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THREE PHASE INDUCTION MOTOR CONVERSION TO THREE PHASE INDUCTION GENERATOR USING CAPACITORS

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Abstract:
This paper presents an experimental investigation of the conversion the three phase induction motors (IM) to run as three phase induction generator (IG) by using capacitors which proportional to the load power and the generator power. The potential of these capacitors must not be less than 450 V and connected in parallel with three phase output. The generator must be run on full load to balance the inductive loads which connect on generator with the capacitive loads. The experimental results indicate that the three phases IM with high power reaches to 90 KW can be lead as three phases IG with power (112.5 KVA).

Keywords: *Three-phase IM, Three-phase IG, Power load, Capacitors.*

تشغيل محرك حثي ثلاثي الأطوار كمولد حثي ثلاثي الأطوار باستخدام متسعات

الخلاصة:
أوضحت نتائج هذه الدراسة انه يمكن تشغيل المحرك ألحثي الثلاثي الأوجه كمولد حثي ثلاثي الأوجه باستخدام متسعات ذات سعات عالية تتناسب مع قدرة الحمل وقدرة المولد وعلى أن لا تقل فولتية المتسعات عن 450 فولت وتربط هذه المتسعات على التوازي مع الأطوار الثلاثة للخرج على أن يتم تشغيل المولد على الحمل الكامل قدر الإمكان لكي تتوازن الأحمال الحثية المربوطة على المولد مع الأحمال السعوية. في هذا البحث تم التوصل إلى تشغيل محرك حثي ثلاثي الأوجه ذات قدرات عالية تصل إلى 90 كيلو وات كمولد حثي ثلاثي الأوجه وبقدرة (112,5 KVA) .

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1. Introduction

The conversion of three phases *IM* to the three phase *IG* using Capacitor widely employed in Iraq because of its high capacity, accessibility, low price, high performance and this motor does not demand to maintain because of the lack of commutators and Carbone brushes, and study the possibility of supplying electrical power from this generation for all varieties of electrical loads. In the operation of generating electric power demands three basic conditions cannot be administered. One of these conditions is the bearing of a magnetic discipline, where a coil for cutting this field should spin within this region, which is known as the process of transferring the mechanical power to electrical power. The *IG* which is connected to the network has a reactive power of the network to provide a source of the magnetic field. In this case it must be provided a permanent source for the reactive power to produce a magnetic field which is done by using capacitors connecting in parallel with the terminals of the *IG* and the terminals of the load [1]. These generators which do not depend on the external power source called self-excited *IG*. The choice of the capacitors must be one type of that which remains in the circuit during the period of (motor run capacitor) and these capacitors provide the necessary feed to build the circulated magnetic field [2]. The theory of generating the voltage with an approximate equivalent circuit to the self- excitation *IG* is shown in the Fig.1. It is shown that capacitors are connected in parallel to the output terminals. The resistance (R_{fe}) shown in pointing line has high value comparing with X_m which can be neglected since its effect is limited in building the generated voltage, furthermore, when it is not loaded, the slip will equal zero and this will make R_2/s equals endlessly so the circuit is opened, so the current passing in the pointed line equals zero.In this case, the components must be neglected in order to remain X_m only Xc [3].

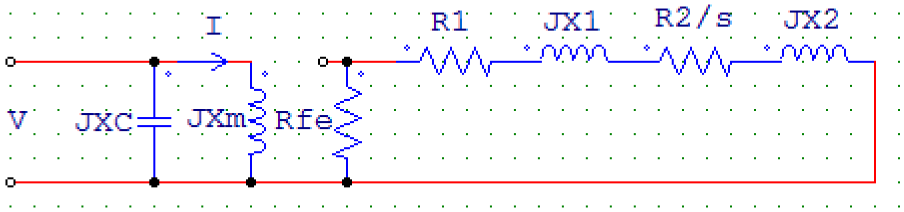

Fig.1. Approximate equivalent circuit of the self-excitation induction generator

$$Pi = V\ I\ \cos\Phi \quad (1)$$

The reactive component of current

$$I\ \sin\Phi = \frac{V}{Xm} \quad (2)$$

$$X_m = V/(I\sqrt{(1-cos)\ \Phi^2} \quad (3)$$

So when the *IG* running by the mechanical motor and the presence of weak residual magnetism hanging on the iron that the *IG* is built, the generated voltage will be low in X_m and this low voltage appears on the capacitors Xc causing a small current passing in the X_m and the capacitors Xc this current will generate the voltage I_mX_m which is appeared on the

V_{out} and this voltage is higher than the generated voltage from magnetism which makes the current passing in the capacitors high which feeds the X_m till the voltage of generator becomes 380V and the frequency 50 Hz and the value of this frequency depends on the speed of the mechanical motor that runs the *IG* in which the speed directly gone with the frequency. The generated voltage and frequency in the generator will be specified in the number of the coil of the stator and the speed of rotational of the rotor and the load connected on the generator [4].The applications of the *IG* isolated from the network are overcome by the loads which has no great effect in changing the frequency, like heating, irrigation or means of resisting the fire. The application of the power of the wind is suitable for the *IG* (either it is isolated or connected to the network) because the frequency is changeable because of the changing speed and this will make the *IG* equivalent to the synchronous generator in this case .The *IG* is distinguished in two matters which are: The simple structure and the high flexibility to harmonize with characteristics of the air turbines[5]. The value of the generated effort depends on the same past factor in addition to the capacity of the capacitors and the frequency in this case will depend on the number of the poles of the generator and the speed of the rotation. The past studies and researches[6] shows the possibility of running any kind of the single phase *IM* single phase as an *IG* single phase by the turn of the rotor by a mechanical machines, because single phase *IM* have been run like, water pump, air cooler, washing –machine and others of the small housing motors by using capacitors connected parallel with the coil of the motor to provide the necessary voltage to increase the magnetic field in which the rotating voltage is generated to fed the loads of lighting ,fans and some of the housing equipment that has small powers. The past studies[7] has shown the results of the impossibility of running the electric motors as loads of these generators because of the low power for these generators which are not exceeding than 500 W which are developed and many experience and studies have been done on the generators that its power is about 2000 W. The direction of the rotation must be in the correct direction of the *IG* with single phase in order the generation must be done and if the generator has gone in opposite direction, the generation will not be done. If the *IG* left for a long time without running or if it is objected to hammering or heating, it will be lost the residual magnetism which will lead for not generating the electric power and in this case the *IG* must be run as *IM* without connecting the capacitors for a short time or excited it by the *DC* supply for a short time and then must be used in generating the electrical power. The generator of this kind must be loaded completely when its voltage reached to the rated voltage (380 VL-L). The generator is destroyed if it is run with high speed without load because the capacitors used as full capacitive load which will lead them to draw higher current and destroy the stator coils.

2. How to choose the capacitors

There are several mathematical equations used to calculate the value of the capacitors as follows:

1-Value of the capacitors when the current *I*, the voltage *V* and the frequency *f* are known.

$$c = I / 2\pi \times f \times V \qquad (4)$$

2-Value of the capacitors when the reactive power *KVar*, the voltage *V* and the frequency *f* are known.

$$c = (KV_{ar} \times 10^3) / 2\pi \times f \times (KV)^2 \qquad (5)$$

3-Value of the capacitors when the capacitive *Xc* and the frequency *f* are known[8].

$$c = 10^6 / 2\pi \times f \times X_c \qquad (6)$$

3. Experimental Part

This paper selected the Chinese IM. Specification of this IM is represented in table ١.

Table ١. Specification of the IM

Parameter	*Value*	*unit*
Rated input power	90	Kw
Rated input voltage	380	V
Rated input current	١35	A
Rated input frequency	50	Hz
Power factor	0.8	
Rated speed	1500	RPM
No. of poles	4	

The stander wire gage (*S.W.G.)* of the coils are changed for this *IM* and changing the connection of the coils to get 121A for each phase. The *IM* is driven by diesel machine that has a mechanical power 135 Hp as shown in Fig.2. The rotation motor runs with speed of 1500 RPM by electrical motor or diesel. In general the *IM* get about 4V from the remaining magnetism and the frequency 50 Hz without any connection of capacitors as shown in Fig.3. Effects of capacitors on the output voltage of *IG* will discussed her, the output voltage will increase from 4V to 380V and the frequency at 50 Hz. The capacitors are connected as delta on the output of the generator and the value of each capacitors is 2250 µF. It has been found that the drawing current by the capacitors is about 134A for each phase and it is possible to connect the capacitors as star on the output of the generator parallel with the load [8]. Fig.4 shows the connection between the induction generator and the capacitors. At fully load, the generated voltage will be 380 volt and the frequency 50 Hz but the drawing current from the capacitors was 104 A for each phase and the drawing current by the loads as shown in Fig.5. The disparity of the currents between the three phases happened because the loads has unbalance on the three phases.

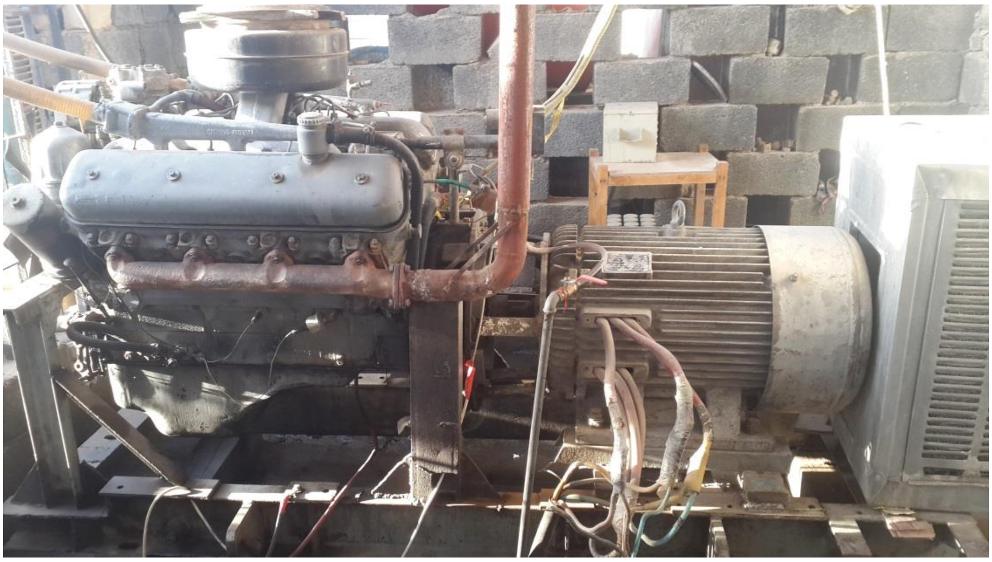

Fig.2 Show the connection of the engine and the induction generator by coplen

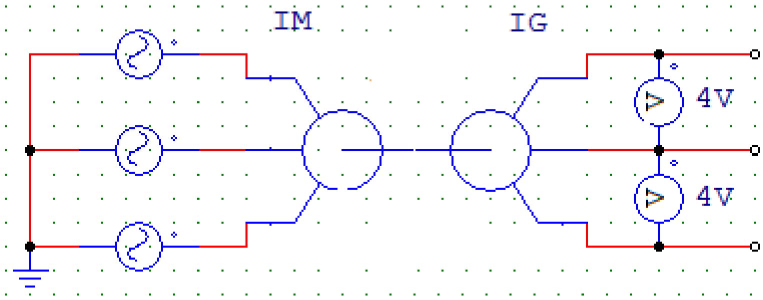

Fig.3 IG operating without capacitors

Fig.4 Show the connection between the induction generator and the capacitors

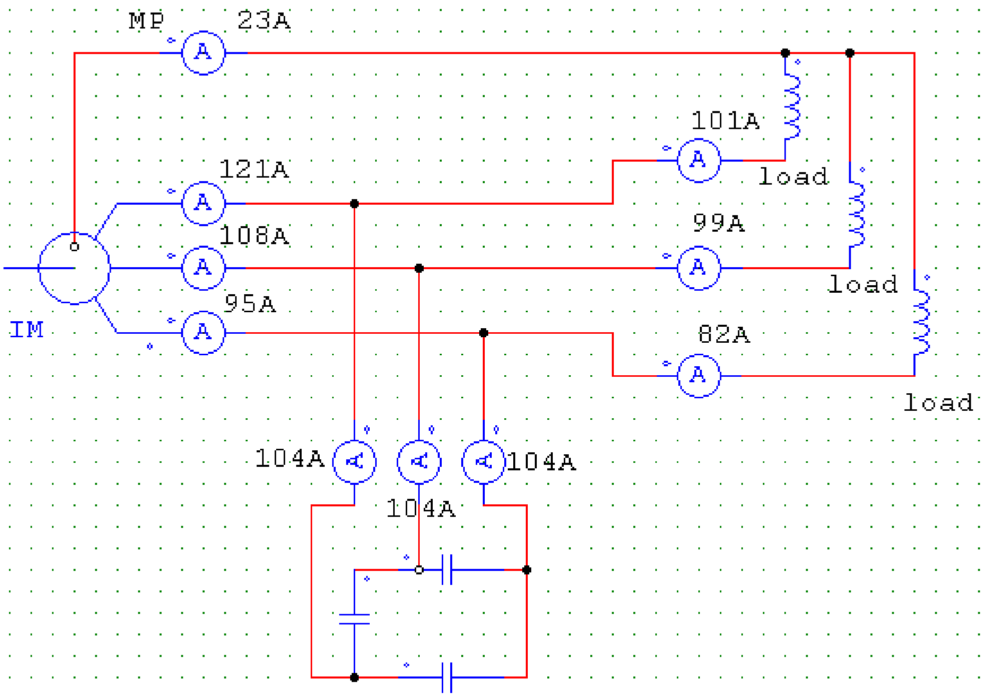

Fig.5 connecting full load on the IG

4. The choice of the capacitors

Fig.6 shows the capacitors value which are required to be connected with the *IM* terminals at the speed of the three phase *IG* is (2500-3600) RPM. An increase in output power caused increase capacitors value. In fact, an increase in *IM* speed decrease in capacitors value under the same value of output power value as shown in Fig. 6a,b,c.

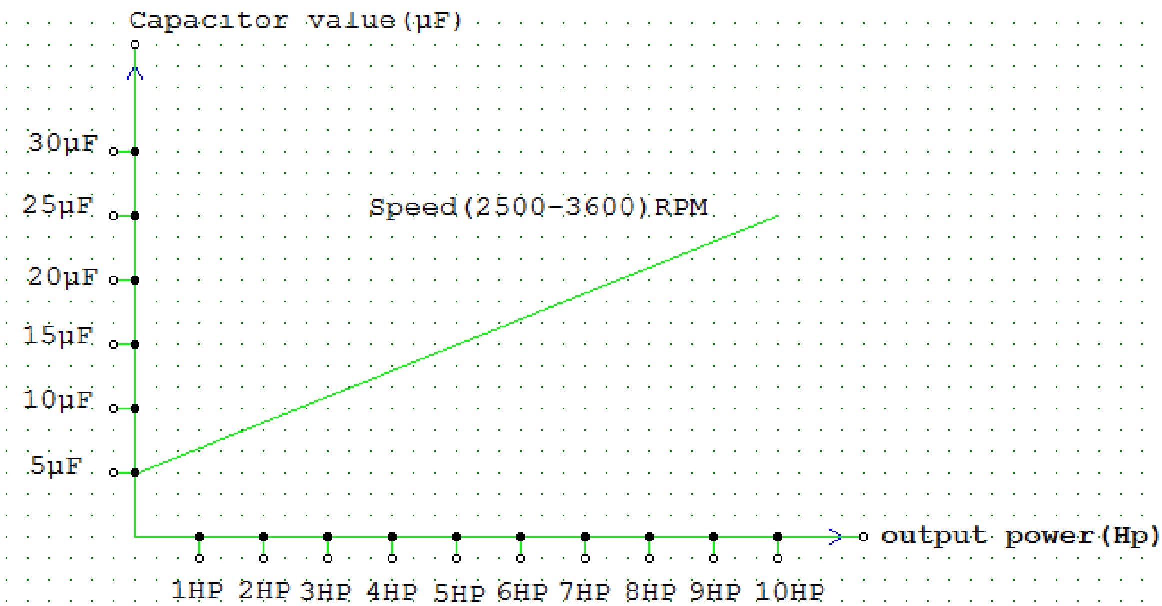

Fig.6. (a) Relation between the outputs power in HP and the value of the capacitors in μF when the speed is (2500 to 3600) RPM.

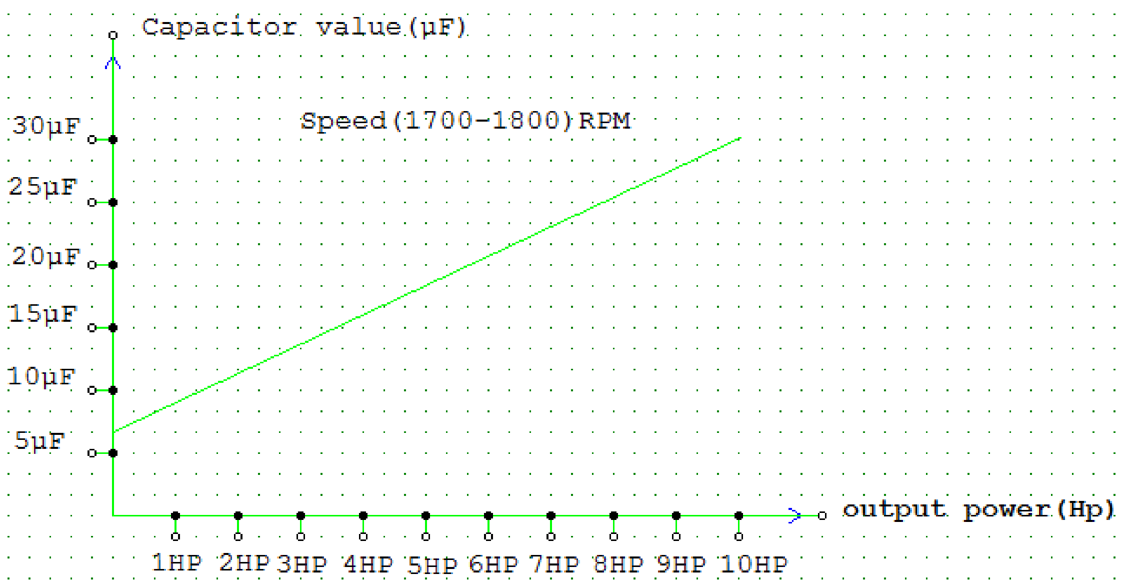

Fig.6. (b) Relation between the out power in HP and the capacitor value in µF when the speed is (1700 to 1800) RPM.

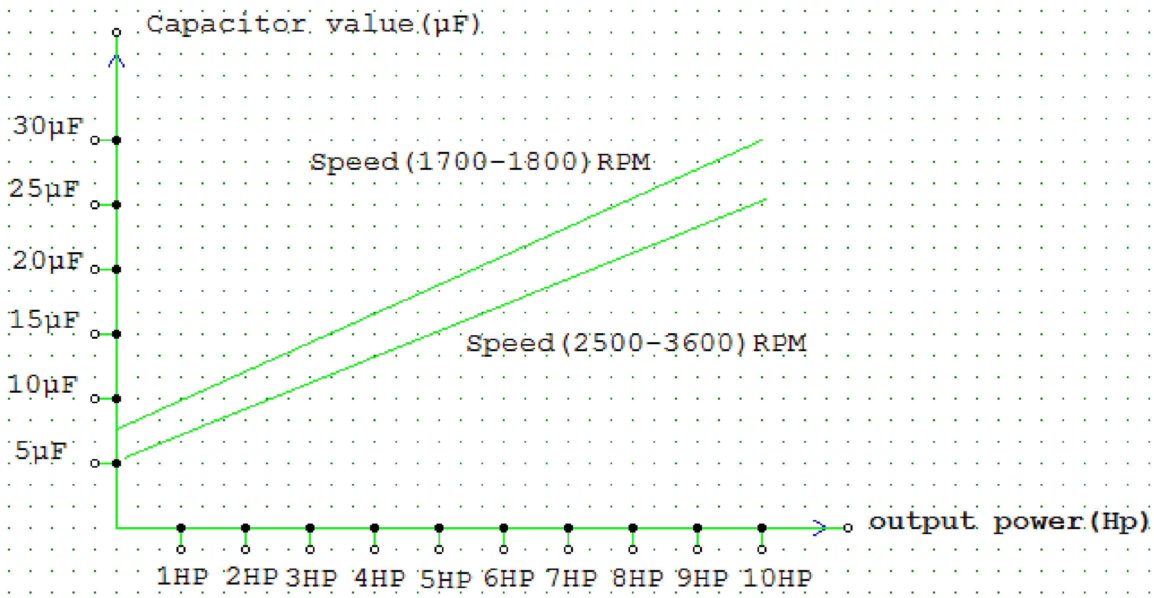

Fig.6. (c) Relation between the out power in HP and the capacitor value in µF for both speed ranges (1700 to 1800) RPM and (2500 to 3600) RPM

Fig.7 shows the relation between the output power of the generator in *KVA* and the value of the capacitors in µF. The effect of *IG* capacity on capacitor value is shown in Fig. 7. The Figure indicates that the capacitor value has gradually increase when the *IG* capacity increase. Increasing the generator capacity from 12.5KVA to 112.5 KVA increasing the capacitor value from 250 µF to 2250 µF at the speed of the *IG* is 1500 RPM.

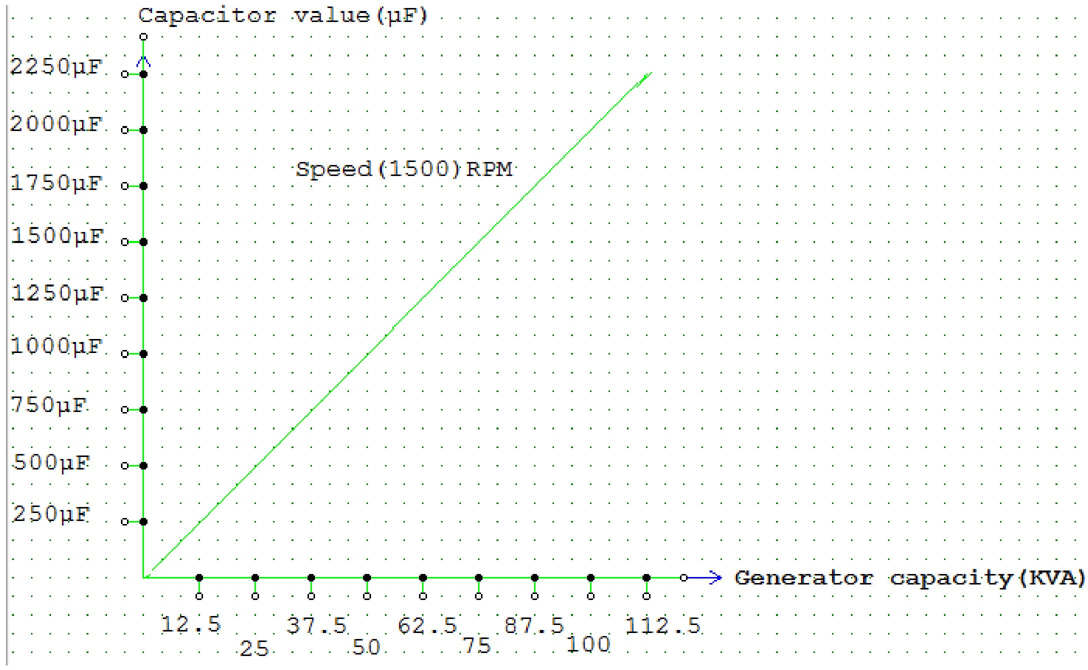

Fig. 7 The relation between the out power of the generator in KVA and the value of the capacitors in µF (speed is 1500) RPM

Table ٢ shows that the more capacity increasing amount of current drawn which shows that the current drawn at apparent power 112,5 KVA is 155 A and the value of the capacitors is 2250 µF for each of the three capacitors connected as delta.

Table ٢. choices of capacity of capacitors

Power (KVA)	*C(µF)*	*Ic (A)*
12.5	250	17
25	500	34
37.5	750	51.5
50	1000	69
67.5	1250	86
75	1500	103
87.5	1750	120
100	2000	137
112.5	2250	155

5.Results and Discussion

A Chinese *IM* with 90KW of power and speed of 1500 RPM has been chosen in this research, because when low speed *IG* chosen, it will be demanded using capacitors that has large value and as shown in Fig.2. It is necessary to run the *IG* without loads where the suitable frequency and voltage investigate the load are connected. There is no problem for connecting the capacitors on *IG* coils when it is switched off, this will make it ready for running at any time. When the *IG* starting without load the frequency and the voltage are generated at any direction and the output is sine wave.

For generating 500 watts, the power of diesel motor must should be at least one horse. This case for lightening load or loads without electrical motors because the electrical motor draw current 5 times more than the rated current at the starting operation for a short period. The process of checking generating done by controlling the generator speed however the high speed leads to generate high voltage. The high voltage effects on the capacitors and it leads to damage the capacitors. Inductive light-bulbs are used to check the voltage that are generated. When the generator speed decreased to 1000 RPM the light bulbs switched off which means that the generated voltage is not enough to lighting the bulbs. This reason can be expressed as follows, the capacitors values are not enough at this load and speed. When the motor speed reaches to the rated speed (1500) RPM, the line to line output voltage is 380 V, 220 V for single phase with frequency 50 Hz. In some times, when the *IG* speed reach rated speed and the capacitors are connected on the coils, the voltage are not generated. This caused by the low values of capacitors or by losing the magnetism in the generator. In this case, we can solve this problem by increasing the value of capacitor or by feeding the generator coils with DC 12V from the battery. The reason behind the presence of current is that the neutral line is equal to 23A which is the difference between the load in each phase. In this case the voltage between any phase and neutral is less than 220V in spite of that the voltage between these three phases is 380V. It is possible to solve this mater by normalizing the neutral current to zero, and the voltage becomes between each phase and the neutral is 220V. This solving becomes into two ways, either connection the neutral to the earth or by balancing the three phases. Fig.8a shows the waveform between the voltage line and the time and Fig.8b shows the waveform between the current line and the time.

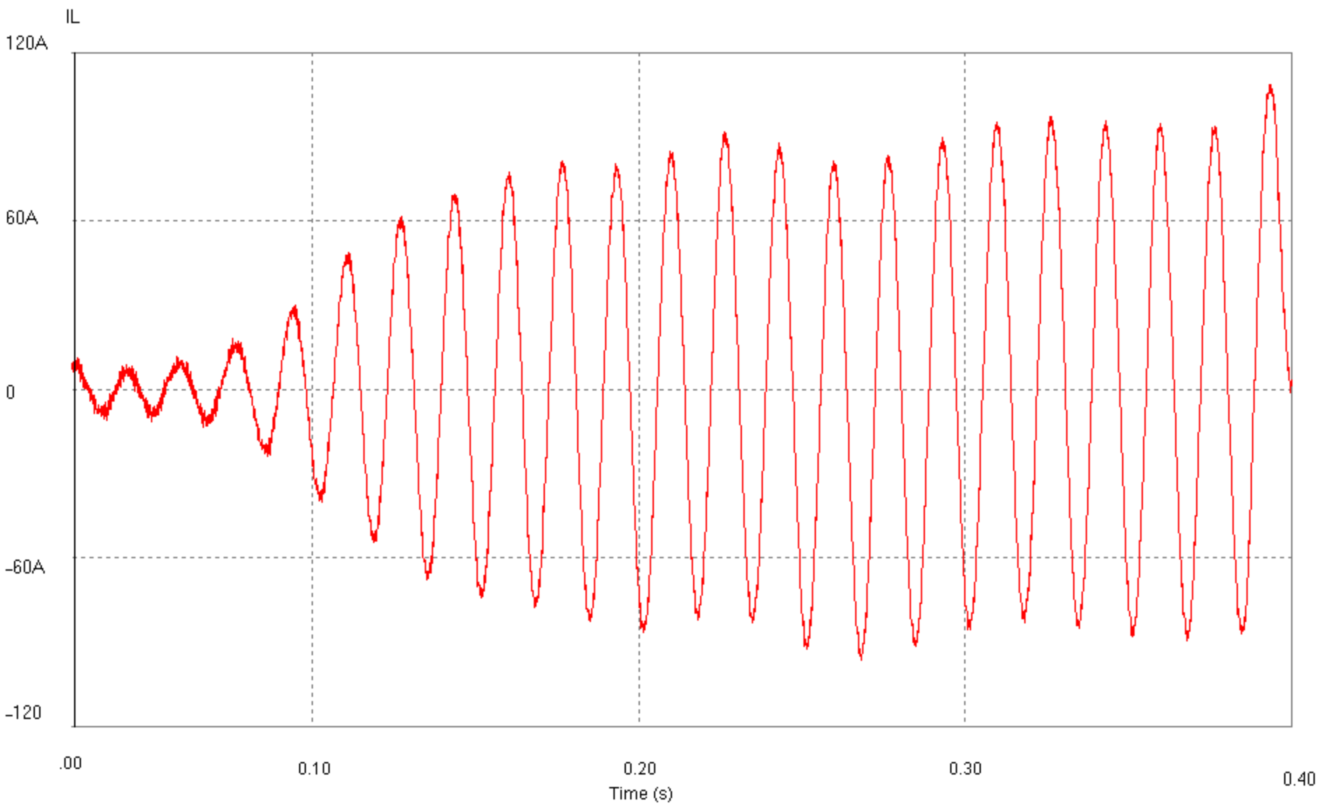

Fig. 8 (a) the waveform between the line current & time

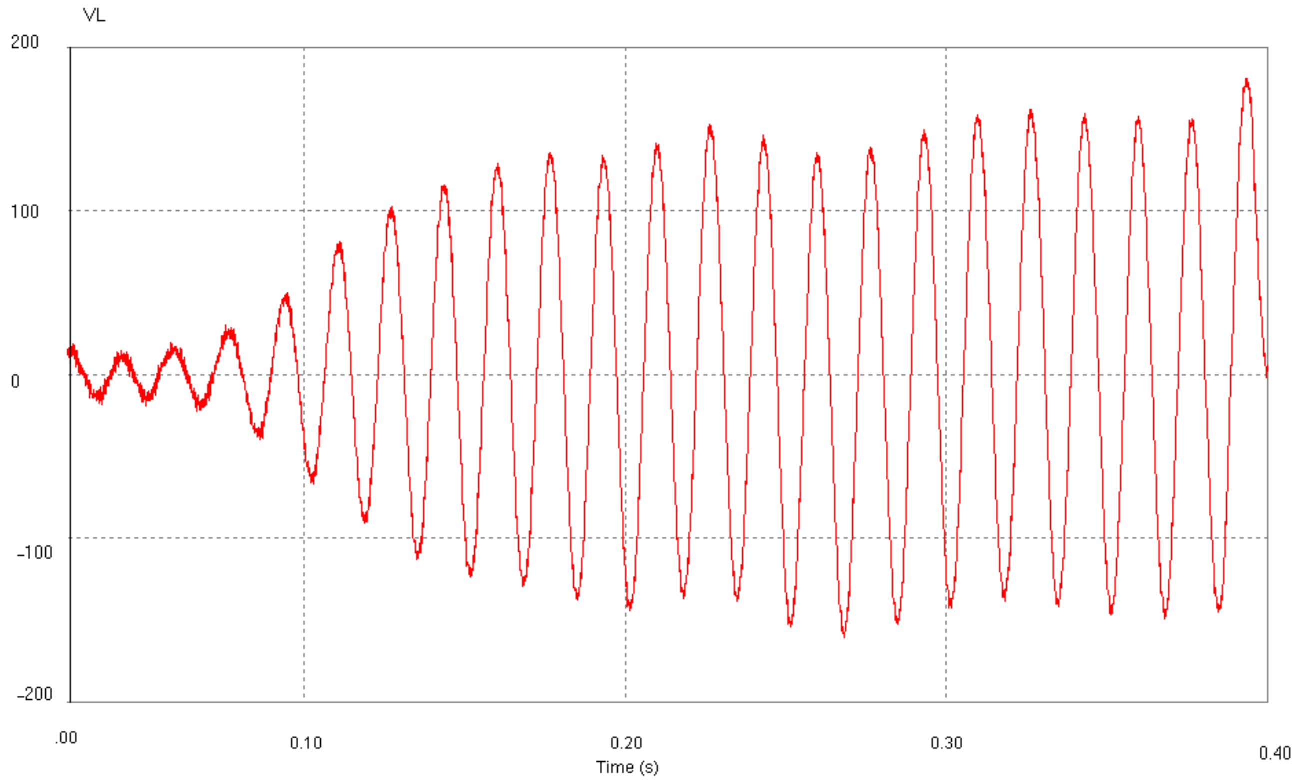

Fig. 8 (b) the waveform between the line voltage & time

6. Conclusions

An experimental study was carried out to evaluate the performance of running the *IM* as *IG*. From the analysis of experimental data can be summarized by:

1- *IG* runs without loads and the neutral line connects to the earth.
2- Increasing the capacitors values with decreasing the rotating speed of the IG.
3- Increasing the capacitors values with increasing the power of the generator.
4- The mechanical capacity of diesel engine must be more than the generator power.

Nomenclature

IM	Induction Motor
IG	Induction Generator
C	Capacitance, µf
F	Frequency, Hz
I	Current , A
V	Voltage, volt
X_C	Capacitive, Ω

X_L Inductive, Ω
S.W.G. Stander wire gage

Subscripts

KV Kilo Volt
KV_{ar} Reactive power

Acknowledgments

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