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Simulation and Experimental Modeling of Inverter Triggering Circuits Using Zero-Crossing Detector (ZCD) Based on Microcontroller

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KEYWORDS:
Zero crossing detector, Microcontroller, Inverter, Synchronization, Triggering pulse, Interrupt.

***Abstract*—A zero-crossing detector (ZCD) is one type of synchronization method. An impulse is generated by the ZCD circuit when the AC sine wave crosses zero. The width of this impulse circuit has a bad effect on the working of other circuits. The width of this impulse is dependent on the elements used. The circuit output will be studied by generating two complementary pulses for the inverter. ZCD circuit facilitates the integration of photovoltaic (PV) power systems with other systems. The proposed design can be a good choice to allow connection for different sources for certain loads. Such as in the case of isolated load or microgrid feed by different distributed generators, such as synchronous generator (diesel) and PV. There is a big challenge to choose high-quality elements of the ZCD circuit to generate the accurate impulse, leading to higher performance of the used system. So, this paper will study two elements. Transistor 2N3904 and optocoupler 4N27 are used and the obtained results are compared and analyzed to choose the suitable one. The system used is designed once based on the transistor and then with an optocoupler. Finally, the results obtained from the different designs are compared and analyzed. The proposed system is simulated based on Proteus software and the corresponding results are clearly depicted with detailed analysis and compared with an experimental prototype that is accurately created. It is found that there is a good agreement between the simulation and the experimental results, which inform the quality of the designed system.**

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I. INTRODUCTION

BILLIONS of people reside in remote and rural areas, where the power grids are unreliable or non-existent [1], [2]. In remote and rural areas people usually depend upon diesel generators to fulfill their requirements but due to the increase in the cost of fossil-based fuels in addition to the cost of transportation, a need for other sources of energy has been raised to assist in cover the electricity demands of the consumers in those areas. Indeed, remote and rural areas are well endowed with solar sources, especially in the regions of the Sun Belt. Integration of photovoltaic power systems with a diesel generator is the way to tackle and reduce the dependency on fossil fuels, which are known to deplete sooner or later [3]. Integration of renewable energy sources into the grid would assist in expanding electricity access. Renewable energy sources such as wind or solar are often the most efficient option for making electricity available for those people [4], [5].The combining of two or more kinds of components that produce the same results is called a hybrid system. Hybrid renewable energy systems include PV-battery, PV-diesel, wind-battery, wind-diesel, PV-wind-battery, and PV-wind-diesel-battery systems [6], [7]. Hence, different methods based on Fourier transforms, zero-crossing detection (ZCD), Kalman filters, phase-locked loops, and others are present nowadays for this synchronization [8], [9].Two different types of synchronization methods can be identified in the literature first one is oriented to the phase-locked loop (PLL) method and the second one is oriented to the ZCD method [10]-[20]. The phase-locked loop is a common technology to obtain phase information. Nowadays with the rapid development of renewable energy technology, PLL has been widely used in the grid synchronization of the distributed power generation systems. A zero-crossing detector is simple and easy to implement to obtain grid information such as phase angle by detecting the zero-crossing point of the utility voltages and is reported in [21], [22] as being robust to a small amount of distortion. Generated power by renewable energy systems, such as solar photovoltaic and wind energy, can be injected to the grid by means of power electronic converters. In this paper ZCD method is used to generate gate pulses for these converters. This paper aimed at modeling triggering circuits for inverters using a simple ZCD method and examines the ZCD circuit with two different components a transistor and an optocoupler. The zero-crossing detector method has been used in this paper to synchronize a PV power system with a diesel generator for a standalone PV power system and it is accomplished by taking frequency into consideration.

The manuscript is organized as follows: part 1 contains the description of the ZCD circuit and a discussion of simulation, and experimental results. Part 2 presents the design and implementation of the proposed inverter circuit, synchronization of the PV power system with a diesel generator, and ended with a discussion of simulation and experimental results.

II. ZERO-CROSSING DETECTOR

The zero-crossing detector can quickly detect the zero-cross point of the AC signal and immediately notify the micro-controller that the zero-cross occurred [23], [24]. The main components used in the ZCD circuit are represented in the block diagram of the zero-crossing detector circuit, Fig.1.

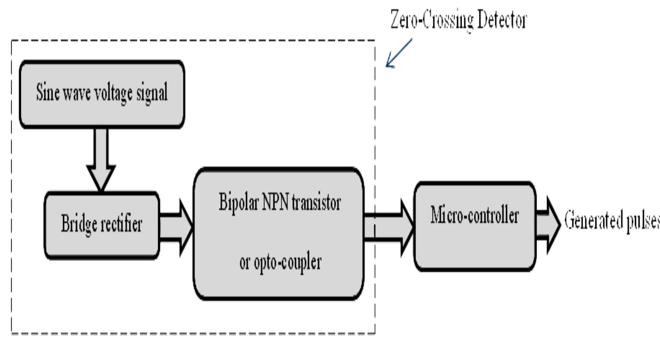

Fig. 1 Block diagram of ZCD circuit coupled with the pulse generator

The zero-crossing detector circuit in this paper is constructed with NPN transistor 2N3904 and coupler 4N27. The overall schematic of the zero-crossing detector circuit is shown in Fig.2.

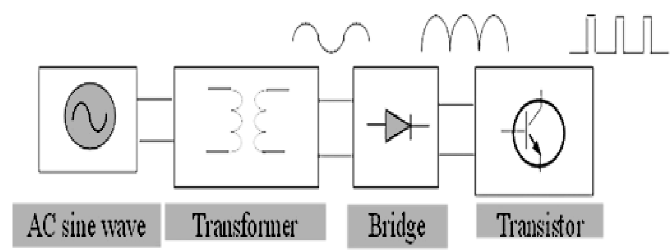

Fig. 2 Overall schematic of ZCD circuit

A small voltage signal from a diesel generator is used to generate triggering pulses synchronized with the AC source. A small sine wave voltage signal is obtained by decreasing the AC voltage with the help of a transformer. Because of the transformer, this circuit has complete galvanic isolation with the mains supply so that it is risk-free from destroying the microcontroller. A transformer with specifications of *(220/ 9) V* and *500 mA* is used to achieve the previous purpose. A full-bridge rectifier circuit is used to convert a negative half cycle of AC voltage source into a positive half cycle.

NPN type of transistor is used in the circuit because their majority charge carriers are electrons which have high mobility as compared to holes. Transistor is used to detect the zero-cross of AC sine wave. Transistor remains on for most of the cycle except when the AC sine wave "crosses zero logic" (which is equal to $V_{BE\ (sat)}$, *0.65V* for the transistor used in this study). Transistor has a type of 2N3904 with a specification of, $I_{C(sat)}$ = *200mA*, V_{CEo}= *40V* and h_{FE} = *60*, are used in this paper. The transistor in the ZCD circuit must be of a high switching time. This means that $t_{(ON)}$ and $t_{(OFF)}$ must be chosen with very small values. The transistor circuit contains two resistors elements, R_1 and R_2 as shown in Fig.3. These resistors are connected with the transistor base as well as its collector. The design of these resistors requires technical data from the transistor datasheet. These are $I_{C(sat)}$,$V_{BE(min)}$,V_{CC},$V_{CE(sat)}$, and h_{FE}. The transistor circuit consists of two resistors R_1 and R_2. Resistor R_1 is connected with the base and R_2 with the collector.

The maximum I_C is equal to *200mA*. According to this value, we can specify the value of base current that will ensure the transistor's working in the saturation region.

$$I_C = h_{FE} * I_B \quad (1)$$

where I_B is the base current.

I_B is found equal to *3.33mA*. The suitable value of the base resistor $R_1$is calculated as follows:

$$V_{in} - I_B * R_1 = V_{BE\ (sat)} = 0 \quad (2)$$

where V_{in} is the input voltage of the transistor.

The calculation is carried out with the peak value of V_{in}, which is equal to *12.73V*. With the help of equation (2) and base current obtained from equation (1), base resistor R_1 is found to be *2.2K*Ω. Usually, a resistor of *10K*Ω is employed as a pull-up resistor which is named as R_2 in this circuit as shown in Fig.3. This value prevents the microcontroller pins from short-circuited with V_{CC} while also using a low amount of current. The coupling of the microcontroller together with the ZCD circuit named as a synchronization circuit.

Synchronization circuit is performed with Arduino Mega2560. The microcontroller receives an impulse generated by the ZCD circuit to generate two complementary triggering pulses synchronized with this impulse.

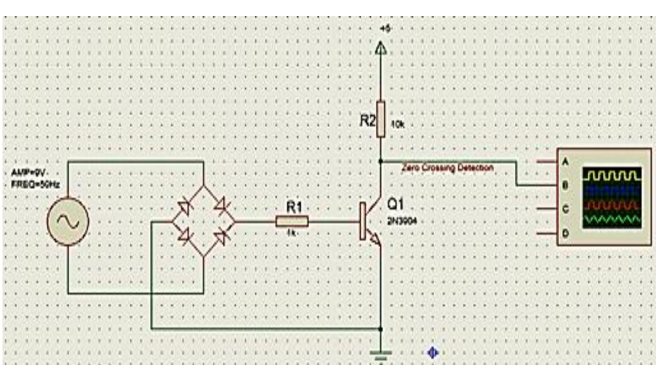

Fig. 3 Protous schematic of ZCD circuit

III. PROPOSED ZERO-CROSSING DETECTOR DEVICE

Fig.4 shows a prototype of the ZCD circuit with Arduino Mega2560. The ZCD board contains both a transistor and an optocoupler. The initial design of the device is examined with many steps and the two components to decide the suitable component with the best results. The device is first examined with the transistor and then with an optocoupler.

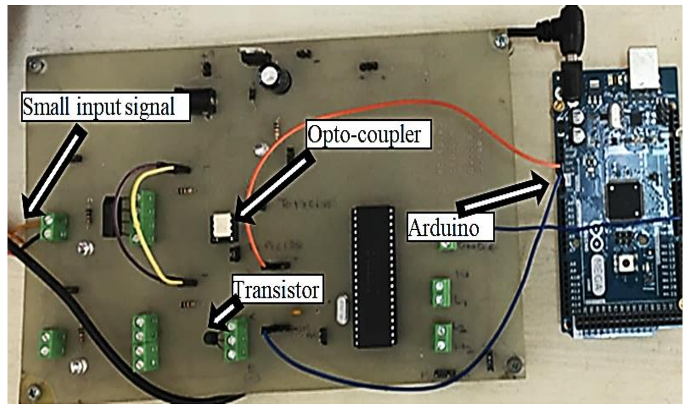

Fig.4 Picture of prototype of ZCD circuit

Microcontrollers *'0'* logic and *'1'* logic values are important in the design of the synchronization circuit. The output value of the transistor in ON state equal to the value of $V_{CE(sat)}$, which is equal to *0.2V* for transistor 2N3904. The output value of the transistor in the OFF state is equal to V_{CC}. Arduino pin *2* is used as an input pin, and pins *9* and *10* are used as output. The output from pins *9* and *10* are sent to the driver circuit of the inverter.

IV. SIMULATION RESULTS

ZCD circuit is now simulated for each of the two elements, a transistor, and an optocoupler.

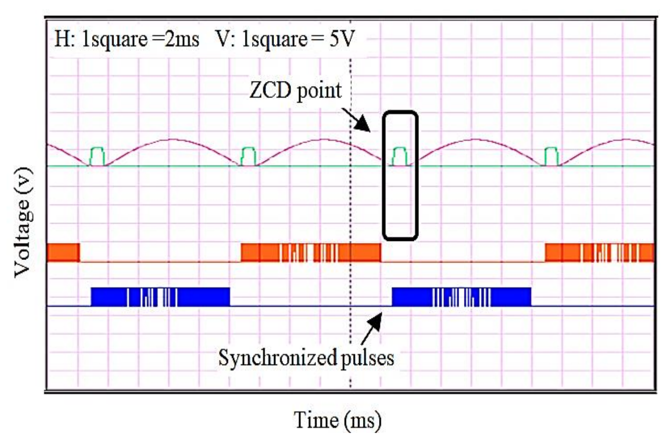

Fig. 5 Pulses synchronized with ZCD small signal in case of a transistor

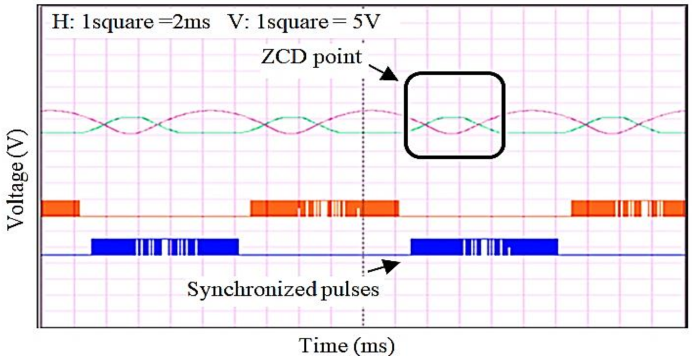

Fig. 6 Pulses synchronized with ZCD small signal in case of an optocoupler

As it is depicted in Fig.5, transistor 2N3904 produces a small signal (impulse) at every zero-cross of AC sine wave. The width of this impulse is found to equals *1ms*. Fig. 5 and Fig.6 show the pulses generated at pins *9* and *10* of Arduino Mega2560. The triggering pulse width is *9ms* with a dead time of *1ms*. Triggering pulse width is specified by the designer. The value of $V_{BE\ (sat)}$ affects the width of the impulse. As a transistor with a small value of $V_{BE\ (sat)}$ is selected, an impulse with less width is produced.

In the case of the optocoupler, the width of the small-signal is found equals to *5ms*. The width of signal produce with ZCD affects the triggering pulses generated by the microcontroller that is observed in simulation by the oscillation of pulses as well as while doing the experiment in fluctuations of lamps light. While writing the code, the width of this small signal should be taking into consideration.

Arduino Mega2560 in Fig.4 is replaced with PIC16F877A to study the performance of different microcontrollers within the circuit. The difference is observed in the time starting of triggering pulse generated by the microcontrollers, Arduino Mega2560 and PIC16F877A. The difference can be referred to the latency of the microcontroller.

V. EXPERIMENTAL RESULTS

The prototype in Fig.4 with transistor 2N3904 and optocoupler 4N27 is now practically examined.

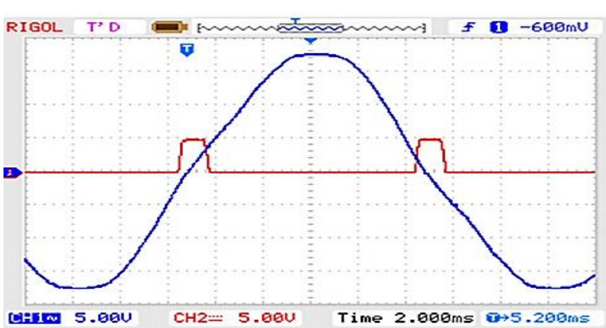

Fig. 7 Zero-Cross points at each zero-crossing point of AC sine wave

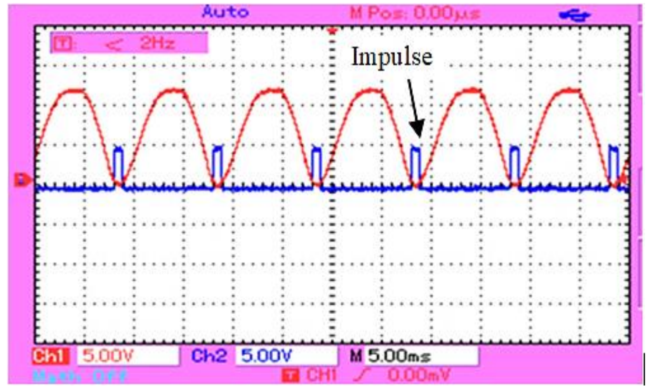

Fig. 8 Rectified pulsating DC voltage and zero-crossing points

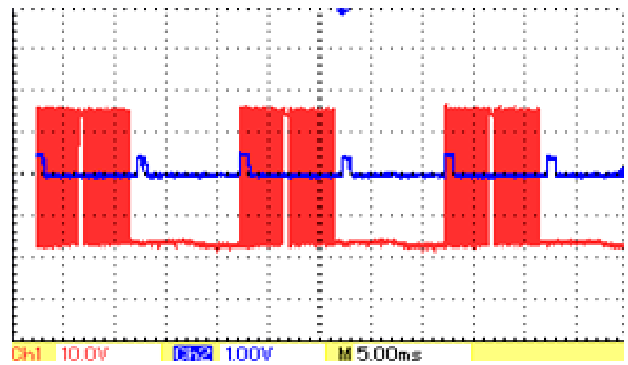

Fig. 9 Pulse synchronized with impulse generated by ZCD circuit

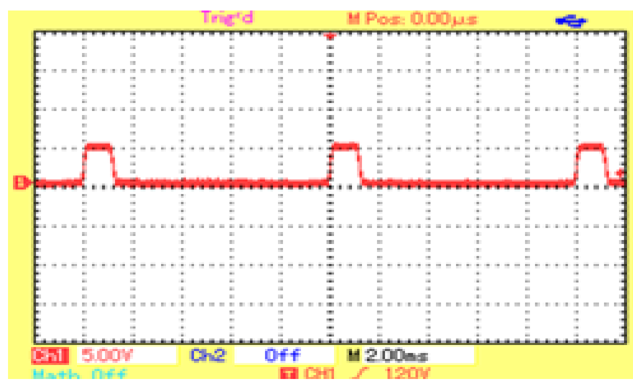

Fig. 10 The impulse generated with an optocoupler

As it is clear in the above results, the ZCD circuit maintains the expected behavior. The results are shown in figures 7, 8, 9, and 10.

Fig.7 depicts the generation of impulses at every zero-cross of AC sine wave voltage. The width of this impulse is specified by the type of elements used. Fig.8. shows the rectified pulsating DC voltage and impulses. This rectified voltage is supplied to the input of the transistor and according to it an impulse is produced at the output terminals of the transistor. Fig.9 depicts the synchronization of generated SPWM pulse with the impulse produced by ZCD circuit in case of transistor element. The width of the SPWM pulse is equaled *9.2ms* and can be change in the code by the designer according to design requirements. The width of the impulse (small-signal) equals *0.8ms.*

Fig.10 represents the impulse produced by the optocoupler and the width is observed to be *1.4ms.* This value is approximately twice that in case of transistor. For this reasons a transistor is selected in this design.

VI. PHOTOVOLTAIC MODULE

PV cells provide DC supply to the inverter. The characteristics of the PV module used in this design are given in Table 1. This PV module provides approximately *44V*, which is then boosted to *311V* with a booster. Fig.11 illustrates the photovoltaic modules used.

TABLE 1

PHOTOVOLTAIC MODULE CHARACTERISTICS
SOLAR MODULE TYPE: JKM435M-78H-V

Maximum power (P_{max})	435W
Maximum power voltage (V_{mp})	43.55V
Maximum power current (I_{mp})	9.99A
Open circuit voltage (V_{OC})	51.61V ±3%
Short circuit current (I_{sc})	10.67A±4%
Maximum system voltage	1500V DC
Maximum series fuse rating	20A

Fig. 11 Photovoltaic modules

VII. DC/AC INVERTER

A DC/AC power inverter is used to convert the DC input voltage gathered from PV cells into AC voltage. DC/AC inverter takes the DC voltage at the input and provides AC output voltage and frequency as per desired design specifications to the load. A low input DC voltage from PV cells is boosted to a *311V* with a DC/DC booster. The design of the DC/AC inverter is an important part of this paper as its functionality determined the success of the design of the entire system. In this paper, the voltage source inverter (VSI) is presented to obtain a sine waveform at the inverter output. The block diagram of the complete designed inverter is given in Fig. 12. It consists of two parts, a control circuit, and a power circuit. The control circuit contains a microcontroller (Arduino Mega2560 board), and a drive circuit. The power circuit consists of power switches (H-bridge inverter) and filters. The required output from this inverter circuit is a *220V (rms)* of *50 Hz*.

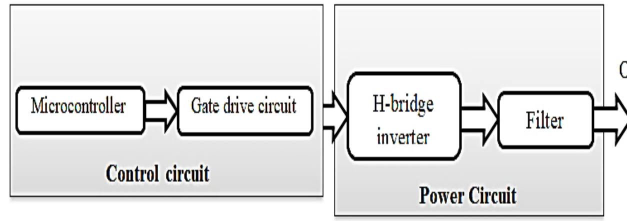

Fig. 12 Block diagram of the complete designed inverter

H-bridge inverter is the commonly used topology that contains four switches as shown in Fig.13. Each pair of switches is operating alternately. That means when S_1 and $S_2$are opened, S_3 and S_4 are closed and when S_1 and S_2 are closed, S_3 and S_4 are opened. The switches on the same arm, S_1 and S_4 or S_3 and S_2, must not work simultaneously to avoid a short circuit.

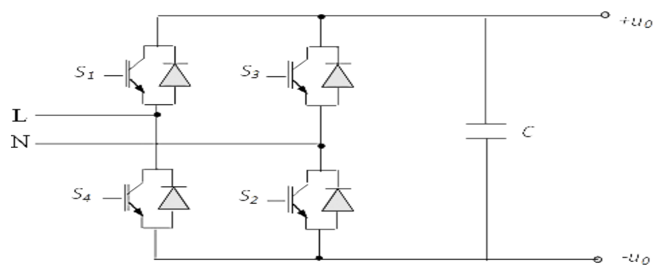

Fig. 13 DC/AC H-bridge converter

7.1 Microcontroller

Arduino Mega2560 is used as a pulse generator in this design. Arduino Mega2560 is a microcontroller board-based sinusoidal pulse width modulation (SPWM) generator for the inverter for photovoltaic applications. Arduino Mega2560 is an *8*-bit board with *54* digital pins, *16* analog inputs, and *4* serial ports, a *16MHz* crystal oscillator. Arduino Mega2560 is able to store the commands required to produce SPWM.

The sine look-up table is created with a fixed number of samples of a sinusoidal within a predefined frequency. These values are initialized at the beginning of the program code in Arduino software to generate SPWM signals. The look-up table serves as the virtual sine reference wave. The width of the pulses generated is modulated to obtain the inverter output voltage control and to reduce harmonic. Arduino generates two complementary SPWM pulses after being receiving the signal from the ZCD circuit. ZCD acts as a reference signal for the control pulse. These pulses control the opening and closing of the gate of the four switches of the inverter. Pulses are then sent to the gate driver circuit. Arduino Mega2560 generates a *4 KHz* SPWM switching signal. Therefore, the complete cycle of sinusoidal output will contain *80* samples.

7.2 Sinusoidal Pulse Width Modulation

SPWM method gives the nearest wave to a pure sine wave by increasing the switching frequency. SPWM technique is characterized by constant amplitude pulses with different duty cycles for each period. The pulse width is modulated to control the output of the inverter and to reduce the harmonics content [25], [26].

7.3 Gate Driver

Gate drive circuit has two main functions, isolation between high and low power circuits and amplifying the microcontroller signal. The power of signals generated by Arduino is not sufficient to open and close the switches. Therefore gate drive circuit is placed in between to supply the switches with suitable power to ensure the opening and closing of switches. Gate driver TLP250 is employed for this design. TLP250 is a high-speed linear optocoupler with an *11mA* supply current. For diode side input of *5V*, it will need a *470*Ω resistor to supply a suitable driving current. TLP250 consists of a light-emitting diode (input) and an integrated photo-detector (output). TLP250 is suitable for the gate driving circuit of IGBT or power MOSFET. Four TLP250 drivers are required, one for each IGBT of the H-bridge inverter. Fig. 14 illustrates the pin configuration of TLP250.

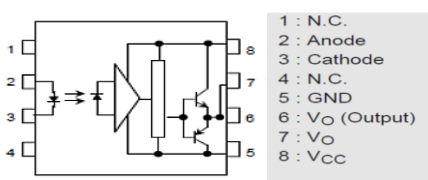

Fig. 14 Pin configuration of TLP250

Fig. 15 provides the drive circuit diagram of the inverter circuit. Each switch of a single-phase inverter will require a separate drive circuit. Therefore four drives circuit are required for the design of this inverter. The drive circuit contains a center-tape transformer, two diodes, and two capacitors C_1 and C_2 each of *100µF*. By this circuit, voltages of *+17V* and *-17V* are obtained. These voltages are used to supply TLP250 at pins *8* and *5*, respectively to drive the inverter. Because of gate capacitive features in IGBTs, discharging of IGBTs takes time. With this circuit, IGBTs are discharged quickly. Capacitors C_3 and C_4 have values of *100µF*, and capacitors C_5 and C_6 have values of *0.1µF*.

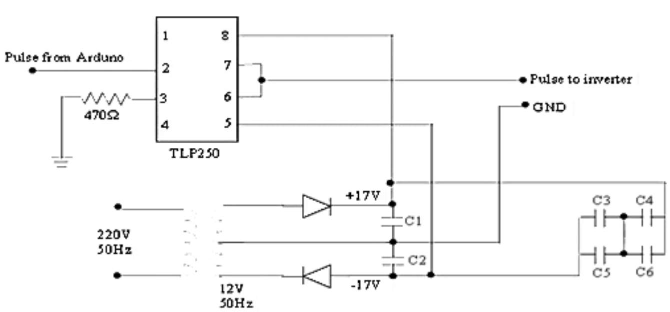

Fig. 15 The drive circuit hardware diagram of the inverter circuit

7.4 Power Switches

Two types of switches for the H-bridge inverter are usually considered. Metal-Oxide Semiconductor Field Effect Transistor, MOSFETs and Insulated Gate Bipolar Transistor, IGBTs. After comprehensive considerations and burning of many MOSFETs, IGBTs are selected to use in this design. H-bridge inverter contains four IGBTs acting as high switching switch. It is known that in a bridge inverter the highest voltage a single switch will experience while off is equal to the voltage of the DC power rail, which is in this case equal to *311V*. A safety margin above this voltage as well, with doubling the value being a good idea. Switch rating voltage of *500-600V* is a good choice. A *1kW* output power is a target with this design for the load characteristics of a single-phase induction motor given in Table (2). This means that the maximum rated current will be *4.55A*. In addition to this, switch needs to be relatively fast switching. IGBT type 2MBI100U4A is used in this design. Cooling devices composed of fans and heat sinks are also employed in this design.

The bridge inverter consists of four switches, two on each arm that allows the voltage to be applied across the load in either direction. The four switches must be identical.

DC/AC inverter has two inputs. One of the DC/DC booster and the other is the gate triggering signal generated by the microcontroller. The microcontroller synchronizes the inverter output with the diesel generator signal. A snubber capacitor of *2µF*, *400V* is connected across the inverter to protect it from the high surge voltages. The final design is simulated in Proteus software, and to validate the output results a prototype is constructed.

TABLE 2
SINGLE-PHASE INDUCTION MOTOR DATA

Power	**550W**
Current	1.6A
Voltage	220V
Frequency	50Hz
Speed	1390 rpm
Capacitor	20µF

VIII. SYNCHRONIZATION OF PV POWER SYSTEM WITH DIESEL GENERATOR

This part of the paper aims to generate triggering pulses for an inverter to be synchronized with a diesel generator. Basically, PV systems complement the diesel generator sets. PV power systems can supply extra energy when loads demands are more than the capacity of the generator set or to minimize the fuel consumption. Voltage, frequency, and phase of inverter output must be synchronized with the waveform of the diesel generator.

A proposed synchronization system of PV power system with a diesel generator is shown in Fig.16. A small AC signal waveform from a diesel generator is taken as a reference for generating triggering pulses of inverter switches. Arduino Mega2560 received a signal from the ZCD circuit and according to this signal it generates two complementary SPWM pulses.

SPWM signals produced with Arduino Mega2560 are ensuring that the output voltage at inverter terminals is of the same frequency as that of the reference source. This results in the synchronization of the inverter output with the diesel generator.

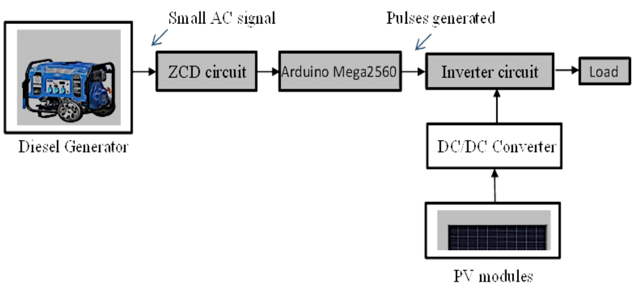

Fig. 16 Proposed synchronization of PV power system with diesel generator

In this paper, the inverter output is synchronized with the diesel generator in terms of frequency only using zero-crossing detector method.

IX. INVERTER STRUCTURE

Inverter circuit simulation model in Proteus schematic is shown in Fig. 17. Simulation results are shown in figures 19 and 20. A prototype of the complete designed inverter is shown in Fig.18. The results are presented in figures 21 and 22.

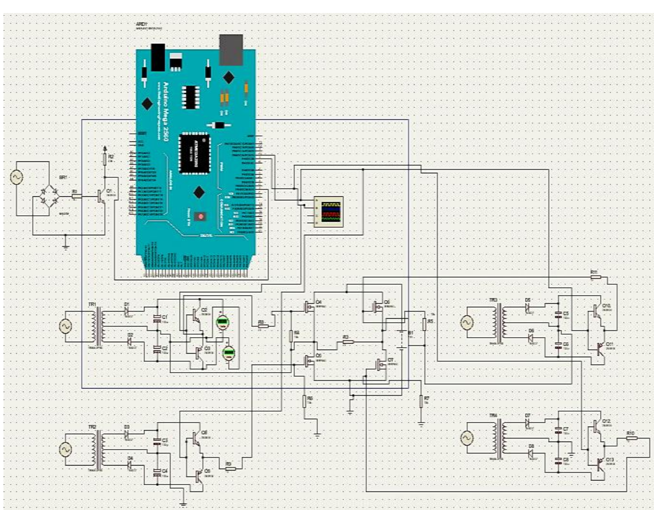

Fig. 17 Proteus schematic of inverter

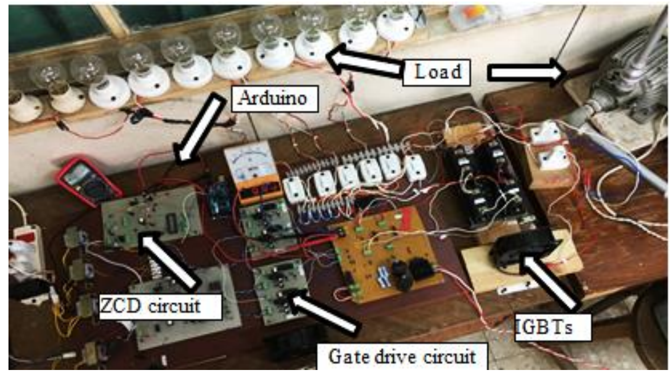

Fig. 18 Proposed hardware prototype of inverter

Fig.18 represents the proposed hardware prototype of the implemented inverter circuit. Inverter designed is finally tested with different loads. First, tested with a static load, *200W*, *400W*, *600W*, and *800 W* resistive load (lamps). Second, tested with dynamic load represented by a single-phase induction motor having characteristics are given in Table (2). Recorded readings for static load are given in Table (3).

TABLE 3
RECORDED READINGS FOR STATIC LOAD

S.NO.	Input (DC)			Output(AC)			Efficiency %
	V_{in} (V)	I_{in} (A)	P_{in} (watt)	V_{out} (V)	I_{out} (A)	P_{out} (watt)	
1.	200	0.83	166	190	0.73	138.7	83.5
2.	200	1.5	300	188	1.4	263	87.7
3.	200	2.2	440	187	2.1	392.7	89.3
4.	200	2.8	560	186	2.75	511.5	91.3
5.	200	3.5	700	185	3.5	647.5	92.5

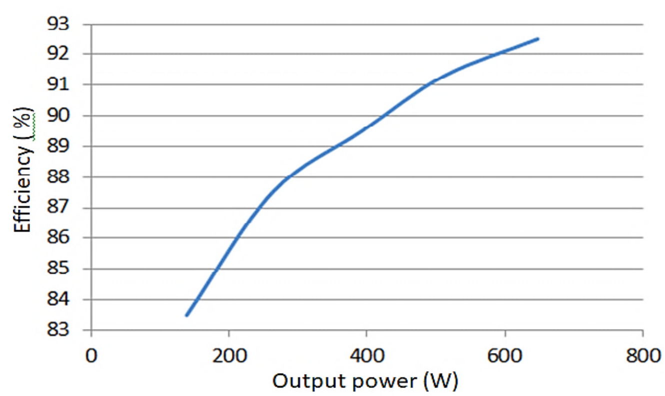

Fig. 19 Efficiency against output power curve

According to Table 3 curve of efficiency against output power is plotted as it is shown in Fig.19. From this figure and Table 3 it is observed that the efficiency is low at low loads and increase as the load increased. The efficiency has its highest value at full load.

X. SIMULATION RESULTS

Simulation of the complete circuit of the inverter has been performed with Proteus version 8. Compiled hex file from Arduino software is attached to the properties of Arduino model in Proteus schematic.

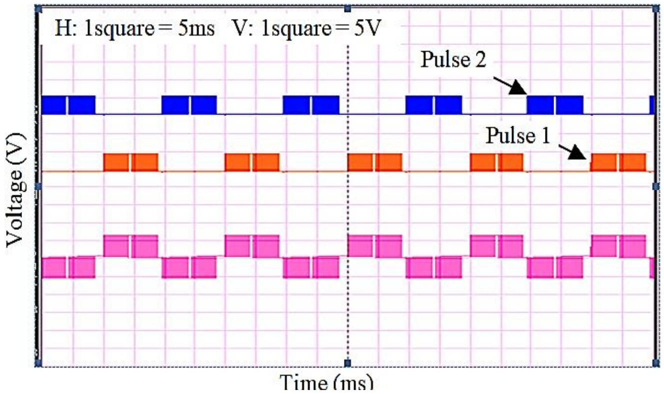

Fig. 20 Inverter output voltage

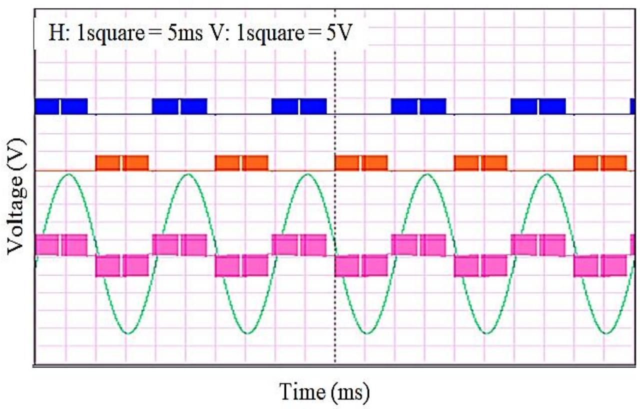

Fig. 21 Inverter output synchronized with diesel generator

In Fig.20, a SPWM output with amplitude equal to the input DC source is generated at the output terminals of the converter. It is assumed that switches S_1 and S_2 are making the positive half cycle of output voltage and switches S_3 and S_4 are making the negative half of output voltage. Pulse *1* represents the triggering pulse for switches S_1 and S_2 while pulse *2* represents the triggering pulse for switches S_3 and S_4.

Fig. 21 illustrates the synchronization of the inverter output with the reference signal and hence with a diesel generator. The inverter output shows symmetric SPWM AC output voltage of frequency same as that of the diesel generator. A delay time is needed to add between the two SPWM pulses of the inverter to prevent from shoot-through in voltage source inverter and consequently damage of switches. The dead time must be of suitable value. As too small value leads to the short-through problem as well as the large value of dead time increases harmonics in the system.

XI. EXPERIMENTAL RESULTS

The experimental results are recorded using a two channels digital storage oscilloscope UTD2052CL. The results are shown in Figures 22 and 23.

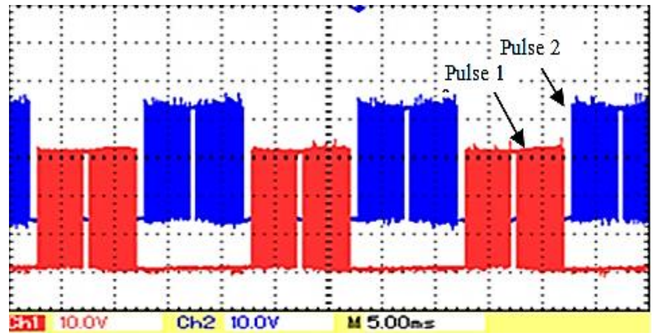

Fig. 22 The switching pulse pattern of the inverter

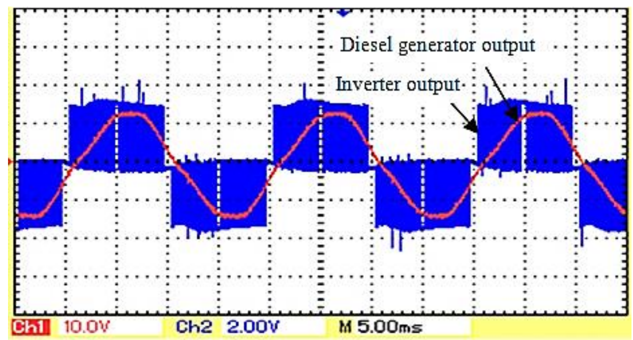

Fig. 23 Inverter output synchronized with diesel generator

Fig. 22 depicts the switching pulse pattern of the inverter. Two complementary pulses are generated with the Arduino Mega 2560 board that controls the closing and opening of switches of the inverter circuit. The switches S_1 and S_4 represent the positive switching pulse named as pulse 1 and switches S_3 and S_2 represent the negative switching pulse named as pulse 2 in Fig. 22. The output of a square PWM waveform with a switching frequency of a *4 KHz* is obtained when a resistive load is connected at inverter output terminals as shown in Fig.23. The inverter output has a periodic waveform that is not a sinusoidal waveform. A pure sine wave output is obtained by adding a suitable filter type at the output terminals; usually, an LC filter is employed. The frequency obtained experimentally and from the simulation is *50Hz*, which is the same as that of a diesel generator. The complete circuit is tested with a different resistive load (lamps) and with a *550W* single-phase induction motor. Different readings have been recorded in Table 3.

XII. CONCLUSION

Integration of renewable energy sources into the grid would assist in expanding electricity access. Photovoltaic power systems use power electronics converters to inject the power generated into the grid. In this paper, a design and implementation of an H-bridge single-phase inverter that has symmetric AC output of desired voltage and frequency is presented. The inverter consists of four switches firing with two complementary SPWM signals.

Different methods of synchronizations are present nowadays, such as PLL, frequency-locked loop (FLL), Kalman filters, ZCD, and adaptive ZCD. The interfacing of PV power systems with a diesel generator for a standalone system is performed using the ZCD method which is the simplest way of synchronization taking frequency into consideration. Also in this paper, two elements are examined within the ZCD circuit, a transistor 2N3904, and an optocoupler 4N27. The final design of the ZCD circuit is accomplished with a transistor 2N3904. A SPWM gate pulses for the four IGBTs inverter switches are generated with Arduino Mega2560 after receiving a signal from the ZCD circuit.

The whole system is simulated in Proteus and a prototype is accurately created. It is found that there is a good agreement between the simulation and the experimental results, which inform the quality of the designed system.

XIII. ACKNOWLEDGMENT

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AUTHOERS CONTRIBUTIONS

1. Idea of the presented work. ***Dr.Saad Eskander***.
2. Data collections, ***Hanan Hasan AL-Beihani***.
3. Data analysis and interpretation, ***Dr.Mohammed Adel Elsayess and Hanan Hasan AL-Beihani.***
4. Performing the computations and implementation of the prototype, ***Dr. Eid Gouda and Dr.M. Ammar***.
5. Comparison between simulation and experimental results, ***Hanan H. Al-Baiahni and Alaa Bunyan.***
6. Writing the manuscript, ***Hanan Hasan AL-Beihani.***

The corresponding author is reasonable for ensuring that the description are accurate and agreed by all authors.

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Title Arabic:

المحاكاة والنمذجة لدارات الزناد العاكس باستخدام كاشف التقاطع الصفري القائم على متحكم دقيق

Arabic Abstract:

تم تخصيص هذه الورقة للمحاكاة والنمذجة لدارات تشغيل العاكس باستخدام كاشف العبور الصفري على أساس متحكم دقيق. كاشف العبور الصفري هو أحد أنواع طرق المزامنة ويستخدم للكشف عن العبور الصفري لموجة جيبية التيار المتردد. يتم إنشاء إشارة صغيرة (نبضة) عندما تتجاوز الموجة الجيبية الصفر. النبضة التي تولدها دائرة لها تأثير سيء على عمل الدوائر الأخرى المرتبطه بها .عرض هذا النبضه يعتمد على العناصر المستخدمة. ستتم دراسة خرج الدائرة عن طريق توليد نبضتين متكاملتين للعاكس. دائره العبور الصفري تسهل تزامن الخلايا الفوتوفولتيه مع النظم الأخرى. يتم توليد النبضات بواسطة اردوينو. يمكن أن يكون التصميم المقترح اختيارًا جيدًا للسماح بتوصيل مصادر مختلفة لحمل معين، مثل مولد الديزل والخلايا الفوتوفولتيه . هناك تحد كبير لاختيار عناصر عالية الجودة لتوليد النبضه الدقيقه التي تؤدي إلى أداء أعلى للنظام المستخدم. لذلك ستدرس هذه الورقة عنصرين. يتم استخدام الترانزستور الاوبتوكبلرويتم مقارنة النتائج التي تم الحصول عليها وتحليلها لاختيار النوع المناسب. تم تصميم النظام المستخدم اولاً على أساس الترانزستور ثم باستخدام الاوبتوكبلر . أخيرًا ، تمت مقارنة وتحليل النتائج التي تم الحصول عليها من التصميمات المختلفة و تمت محاكاة النظام المقترح ومقارنتها بالنموذج الأولي التجريبي الذي تم إنشاؤه بدقة. لقد وجد أن هناك توافق جيد بين المحاكاة والنتائج التجريبية ، والتي تحدد جودة النظام المصمم