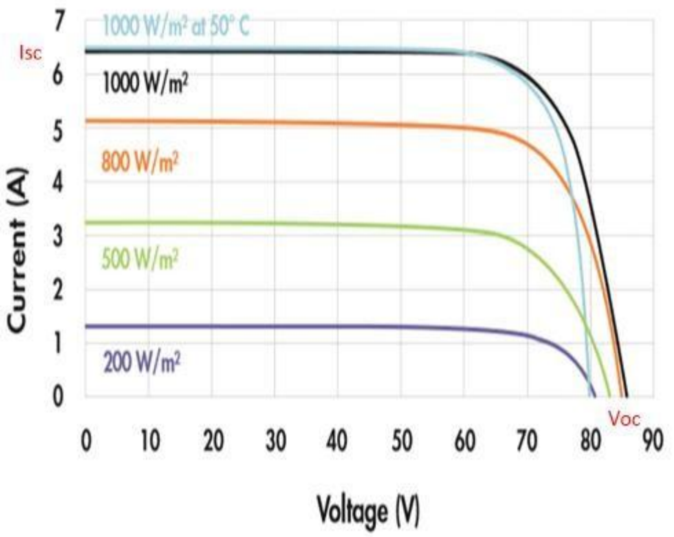

Fig. 3. I-V characteristics of SPR-435NE-WHT-D solar PV panel.

TABLE I. STANDARD PARAMETERS OF SOLAR PANEL

MODEL : SPR-435NE-WHT-D solar PV panel.		
Rated Voltage	Vmpp	72.9 V
Rated Current	Impp	5.97 A
Open Circuit Voltage	Voc	85.6 V
Short Circuit Current	Isc	6.43 A
Maximum system voltage	UI	600V
Temperature Coefficients	Power (P) Voltage (Voc) Current (Isc)	-0.38%/K - 235.5mV/K 3.5ma/K
Assume Atmospheric Temperature	Tatm	45°C
Assume Temperature of Panel	Tp	75°C
No. of panels in parallel	Pparallel	41
No. of panels in series	Pseries	19

III. MATLAB SIMULINK MODEL

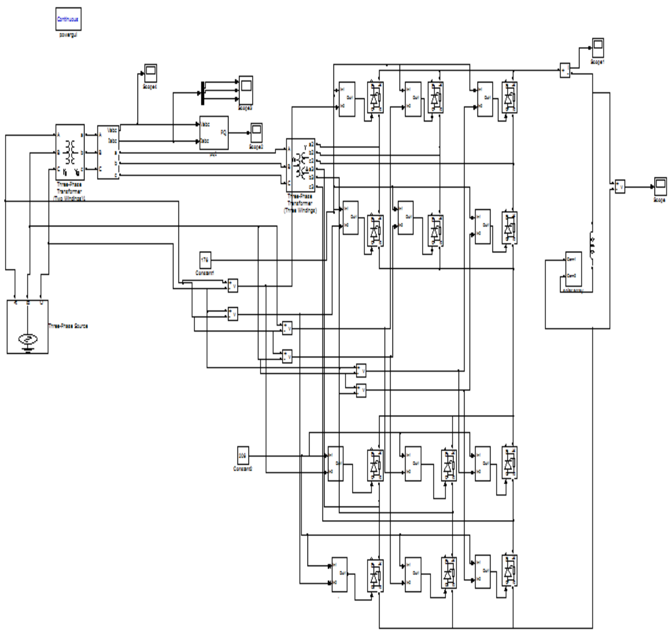

Fig. 4. MATLAB Simulink model of line commutated twelve pulse converter

IV. SIMULATION RESULTS

Without commutation failure, the proposed topology operates when firing angle is 176°. For firing angle α=176°, the simulated results are shown.

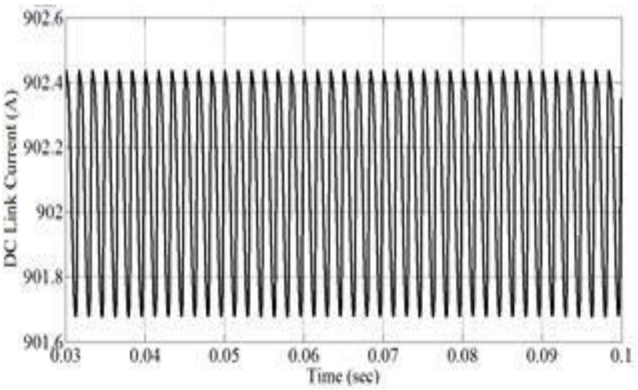

Fig. 5. DC link Current.

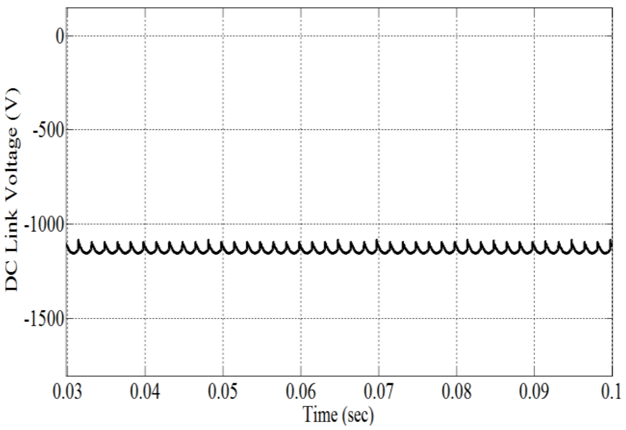

Fig. 6 . DC link Voltage.

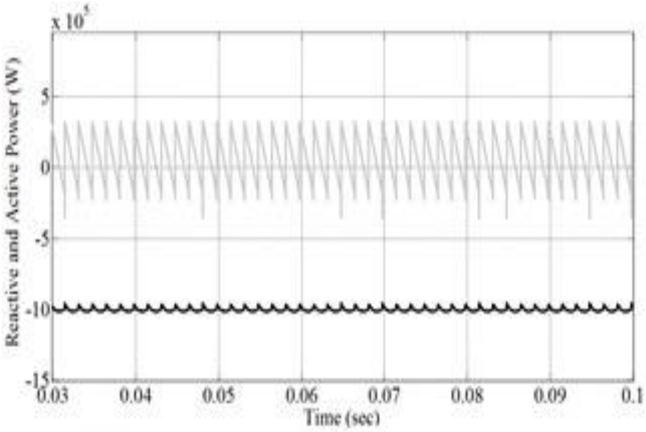

Fig. 7 . Reactive and active power.

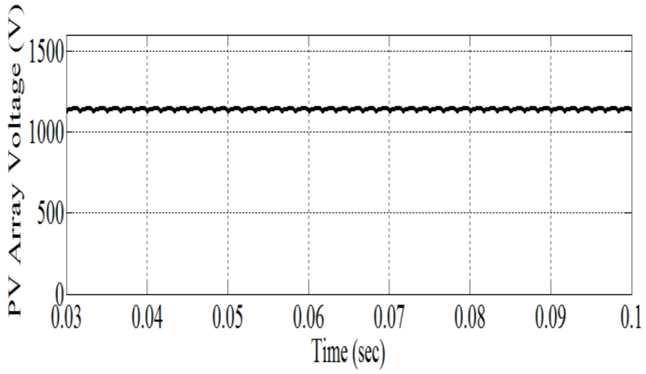

Fig. 8. PV array voltage at 1000 W/m2 irradiance.

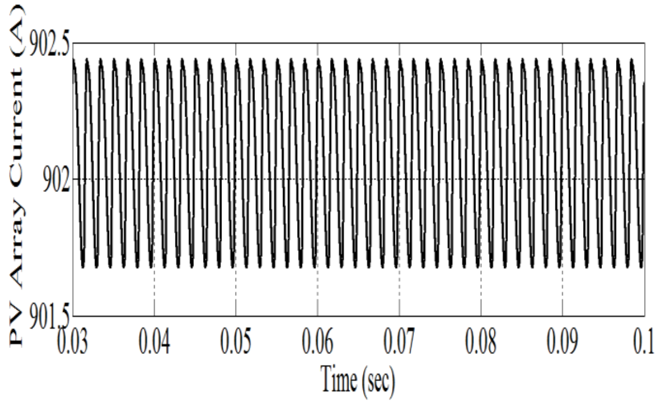

Fig. 9. PV current voltage at 1000 W/m2 irradiance.

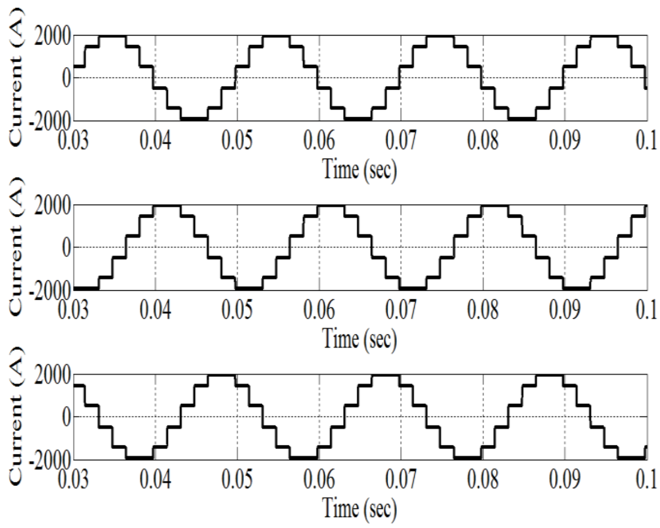

Fig. 10. phase ‘a’ current, (c) phase ‘b’ current, (d) phase ‘c’ current at ac terminal of converter.

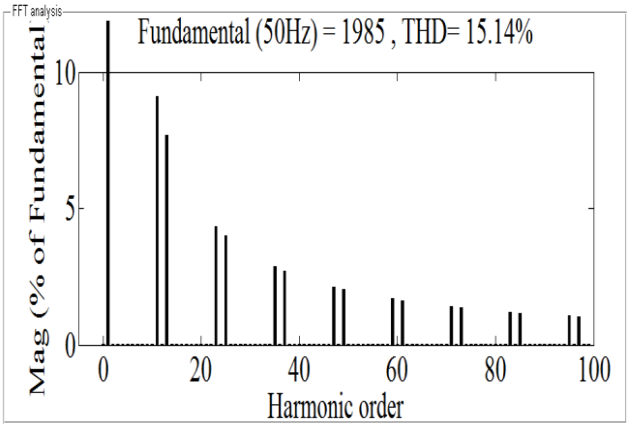

Fig. 11 . FFT Analysis of twelve pulse converter.

V. CONCLUSION

The line commutated twelve pulse converter used has THD of source current half as compared to six pulse converter. The SCR are line commutated and there is no need of synchronization of converter and grid.

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