Design and Implementation of Three-Phase Two-Stage Grid-Connected Module Integrated Converter

[1]Wasim Akram,, [2] Dr. Prabodh Kumar Khampariya

[1]M.Tech Scholar, Department of Electrical Engineering, Sri Satya Sai University of Technology & Medical Science, Sehore, Bhopal

[2]Asso. Professor, Department of Electrical Engineering, Sri Satya Sai University of Technology & Medical Science, Sehore, Bhopal

ABSTRACT

Module integrated converters (MICs) in single phase have witnessed recent market success because of unique features such as improved energy harvest, improved efficiency of the system, lower installation costs, plug-and play operation, and enhanced flexibility and modularity. A niche market has been grown by the MIC sector to mainstream, especially in the United States. Assuming further expansion of the MIC market, this paper presents the micro inverter concept incorporated in large size photovoltaic (PV) installations such as megawatts (MW)-class solar farms where a three-phase ac connection is employed. The first stage mainly considered for a high efficiency full-bridge LLC resonant dc–dc converter which interfaces to the PV panel and produces a dc link voltage. A center point's iteration algorithm developed specifically for LLC resonant topologies is used to track the maximum power point by the PV panel. The second stage is comprised of a three-phase dc–ac inverter circuit which employs a simple soft-switching scheme without adding auxiliary components.

Keywords- *Center points iteration (CPI), maximum power point tracking (MPPT), module integrated converter (MIC), three phase two stage converter.*

I INTRODUCTION

The energy which is harvested from the herbal assets like sunlight, wind, tides, geothermal warmth and many others.is referred to as Renewable energy. As those sources can be obviously replenished, for all realistic purposes, these may be considered to be infinite in contrast to the tapering conventional fossil fuels. the global strength

crunch has furnished a renewed impulsion to the growth and development of clean and Renewable strength sources. clean development Mechanisms (CDMs) are being followed by groups all throughout the globe. every other gain of making use of renewable resources over conventional strategies is the huge discount in the level of pollution related. The value of traditional energy is growing and solar energy has emerged to be a promising alternative. They are abundant, away from pollution, allotted for the duration of the earth and recyclable. PV arrays encompass parallel and series connection of PV cells which might be used to generate electrical power depending upon the atmospheric specifies (e.g. sun insolation and heat).

This increase in manufacturing and proliferating purchaser call for has caused a global-huge interest inside the improvement of latest programs for photovoltaic technology. This enlargement in R&D efforts has additionally been pushed by federal and state subsidies and company dates, which might be in turn selling a positive direction of environmental cognizance in both the power manufacturer and the customer. There are crucial programs of photovoltaic under improvement that without delay relate to the sector of power electronics, making floor for new possibilities in programs for low, medium and excessive energy, for each dc and ac systems. the first location of research is in low-value thin film solar cells. Because of their decreased material, electricity and handling charges these may be a value competitive product even without economic subsidies. [1]

II. SYSTEM ANALYSIS AND DESIGN

2.1 Architecture of Two-Stage Three-Phase grid-Tie Inverter System:

On the way to provide galvanic isolation, various isolated converters for excessive step up programs were proposed. In standard, the topologies with galvanic isolation suitable for this software can be categorized into corporations: single - switch topologies and multi switch topologies. Recently, the LLC resonant topology has emerged as attractive due to its desirable consisting of excessive efficiency and natural zero voltage switching (ZVS)/zero current switching (ZCS) commutation. Consequently, a full-bridge LLC resonant converter is hired in the first stage to attain high performance and track the maximum power point of each PV panel.

For the three- phase dc/ac converter within the second stage, a variety of active soft-switching topologies have been proposed in closing three decades. Maximum of them may be divided into 3 groups: auxiliary resonant commutated pole (ARCP) group, resonant dc-link inverter (RDCLI) group, and resonant ac-link converter (RACLC). The ARCP can be implemented broadly for the voltage-source kind unmarried-section or 3-phase inverters however it calls for a massive wide variety of auxiliary components. Compared to the ARCP, the RDCLI has the benefits of fewer auxiliary switches and a less difficult circuit. Several smooth-switching topologies are proposed to gain the minimal range of more additives. But, the driving alerts of the auxiliary switches are very sensitive to the noise from the principle circuit. For the reason that RACLC can attain voltage boosting and electric isolation at the equal time, its miles extraordinarily favored for renewable energy strength era. Regrettably, the control circuit for the RACLC is complex and bidirectional switches are required. In reality, auxiliary components are unavoidable for all of the tender switching topologies cited in advance.

Figure .1 PV Panel with Load

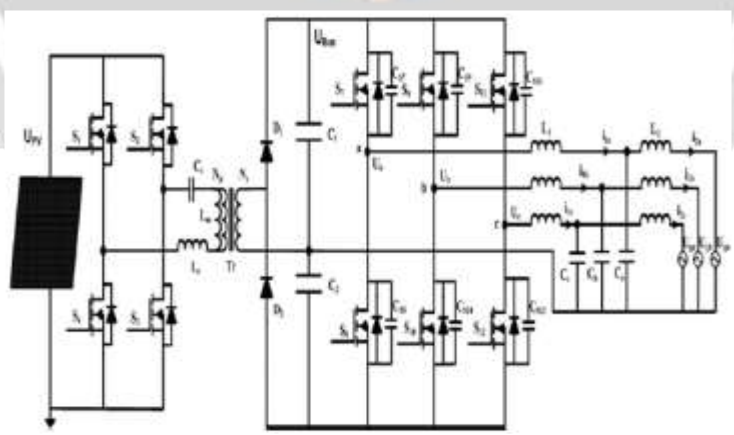

Figure 2: Two-stage three-phase four-wire grid-tie inverter system.

2.2 LLC Resonant Converter

Now a day's particularly competitive commercial environment fashion designer usually try for highly efficient, reliable, and surprisingly compact layout. DC-DC converter generation has evolved from earlier linear power converters to superior resonant converters. Issues including excessive switching losses and incapacity to function at high frequencies, associated with the PWM converters can effortlessly be triumph over by the use of resonant converters. For frontend DC-DC utility LLC is the first-class suitable topology as compare with the other resonant converter .hassle associated, with the series resonant converter which include incapability to alter the output voltage at no-load circumstance and that with the Parallel resonant converter together with presence of excessive circulating electricity can effortlessly be conquer through LLC resonant converter.

In resonant topologies, Series Resonant Converter (SRC), Parallel Resonant Converter (PRC) and Series Parallel Resonant Converter (SPRC, also called LCC resonant converter) are the 3 maximum popular topologies.

Several aspects of LLC resonant converter are mentioned in many papers. Excessive frequency operation effects in decreased length of magnetic components. But in resonant converters the advantage won with the high frequency operation is lost because it requires extra reactive factors. With the integrated magnetic several magnetic components can be constructed in one magnetic core. Major gain of LLC resonant converter is that the leakage inductance of the transformer con be used as resonant inductance and collectively with the resonant capacitor it takes part inside the power transfer mechanism. However the integrated magnetic structure outcomes in the inclusion of equal quantity of leakage inductor on secondary aspect too. So that LLC with the center tapped secondary rectifier will reports a big voltage oscillation, due to the presence of secondary leakage inductance. In LLC resonant converter it's miles feasible to modify output voltage even at no-load circumstance. Every other massive advantage of LLC is ZVS activate the switches; this reduces the switching losses dramatically.[6]

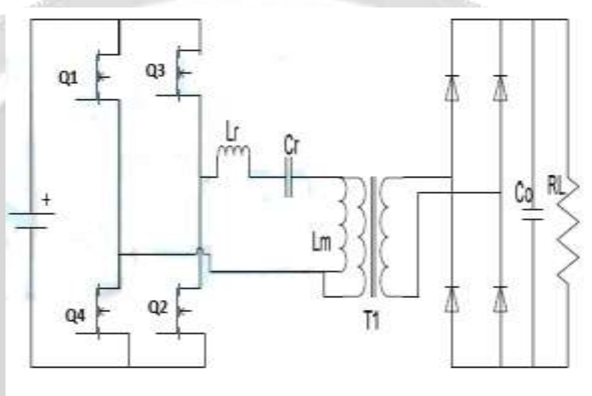

Figure 3. LLC Resonant Converter

2.3: Operation Mode Of The Proposed ZVS Three-Phase Four-Wire Dc/Ac Converter

Due to the fact many articles about LLC resonant converters were published over the past decade, this paper does not talk it in great detail. The running modes of the proposed ZVS 3-phase 4-wire dc/ac converter are offered in this section. As shown in Fig.3.3.7, the 3- phases of the dc/ac second stage are symmetrical across the neutral factor; consequently

Interval 1 [t_0− t_1]: Prior to t_0, S_7 is off and S8 is still turned ON. Assume that the current direction through L_1, as shown in Fig. 3.3.7, is already from right to left at t_0. Then S_8 is turned OFF and the voltage across the parasitic capacitor CS_8 of low side MOSFET S_8 starts increasing due to the inductor current. As CS_8charges the voltage across S_7decreases .This interval ends once the voltage across S7 reaches zero.

Interval 2 [t_1− t_2]: The body diode of S_7 will be conductingatt_1 and S_7 can be turned ON with ZVS. The current flow decays linearly from right to left due to the fact that U_{bus}/2 minus the voltage across L_1. This mode ends when the inductor current decays to zero.

Interval 3 [t_2− t_3]*:* S7 is conducting and the current directionthroughL_1 is now changed from left to right and increasing linearly. This is the power delivery interval.

Interval 4 [t_3− t_4]:Att_3, S_7 is turned OFF and its parasiticcapacitorCS_7 is charged by the inductor current while CS_8isdischarging. Once the voltage across CS_8 drops to zero, the parasitic body diode of MOSFET S_8 conducts since the currentdirection through L_1 does not change.

Interval 5 [t_4− t_5]: Continuing from the previous interval 4,the body diode of S_8 continues conducting which creates a ZVS condition when S_8 is turned ON. The length of this interval is typically quite short and ends once S_8 is turned ON.

Interval 6 [t_5− t_6]:S_8 is turned ON under ZVS condition att_5. The current through S_8 is gradually decreasing due to the fact that U_{bus}/2 plus the output voltage appears across the inductorL_1Interval 7 [t_6− t_0]: The current through S_8 continues to flow and the current direction will change once the current decays to zero at t_6. Once the current through S_8 changes direction from top to bottom

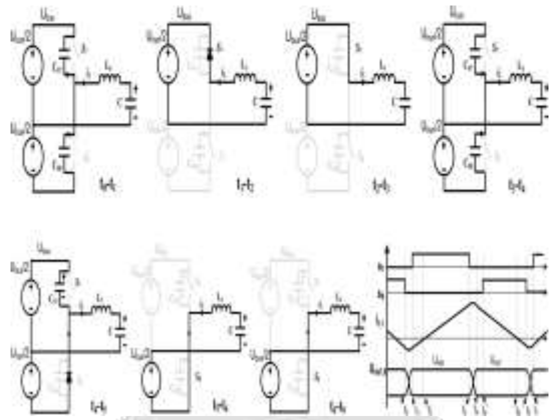

Fig.4. Theoretic waveforms and operating intervals of a single-phase dc/ac converter Interval 1: [$t0 - t1$], interval 2: [$t1 - t2$], interval 3: [$t2 - t3$], interva4: [$t3 - t4$], interval 5: [$t4 - t5$], interval 6: [$t5 - t6$], and interval 7: [$t6 - t0$]

III.Interleaved Three Phase LLC Resonant Converter –

LLC resonant converters exhibit a massive voltage ripple on output clear out capacitor because of the rectified sine-wave current injected through the transformer secondary windings. So that you can reduce the capacitor size and/or the consistent-state output voltage ripple, the interleaved technique can be profitably carried out. In figure 4 a multi-phase LLC resonant converter is depicted: 3 equal modules (specifications listed in table 1.2) are parallel connected and switched at the equal frequency however with a 120 degrees phase-shift of their driving signals. Figure 3.3.7 shows the benefit of an increasing number of parallel modules on the total rectified current ripple, this is the peak -to-peak ac current day injected into the output filter capacitor. The results in figure 3.3.7 are obtained from MATLAB simulink simulations with 400 v input voltage, 24 v output voltage and exceptional output currents. The large reduction of general current ripple within the 3 modules solution may be favored in comparison to one and modules opposite numbers, suggesting the opportunity to extensively reduce the output filter out capacitor size. The use of parallel connected LLC resonant converters to supply the equal load and share the equal output filter capacitor presents limitations and disadvantages because of resonant devices mismatch. The modules are operated at the same switching frequency managed with the aid of the voltage regulation loop, even as resonant factor mismatch causes the three phases to showcase one-of-a-kind voltage conversion.

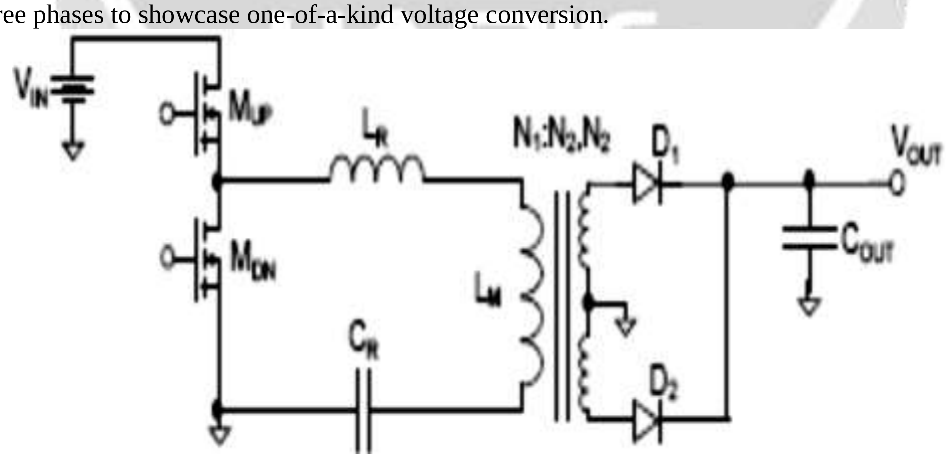

Figure 5. Scheme of a single module LLC resonant converter.

IV. SIMULATION MODEL AND RESULT :

The simulation is achieved inside the MATLAB Simulink . The dc voltage converted into ac by using use of full bridge inverter. The resonant tank connected to inverter, usage smooth switching technique both voltage or current is zero at some point of switching transition, which largely lessen the switching loss and also increase the reliability.

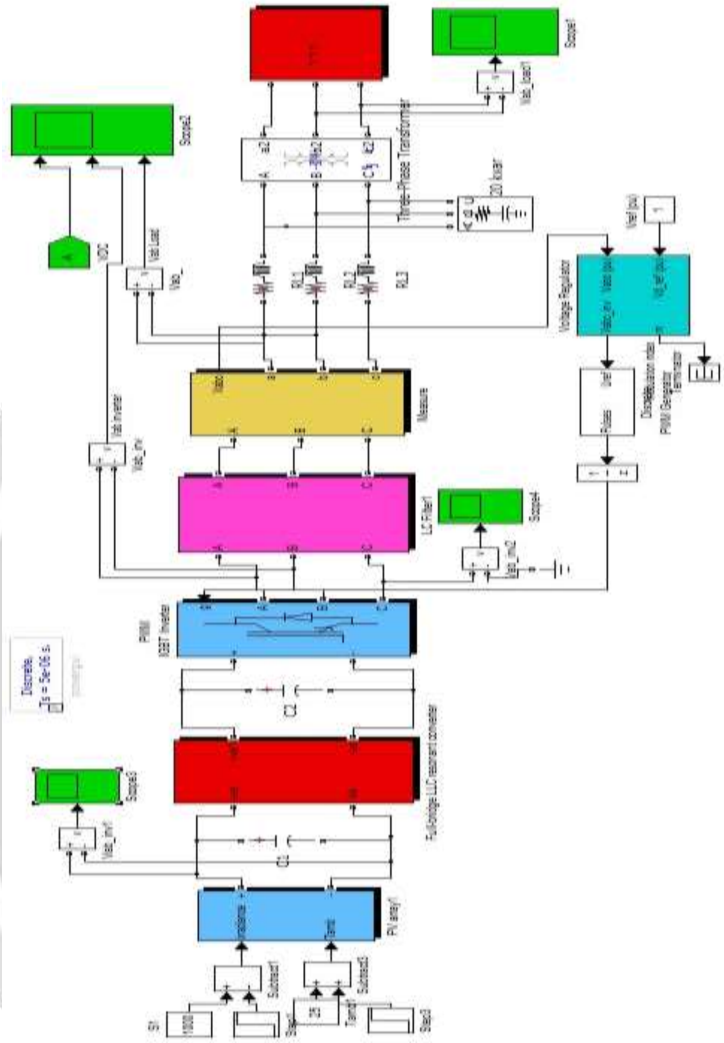

Figure 6: SIMULINK model of complete photovoltaicgrid connected

Table 1.5: Main Parameters of Simulation Results

LLC Resonant Converter	
Input voltage	35V-55V
Output voltage AC	400V
Magnetizing inductance L_m	16.279 µH
Resonant inductance L_r	2.27µH

C_1	1500 µF
C_2	3000µF
DC-DC Converter resonance frequency	100 kHz
Three phase four wire DC to AC converter	
Output voltage AC	440V
Frequency	50Hz
Grid nominal line voltage	25kV

4.8 EXPERIMENTAL RESULTS

A 3-phase 4-wire MIC with both-stage ZVS changed into built as proven in Figure with the following specifications: output energy 550 W and output voltage 600V AC key parameters are shown in Figure 1.5. The renewable source is a PV panel from advanced sun photonics. The input voltage variety for strength monitoring is from 35 to 55 V. Due to the fact the open-circuit voltage is much less than 60 V, Fairchild MOSFETs with low Rds (on) are used within the full-bridge LLC resonant dc-dc converter. The second one degree is a 3-phase 4-wire inverter that connects the dc-bus to the grid through an inductance of 2.25µH. The dc-bus voltage reference is 400 V and the grid voltage peak value is 500 Vac.

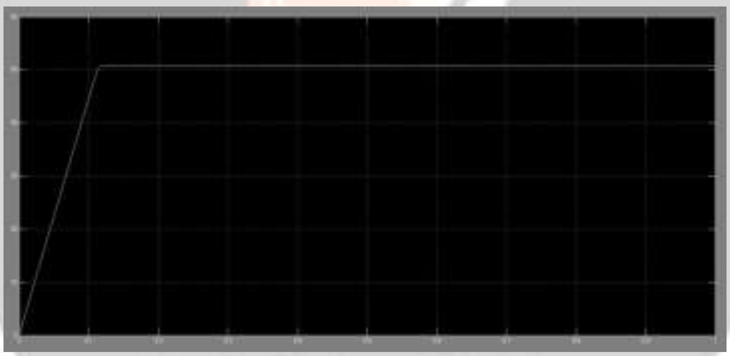

Fig 7 Voltage characteristics of PV panel

In LLC resonant converter the pulse generator is used as a controller for MOSFET. The Pulse Generator block generates square wave pulses at regular intervals. The block's waveform parameters, Amplitude, Pulse Width, Period, and Phase delay, determine the shape of the output waveform.

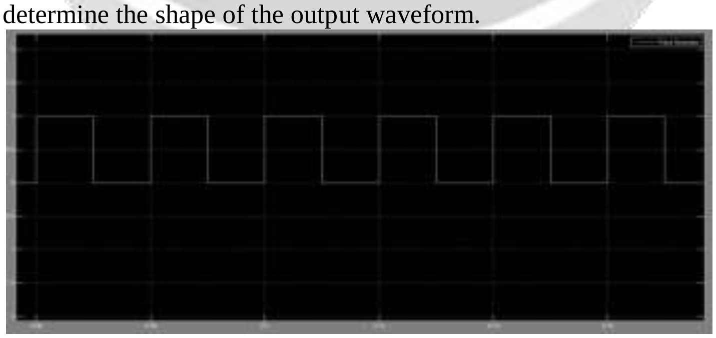

Figure 6 Characteristics of PWM

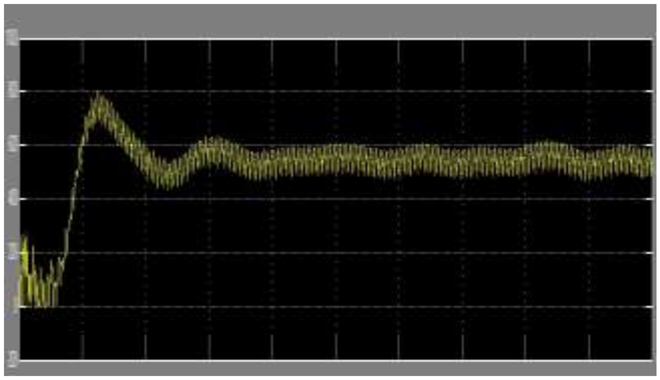

Figure 8 Voltage characteristics of LLC resonant converter

This DC signal is fed to the LLC resonant converter which boosts up the 50V DC into 500v AC.
DC Output obtained from LLC resonant converter is fed to an inverter which converts DC into AC. As shown in figure.4.4.12

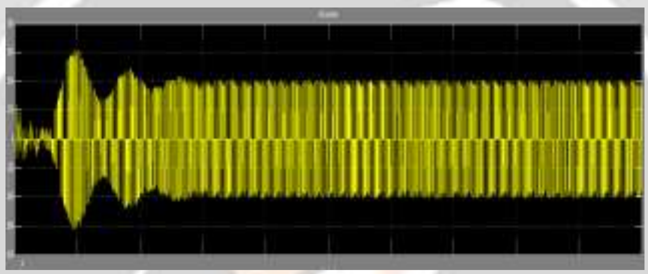

Figure9 Voltage characteristic of Inverter

The output obtained from Inverter is fed to filter and then to the utility grid. At utility the voltage of 5000 volts is seen.

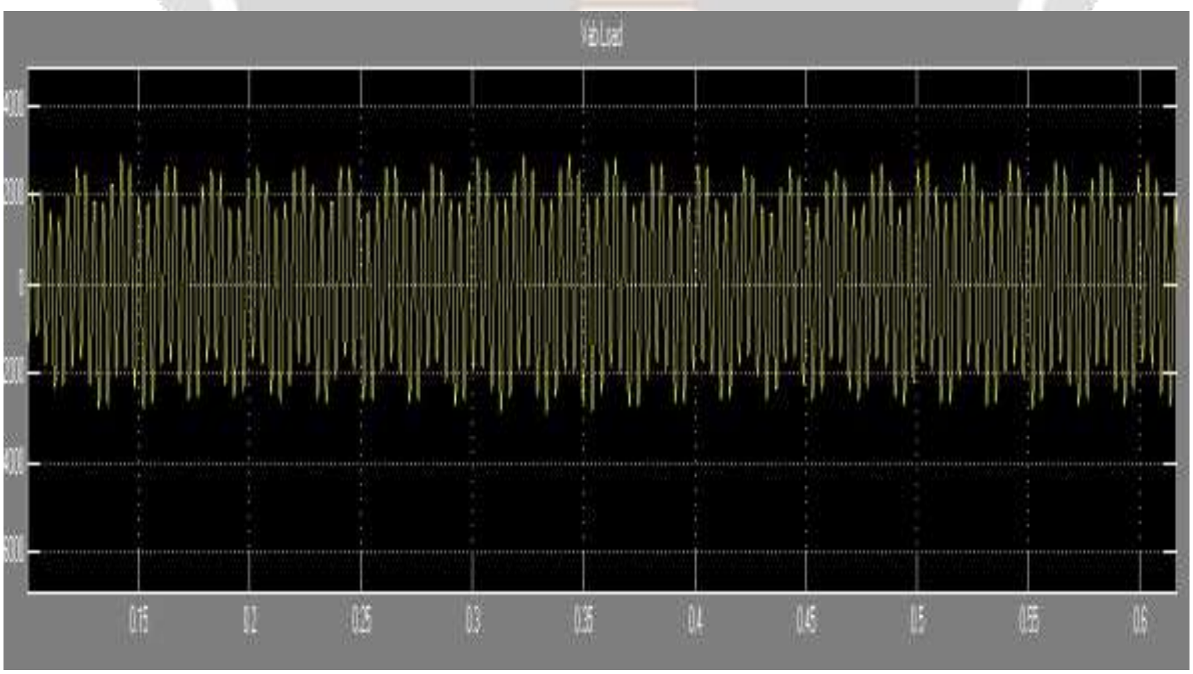

Figure 10 Voltage characteristic of Grid

IV CONCLUSIONS

This paper has presented a utility of a full bridge LLC resonant converter in a three phase grid related photovoltaic (PV) system. The LLC has the advantage of zero voltage switching, which results in a higher performance in contrast to conventional increase converters. Due to its operation at high frequencies, using smaller and cost effective magnetic additives is possible. Moreover, DC-link capacitor for the inverter will be chosen smaller way to the excessive switching frequency and speedy dynamic response of the converter. The inverter controller consists of the outer loop to maintain the DC bus voltage steady, and the internal loop to synchronize the output voltage of the inverter with the grid voltage and also keep the output current in phase with voltage. The simulation effects showed the effectiveness of the system to provide and make sure appropriate strength and unity power factor the grid, as well as DC-link voltage stability. The capacity of the DC-DC converter to extract most energy from the sun arrays underneath fast changing irradiance, has also tested. In an effort to construct a PV grid linked device, a number of parameters need to be contemplating and to be optimized in order to attain most power technology.

There have additionally been several enhancements in switching device generation given that the start of this work. Silicon carbide-based transistors, MOSEFET and diodes had been shown many big advantages such as lower conduction losses, higher frequency operation.

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