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Power Conditioning Unit for Photovoltaic Energy System Using Z Source Inverter

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Abstract--- *The present paper relates to "Power Conditioning Unit". The system uses Z-source type inverter as a power conditioning device. The energy demand is increasing day by day, after various analysis by different researchers it is observed that solar systems are superior options due to its fresh, non-polluting, and never ending nature. There is an intermediate stage when power processes from source to the load and this stage comprises of "Power Conditioning unit". This unit converts sun radiations into electrical form of energy. Generally this unit consists of inverters. In this work, a different method is used by joining ZSI into PCU which offers a single stage power transformation. In the projected scheme ZSI is also integrated with MPPT. Normal boost control scheme is used for providing gating control signals which makes the system more efficient and decreases THD.*

Index Terms--- *Power Conditioning Unit, MPPT (maximum power point tracking), Z source inverter, Photovoltaic system, THD (Total Harmonic Distortion).*

I. INTRODUCTION

The total power demand is increasing day after day and shortage of fossil fuels is also enhancing on the earth that has enforced the researchers to focus on new resolution to accomplish the demand of energy. The population has not used fossil fuels properly according to the capacity. Nowadays, this is the time when reserves are decreasing as energy is in mischievous situation for human and recapping us of the wasted power. New inventions are being done with time. These inventions are sufficient to make easy lifestyle. Perhaps all its advantages are not being utilized properly. To resolve raised new task before and to resolve energy emergency a solution is needed that will not decrease or deteriorate with time. Here response to the task is "Renewable, Non- conventional Energy Resources". The foremost advantage of these renewable energy resources is they are all-time availability, fresh, inexpensive, source of energy, pollution free[1]. They've been used as energy producing resources from ages and this is the time when human-being is relying on non-conventional resources in the case of less energy production even with the production by various conventional sources which has been observed after various analysis[2].

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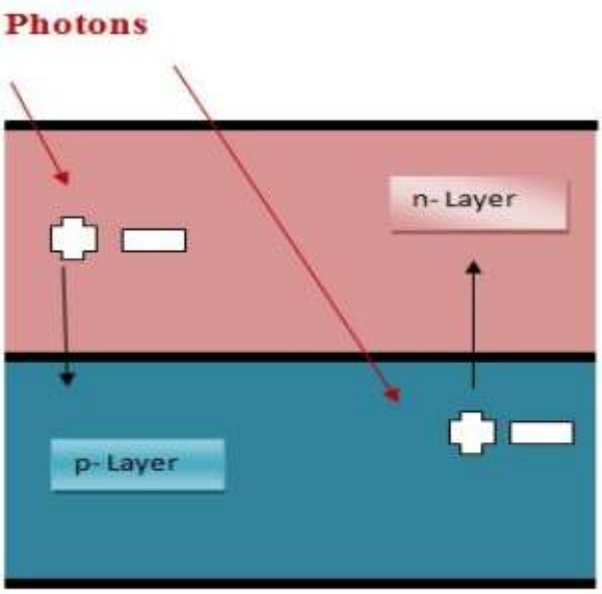

Figure 1. Photovoltaic cell

Now, there are various non-conventional energy resources produce energy but the task is to meet the energy demand. Therefore an analysis on these sources should be done to check which of the source is capable of meeting the energy demand. The different choices include solar energy, wind energy, tidal energy, hydro power, ocean energy etc. From various analysis it is examined that Sun radiations are the finest way when all the sources are considered along with utilization of produced side effects in a superior manner[3]. The energy which is obtained by the sun rays is called "Photovoltaic energy" for this there are photovoltaic cells which produce electricity by conversion of sun radiations[4]. As the time is passing the energy demand is amplifying day by day. The energy generated from sun radiation using photovoltaic cell requires a stage where it's passed through a unit called as "Power Conditioning Unit" before supplying to load. Consequently the improvement in this unit is necessary time by time. This unit is generally made up of inverters, according to the role of these used inverters the efficiency of the unit varies [5]. Generally "Voltage source inverters" and "Current source inverters" both are used for conditioning purpose and introduce faults in the system when used as "Power Conditioning Unit". So, here in the paper an impedance source inverter is used in power conditioning unit[6].

II. ANALYSIS OF CONVENTIONAL INVERTERS AND Z-SOURCE INVERTER

There are 2 kinds of conventional inverters exist and these are "Current Source Inverter" and "Voltage Source Inverter".

II.I. Voltage Source Inverter:

There are some reasons for limited use of these types of inverters:

These inverters act as buck converter when they are used for AC to DC conversion while boost for DC to AC conversion. Therefore the main thing is they are not capable to work as both buck and boost for the same circuitry. Gate cannot be provided to the power switching device at time while having same phase leg and it would extinguish

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the circuitry because of the present EMI noises due to the mis-gating operation[7]. For producing pure sinusoidal waveform at the output of load, an LC filter is required.

II.II. Current Source Inverter:

The drawbacks for these type of inverters are:

These inverters are boost type converters for DC-AC transformation while buck in case of AC-DC conversion. They are also not capable of working as both step up/down at a time. In these inverters, similar phase legged both the switching devices are not able to be switched off at a time. Because of the noises of EMI generation of some problem like mis-gating off occurs and due to this the inverter circuit comes under shoot and this circuitry would get destructed[7].

II.III. Z Source Inverter:

They are also called as "Impedance Source Inverters", and they utilizes a different network of impedance and therefore known as "Z source inverters". The network of this type inverters involve 2 inductors linked in divided phase or individually and 2 different capacitors in a shape like X[8]. There are some features mentioned below which are the reason for enhanced energy:

- These can be employed as step up or down at a time which is not possible in case of current and voltage source inverters.
- These can be used for any type of conversions like DC to AC, AC to DC, AC to AC and DC to DC.
- There is only one stage is required to do the conversion.
- Voltage value can be increased by using "Shoot Through States.
- These inverters use "SVPWM (state vector pulse width modulation)" method for controlling.
- Based on modulation index Z source inverter acquire a different up-down feature.
- The inverter can also be employed in MPPT (maximum power point tracking) of solar energy.
- It's less switches, therefore less losses due to switching and also less value of THD.
- When capacitors and inductors having same rating are used in ZSI, then there value is lesser.

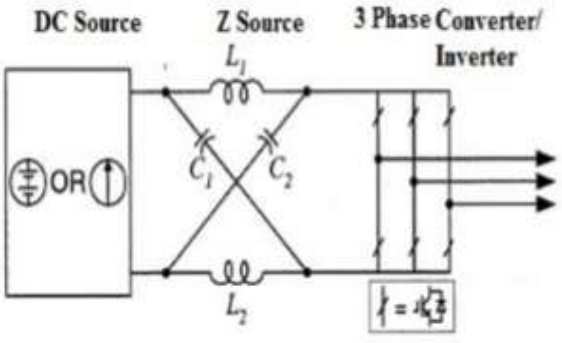

Figure 2. ZSI

A suitable structure of switching is used here for impedance network. This permits an appropriate boost in voltage value without introducing an additional stage of converter. The ZSI only consists of passive components under the increased voltage scheme and that would lead to reduced switching losses. Though, the scheme involves 2

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parts wherein first one is 3-phase inverter alignment and other one is Z source network but still they're reflected as one system and not able to be functioned individually along the provided gate control. These parts are considered as a single stage[9][10].

III. CONTROL AND OPERATION PRINCIPLE

In case of normal boost scheme shoot through states consider all the conventional "0 states" for cycle of switching. Remaining active states are in unchanged situation similar to the case of modulation methodology and conventional inverters. 2 lines which are straight, used to acquire "Shoot Through Duty Cycle Ratio" wherein amplitude of 3 lines in combimation make a single line of sinusoidal shape and other one is exactly a mirror image in negative direction [5][11][12].

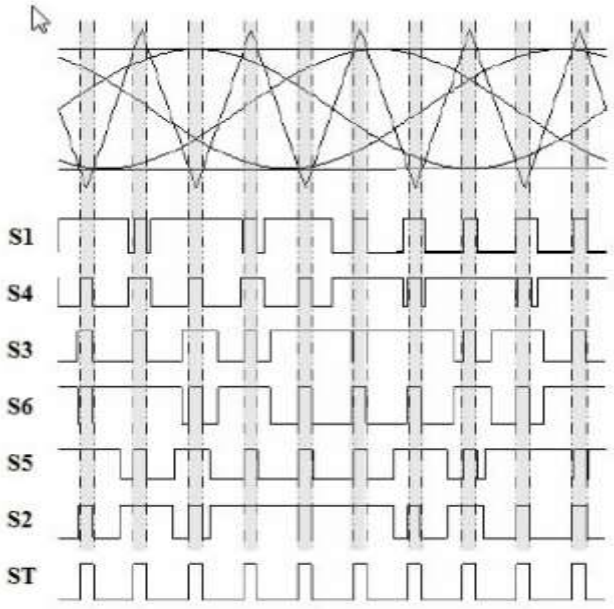

Figure 3. Simple Boost Control

The comparision between 3-ϕ sinusoidal shape carrier signal and triangular shape signal is done in case of "SPWM (sinusoidal pulse width modulation) methodology" to achieve gate pulses. 2 "0 states" in combination with 6 active states are achieved in a single cycle operation. Therefore, it is not able to control the output voltage. The "Shoot Through States" must consider 2 "0 states" for increasing the outcoming voltage value. If all 3 sinusodal shaped signals are lesser or greater in amplitude than amplitude of carrier signal which is taken as a reference signal then "0 states" are achieved in switching cycle of inverter. Consequently, 2 signals namely VP and VN which are steady state signals are needed to be compared with carrier signal which is taken as reference signal then the "Shoot Through States" goes to " 0 switching states. The signal which are used VP and VN are equal in amplitude and have opposite polarity to the sinusoidal signal.

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Voltage gain is:

$$\frac{\hat{V}_{ac}}{V_{pv/2}} - MB \tag{1}$$

Here i/p DC voltage is denoted by Vpv, modulation index by M and Boost factor by B. When the product of B and M is swapped by G:

$$\hat{V}_{ac} = G\frac{V_{pv}}{2} \tag{2}$$

The modulation index is:

$$B - \frac{T}{T_1 - T_0} - \frac{1}{1 - (\frac{2T_0}{T})} \tag{3}$$

"T0" denotes "Shoot Through Time Interval",
"T" denotes total switching cycle of duration,
Therefore, T0/T is the "Shoot Through Duty ratio".

Fig.3 represents a normal boost control strategy wherein 2 straight lines i.e VP and VN are taken. In case if the triangular shaped carrier signal's amplitude is greater than VP (Upper Shoot Thorugh Envelop), or lesser than VN (Lower Shoot Through), then this inverter is assigned to a shoot through state. Active states occur between these shoot through states in case of traditional inverters. The modulation index and shoot through duty ratio are inversely proportional to each other. (1-M) is the maximum shoot through duty ratio of the normal boost control strategy and final value can be 0 with modulation index of one[13]. In normal words, if the output voltage gain is desired to be high then the modulation index value would be lower .

$$G = MB = \frac{M}{1 - 2D_0}$$

Since, $D_0 = 1 - M$.

$$G = \frac{M}{1 - 2D_0} = \frac{M}{1 - 2(1 - M)} = \frac{M}{2M - 1}$$

$$\hat{V}_{ac} = M\frac{BV_{pv}}{2} \tag{4}$$

BVpv denotes DC input voltage.

The voltage stress on the inverter components is given by:

$$V_{inv} = BV_{pv}$$

$$V_{inv} = \frac{1}{2M - 1}V_{pv} = (2G - 1)V_{pv} \tag{5}$$

With the rise in outcome voltage gain, the voltage stress also increases. Therefore this method donot give higher gain.

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IV. METHOD FOR THE PROPOSED CIRCUIT

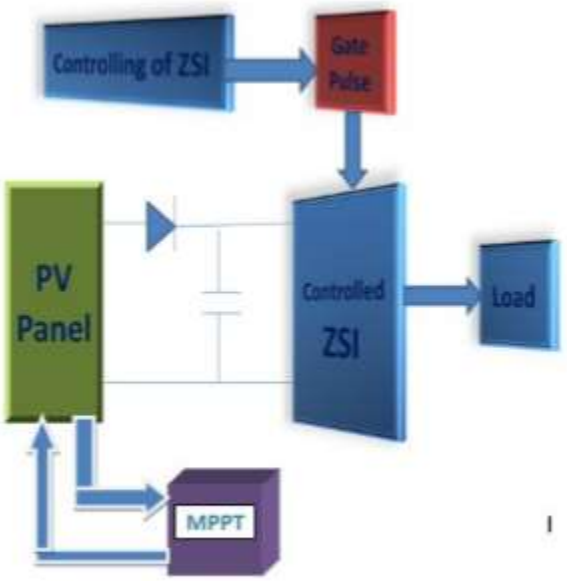

Figure 4. Block Diagram of Proposed Circuit

Typically every "Power Conditioning Unit" comprises of 2 stage methodology to impliment the accurate circuitry function. Based on a methodology which uses PCU based on ZSI, there is no requirement of additional circuitry like DC-DC regulator for regulating the output voltage to deliver the effectual outcome due to the presence of ZSI. Though, an improved THD decrease and effective outcome is gained while using traditional ZSI based PCUs but further improvement can be achieved because there are various ways of improvement. In the proposed work an MPPT block for getting maximum amount of power in the PCU is used. This MPPT uses parallel way when used in single stage PCU. Whole operation can be done under a single stage of circuit. Figure 4 shows its block representation.

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V. SIMULATION RESULTS

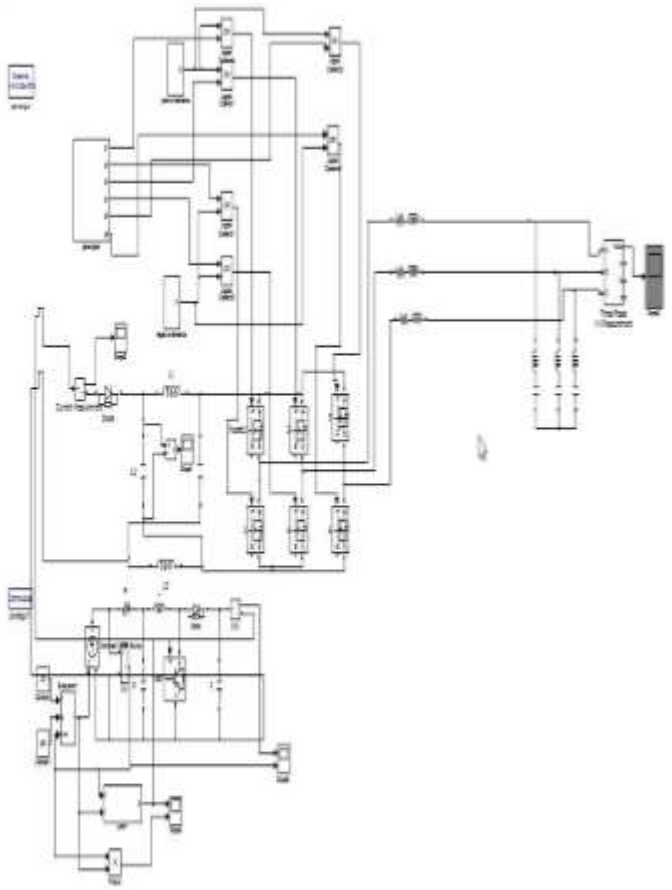

Figure 5. Simulink Model of Proposed PCU

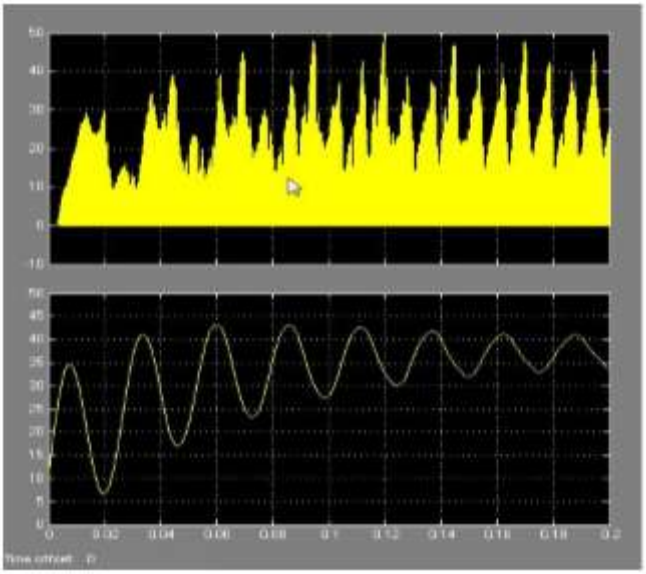

Figure 6. Output current and voltage waveform of PCU without using MPPT

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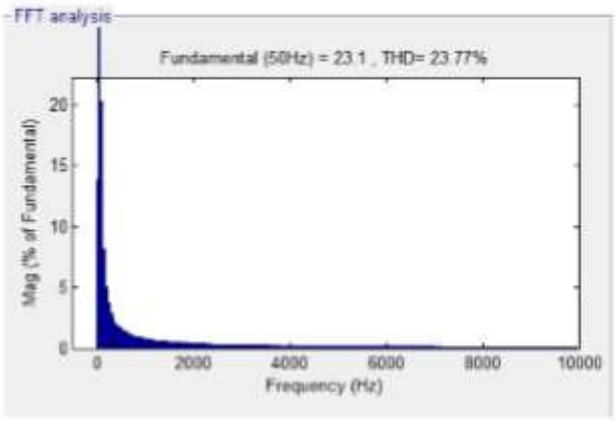

Figure 8. FFT analysis of the PCU without MPPT

A system "MPPT" involving a single stage "Power Conditioning Unit" for solar system is projected and tested through the simulation. From Figure 5 one can see the simulation results of the work. Figure 6 represents output current/voltage waveforms in case of PSU based on conventional "ZSI" in the absence of MPPT and Figure is the representation when the MPPT is used.

In the absence of MPPT the outcome is 42 volts and the value of THD is near to 23.80% while in the presence of MPPT the outcome is 440 volts and THD is near to 23.30%.

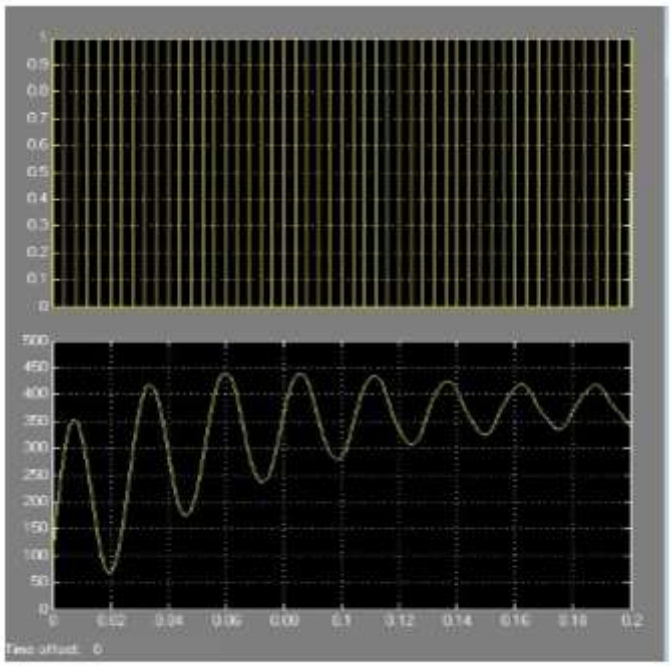

Figure 7. Output current and voltage waveform of proposed PCU using MPPT

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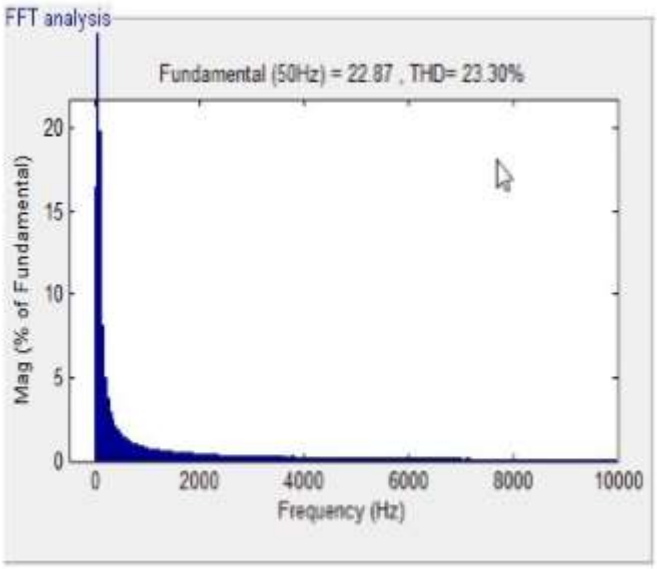

Figure 9. THD of the proposed PCU

VI. CONCLUSION

The work on "Single Stage Power Conditioning Unit for Photovoltaic Energy System" has been implemented using Z source inverter. It is observed that the same solar panel working under same functioning circumstances, for PCUs in the absence of MPPT and in the presence of MPPT gives the ocutcomes of 42V and 440V and the value of THD is 23.77% and 23.30% respectevely.

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