Hameed G. Juma'a and Thamir H. Atyia*

Electrical Engineering Department, University of Tikrit, Tikrit, Iraq

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Design a 91-Multilevel Inverter Circuit Using Solar PV System Sources

Abstracts/ *The process of power conversion reduces power stability while raising harmonics and losses. The benefits of multilayer inverter technology can help traditional inverters make up for their drawbacks. Technologies using multilevel inverters have lately acquired popularity as an affordable substitute for a variety of industrial applications. A few distinguishing features of this topology are a reduced component count, decreased switching losses, and an improved output voltage/current waveform. The reduction of harmonic components in the inverter output voltage/current is the most important requirement for multilevel inverters. Five distinct renewable energy sources make up the system that this study proposes. It is advised to use five PV solar systems with voltages of (1:3:5:15:21E) values. The complete DC sources were added together to provide a 91-level output voltage, which is (1:3:5:15:21E). The MATLAB application is used to design the system.*

Streszczenie*. Proces konwersji mocy zmniejsza stabilność zasilania, jednocześnie zwiększając harmoniczne i straty. Zalety wielowarstwowej technologii inwerterowej mogą pomóc tradycyjnym inwerterom nadrobić ich wady. Technologie wykorzystujące falowniki wielopoziomowe zyskały ostatnio popularność jako przystępny cenowo substytut dla różnych zastosowań przemysłowych. Kilka cech wyróżniających tę topologię to zmniejszona liczba elementów, mniejsze straty przełączania i ulepszony przebieg napięcia/prądu wyjściowego. Redukcja składowych harmonicznych w napięciu/prądzie wyjściowym falownika jest najważniejszym wymaganiem dla falowników wielopoziomowych. Pięć różnych źródeł energii odnawialnej tworzy system proponowany w tym badaniu. Zaleca się stosowanie pięciu systemów fotowoltaicznych o napięciach (1:3:5:15:21E). Kompletne źródła prądu stałego zostały dodane razem, aby zapewnić 91-poziomowe napięcie wyjściowe, które wynosi (1:3:5:15:21E). Do zaprojektowania systemu wykorzystano aplikację MATLA.* (***Projekt 91-poziomowy obwód falownika z wykorzystaniem źródeł systemu fotowoltaicznego***)

Keywords: Renewable energy, PV system, multilevel inverter, standalone, reduce switches.
Słowa kluczowe: Energia odnawialna, system PV, falownik wielopoziomowy, wolnostojący, przełączniki redukujące

Introduction

The use of renewable energy sources (RESs) has grown recently as a result of their durability, environmental friendliness, and independence, making them a reliable system that could displace conventional generation units. The primary drawbacks of fossil fuels are their ongoing maintenance requirements, finite supply, and contribution to climate change and ecosystem imbalance. These elements increase interest in creating and increasing RES-based power generation. As loads rise, more RES will be needed, making this a potential option for electrical technology applications to sustain the system [1]. There are many different types of RES, including geothermal energy, wind energy, solar energy, and other regenerative resources. Solar and wind energy are the most widely used RESs [2]. The main issue that RES may face is electrical energy production, which is represented in unregulated DC or AC power sources and must be converted into regulated DC or AC power [3]. When compared to fossil fuel units, RES continues to dominate the scene of stand-alone network local power production. RES are highly efficient and have low operating costs. This project presents photovoltaic (PV) system to provide a stand-alone system with excellent dependability and security under a variety of operating conditions (variable irradiations). Multilevel inverters are the best way to implement stand-alone inverters in the kilowatt range [4].

Inverters are used to convert DC electricity into AC power, which has an impact on the system's power and stability. Multilevel inverter (MLI) technology can be utilized to enhance power quality and stability. The key benefits of MLIs over conventional inverters include improved output voltage and current waveforms, less EMI, reduced size, and decreased Total Harmonic Distortion (THD). These benefits are representative of all the benefits of these inverters. In order to stress the importance of grid-connected and PV systems, the features of MLIs are condensed. New converters are then employed to enhance energy conversion in existing energy systems. The redesigned MLIs are prospective options for PV solar systems and other renewable energy systems,.

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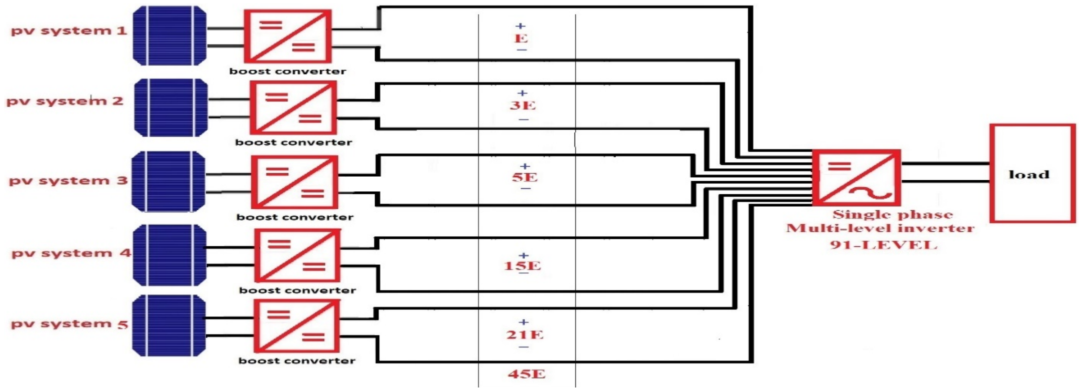
a)



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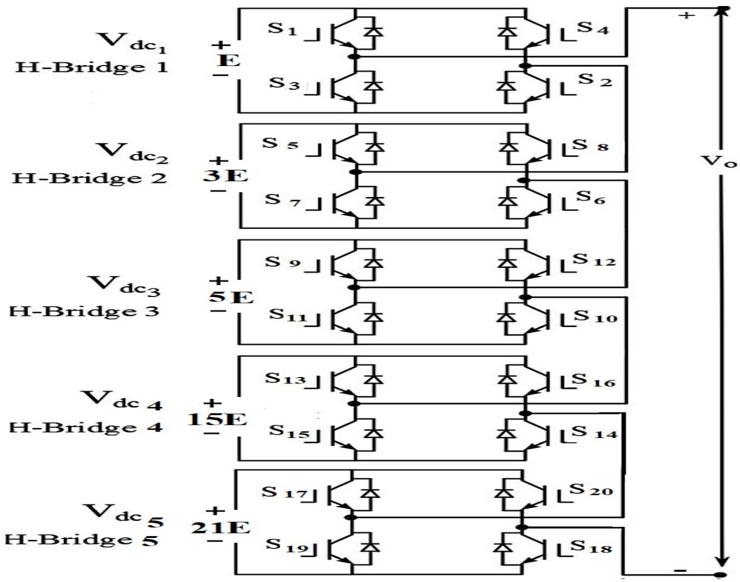

Fig. 1. (a) Proposed system (b) power electronics circuit.

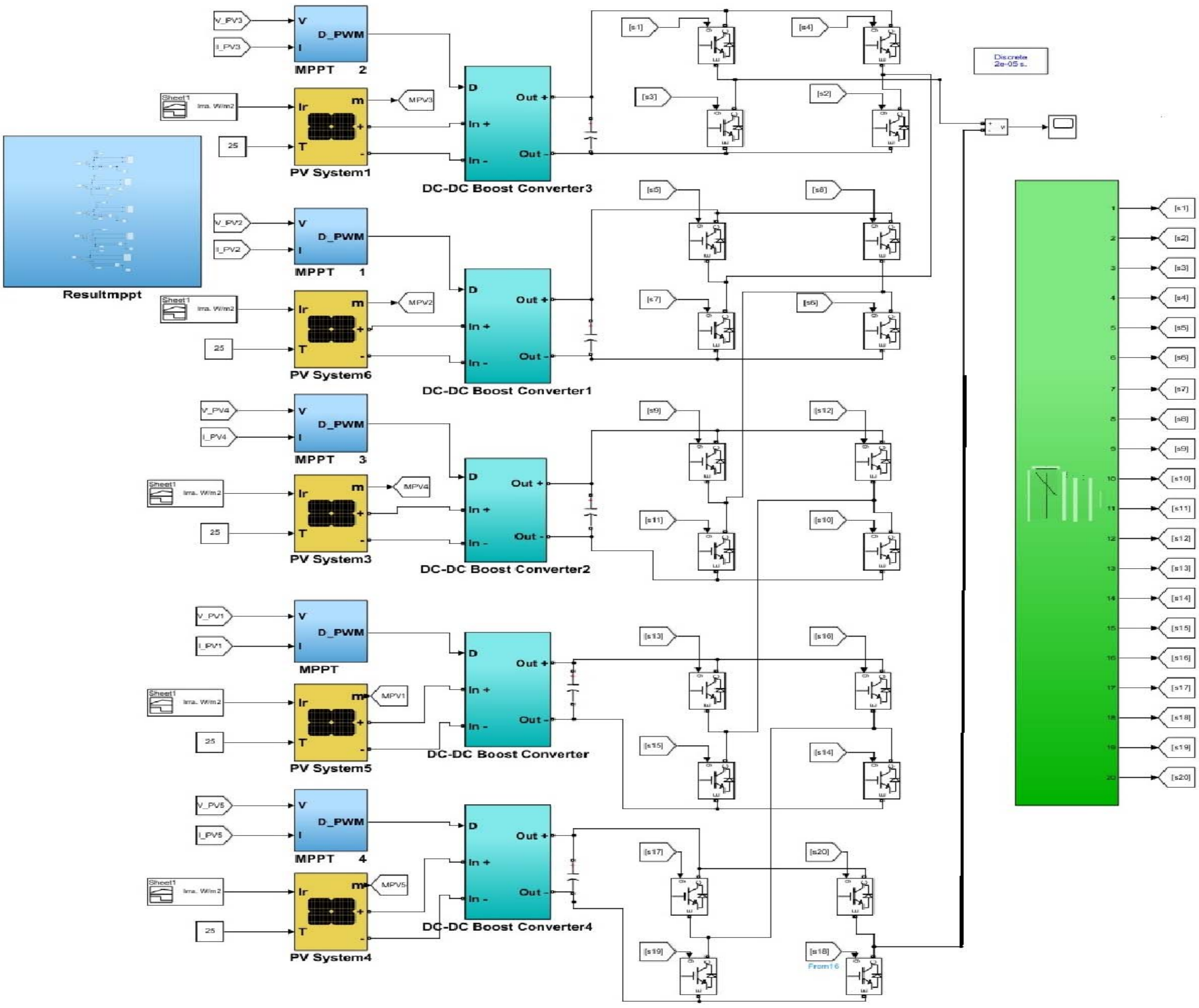

Fig. 2: Modeling circuit of the proposed system.

A single-phase cascaded H-bridge MLIs based on RES (PV-solar system) for a stand-alone system is planned and executed in this study in accordance with the aforementioned. A new logical switching Pulse Width Modulation (PWM) approach using five H-bridge cells generates an output voltage level with 91 levels. This study suggests the use of five PV-solar system and models them using the MATLAB/Simulink software. In order to provide a voltage of 91 levels, the power sources are configured thus (1:3:5:15:21E).

Configuration of the Proposed System

To reduce the negative effects of mismatches and improve the performance of the PV system, the PV cells must operate at different voltages to maximize utilization per PV module [5].To reduce the value of THD must increase the level's number of multilevel inverter [8]. The suggested system, represented in Fig. (1), is made up of a five PV solar systems with voltage (1:3:5:15:21E) are recommended, where (E) is the input voltage value of the H-bridge cell. The total number of dc sources was combined in the ratio (1:3:5:15:21E) to produce an output voltage with 91 levels (+45E to -45E). The MATLAB application models the suggested system as depicted in Fig (2).

PV Solar System

The photovoltaic effect is used in the PV system to convert sunlight into direct current (DC). To generate adequate voltage and power, the module needs many solar cells coupled in series or parallel [9]. Fig (3) depicts the PV cell's circuit diagram. To achieve the desired A DC-DC step-up converter is necessary for the DC bus voltage.. Using the MPPT algorithm technique, the maximum generation power of the PV solar system can be achieved. To maximize output power in solar systems, several control approaches or strategies can be used [10]. The Perturb and Observe (P&O) method is used in this study. Fig (4) depicts the (V-I) and (P-V) characteristics curves of the proposed PV systems. which is optimized according to the flow chart shown in Fig. 5.

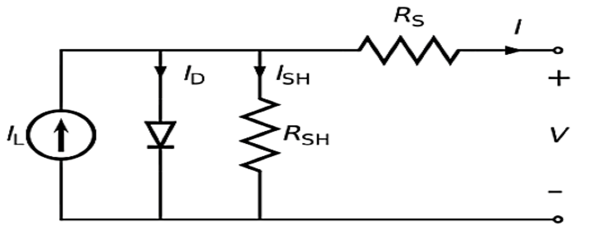

Fig. 3: Circuit diagram of PV-cell

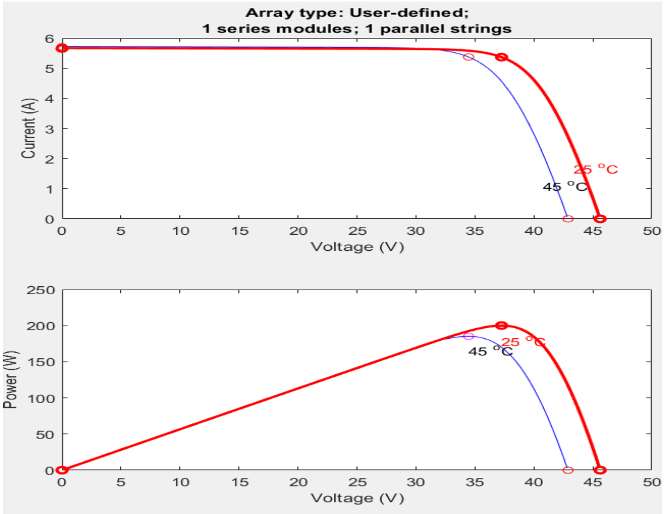

Fig. 4: The (V-I) and (P-V) characteristics of each solar panel

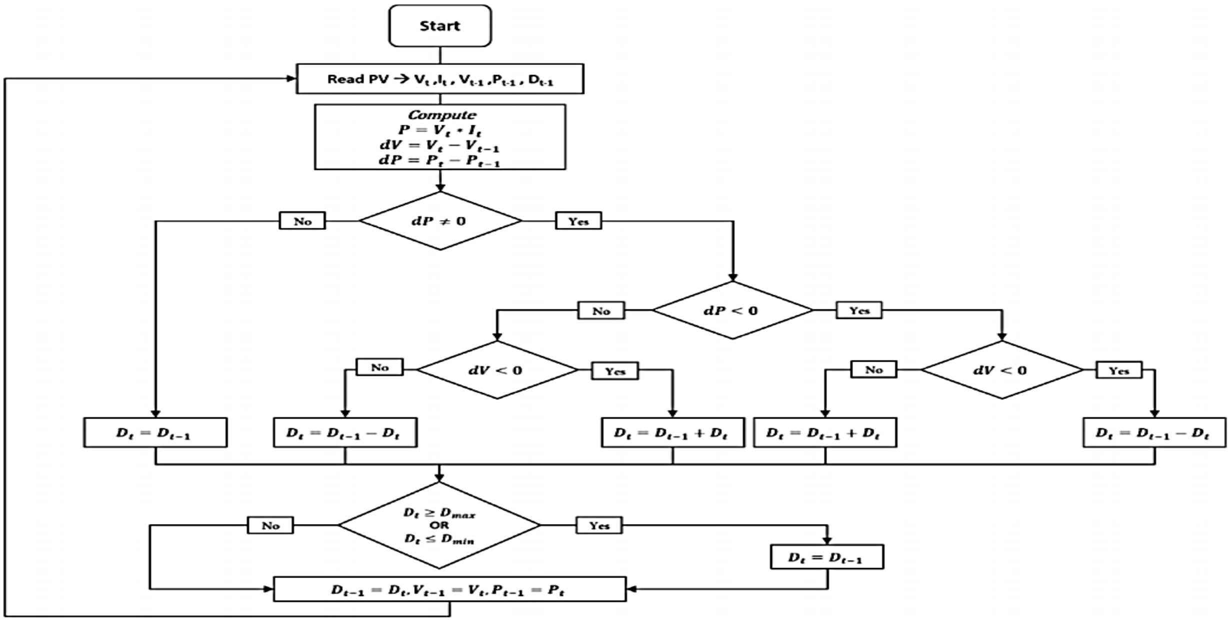

Fig. 5: Flow Chart of the P&O technique.

DC-DC Boost Converter

A DC-DC converter is a circuit that increases a PV cell's or PV array's output level using power electronic switches. A number of variables, including the switching devices used in the circuit, the switching methods used to switch those devices, the MPPT algorithms used to switch those devices, and more, affects these converter circuits' efficiency. Together with regulating the PV systems' maximum output power, these converters are crucial in the many applications for which they are utilized [13]. Fig. (6) depicts the boost converter's circuit diagram [7].

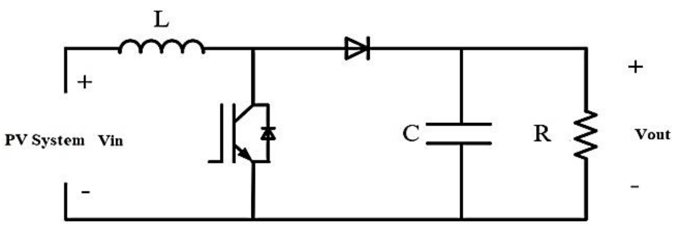

Fig. 6: Circuit diagram of DC-DC step up converter .

Table (1) Inverter output voltages and switching status

Levels	S 1	S 2	S 3	S 4	S 5	S 6	S 7	S 8	S 9	S 10	S 11	S 12	S 13	S 14	S 15	S 16	S 17	S 18	S 19	S 20
45E	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0
44E	1	0	0	1	1	1	0	0	1	1	0	0	0	1	1	0	1	1	0	0
43E	1	1	0	0	0	0	1	1	1	1	0	0	1	1	0	0	1	1	0	0
42E	1	1	0	0	1	0	0	1	1	1	0	0	1	1	0	0	1	1	0	0
41E	0	0	1	1	0	0	1	1	1	1	0	0	1	1	0	0	1	1	0	0
40E	1	1	0	0	1	1	0	0	0	0	1	1	1	1	0	0	1	1	0	0
39E	1	0	0	1	1	1	0	0	0	0	1	1	1	1	0	0	1	1	0	0
38E	0	0	1	1	1	1	0	0	1	0	0	1	1	1	0	0	1	1	0	0
37E	1	1	0	0	1	0	0	1	1	0	0	1	1	1	0	0	1	1	0	0
36E	1	0	0	1	1	0	0	1	1	0	0	1	1	1	0	0	1	1	0	0
35E	0	0	1	1	1	0	0	1	1	0	0	1	1	1	0	0	1	1	0	0
34E	1	1	0	0	0	0	1	1	1	0	0	1	1	1	0	0	1	1	0	0
33E	1	0	0	1	0	0	1	1	1	0	0	1	1	1	0	0	1	1	0	0
32E	1	1	0	0	0	0	1	1	1	0	0	1	1	1	0	0	1	1	0	0
31E	1	0	0	1	1	0	0	1	0	0	1	1	1	1	0	0	1	1	0	0
30E	1	1	0	0	1	1	0	0	1	1	0	0	1	0	0	1	1	1	0	0
29E	1	0	0	1	1	1	0	0	1	1	0	0	1	0	0	1	1	1	0	0
28E	0	0	1	1	1	1	0	0	1	1	0	0	1	0	0	1	1	1	0	0
27E	1	1	0	0	1	0	0	1	1	1	0	0	1	0	0	1	1	1	0	0
26E	1	0	0	1	1	0	0	1	1	1	0	0	1	0	0	1	1	1	0	0
25E	0	0	1	1	1	0	0	1	1	1	0	0	1	0	0	1	1	1	0	0
24E	1	0	0	1	1	1	0	0	1	0	0	1	1	0	0	1	1	1	0	0
23E	0	0	1	1	1	1	0	0	1	0	0	1	1	0	0	1	1	1	0	0
22E	1	1	0	0	1	0	0	1	1	0	0	1	1	0	0	1	1	1	0	0
21E	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	1	0	0
20E	0	0	1	1	1	0	0	1	1	0	0	1	1	0	0	1	1	1	0	0
19E	1	1	0	0	1	1	0	0	1	0	0	1	1	0	0	1	1	1	0	0
18E	1	0	0	1	0	0	1	1	1	0	0	1	1	0	0	1	1	1	0	0
17E	0	0	1	1	1	1	0	0	1	0	0	1	1	1	0	0	1	0	0	1
16E	1	1	0	0	1	0	0	1	1	0	0	1	1	1	0	0	1	0	0	1
15E	1	0	0	1	1	0	0	1	1	0	0	1	1	1	0	0	1	0	0	1
14E	0	0	1	1	1	0	0	1	1	0	0	1	1	1	0	0	1	0	0	1
13E	1	1	0	0	0	0	1	1	1	0	0	1	1	1	0	0	1	0	0	1
12E	1	0	0	1	0	0	1	1	1	0	0	1	1	1	0	0	1	0	0	1
11E	1	1	0	0	1	0	0	1	0	0	1	1	1	1	0	0	1	0	0	1
10E	1	0	0	1	1	0	0	1	0	0	1	1	1	1	0	0	1	0	0	1
9E	1	1	0	0	1	1	0	0	1	1	0	0	1	0	0	1	1	0	0	1
8E	1	0	0	1	1	1	0	0	1	1	0	0	1	0	0	1	1	0	0	1
7E	0	0	1	1	1	1	0	0	1	1	0	0	1	0	0	1	1	0	0	1
6E	1	1	0	0	1	0	0	1	1	1	0	0	1	0	0	1	1	0	0	1
5E	1	0	0	1	1	0	0	1	1	1	0	0	1	0	0	1	1	0	0	1
4E	0	0	1	1	1	0	0	1	1	1	0	0	1	0	0	1	1	0	0	1
3E	1	0	0	1	1	1	0	0	1	0	0	1	1	0	0	1	1	0	0	1
2E	0	0	1	1	1	1	0	0	1	0	0	1	1	0	0	1	1	0	0	1
1E	1	1	0	0	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1
0E	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1

By reflecting the cases of switches in the positive part, the negative part can be achieved.

The duty cycle (D) of the boost converter is calculated as [7]:

$$D = 1 - \frac{V_{in}}{V_{out}} \quad (1)$$

The inductor and the output capacitor of the boost converter are determined as [7]:-

$$L_{min} = \frac{D\,(1-D)^2\,R}{2\,f} \quad (2)$$

$$C = \frac{D}{R\left(\frac{\Delta V_o}{V_o}\right)f} \quad (3)$$

Where $\left(\frac{\Delta V_o}{V_o}\right)$ outputs ripple voltage is 1%, "*R*" is output resistance, and "*f*" is the frequency.

Multilevel Inverter (MLI)

Electricity electronics called inverters are used to convert DC power to AC power. High-power switching applications used in industrial sectors, electrical vehicles, and train traction drives are increasingly using MLIs made up of multiple switches [6]. MLIs have a number of benefits over traditional types, including lower THD, EMI, and dv/dt switch stress [14]. The MLI in this study is built using five cascade H-bridges with different DC voltage sources. To reduce the output THD value, a multicarrier PWM method with shifted levels is employed [13]. The multicarrier PWM utilized to generate a 91-volt level using a sine wave reference is depicted.

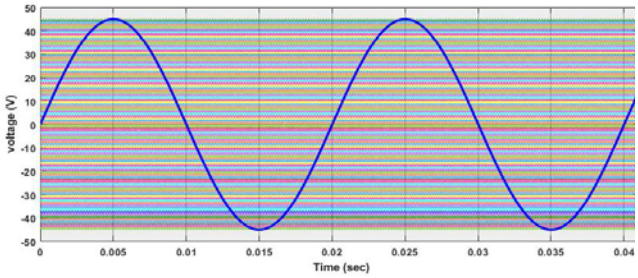

Fig. 7: Multicarrier PWM algorithm for 91- level inverter.

In this study, a 91-level inverter topology is used by connecting five cells in a cascaded fashion, as shown in Fig. (1). The five H-bridge units' input DC voltages (H5, H4, H3, H2, and H1) are in the form (1:3:5:15:21E), respectively. The output voltage is the algebraic sum of each cell's output voltage, which equals 45E. Table (1) describes the switching pattern of the proposed MLI

Simulation Results

The modeling MATLAB circuit of the proposed system is illustrated in Fig. (2). The system consists of a five PV systems with output DC voltages (40V, 120V, 200V, 600V and 840V respectively). Each 40-Volt is equivalent to E. The temperatures for all PV system are assumed to be constant 25C^{o}, while the irradiance is variable as shown in Fig. (8). The output power of the each panel is 200 W. The voltage and current values of each panel are 37.26 V and 5.37 A respectively. Fig. (9 a & b) shows the output voltage, current and power of the PV system for H1 and H2 cells which is consisting of (3*1) panels. While Fig. (9 c) shows the output voltage, current and power of the for H3 cell which is consisting of (3*2) panels and Fig. (9 d & e) the PV systems of H4 and H5 cells are consisting of three parallel strings and three series to get 800W (4*200W). Table (2) shows the parameters of the PV boost converters based on switching frequency of 4 kHz and the outputs ripple voltage is 1%. The inductor and the output capacitor of the boost converter in Table (2) are achieved by applying equations. (2) and (3). Figure (10) shows the output voltage of the boost inverters.

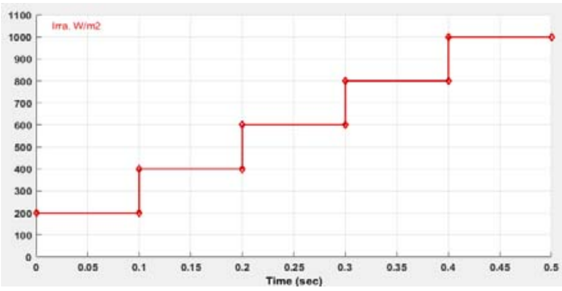

Fig. 8: The proposed irradiation

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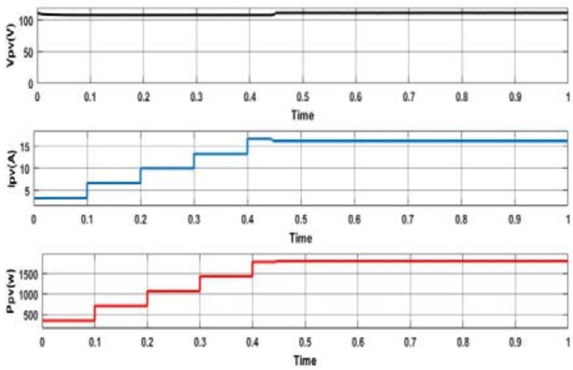

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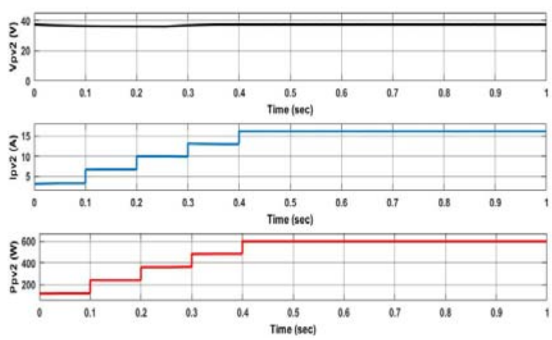
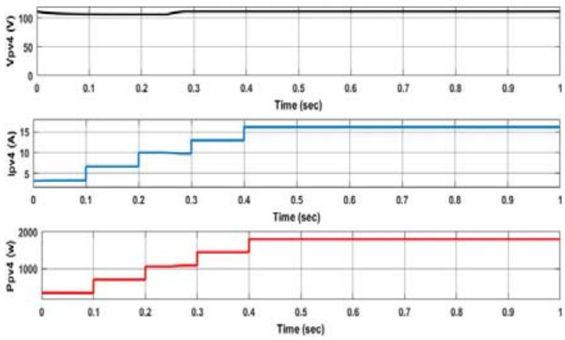
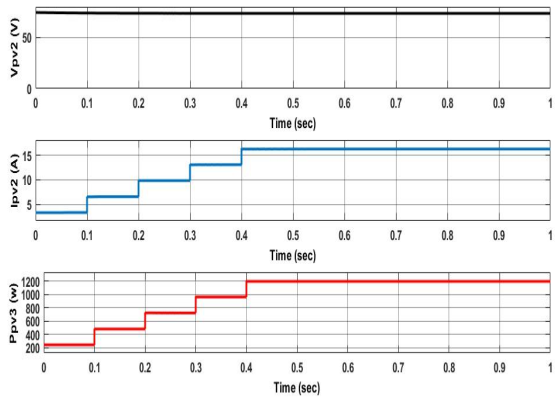


c)



d)



e)

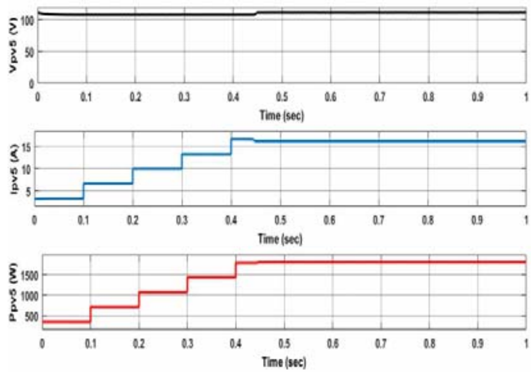
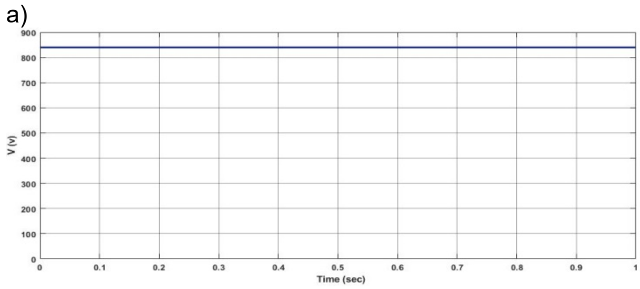


Fig. 9: The output PV voltage, current and power of the (a) H1cell (b) H2 cell (c) H3 cell (d)H4 cell and(e)H5 cell.

a)



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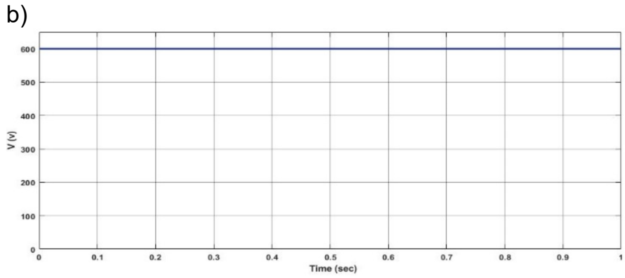

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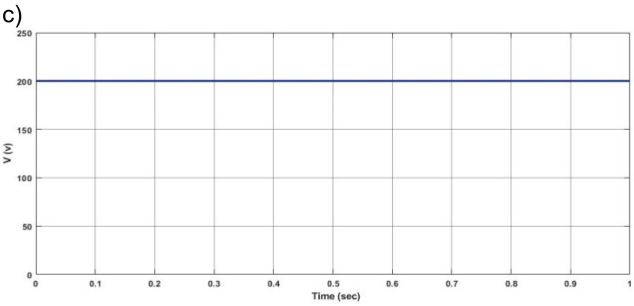

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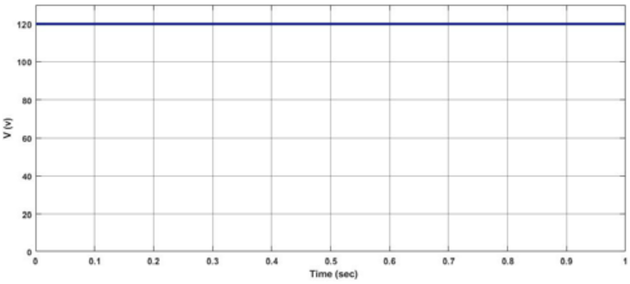

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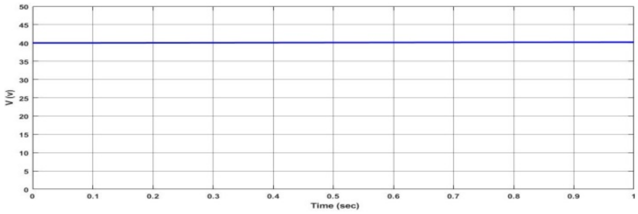

Fig.10: Output voltage of the boost converters of (a) H5-cell (b) H4-cell (c) H3-cell (d) H2-cell (e) H1-cell.

The control circuit is built using the multicarrier PWM technique, as shown in Fig. (11). To control the gate pulses, a simple PWM approach is used. A PWM pulse generator generates the gate pulses for the switches. Fig. (12) depicts the 91-level voltage waveform. The maximum value of harmonics at the low voltage side (below 1 kV) should be less than 5%, according to IEEE519-2014 harmonic standards. The THD value of the output voltage at 5000 HZ is 1.29%. Fig. (13) depicts the FFT spectrum analysis.

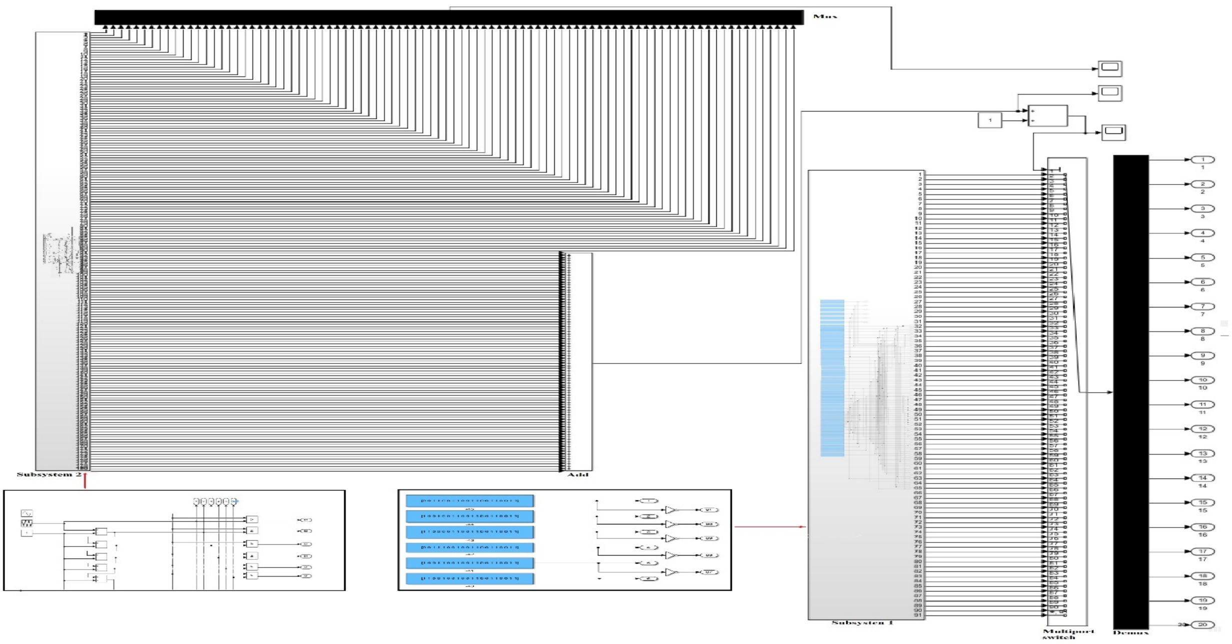

Fig.11: Modeling circuit of the suggested control system

Table (2) Boost converters parameters

Converter No.	Input voltage (V)	Output voltage (V)	Power (W)	Duty cycle	Inductor (mH)	Capacitor (uF)
1	37.26	40	400	0.76	0.14	760
2	37.26	120	400	0.69	0.21	690
3	74.52	200	600	0.63	0.27	630
4	111.78	600	800	0.81	0.09	840
5	111.78	840	800	0.86	0.05	860

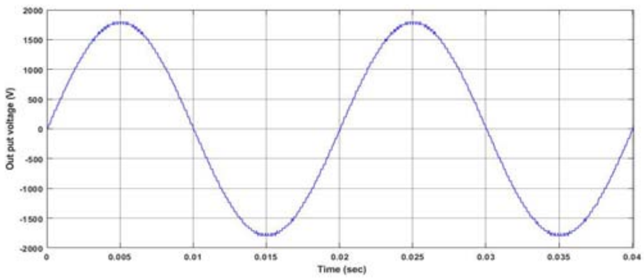

Fig. 12: The 91-level output voltage at 5000 HZ.

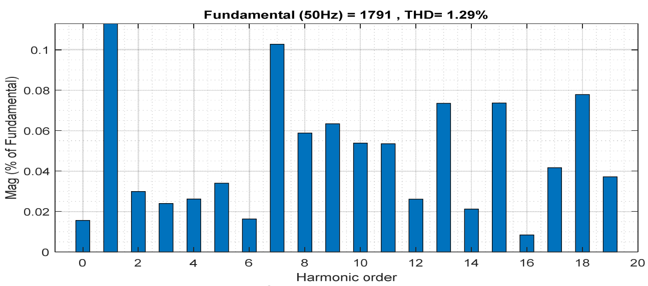

Fig. 13: The FFT analysis of the output voltage at 91-level.

Conclusion

In this study, a single-phase five-cascaded H-bridge cell based stand-alone system with 91-level output voltage based on PV-solar system has been designed and modeled. As energy sources, this study suggests five PV solar systems. The input power voltages are organized in the following way: (1:3:5:15:21) E. The multicarrier PWM technique was used in the design of the control circuit. The system produced positive results, which explains how well the power and control circuits were designed and suggested.

Authirs. Hameed G. Juma'a and Thamir H. Atyia*

Master Student, Electrical Engineering Department, University of Tikrit, Tikrit, Iraq

** Assist. Prof., Electrical Engineering Department, University of Tikrit, Tikrit, Iraq*

E-mail: dr.thamir.atyia@tu.edu.iq

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