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# Design and Implementation of Solar Power Converter base on P/O Super-Lift Luo Converter

Bahman Khaki

**Abstract:** The solar energy system consists of solar panels and inverting system that converts DC power to AC. The DC power should convert to AC power to be usable at homes by single phase AC power, or Three phase AC power for industrial use. In the proposed procedure of solar conversion, the prototype circuit consist of two level: First, a DC/DC converter to step-up the voltage level to desired level, and then a level for DC/AC three phase inversion to achieved desired AC output for three phase use. The DC/DC converter which developed in this paper is P/O Super-Lift Luo converter, which its function and voltage output compared with conventional boost step-up DC/DC converter.Super-lift (SL) technique is more powerful than voltage lift (VL) technique; its voltage transfergain can be a very large number. SL technique facilitates the output voltage increase in geometric progression, stage by stage. It effectively enhances the voltage transfergain in power series. Design of the total system, DC/DC/AC done and the AC output voltage investigated. Results show the suitable three phase voltage waveforms that can be use as solar inverter in photovoltaic applications. The improved efficiency, wider usability through duty cycle, and faster response of feedback output voltage are some of advantages of this proposed conversion system for photovoltaic systems applications.

**Index Terms:** Photovoltaic Solar energy system, Solar inverter, DC/DC converter, Super lift Luo Converter, three phase inverter, Sinusoidal pulse width modulation.

## I. Introduction

The power electronic interface for PV-grid systems has two main tasks: First, to amplify DC voltage and invert the generated DC power into a suitable AC current for the grid. Second, to control the PV module so as to track the Maximum Power Point (MPP) for maximizing theenergy capture. The MPP is tracked by means of a MPP Tracker (MPPT) device.The PV module cannot be operated at the MPP if this alternating power is not decoupled bymeans of an energy buffer, as will be seen later.Finally, the current injected into the grid must obey the regulations, such as the EN61000-3-2,and the IEEE std. 1547,which state the maximum allowable amount of injected currentharmonics.

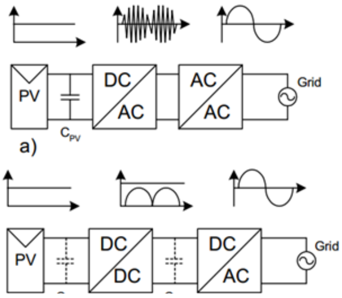
In this paper we propose a new topology for DC/DC/AC conversion mostly use in solar inverters, base on P/O Super-Lift Luo converter. Voltage lift (VL) technique has been successfully employed in the design of DC/DC converters and effectively enlarges the voltage transfer gains of the VL converters. However, the output voltage increases in arithmetic progression stage by stage.Super-lift (SL) technique is more powerful than VL technique; its voltage transfergain can be a very large number. SL technique facilitates the output voltage increase,in geometric progression, stage by stage. It effectively enhances the voltage transfergain in power series [1-6]. Three phase inverters are six pulse circuits with six IGBTs or MOSFETs, which implemented in this paper beside Luo DC/DC converters to form a suitable DC/DC/AC conversion system. It receives DC input signal and converts it to three AC signals, each has 120 degrees' difference to form a symmetrical three phase system based output voltage[7-8]. The remaining parts of the paper is as following. In part 2, we will express different types of inverter topologies mainly use in solar photovoltaic solar systems. In section 3, we will investigate proposed DC/DC Luo converter and its comparison with conventional Boost DC/DC converters. Section 4, is about three phase inverter and use of sinusoidal pulse width modulation (SPWM) strategy in this structure that converts DC input signal to three AC signal each has 120 degree's difference per phase. In section 5, the total system for DC/DC/AC conversion will propose for solar photovoltaic applications and the output voltage will investigate and possibilities of connection to electricity grid.

## II. Different Types of Solar Inverters

The selection of a suitable power electronic topology for the inverter depends on many differentissues besides the electrical specifications, such as: cables; electrolytic capacitors; mechanical /thermal / enclosure demands; silicon devices; magnetics; and efficiency, etc. All the items abovemust carefully be evaluated for each system layout and inverter topology, in order to find thebest inverter topology.

### A) Topologies with a High Frequency (HF-link):

The High Frequency (HF) link inverter uses a HF DC-AC inverter to amplify the voltagegenerated by the PV module, and to modulate the sinusoidal grid current. An AC-AC inverter,which converts the HF current to a Low Frequency (LF) current for the grid, follows the DC-ACinverter. This involves that power decoupling must be performed with a large electrolyticcapacitor in parallel with the PV module.

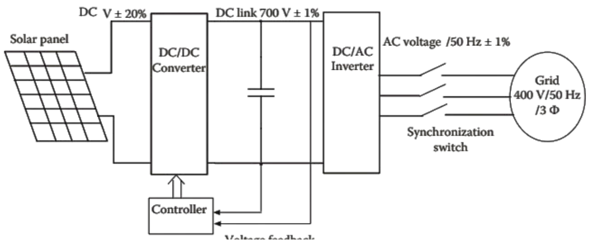



Figure(1): Fundamental schematics and waveforms of two types of inverters. A) HF-link, B) DC-link.

**B) Topologies with a DC-link:**

The DC-link inverter uses a HF DC-DC converter to amplifying the voltage generated by the PVmodule. A DC-AC inverter, which inverts the DC current to a sinusoidal current for the grid,follows the DC-DC converter. A small capacitor can be added in the DC-link forpower decoupling, if the only task for the DC/DC converter is to amplify the voltage levelgenerated by the PV module. Besides this, it is sufficient to design the DC-DC converter for thenominal power and the DC-AC inverter for twice the nominal power, because of the energybuffer between the two stages. On the other hand, a large electrolytic capacitor must be added inparallel with the PV module and both stages must be designed for twice the nominal power, ifthe DC-DC converter also has to modulate the grid current, because no energy-buffer is present.

The topology used in this paper is DC-link as figure(1) part b. The diagram of total solar energy system is shown in figure (2). It consists of a solar panel, then a DC/DC converter, following by a DC link and three phase DC/AC inverter. This configuration can connected two three phase grid.



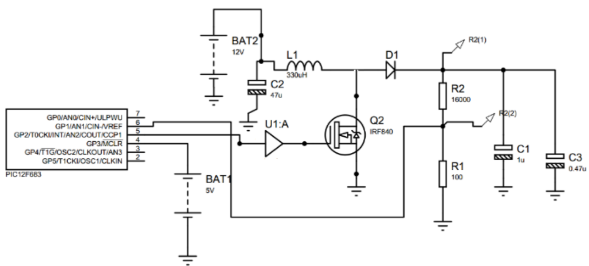

Figure(2): proposed topology for solar energy system

## III. DC/DC Conversion System

DC/DC converters develop and design according to their applications and name by their function like Buck (step-down), Boost (step-up), Buck-Boost, zero current switching (ZVS), zero voltage switching converters. In this paper we focus on step-up converters. The conventional DC/DC step-up converter is Boost converter. The schematic diagram of boost converter which implemented in this paper is shown in figure (3).

A) **Boost DC/DC Converter:**

The proposed boost converter has feedback control (voltage divider) that sends output voltage to microcontroller to control output voltage and to fix it to desired value. The switch is MOSFET, IRF840, and The microcontroller used is PIC12F683, which provides the proper signal to trigger the MOSFET gate. A gate driver IC should be use to increase microcontroller based pulse to desired magnitude level to drive the MOSFET. It can be IR2110,IR2112 or other gate driver ICs.



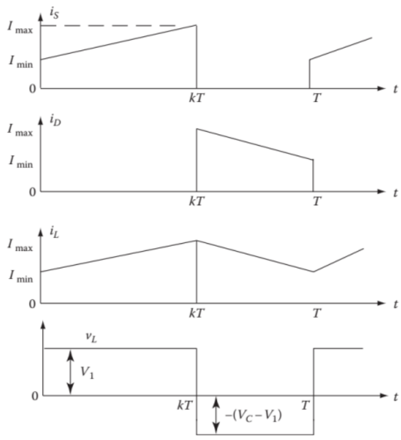

Figure(3): Boost converter with feedback control to fix output voltage.

When the switch is on, the inductor current increases:

$$\frac{di_L}{dt} = \frac{V_1}{L} \quad (1)$$

Since the diode is inversely biased, the capacitor supplies current to the load, and thecapacitor current *ic*, is negative. Upon opening the switch, the inductor current must decrease so that the current at the end of the cycle can be the same as at the startof the cycle in steady state. For the inductor current to decrease, the value *Vc=V2*must be greater than *V1*. For this interval with the switch open, the inductor currentderivative is given by

$$\frac{di_L}{dt} = \frac{V_1 - V_c}{L} = \frac{V_1 - V_2}{L} \quad (2)$$



Figure(4): Boost Converter Currents and voltages waveforms

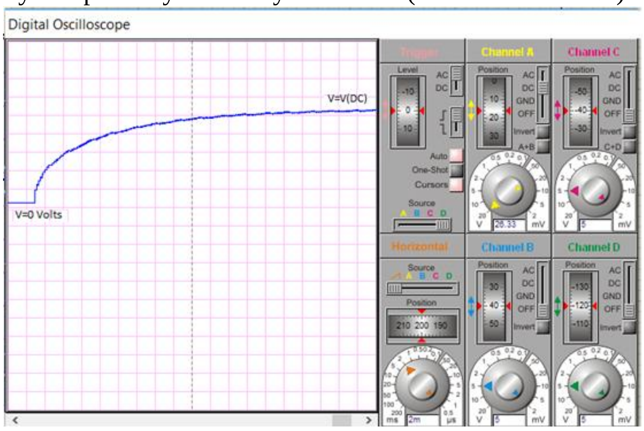
The increment of *iL*during switch-on must be equal to its decrement duringswitch-off.

$$I_{max} - I_{min} = \frac{V_1}{L} kT \quad (3)$$

$$I_{min} - I_{max} = \frac{V_1 - V_c}{L} (1-k)T \quad (4)$$

$$V_o = V_c = \frac{V_1}{1-k} (5)$$

From Equation (5), we can see that if *k*is large, output voltage *V2* can be very large.In fact, as *k*approaches unity, the output voltage decreases rather than increasesbecause of the effect of circuit parasitic elements. The value of *k*must be limitedto less than certain upper limit (say 0.9) to prevent such a problem. Practical limits to this also become important for an increase in the voltage transfer gain, for example, 10. The switch may be open only for a very short time (0.1 T since k = 0.9).

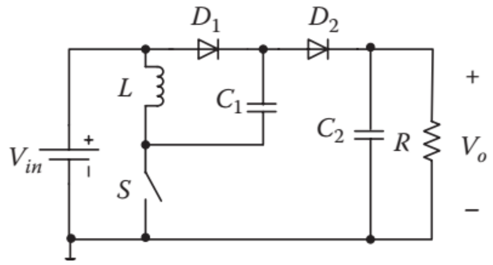



Figure(5): The voltage output waveform of feedback controlled Boost converter

B) P/O Super-Lift Luo DC/DC Converter

The positive-output super-lift Luo converter [4–6] is shown in Figure 6. It consists of a switch S, an inductor L, two capacitors C1 and C2, two diodes D1 and D2, aresistive load R, and input voltage *Vin*and output voltage *Vo*. The switch frequency is*f*and the period *T=1/f*, and the switch-on duty cycle is *k* (to avoid the parasitic effect,*k*should be 0.1–0.9).When the switch *S*is on, the source voltage Vin charges the capacitor C1 to Vin andprovides the current flow through the inductor L. Then the inductor current increases:

$\Delta I_L = \frac{V_{in}}{L}(k)T$(6)




Figure(6): Positive-output super-lift Luo converter

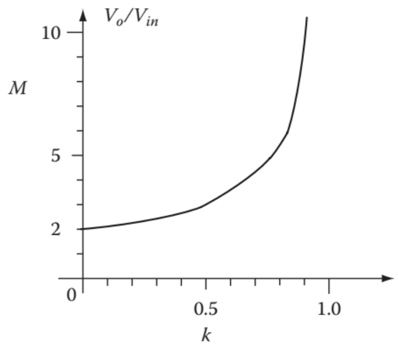



Figure (7): The voltage's transfer gain *M*versus duty cycle *k*

When the switch S is off, the inductor current decreases with the applied voltage(Vo- 2Vin). Therefore, the inductor current decrement is:

$\Delta I_L = \frac{V_o - 2V_{in}}{L}(1-k)T$(7)

In the steady state, the inductor current increment must be equal to its decrement.Therefore, we obtain the voltage transfer gain M as follows:

$M = \frac{V_0}{V_{in}} = \frac{2-k}{1-k}$ (8)

This voltage transfer gain is much higher than that of the boost converter and positive-output Luo converter. When *k*is very small, the voltage's transfer gain *M ≈2*.When *k=0.5*, the output voltage *Vo*is equal to *3 × Vin*. The voltage transfer gain *M*versus the duty cycle *k*is shown in Figure 7.It is very good for high voltage transformation and is used in solar panel energysystem.

The input current ($I_{in}$) is equal to ($I_{L_1} + I_{C_1}$) in switching period and is equal to ($I_{L_1}$) when the switch is off. Capacitor current ($I_{c_1}$) is equal to ($I_{L_1}$) when the switch is off. In steady state, the average charges across capacitor *C1*, should not vary. Therefore, we have;

$I_{in-off} = I_{L1-off} = I_{c1-off}$ (9)

$I_{in-on} = I_{L1-on} + I_{c1-on}$ (10)

Considering ($T = \frac{1}{f}$) , ratio of voltage and current is as:

$\frac{V_{in}}{I_{in}} = (\frac{1-k}{2-k})^2 R$ (11)

The resulting change ration of inductor current (IL1) will be:

$\varepsilon_1 = \frac{k(1-k)^2}{2(2-k)} \frac{R}{fL_1}$(12)

The ripple value of output voltage will be:

$\Delta V_0 = \frac{\Delta Q}{C_2} = \frac{I_o(1-k)T}{C_2} = \frac{(1-k)V_o}{fC_2 R}$ (13)

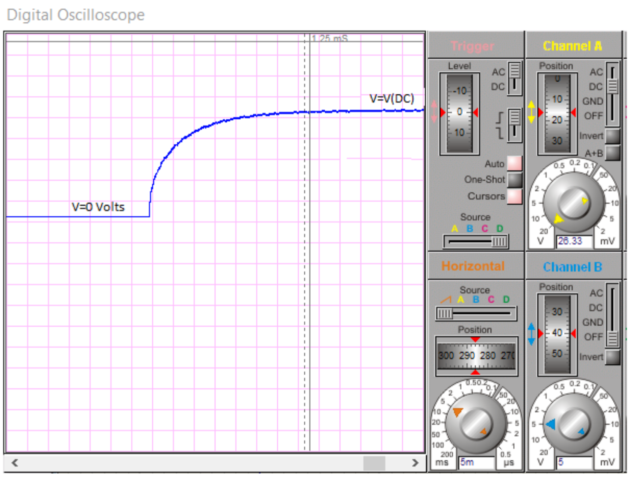
So, the change ratio of output voltage will be:

$\varepsilon_2 = \frac{\Delta V_o}{2V_o} = \frac{(1-k)}{2RfC_2}$ (14)

In following section, the parameter of DC/DC converter's prototype is a below:

| Parameters | Symbols | Value |
|---|---|---|
| Input voltage | $V_{in}$ | 12 volts |
| Output voltage | $V_o$ | 622 (Vp-p) per phase |
| Inductor | $L_1$ | 100uH |
| capacitors | $C_1 . C_2$ | 10uF |

The output voltage has feedback control by micro-controller. As we can see from figure(8) voltage will reach the desired value by proper calculation of resistors in output voltage divider.



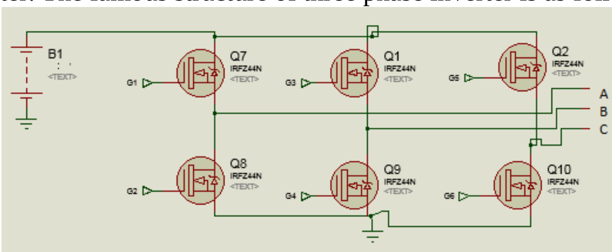
Figure(8): Feedback controlled Output voltage waveform of Super-Lift Luo converter.

According to figure (8) comparing to figure (5), the output voltage of Super-Lift Luo converter reach to desired DC value faster than conventional boost DC/DC converter.

## IV. Three Phase Inverter

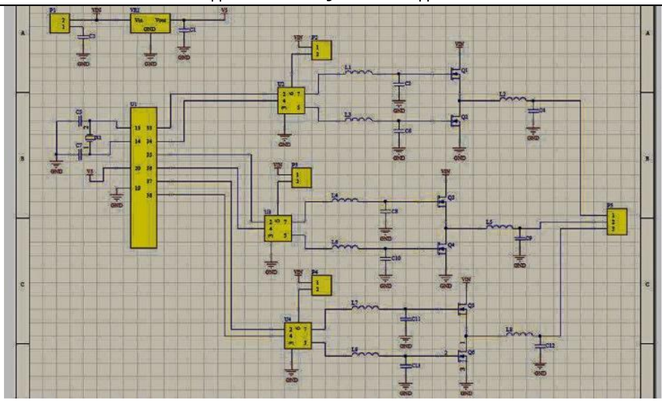
Switch ingstrategies mostly used PWM and SVM. We choose PWM based three phase inverter for design and implementation that are utilized more in market.

We can also shape our three phase six pulse inverter either by putting 6 switches separately orwe can use a pack three phase inverter. The famous structure of three phase inverter is as following figure (9).



Figure(9): three phase 6 pulse inverter.

Implementation of prototype experience shows that the gate signal of MOSFETs (here we use IRF840) should be filtered properly (here with use of LC filters). Also voltage output signal of the three phases should also implemented by a filter for each phase to reach proper output voltage without distortions and eliminate harmonics. Therefore, filter design is an important part of the project. The resulted schematic diagram of three phase inverter is as figure (10).



Figure(10): schematic diagram of proposed three phase 6 pulse inverter for prototype implementation.

If we use and design switches separately to form our structure we need three gate drivers for eachtwo high and low switches in each leg of the inverter structure. So, for e.g. we can use three IR2110, IR2101, orIR2112 or other gate driver ICs. And else if we want we can use pack three phase gate drivers available in market likeICs: IR2130, IR2233. The microcontroller is expected to provide PWM signals. We will do this by using PIC18F4431microcontroller by Microchip® company to have sinusoidal PWM. It will produce 3 HIL, and NIL signal to input 3 gatedrivers or to input one compact three phase gate driver.The pulse-width modulation technique is a popular method to implement DC/ACinversion technology. A sinusoidal pulse-width-modulated (SPWM) voltage source inverter(VSI) is used for this design.The triangular and modulating signals are shown in Figure 10.There are two important modulation ratios for the PWM technique. We define theamplitude modulation ratio $ma$, as:

$m_a = \frac{V_{in-m}}{V_{tri-m}}$(15)

Where$V_{in-m}$ is the amplitude of the control signer (sine) waveform, and $V_{tri-m}$ is the amplitude of the triangle waveform.

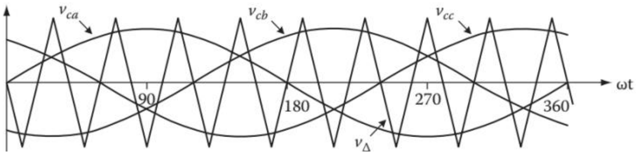
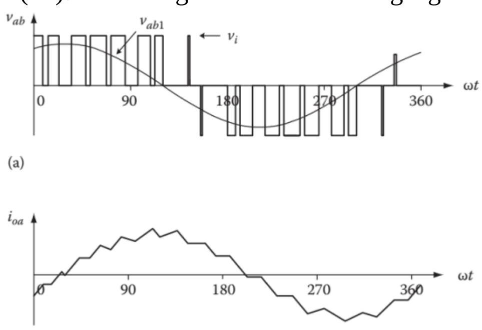



Figure (11): The triangular and modulating signals.

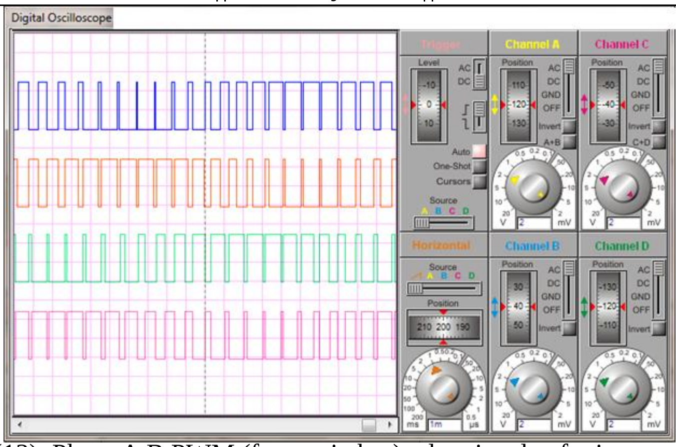



Figure(12): The AC output (a) voltage and (b) current (each phase).

Usually, for non-distorted inversion the amplitude modulation ratio *ma* is selected tobe smaller than 1.0.We also define the frequency modulation ratio *mf*,

$m_f = \frac{f_{tri-m}}{f_{in-m}}$ (15)

Where$f_{in-m}$ is the frequency of the control signer (sine) waveform, $f_{tri-m}$ is the frequency of the triangle waveform· Usually, for non-distorted inversion the frequency modulation ratio *mf*is selected tobe a large figure that is greater than 21. The AC output voltage and current (eachphase) are shown in Figure 12.The PWM signals are as below in figure (13):




Figure(13): Phase A,B PWM (four switches)pulse signals of microcontroller.

## V. Implementation of Proposed Solar Energy System

The proposed solar power converter modeled according to previous sections, consist of DC Super-Lift DC/DC converter, a DC link connected in parallel, and a three phase inverter. The total conversion system is shown in figure(14). The DC/DC Super-lift converter has a MOSFET switch that its pulse provided by a PIC12F683 microcontroller, which is PWM signal following by a gate driver IC to reach enough voltage level to trigger switch's gate. The three phase inverter has six MOSFETs that their six pulses provided by sinusoidal PWM (SPWM) technique through PIC18F4431 microcontroller. The signal frequency is 50 Hz. There are three gate driver, each used for driving MOSFET gates of one leg of the inverter (each phase in three phase system.

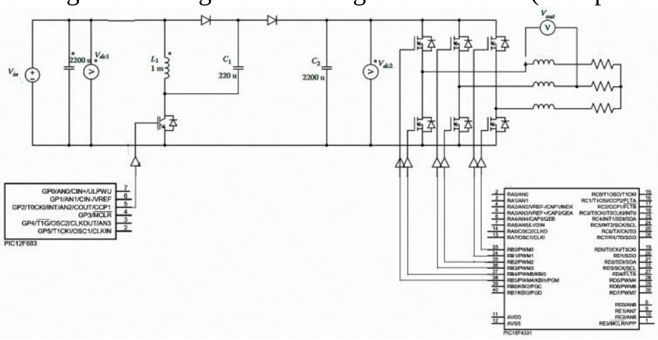


Figure (14): The circuit of proposed solar energy system.

According to figure (10) each output phase has a LC filter, that is necessary to receive pure sine wave for each phase without any distortion. The pulse signals which are the outputs of gate driver ICs has also a LC filter which is also necessary to provide suitable output voltage in each phase.

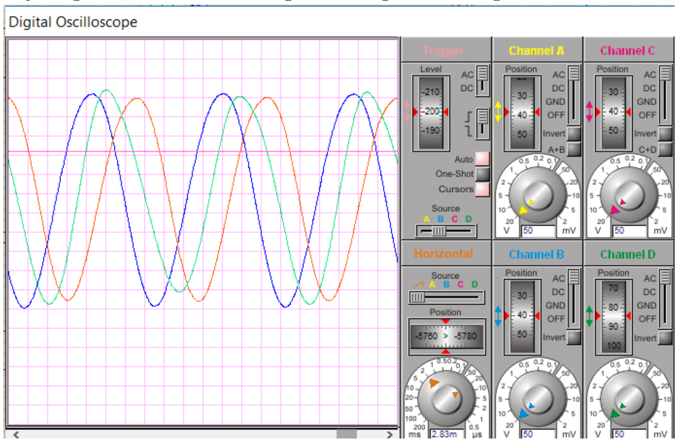



Figure (15): three phase symmetrical output voltage of the proposed solar energy system.

## VI. Conclusion

In this paper a new structure proposed for DC/DC/AC conversion system mostly use in solar energy systems. It consisted of an advanced DC/DC converter, namely, Super-Lift Luo DC/DC converter. In comparison to conventional boost DC/DC converters and other step-up converters, the proposed Luo converter has better efficiency and wider work period according to more flexible voltage gain and duty cycle.

Voltage lift (VL) technique has been successfully employed in the design of DC/DC converters and effectively enlarges the voltage transfer gains of the VL converters. However, the output voltage increases in arithmetic progression stage by stage.Super-lift (SL) technique is more powerful than VL technique; its voltage transfergain can be a very large number. SL technique facilitates the output voltage increase, in geometric progression, stage by stage. It effectively enhances the voltage transfergain in power series. The feedback used for output DC voltage of DC/DC converter. Comparing figure(5) with figure (8) shows that the output voltage of Super-Lift Luo converter is reach to desired level of voltage faster than conventional boost DC/DC converter, that can be of one of the advantage factors in choosing and implementation of Super-Lift Luo DC/DC converter. The combination of this converter with three phase inverter to form DC/DC/AC conversion system can also have desirable AC voltage,which can be use in commercial solar converters for secure and efficient connection to three phase electricity grid.

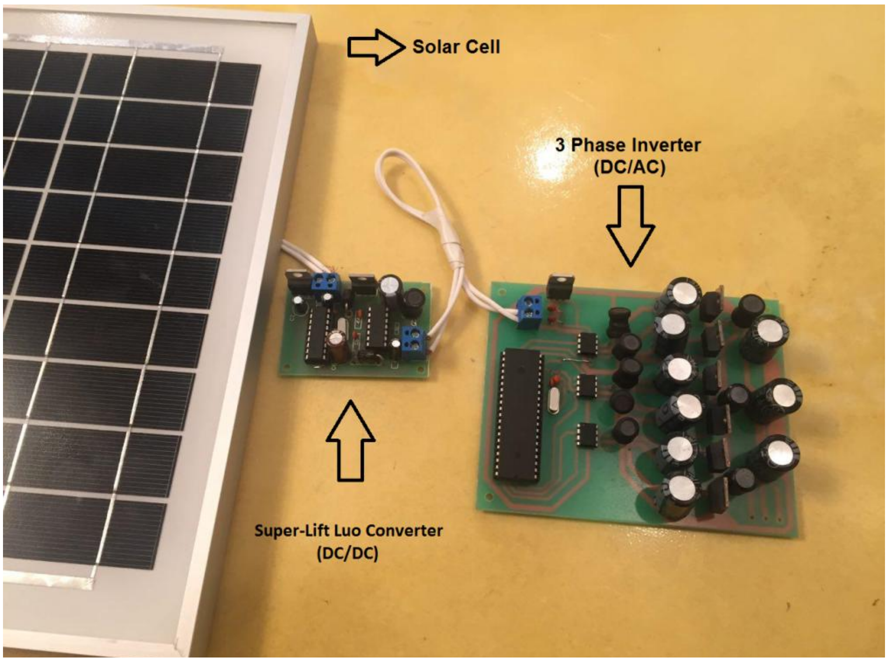



Figure (16): Implementation of Solar Energy system with proposed DC/DC/AC converter.

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