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DESIGN OF THE INVERTER IN HIGH ACCURACY AND DEVELOPMENT OF WORK THEREIN BY USING COMPOUND LIGATION

A ligation (CL) system with a very high frequency in an inverter was used, it is a novelty in this study. We also employed a three-phase dynamic load (positive sequence voltage) to correct the power factor and account for active and reactive power in the output system this work is a novelty. The technique through compound ligation (CL) can improve inverter output waveform by reducing losses caused by ingrained agents in voltage source inverters (VSI), such as dead time caused by overload or voltage drop in an inverter's output, or abnormal load current conditions such as a short circuit current occur in the output stage of the inverter, and so on. The invention relates to the conversion of D.C. to A.C. power inverters, it is preferable to use compound ligation to achieve high efficiency, the device is lightweight, and has low losses and good precision. In addition, the present invention relates to improving an inverter load request sensation circuit, smoothing operational current, inverter response, and inverter spontaneous power factor improvement, as well as correction of the reactive power of passive components. In addition, an inverter with high active power (P) equal to (2.6×10^6 Watt), reactive power (Q) (5.4×10^7 VAR), was designed, and used positive sequence voltage (1.6×10^8 Watt), as well as the switching period (10µs), The system's total harmonic distortion (THD) in voltage and current was 0.11 percent, while the system's accuracy was 99 percent. This is developed by using FPGA and oscillator circuit and programmable peripheral interface 8255 A as well as, ultrasonic PWM with a high-frequency range of (20–500 kHz) as demonstrated evidenced by the results obtained

Keywords: Compound ligation (CL), three-phase dynamic load, VSI, FPGA, PPI 8255A, Ultrasonic PWM, Oscillator circuit

Muhammed Hussein Baqir
Corresponding author
Assistant Professor, PhD Student*
E-mail: muhammedhussein176@gmail.com
Nor Mohd Haziq
Doctor*
Noor Izzri Abdul Wahab
Doctor
Department of Electrical and Electronic Engineering
University Putra Malaysia
Serdang, Selangor, Malaysia, 43400
*Department of Electrical and Electronic Engineering
University Putra Malaysia
Serdang, Selangor, Malaysia, 43400

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1. Introduction

D. C. conversion to A. C. is commonly by the usage of thyristor transistors or silicon control rectifiers (SCR), Metal oxide semiconductor field-effect transistors (MOSFETs) [1], integrated gate bipolar transistors (IGBTs), and Gate turn-off Thyristors (GTOs). The types of the inverter are two, voltage source inverter (VSI) and current source inverter (CSI). These inverters are different within their products, provided that changing standards on competence and deformation can affect electronic systems through various roads. That the required of the inverter should be teeny volume and lightweight. This can be accomplished by utilizing ultrasonic PWM (UPWM) with an inverter. The proposed use in our research is used the power electronic component type of MOSFETs, this component has many advantages over other components of power electronics.

A MOSFET has lower switching losses, high accuracy of operation in an inverter and accompanying it to work at high frequency, high current gain, and high working ability, the switching speediness through the transistors of $S1$, $S2$ ..., is very high, and it has linear features and high thermal stability [2, 3]. According to the properties of the MOSFETs, the employ of ultrasonic PWM with high frequencies may reach (20–100 KHz), leading to control of the switching period, taking into account the components used in the project to increase accuracy, and reduction of losses.

2. Literature review and problem statement

In is proposed in [1] to use an oscillator circuit with ultrasonic sensor frequency to treat vascular conditions, and this requires controlling many factors, including the use of well-interacting materials to generate high currents such as CMOS for consistency with frequency, as well, as low power consumption through flexible of controlling the time of the signal. So, the proposed proposal is to use an analog to digital converter to control the signal generating to reduce the losses in output. Design an ultrasound circuit with an oscillator circuit, which is applied to the inside of the blood vessels the readings are checked using ultrasonic PWM and AC chip. The CMOS is integrated with a capacitive micromachined ultrasonic transducer (CMUT) with an amplifier for the frequency signal. There is an injection into the transistor to reduce power consumption. The chips have been made from 0.35 CMOS CMUT and using a frequency of 1 MHz to 4 GHZ it consumes 281.7 µW of power and power consumption of 25.4 µW. The design of the inverter [2] has low losses through the use of injection and using a crystal oscillator, as well as a modulator was also used to generate random pulses, I think it is not needful to use random pulses, but generating the modulation is sufficient to improve the signal in the output. The results were acceptable and require higher accuracy by choosing a larger injection area. suggested these design a low-distortion reflector that operates from digital to frequency of oscillator ranging, uses a frequency constant from the crystal, then works by randomly applying rotations around to give liner context to the reflector. Knowing that the high-frequency time leads to a reduction in the distortion, it was applied to the MUC CMOS at 65 nm technical, after which a frequency in the range of 390 to 640 MHz with A.C current was generated with a little distortion. The suggested use of processing [3] is to increase the switching frequency until it reaches the zero-crossing point, and on this basis, an algorithm was created to determine the time and the effect of the unwanted pulse, by sure the switching frequency is should exist larger than the resonance frequency (*fo*) so that work under zero voltage switching (ZVS) conditions and deviation frequency must be less than ten percent to obtain high power, very small electromagnetic interference (EMI), and high accuracy; as well as we do avert process rises the AC mains input so that avert deformation and regulate of energy brought to the load. It is used to address the subject of discontinuous pulse width modulation, which leads to distortion reduction, and the suggested use of processing is to increase the switching frequency until it reaches the zero-crossing point, and on this basis, an algorithm was created to determine the time and the effect of the unwanted pulse, and this algorithm adopts the carrier frequency, and a simulation system was used to achieve this results. In these papers [4], the author believes that the impedance network in the inverter is the best alternative to the VSI and CSI inverter. However, the constant switching frequency is what drives the inverter to work at a low voltage, which results in an impedance network. Therefore, the author specifies that there is a relationship between the shoot-through and modulation index that makes a trade-off between the voltage gain and the damping index. Through my research that using the impedance network is more complicated to use and leads to distortions, I think that the method of using (M–1) to determine the voltage gain and reduce the losses is the best for many reasons, one of which is reducing the size of the device.

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Ultrasound is used for several applications, including chemical and industrial applications, because it is characterized by dual action to convert energy, and hence the negative effects of the action of some negative components in distortion THD and PF, in these papers the author relied on the use of a controller based on an artificial neural network, which includes work of little distortions in the output system. The research [6] is based on passive components of reflector design, as they play an important role in reducing harmonic distortions. It also used the fixed framework of the coefficients αβ and dq to improve the output of the system, and the results were positive. In the papers [7] an impedance matrix model is proposed and outlined for cross frequencies to describe the terminal properties of DC, and then designing a high-frequency circuit model to address the high pulse frequencies in the reward electronic systems, which may avert the interaction of these transformers with different other frequencies.

It is proposed in [8] to design the inverter near the source of the flow to the LC, which is the positive case to get rid of unwanted ripples voltage, and it also contributes to reducing the effects of parasitic capacitance, which is generated by the magnetic field that is affected by the increase in the current in the inductance, and the chips work to increase the gain voltage in a way to reduce the differences in voltage amplitude. We think the results were acceptable. In [9], the distortion in the wave has been treated by using a separate feed with a frequency value of 100Hz, in the double-active bridge converter, in addition to that the proposed work has been integrated between the full bridge conversion, and the work of the system from the LLC to the purpose of reducing distortion and ripple voltage in the wave using the frequency of 100 Hz, knowing that the results are acceptable but the work is not with the required accuracy in the case of raising the frequency value more than of 100 Hz. Therefore, one of the disadvantages of the system is that it becomes unstable in the event of an increase in frequency. In the papers [10], a high-frequency injection sensor for synchronous motors is proposed. The injection range is 2 kHz, through a three-phase voltage source inverter (VSI), and operates at a frequency of 50 kHz, FPGA programming array is used to achieve a bandwidth of 200 kH. After executing the algorithm, if the area of the injection worth is sufficient using SiC through a covering of deformation and using FPGA. The work was documented with acceptable results. In [11] it is stated that the power of the inverter is on the order of several hundred kilovolts, ampere and more. The switching frequency is determined by several kilohertz or Megahertz and Gigahertz. Thus, the transition time between S1, and S2 becomes very large. Thus, the distortion in the output is obtained, so the proposal is to use a 1 MHz sample by using a control unit, which is controlled by FPGA to reduce distortion and increase accuracy. That the FPGAs control very high-frequency generation is most welcome because FPGAs work to frequencies of (50 Hz–500 kHz) and include field-oriented control (FOC) [12]. Due to the losses that occur in the SiC-MOSFET when the frequency is increased, the zero voltage switching (ZVS) vacuum direction modulation technology is introduced to increase the power flux of the SiC-MOSFET inverter. The inverter can be operated at the higher switching frequency, which allows reducing the size of the passive components, in addition, SiC-MOSFET with ZVS-SVM are compared with 20 kW power in the frequency of (20 to 300 kHz) range. The device is designed to determine the efficiency by switching frequency, seven die SiC-MOSFET with a low stray inductance of the inverter is designed to reduce the voltage on the inverter and to reduce the power loss. Disadvantages of work are that the devices used are many, and thus the size of the device will have become large, and it is possible to obtain more accurate results through fewer electronic components and high efficiency and low loss.

3. The aim and objectives of the study

The aim of the study is to develop the inverter by achieving high accuracy in the output and very low loss.

To achieve this aim, the following objectives must be achieved.

– design the compound ligation to reduce the losses and increase accuracy that occurs due to RDS (*ON*), parasitic capacitance (*Cs*);

– use a three-dynamic load to compensate for the active power (*P*) and reactive Power (*Q*) and keep a constant power factor;

– use an oscillator circuit as a microcontroller and ultrasonic PWM to enhance the operation of the inverter;

– validate the study.

4. Materials and methods

The decreased loss is at meaning growing the accuracy of power electronic inverters; if a little switching loss this means due to the existence of cooling in a MOSFET and developed filter compound ligation (*CL*) at the output stage. This has an important meaning when the inverter works with a higher switching frequency (*fs*) or ultrasonic PWM. The definition of a transistor refrigeration process demands controls, among another, the switching loss, which is one of the ingredients for the temperature source in each transistor thermic perfect.

Compound ligation is the basis on which the inverter-based (*Lf*, *Cf*) is the inductive frequency and capacitive frequency, through output filter design. When designing, adequate consideration must be made of reducing ripple voltage *RV*) and total harmonics distortion (THD) at linear and nonlinear rectifier (*RC*) resistive capacitive loads. Given the importance, the (*Lf*, *Cf*) value should be calculated by compound ligation design. The total values of (*Lf*, and *Cf*) are the values of reactive power in the inductive and capacitive filter that can be generated. Interactive power coefficients for both should be equal. Demonstration for the balanced astral load linked in Fig. 1. Block *B*

$$Lf=\sqrt{(1/M)}(1/fs)RL \text{ and } Cf=(1/fs)(1/RL), \tag{1}$$

where *RL* is the load resistance, *fs* is the switching frequency, and *M* is the modulation index.

Three-wire delta connection equilibrium load is shown in Fig. 1. Block A. Observation at two of equal PWM

$$Lf=(1/3)(1/fs)RL \text{ and } Cf=(1/fs)(1/RL). \tag{2}$$

The compound ligation of equilibrium load, which shown in Fig. 1 displays four equal PWM

$$Lf=[[\sqrt{(1/M)}](1/fs)(RL)]//[(1/3)(1/fs)RL]],$$

and

$$[Cf>[(1/fs)(1/RL)]//[(1/fs)(1/RL)]. \tag{3}$$

From equation (3), the reactive power of the filter is greater than that of the stars and deltas connection due to doubling the value of *Lf*, *Cf*).

From Fig. 1 *R* has represented the resistance of charging, *L* is represented in *Lf*, and *C* is represented in *Cf*, this component uses as a filter, and *RL* is represented *R*-load. The values of the Ultrasonic PWM depend on the passive components used and are suitable for reducing the amplitude of the ripple voltage. The delay in controlling the PWM signal is shown throughout the switching period for at least one cycle. When computing the worths of stocked for PWM in the memory, the switching period for the pulse's width is changed. The inductance is used as a current source, so when there is an overcurrent, most of this worth will be passing through the filter of the capacitor (*Cf*), thus leading to increasing the output voltage. Hence seem the interruptions in an inverter will be lengthier than the one during the switching period, whereas the overtaking will be similar to the effect of the open circuit [4]. Though the large candidate capacitor has drawbacks, yonder is greatly advanced reactive power in that capacitor also there are great currents in the capacitor, which rise energy losses at the parasitic sequential resistance the product voltage will have taken ample long times. The accuracy of the output voltage controller is the best for the little modulation index *M*, due to the potential raise maybe occur (1–*M*) VDC of the principal harmonics of an inverter bridge output voltage. Production voltage controller accuracy is more effective for lesser productivity filter inductance worths.

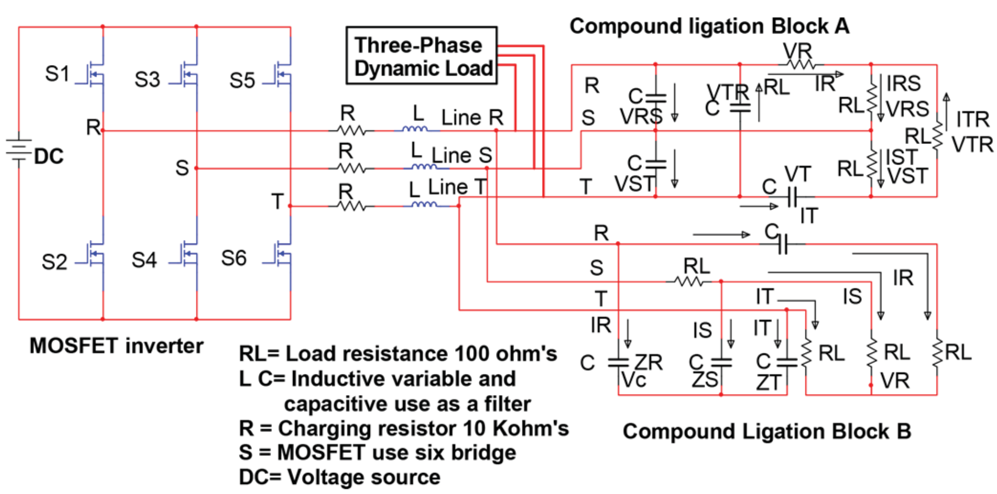


Fig. 1. Block diagram of compound ligation connected in an inverter

For a nonlinear rectifier *RC* load, the worth of the voltage above the filter inductor must be sharply raised as soon as the rectifier starts to behave and pulse current fluxes to the load capacitor. Thereby, the extreme worth of *M* would be bounded according to the equation [5]:

$$M_{max}<[\sqrt{(3)/2})/((Wm\,Lf)/RS+\sqrt{3}/2). \quad (4)$$

Compound ligation in block A used a part of a capacitor to define the redeployment of active power among the phases and recompenses a portion of the reactive power (Q) of load the compound ligation in block *B* used the connected capacitors to recompense the other part of the reactive power (Q) of the load. This technique can make the crew load compensator completely stable and have the desired power factor.

This is the new best technique, In contrast with the traditional compensation system, this technique will conduce to small size, depressed costs, and elastic control, and have high accuracy (99 %) with very low losses (0.11 %) (Table 1).

These results were obtained by using the MATLAB Simulink as in Fig. 2, through the program it is observed that the accuracy of the system and low losses rely on the switching frequency, which is dependent on UPWM and compounds of (Lf, CF, and RL).

The accuracy and very few losses indicate the effectiveness of the compound ligation in compensating for the active and reactive power and stability of the power factor, which leads to high efficiency in the work of the inverter.

Table 1

Demonstrates the relationship between accuracy and low losses relying on ultrasonic PWM and switching period using a three-phase dynamic load

Ultrasonic PWM (kHz) (UPWM)	Switching Period (*Ts*, second)	Switching Frequency (*Fs*, kHz)	*Cf* (Farad)	*Lf* (Henry)	*RL* Ω	Accuracy, %	Losses (*V&I*), %
02	$5.0\times1^{0-}5$	002	$2.0\times10{-}6$	1.0×10^{-3}	001	99%	0.1 %
52	4.0×10^{-5}	052	2.5×10^{-6}	1.0×10^{-3}	001	99 %	0.8 %
72	3.7×10^{-5}	270	2.6×10^{-6}	1.2×10^{-3}	100	99 %	0.2 %
30	3.3×10^{-5}	300	2.0×10^{-6}	2.8×10^{-3}	100	99 %	0.1 %
63	2.7×10^{-5}	360	2.7×10^{-6}	4.6×10^{-3}	100	99 %	0.3 %
93	2.5×10^{-5}	390	2.5×10^{-6}	2.6×10^{-3}	100	99 %	0.8 %
40	2.5×10^{-5}	400	2.2×10^{-6}	3.0×10^{-3}	100	99 %	0.9 %
34	2.3×10^{-5}	430	2.6×10^{-6}	3.2×10^{-3}	100	99 %	0.4 %
50	2.0×10^{-5}	500	2.4×10^{-6}	3.2×10^{-3}	100	99 %	0.6 %
15	2.0×10^{-5}	510	2.4×10^{-6}	3.2×10^{-3}	100	99 %	0.7 %
06	1.7×10^{-5}	600	2.5×10^{-6}	3.5×10^{-3}	100	99 %	0.6 %
70	1.4×10^{-5}	700	2.4×10^{-6}	3.8×10^{-3}	100	99 %	0.6 %
80	1.2×10^{-5}	800	2.2×10^{-6}	2.8×10^{-3}	100	99 %	0.4 %
90	1.1×10^{-5}	900	2.7×10^{-6}	2.9×10^{-3}	100	99 %	0.1 %
001	1.0×10^{-5}	0001	2.7×10^{-6}	3.9×10^{-3}	100	99 %	0.3 %
120	$8.3\times10{-}6$	0021	4.4×10^{-6}	5.0×10^{-3}	100	99 %	0.2 %
135	7.4×10^{-6}	1350	4.6×10^{-6}	5.2×10^{-3}	100	99 %	0.1 %
140	7.1×10^{-6}	1400	4.8×10^{-6}	5.4×10^{-3}	100	99 %	0.1 %
450	2.2×10^{-6}	4500	5.0×10^{-6}	5.8×10^{-3}	001	99 %	0.1 %
500	2.0×10^{-6}	5000	5.2×10^{-6}	6.2×10^{-3}	100	99 %	0.1 %

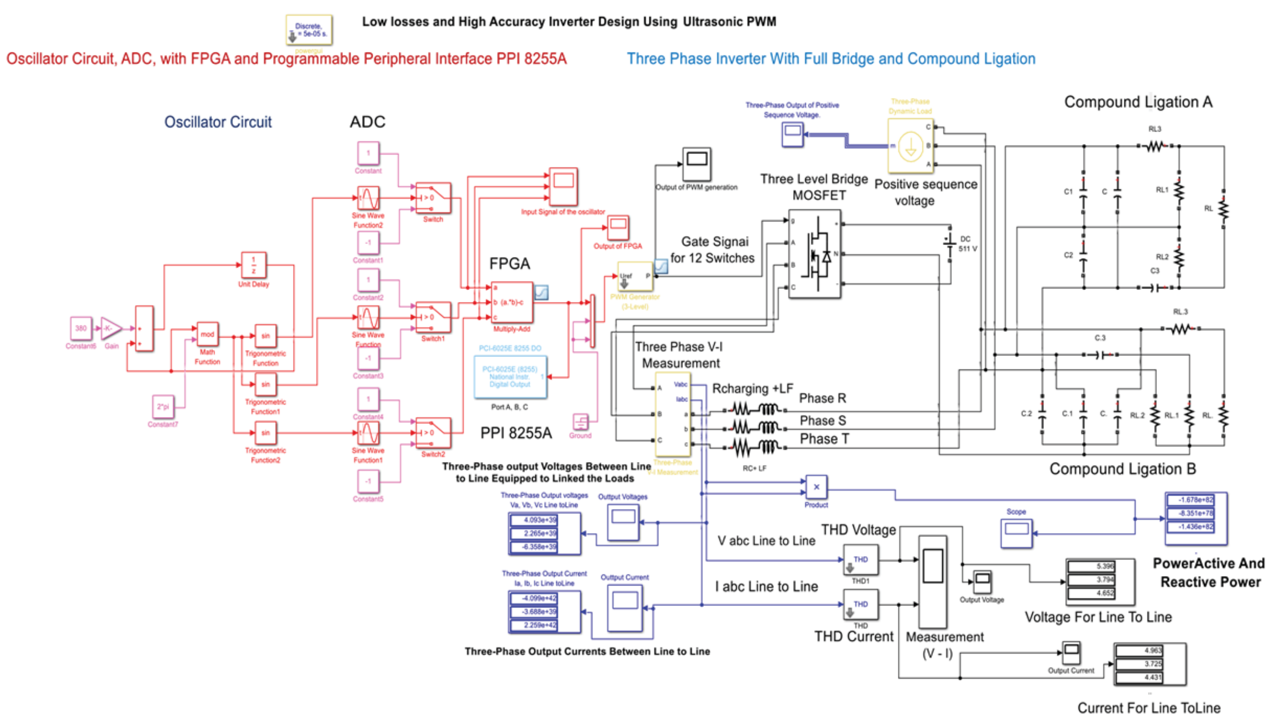


Fig. 2. Block diagram of MATLAB Simulink to generate PWM

5. Results relate to the compound ligation and the three-phase dynamic load

5. 1. Design the compound ligation

Through Table 1, it is clear that the accuracy and losses of the UPWM signal depend on the values of the inductive and capacitive frequency (*Lf*, *Cf* and *RL*). At 20 kHz, active power of 1.5×10^5 watt, and reactive power of 1.8×10^6 VAR were used, knowing that these values depend on the passive components of the compound ligation (*LF*, *CF*, and *RL*) in addition to the ultrasonic PWM and utilize three-phase dynamic load at active power used 8 kW and reactive power are 4 kVAR, the capacitance used of worth is 2.0×10^{-6} farad and the inductance is 1.0×10^{-3}H, and resistance 100 Ω, based on these values, it was obtained THD is 0.1 %, and the accuracy is 99 %. At 30 kHz, the active power is 1.6×10^5 W and the reactive power is 1.9×10^6 VAR. Let's note that these values rely on the passive components of *LF*, *CF*, and *RL*, as well as ultrasonic PWM, and the three-phase dynamic load at active power utilized is 8kW and reactive power is 4 KVAR and used capacitive 2.5×10^{-6} farad and inductive 1.0×10^{-3} H, and resistance 100 Ω, based on these values. It was obtained that THD is 0.8 % and accuracy is 99 % and so the rest of the values of 100 kHz.

5. 2. Three-phase dynamic load

Through Table 1, it is noted that the three-phase dynamic load, has a close relationship with compound ligation as the determination of its actual ability to control the output. For example, when using frequencies120 kHz, 135 kHz, 140 kHz, 450 KHz, and 500 kHz the value of the power system of the three-phase dynamic load and the passive components must be raised to extend the period for signal generation and not cause interference between the current and voltage. Let's note from practical experience and the program of MATLAB SIMULINK that when reducing the power of the three-phase dynamic load device it must be synchronized with the increase in the value of the inductance and capacitance to obtain the signal with low losses and high accuracy and the results indicated prove it. For example, at 500 kHz the capacitive value of 5.2×10^{-6} farad and the inductive 6.2×10^{-3} H were used, the active power of 5.2×10^6 watt and reactive power of 2.5×10^6 VAR were obtained, as well as a THD is 0.1 % and the accuracy 99 %. This is evidence of the effectiveness of three-phase dynamic load to obtain high efficiency in output. As for the value of accuracy, it was made to a single value of 99 % because we controlled the capacitance and inductance values as well as the power in the three-phase dynamic load. Knowing that the active power used in the three-phase dynamic load is 6 kW and the reactive power is 3 kVAR at 500 kHz.

5. 3. Oscillator circuit with 4GHz

The use of an oscillator circuit with 4 GHz has a very effective effect in determining the values of *CF*, *LF*, and *RL* in the quality of the output because the oscillator circuit is not as accurate as required due to the internal RC in the device, so that the use of the *CL* has an effect on the accuracy of the output, as well as that determining the values in Table 1, has a correlation with the accuracy of the oscillator circuit.

5. 4. Validate the study

The study and verification were positive in terms of results, when the values of the frequencies were taken into120 KHz, 140 KHz, 450 KHz, and 500 KHz. The value of the power system of the three-phase dynamic load and the passive components must be raised to extend the period for signal generation and not cause interference between the current and voltage. Let's note from practical experience that when reducing the power of the three-phase dynamic load device it must be synchronized with the increase in the value of the inductance and capacitance to obtain the signal with low losses and high accuracy and the results prove it.

The compound ligation (A&B) is attached to the three-phase dynamic load this represented positive sequence voltages, In the balanced load connected to the order of voltages waveform sequence in the polyphase system, so that the phase rotation or polyphase of the voltage source in power phase sequential. When inductance and capacitance loads are used, there are differences in voltage and current. Therefore, this component is necessary to make synchronization between the voltage and current; consequently, utilizing a three-phase dynamic load is suitable used with compound ligation to give low losses and high accuracy of output system achieved by using the programmable MATLAB Simulink and practical part, hence the total harmonics distortion (THD) of current and voltage reached 0.11 %, accuracy 99 %, high active power (4.6×10^7 W), reactive power (5.6×10^7 VAR) and used positive sequence voltage (1.6×10^8 W) as well as the switching period (20 μs).

PWM modification in an inverter is necessary, due to the presence of triple harmonics that is happening because of the neutral point [6]. The use of the compound ligation through three or four wires represented in the compound ligation blocks (A&B) method is balanced and of high accuracy for voltage and current variables. Equation (5) represented a balanced load of matrices Fig. 3.

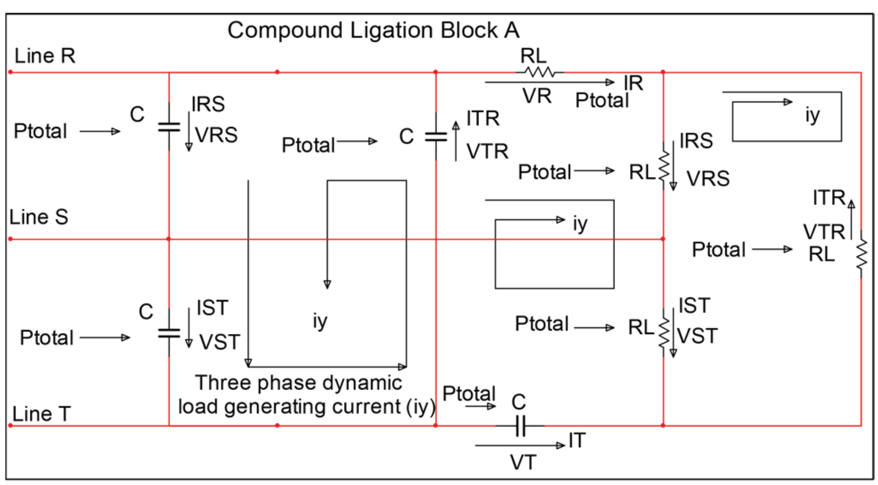


Fig. 3. Block diagram of compound ligation (block *A*)

$[X1\ X2\ X3]^T=$
$=[X1k\cos wt\ X2k\cos(wt-120°)X3k\cos(wt-240°)]^T$. (5)

The compound ligation is used to compensate for the active power, reactive power, and modification of power factor by using a three-phase dynamic load this a new business, these devices are connected from line to line, suppose the grid voltage is ($VGko$), where$k=R$, S, T, phase currentinput, where$k=RS$, ST, TR. The inverter is fed by the organizer; thus, the capacitor voltage is balanced as well as compensation for losses is applied. The determination of the network voltage and output of an inverter lines currents are as follows:

$VRO=V\cos(wt+\theta1)+V\cos(-wt+\theta2)$,

$VSO=V\cos(wt-120°+\theta1)+V\cos(-wt-120°+\theta2)$,

$VTO=V\cos(wt+120°+\theta1\ )+V\cos(-wt+120°+\theta2)$, (6)

$iR=I\cos(wt+\text{positive}(\theta))+I\cos(wt+\text{Negative}(\theta))$,

$iS=I\cos(wt-120°+\text{positive}(\theta))+I\cos(-wt-120°+$
$+\text{negative}(\theta))$,

$iT=I\cos(wt+120°+\text{positive}(\theta))+$
$+I\cos(wt+120°+\text{negative}(\theta))$, (7)

where V and I are the amplitude of positive and negative sequence voltages and currents from the rotation phases, θ1, θ2, positive (θ), negative(θ)are phase angles through esteem to the reference voltage, ω is the necessary frequency of the network voltage. The fixed and synchronous frameαβis displayed by transforming the matrix format as follows:

$[\text{RST-}\alpha\beta]=[(2/3\&-1/3\&-1/3@0\&-1/\sqrt{3}\&1/\sqrt{3})]^T$, (8)

$[\alpha\beta-\text{positive}]=[(\cos(wt)\&-\sin(wt)@\sin(wt)\&\cos(wt))]^T=$
$=[\alpha\beta-\text{negative}]^{T-}$, (9)

where ω is the network frequency, αβ is signifying the fixed frame, and the positive and negative forms (voltage and current) signify the sequence of synchronous frames in series. According to these voltages, current, and transformation matrixes, the positive and negative arrangement ingredients of positive sequence voltage (PSV) and inverter's production currents in the synchronous frame are represented as follows:

$[(Vq@Vd)]=$
$=[\alpha\beta-\text{postive}]^T\cdot[(\text{RST}\&-\alpha\beta)]^T\cdot[(\text{VRO}\&\text{VSO}\&\text{VTO})]^T$,

$[(Vq@Vd)]=$
$=[\alpha\beta-\text{negative}]^T\cdot[\text{RST}-\alpha\beta]^T\cdot[\text{VRO VSO VTO}]^T$, (10)

$[(iq@id)]=[\alpha\beta-\text{positive}]^T\cdot[\text{RST}-\alpha\beta]^T\cdot[\text{iR iS iT}]^T$,

$[(iq@id)]=[\alpha\beta-\text{negative}]^T\cdot[\text{RST}-\alpha\beta]^T\cdot[\text{iR iS iT}]^T$. (11)

The ripple in ingredients from voltages and current is according to dq caused by an imbalance of voltages and a current, resulting in a ripple of 2ωworth between line to line [7], this meaning represents the waveform of one cycle. Extraction of the average voltages and currents should be used in the filter for the above ingredients in equations to avert losses and get high accuracy of the output in an inverter. In addition, the AC adjustment in the output occurs by the use of DC capacitors, so that, continue of capacitor feeding is very important for achieving synchronization with the converter [7], the DC voltages ($Vdckj$, $k=RS$, ST, TR; j=1, 2, and 3) comprise the dual line frequency ripple.

The relationship between the phase currents and the recompense current is illustrated by the use of compound ligation as in the following equations.

$$\begin{bmatrix} i_{RS} \\ i_{ST} \\ i_{TR} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} iR-iS \\ iS-iT \\ iT-iR \end{bmatrix} + \begin{bmatrix} i_r \\ i_r \\ i_r \end{bmatrix}, \tag{12}$$

where the three-phase dynamic load is represented in($ir=Io\text{-}\cos(\omega t+\gamma)$. The rapport between line-to-line voltage and a break-even point for the network is given by the following:

$$\begin{bmatrix} V_{RS} \\ V_{ST} \\ V_{TR} \end{bmatrix} = \begin{bmatrix} V_{RO}-V_{SO} \\ V_{SO}-V_{TO} \\ V_{TO}-V_{RO} \end{bmatrix}. \tag{13}$$

The voltage control of the DC capacitance depends on the supplied energy design. The instantaneous and medium energy losses value is computed as follows.

$$EM = 2\pi f\ /\ 2\pi \int_0^{2\pi/2\pi f} Vkik\,\mathrm{d}t, \tag{14}$$

where $k=RS$, ST, TR.

Power unbalanced load in Fig. 15. Block A if ($ZRS\neq$ $\neq ZST\neq ZTR$) so that the power

$PT=VRS\ IRS\cos\theta RS+VST\ IST\cos\theta ST+$
$+VTR\ ITR\cos\theta TR$. (15)

Three-phase dynamic load contains positive sequence voltage and thus contains positive currents (iq, id) as well as positive voltages (Vq, Vd),and negative sequence voltage, thus contains negative currents (negative (iq)), (negative (id))as well as negative voltages (negative (Vq)) (negative (Vd)). Therefore, the equations are arranged as follows.

– positive sequence voltages:

$$\begin{bmatrix} P_{RS} \\ P_{ST} \\ P_{TR} \end{bmatrix} = \frac{1}{2}\begin{bmatrix} \frac{1}{2}V_{\bar{q}} & +\frac{\sqrt{3}}{2}V_{\bar{d}} & \frac{\sqrt{3}}{2}V_{\bar{q}} & -\frac{1}{2}V_{\bar{d}} \\ -V_{\bar{q}} & 0 & V_{\bar{d}} & 0 \\ \frac{1}{2}V_{\bar{q}} & -\frac{\sqrt{3}}{2}V_{\bar{d}} & -\frac{\sqrt{3}}{2}V_{\bar{q}} & -\frac{1}{2}V_{\bar{d}} \end{bmatrix}\begin{bmatrix} i_q \\ i_d \end{bmatrix}; \tag{16}$$

– negative phase sequence voltages:

$$\begin{bmatrix} P_{\overline{RS}} \\ P_{\overline{ST}} \\ P_{\overline{TR}} \end{bmatrix} = \frac{1}{2}\begin{bmatrix} \frac{1}{2}V_q & +\frac{\sqrt{3}}{2}V_d & \frac{\sqrt{3}}{2}V_q & -\frac{1}{2}V_d \\ -V_q & 0 & V_d & 0 \\ \frac{1}{2}V_q & -\frac{\sqrt{3}}{2}V_d & -\frac{\sqrt{3}}{2}V_q & -\frac{1}{2}V_d \end{bmatrix}\begin{bmatrix} i_{\bar{q}} \\ i_{\bar{d}} \end{bmatrix}. \tag{17}$$

It should note from the equations (16), (17) that they are not balanced, and accordingly, the proposal applied in the research is to determine the period of the switching frequency by changing the values of the passive components (Lf, Cf), thus, can get the best of currents values to obtain the required of high accuracy with low losses.

$$\begin{bmatrix} P_{RS}^{LC} \\ P_{ST}^{LC} \\ P_{TR}^{LC} \end{bmatrix} = \frac{1}{2}\begin{bmatrix} \frac{3}{2}V_q+\frac{\sqrt{3}}{2}V_d+\frac{3}{2}V_{\bar{q}}+\frac{\sqrt{3}}{2}V_{\bar{d}} & \frac{\sqrt{3}}{2}V_q-\frac{3}{2}V_d-\frac{\sqrt{3}}{2}V_{\bar{q}}+\frac{\sqrt{3}}{2}V_{\bar{d}} \\ -\sqrt{3}V_q^+-3V_d^- & -\sqrt{3}V_q^++3V_d^- \\ \frac{-3}{2}V_q+\frac{\sqrt{3}}{2}V_d-\frac{3}{2}V_{\bar{q}}+\frac{\sqrt{3}}{2}V_{\bar{d}} & \frac{\sqrt{3}}{2}V_q+\frac{3}{2}V_d-\frac{\sqrt{3}}{2}V_{\bar{q}}-\frac{\sqrt{3}}{2}V_{\bar{d}} \end{bmatrix} \times \begin{bmatrix} i_{LC}\cos\gamma \\ i_{LC}\cos y \end{bmatrix}. \quad (18)$$

Note: the energy of each phase is one to three of the total power output. In Fig. 5, the Clark transformation is represented by equation (19) as follows.

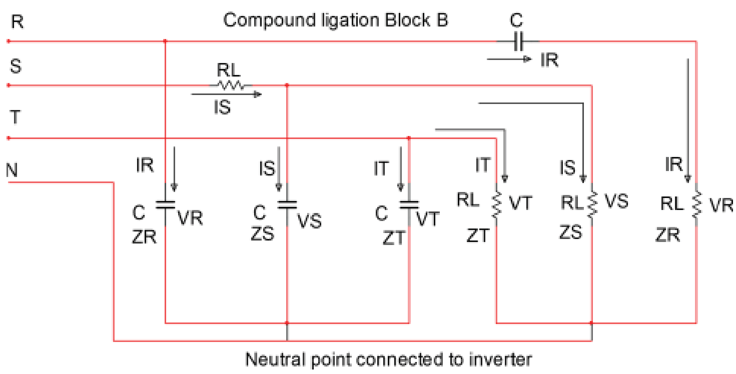


Fig. 4. Block diagram of compound ligation (block B)

$$\begin{bmatrix} x_\alpha \\ x_\beta \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix},$$

$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} x_\alpha \\ x_\beta \end{bmatrix}. \quad (19)$$

The advantage of using βα and dq in the fixed frame is to separate axes from a variable, the control of the fixed frame is achieved through the shift by (90°) of two sine waves, with the reference voltage, but becomes a drawback when the reference voltage is mutable with frequency [8]. Park transformation at fixed αβ and dq framing also uses ωk as the angular basic frequency of the output. α, β, d, qIs the means to separate the orthogonal axes. The equivalent load of the capacitor is equal $CT=Cf$ from Fig. 4.

$$\left(x_{i,\alpha,\beta}\right) = \begin{bmatrix} -\frac{R}{Lf} & -\frac{1}{Lf} \\ \frac{1}{Cf} & 0 \end{bmatrix}\left[x_{i,\alpha,\beta}\right] + \begin{bmatrix} 0 \\ -\frac{1}{Cf} \end{bmatrix}\left[d_{\alpha,\beta}\right] + \begin{bmatrix} \frac{1}{Lf} \\ 0 \end{bmatrix}\left[R_{\alpha,\beta}\right]. \quad (20)$$

Balance the load from the equation by using Park transformation:

$$\begin{bmatrix} x_d \\ x_q \end{bmatrix} = \begin{bmatrix} \cos\omega kt & \sin\omega kt \\ -\sin\omega kt & \cos\omega kt \end{bmatrix}\begin{bmatrix} x_\alpha \\ x_\beta \end{bmatrix}, \quad (20)$$

$$\begin{bmatrix} x_\alpha \\ x_\beta \end{bmatrix} = \begin{bmatrix} \cos\omega kt & -\sin\omega kt \\ \sin\omega kt & \cos\omega kt \end{bmatrix}\begin{bmatrix} x_d \\ x_q \end{bmatrix}. \quad (22)$$

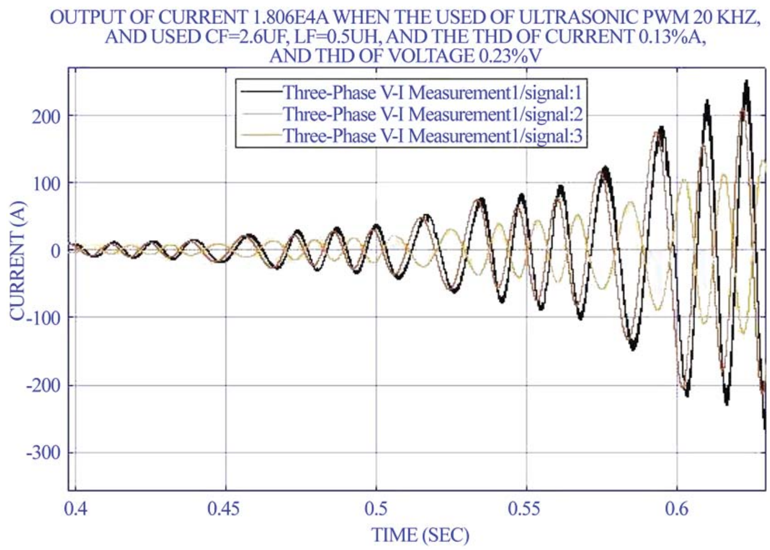
From equation (5), the compound ligation in (block B) is balanced through the components ($Xk=RS=ST=TS$) where ($Xk=X1k=X2k=X3k$), and after Clark transformation equation (18), $x_\alpha=Xk\cos\omega kt$, $x_\beta=Xk\sin\omega kt$, and after Park transformation equations (20), (21), $x_d=Xk$, $x_q=0$.So, appeared two fixed worth, through the rotation phase to change angular frequency between phase to phase [9]. Knowing the two axes are described simultaneously due to αor d and β or q are variables that must be included together because they are interfering with the energy storage of the system simultaneously

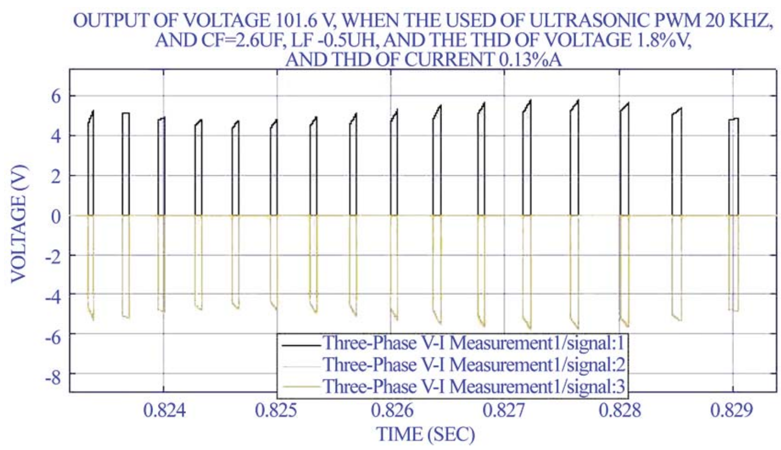
$$P_{x\beta\beta,dq}^{-1} = \left[i_{Lf,\alpha,d}\, i_{Lf,\beta,d}\, V_{o,\alpha,d}\, V_{o,\beta,q}\right]^T. \quad (23)$$

Finally, power equations (23), indicate that the equilibrium of the system is caused by the use of passive components by the variables that worths are bound, hence, the compound ligation gave positive results through high accuracy, low losses, and high-power output.

It is noted in Fig. 5, 6 that there is high accuracy in the voltage and current between the line to line due to the use of high technology through compound ligation (CL) with the three-phase dynamic load and the used oscillator circuit as a microcontroller in the system, it advances the active power (P) and reactive power (Q) and its act on the impose of involves of the positive sequence voltage (Fig. 8–12).

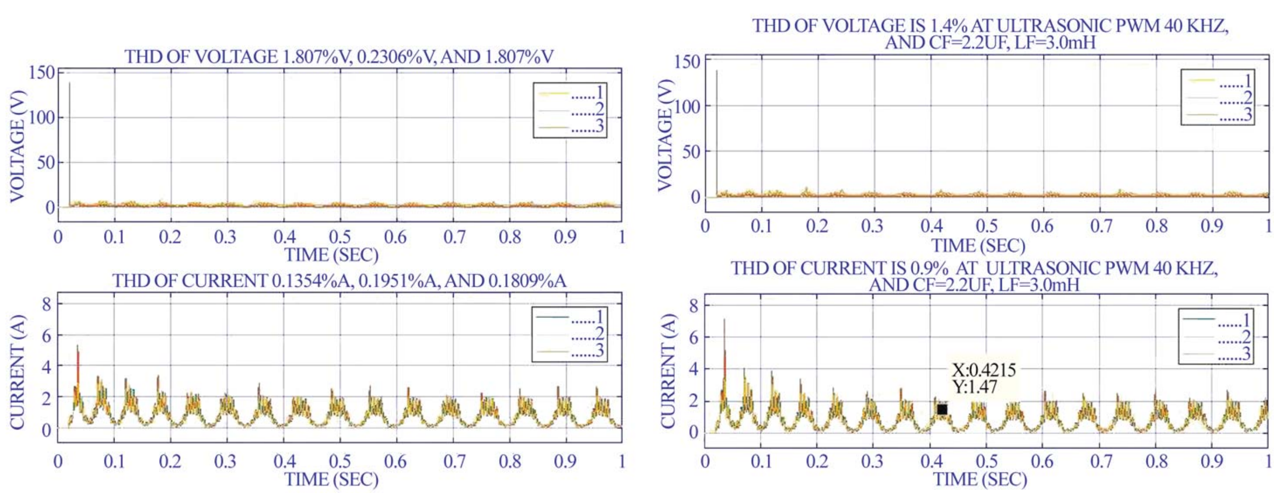
The shapes of the outputs above were obtained based on the information in Table 1. Where the values of the passive components (capacitors, inductors, resistors, and diode) are based on equation (3). It is noted that the high accuracy and low losses control by the selection of suitable values for passive components in proportion to the ability of the three-phase dynamic load. Where any change in the values of the components used in the filter will have negative effects on the output and thus the wave becomes unclear or inaccurate, and the results are proof of that (Table 1).





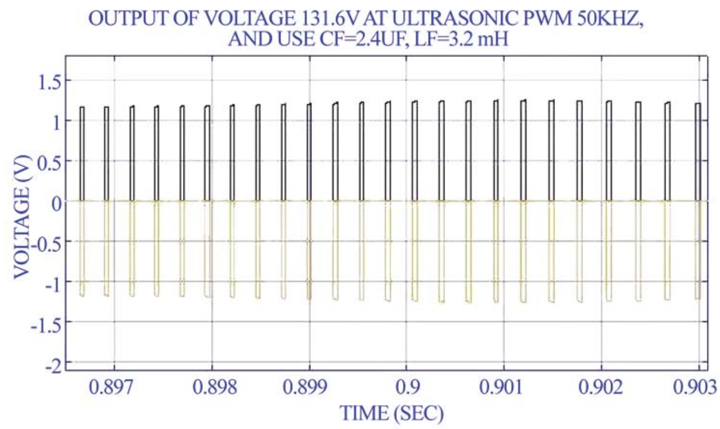
b

Fig. 5. The accuracy of the output is 99 % and losses 0.1 % when the use of the UPWM at 20 kHz: *a* – current; *b* – voltage

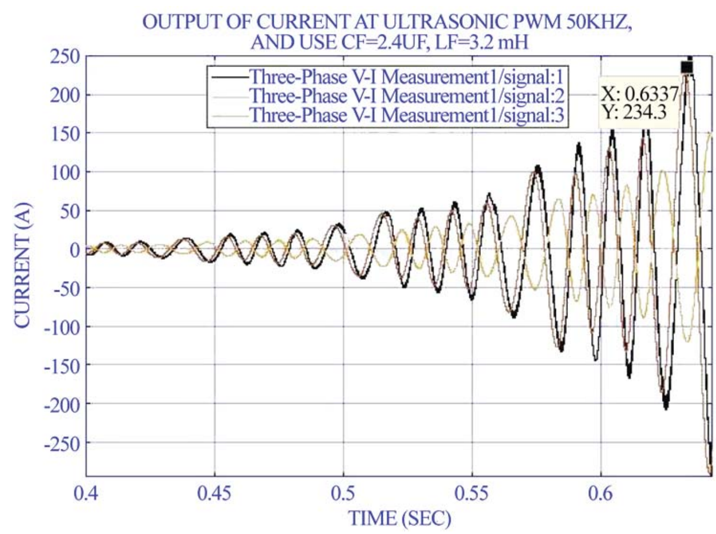


a *b*

Fig. 6. The accuracy of the output is 99 % and THD are 0.14 % when the use of the UPWM 20 kHz:
a – THD of voltage and the current;
b – accuracy of the output is 99 % and THD are 0.9 % when the use of the UPWM 40 kHz

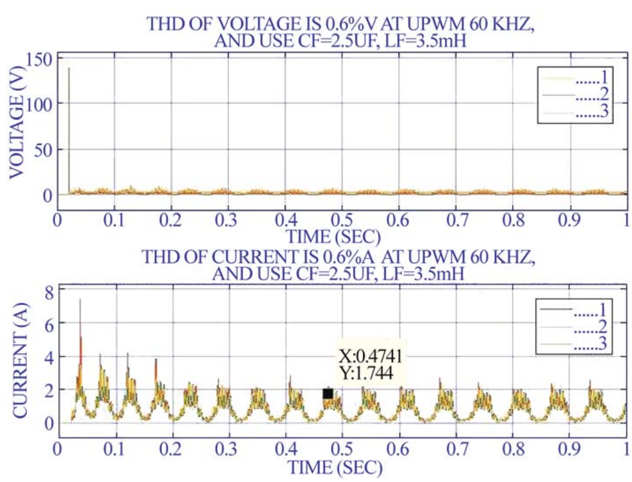


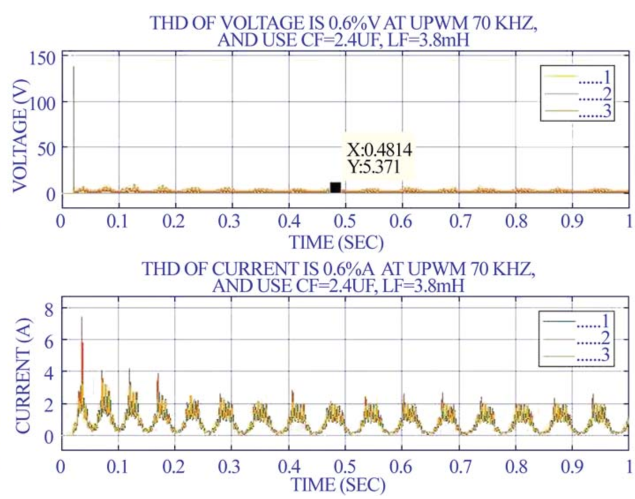
a



b

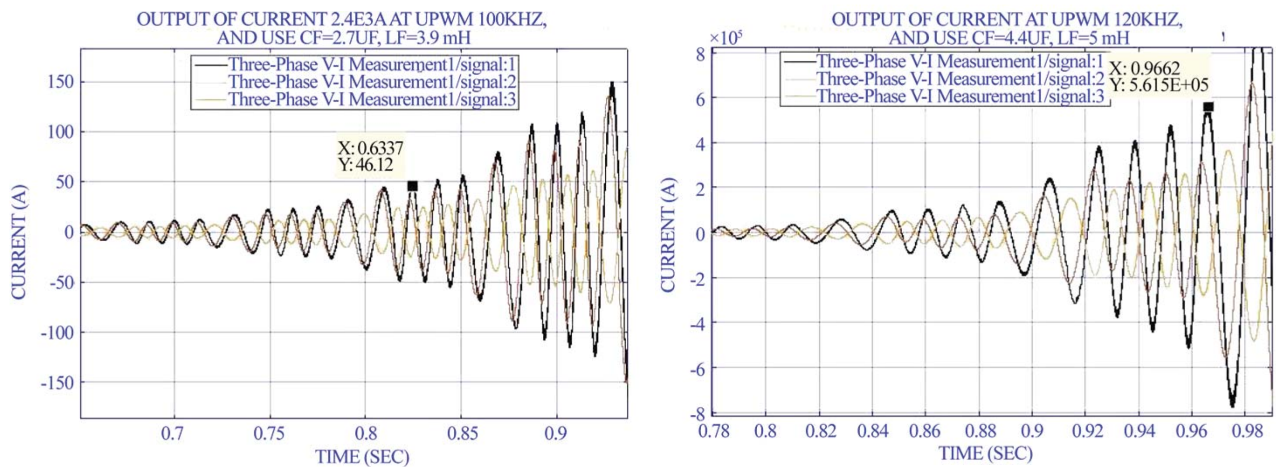
Fig. 7. The accuracy of the output is 99 % and THD 0.6 % when the use of the UPWM 50 kHz:
a — voltage output; *b* — current output





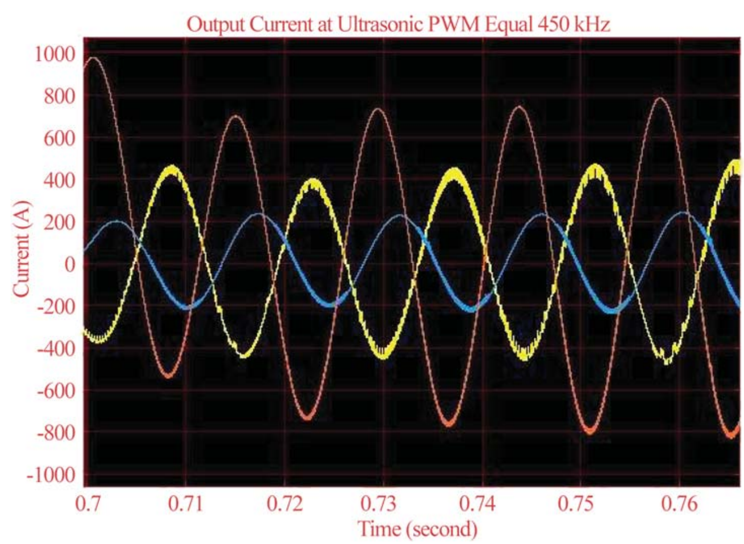
a *b*

Fig. 8. The accuracy of the output is 99 % and THD are 0.6 %:
a — the output of the voltage and current when using UPWM of 60 kHz;
b — the output of the voltage and current when using UPWM of 70 kHz

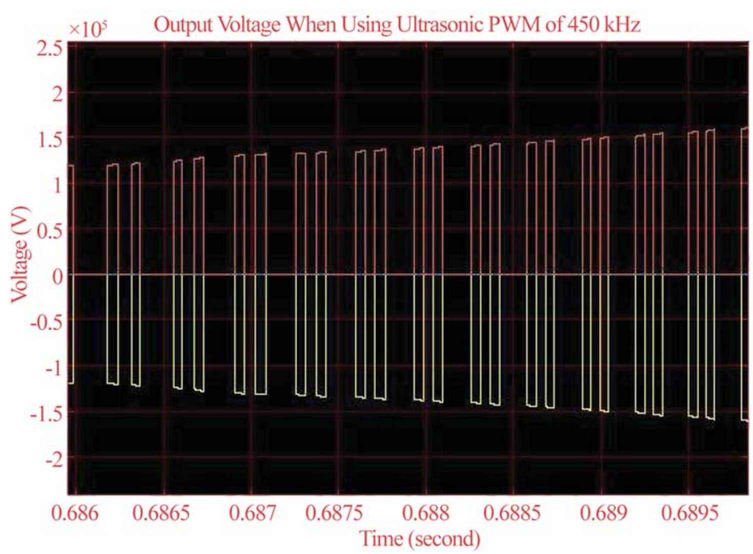


a *b*

Fig. 9. The accuracy of the output is 99 % and THD are 0.3 % when using UPWM 100 kHz: *a* – the output of the current; *b* – the output of the current when using UPWM of 120 kHz

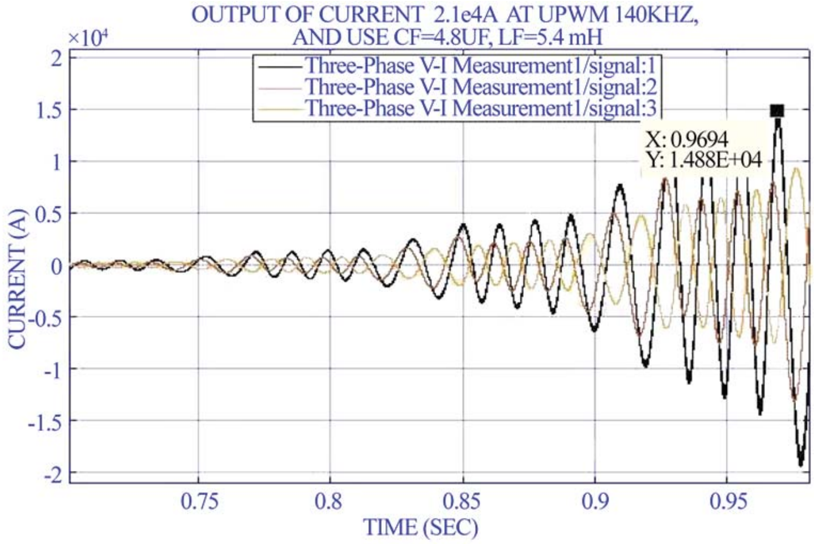


a

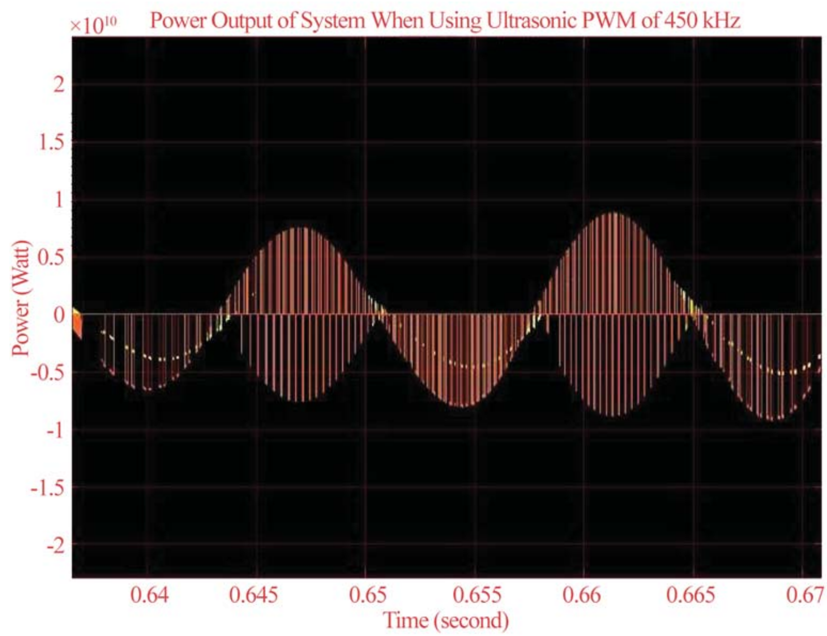


b

Fig. 10. The accuracy of the output is 99 % and THD 0.1 % when using UPWM of 450 kHz: *a* – current output; *b* – voltage output



a



b

Fig. 11. The accuracy of the output is 99 % and THD 0.1 % from: *a* – the output current when using ultrasonic PWM 140 kHz, with used *CF*=4.8 μF, *LF*=5.4 mH; *b* – the power output of the system when using UPWM of 450 kHz

6. Discussion of results of compound ligation (CL) system with a very high frequency in an inverter

Fig. 5, 6 show the output current and voltage in the inverter when using a carrier frequency is 20 kHz, where the phase change is shown based on the values of the passive components (LF, CF, RL, and Diode), according to the resonant frequencies, where the THD from the current and voltage are 0.1 **%**, and accuracy is 99 **%**.

Values were mentioned in Table 1 – inductor, capacitor, and resistor are given, and when the calculation of the values of the components is done by the equation (3), which shows that overcoming the losses in this research is done through the compound ligation, as it works these components to compensate for the active power and reactive by three-phase dynamic load, and these components work to correct the power factor to make it stable to performs at work.

At the values of 30kHz, through Fig. 7, it is noted that there is a lower accuracy than 20 kHz. an increase in frequency leads to an increase in the gate resistance (*GR*) and thus increases the track of resistance in the direction of the MOSFET, it's necessary to avoid this status needful by using external resistance (*RG*) consequently reducing energy waste by reducing the parasitic capacitance (*CS*), where the losses reached 0.8 **%**.

Through Fig. 9, it is noted that the losses in 100 kHz, 120 kHz are less than 50 kHz, and 60 kHz, due to controlling the value of reducing the resistance track towards the MOSFET, and thus wasting energy was controlled due to the reduction in the flow of current through the use of a suitable value of inductance that not works on the flow of random voltage to the capacitor, and thus cyclonic currents not occur and lead to the occurrence of parasitic capacitance, which occurs due to the increase in voltage flowing from the inductance when it is increased.

In Figs. 10, 11, at the frequencies 450 kHz, and 140 kHz the results appear to be very good and with high accuracy due to the appropriate selection of voltage, frequency, and appropriate values of inductance, capacitance, and resistance, and the power of the three-phase dynamic load is 6 kW and 3 kVAR, so the losses are tiny.

One of the disadvantages is the difficulty of obtaining an oscillator circuit with 4 GHz, so an oscillator circuit was designed, also the power devices need to increase their efficiency by improving the snubber capacitor (Cs) and snubber inductor (Ls) with the MOSFET. Future work requires improving the work in the inverter by increasing the power and high of switching operations because experiments have shown that increasing the input voltage leads to an increase in frequency and thus leads to very little distortion and high accuracy in addition to the characteristics of the size of the device is small. This work requires experimental work and programmatically.

7. Conclusions

1. The compound ligation (CL) proposal had very positive results by reducing losses by 0.1 % and increasing accuracy by 99 % in experimental and programmatic work, and the results prove that from Table 1.

2. Three-phase dynamic load after linking it to the compound ligation, the results were expected, as the compensation of active and reactive power was positive and worked to stabilize the power factor, which gave the system stable working conditions, and therefore the results were evidence of that.

3. The proposed to use oscillator circuit with a very high frequency 4 GHz, microcontroller achieved its objectives by not using external components to control the overvoltage, overcurrent, and overtemperature. Thus, the system was distinguished by its small size and low weight.

4. The experimental study was really successful through the achieved results. And this is a new work in that no researcher has ever used three-phase dynamic load and compound ligation to improve output with very high accuracy, and the results achieved that we used a 4 GHz oscillator, which is a new case.

Conflict of interest

The authors declare that they have no conflict of interest concerning this research, whether financial, personal, authorship, or otherwise, that could affect the research and its results presented in this paper.

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The study was performed without financial support.

Data availability

The manuscript has associated data in a data repository.

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