Feasible Study of Restructuring Used Induction Motor for Low Speed Renewable Resource Generator

Wichit Krueasuk, Pornrapeepat Bhasaputra, and Woraratana Pattaraprakorn

Abstract— *This paper presents a feasible study of value added for rebuild used induction motors. The performance of induction motor was degraded by growing number of servicing years and the deterioration structure of induction motor with worst when used the rebuilt induction motor. However it has a potential to transformation induction motor to reused induction generator which mostly requires lower speed at prime mover for standalone generator in the remote rural area with the aim to finding the economic solution to rebuild used induction motor for low speed induction generator. This paper presents in two parts, the first part is an experiment to test the efficiency of used induction motor in the different years of serviced and the second part is a development method to rebuild the used induction motor for the renewable low speed inductor generator by rewiring the new coil in the stator and embedded permanent magnets into the rotor of the induction motor as permanent magnet synchronous generator (PMSG). The first experiment resulted demonstrate the performance of used induction motor in the different groups by year of service. And the finding in the second part of the experience to developed a rebuild used induction motor able to producing an acceptable power as per the designed voltage at low speed induction generator. Finally, this experiment is a new concept for alternative energy from the lower efficiency of used induction motor by rebuilt to low speed induction motor at the economic cost for standalone generator in the remote rural area in the future.*

Keywords— **PMSG, low speed induction generator, alternative energy.**

1. INTRODUCTION

Nowadays, the world's energy consumption is expected to increase dramatically. While fossil fuels will remain an important source of energy, renewable energies will also gain importance, as a result of concerns over high fossil fuel prices, increasing greenhouse gas emissions and energy import dependence. Also, the developing countries challenge facing high price and demand of fuel according to high increasing rate of GDP and economic growth in the country. In the recent year, estimate electrical energy demand in Thailand is growing in average 4%-5% [1-2]. The transport sector is the largest energy consuming sector in Thailand, followed by the industrial and residential sectors, respectively. In order to reduce both imported energy and environmental emissions, energy conservation programs would be implemented [3]. One option, the energy resources from the neighboring countries is become the necessary resources for strategy energy. However, the major concern and worrisome of energy policy and the environmental impacts are playing the difficult role for the energy development agencies. Renewable energy is developing into the major energy supply option for low-carbon energy economies. Disruptive transformations in all energy systems are necessary for tapping widely available renewable energy resources [4]. Then, the improvement of renewable energy technologies will assist sustainable development and provide a solution to several energy related environmental problems as can seen the optimization algorithms constitute a suitable tool for solving complex problems in the field of renewable energy systems is importance [5].

Hence, the drive towards the decentralization of power generation and increasing use of renewable energy sources is one page action plan for case study. The wind energy, bio-gas, solar and hydro potential has become essential to adopt a low cost generating system, which is capable of operating in the remote rural areas in term of study. The wind turbines and micro-hydro-generators as an alternative energy source will be developed because of suitable energy, operational and maintenance simplicity in rural electrification [6-7]. Conversely, the problem of the power generation cost from renewable energy remains expensive per unit of production has a research interest in this issue [8-9]. The induction and synchronous generators are most generators that use in wind and micro-hydro power because of their lower unit cost, inherent ruggedness. In that case, application or modification of the generator for low cost of electric generation is an interesting approach.

According to single and three phases induction motors are normally used in small scale such as house hold until large scale or industry [10-11]. The efforts are enhanced the induction motor for maximize benefit such as the research considers for induction motor drive systems in heating ventilation and air-conditioning applications [12-13]. Or, the intensive researches and experimental to be comparison of the efficiency and losses characteristics of induction motors; that the high efficiency motors should be promoted and even be made mandatory by national

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energy standards and legislations [14-15]. Most of the users generally thought that the motor is very strong performance in all working condition and required a less maintenance. The most induction motor will be working until has the problem such as leakage coil and circuit damage in the motor. The users will focus on the over-current relay or control of the motor cut out (tripped) only. The typical users should finding the real cause of our problems, if not identify the problems and then trial to re-run the machine or motor. The motor will cut off again and recurrence the problem again, the operators are ignored the problem by keeping equipment running. Until the motor is a serious damaged after that the repair to be used again. The motors are repaired or reused, there are the low performances. However, the reused or old motors had widely used in Small Industries or the Small and Medium Enterprises (SMEs) because of the lower cost of initial investment of the capital equipment.

The question of whether induction motors should last longer for many years? What are the key elements that motor should be maintenance which the main components by each element and valid for a few years and what are the potential root cause of the motor damaged. All the potential cause leaded to appropriate of use in the future of the induction motor. Which, if considered key components of the electric motor induction include the insulation of the coil within the motor, bearings that are supporting the movement of the rotor, environment of corrosion, including infrastructure design, installation, motor load, mechanical, motor control and prevention. The open discussion issues; "Is it difficult, how we code the appropriate age or year of service of induction motor?"

Therefore, this paper provides information of testing method and result of induction motors for consideration an appropriate working life of the most induction motor. After that the designed voltage at low speed induction generator for renewable resources by a rebuild used induction motor. According to the three R's of the environment include Reduce, Reuse, and Recycle. First, R is the reducing amount of waste that is the best way to help the environment. There are lots of ways to do this. Second, R is reused, instead of throwing things away; try to find ways to use them again. Third, R is to recycle, many of the things we use every day, like paper bags, soda cans, and milk cartons, are made out of materials that can be recycled. Recycled items are put through a process that makes it possible to create new products out of the materials from the old ones.

First, experiment is testing the efficiency of induction motor in each range of motor's age group. The results of first experiment are showing the difference output performance of the used induction motors in different range of motor's age. Second, experiment is study the induction motor structural and performance of rebuild induction motor for low speed induction generator as a new renewable resource by rewiring the new coil to replace in the stator and add permanent magnets embedded into the rotor of the induction motor as permanent magnet synchronous generator. The proposed of low speed generator is capable to produce and sustain the acceptable voltage per expectation of designed power was present in second experiment result.

The aim of this research to public general guideline to increase the value added into the used induction motor by reused it in the low speed induction generator at low cost and suitable for small industrials with disposer to scrap low performance of old induction motors. The feasibility study of reuse old induction motor for renewable energy resource in low speed induction motor is consideration in term of engineering, economic and environmental. This experience is potential to initiative of renewable electrical energy resource for low speed at prime mover generator in standalone remote rural area at economic price. Finally the result of the experience is demonstrate of the concept design and development of using low efficiency performance old motor for low speed induction generator as the alternative renewable energy source at low cost solution for standalone user and small industrial company in the future.

2. INDUCTION MOTOR AS GENERATOR

The induction generator's ability to generate power at varying speed facilitates its application in various modes such as self-excited stand-alone (isolated) mode; in parallel with synchronous generator to supplement the local load, and in grid-connected mode [16-18]. Using induction motors as generators is a very cost effective way to providing a generator for a turbine system. Especially, the induction motor is working well with single phase or three phase systems that are interconnected to the electrical utility, as an induction system requires no governor controls. Instead of consuming electrical energy but the induction motor was driving at varied speed and the motor becomes a generator. Induction generators are much less expensive than other types of generators, but require excitation to operate. This is why they are ideally suited to interconnect utility applications. It is possible to utilize induction motors as generators in standalone applications, utilizing the residual magnetism in the windings, as well connecting capacitors to supply continual excitation [19-20].

In single phase operations, it is possible to utilize induction motors as generators and get near three phase efficiency by connecting capacitors to the other unused leg of the motor. The machine selection either a three-phase squirrel cage induction motor or a capacitor type motor may be used. From above the two choices, the old three-phase motor makes a better selection. These usually can be located in motor shops, junkyards, etc, for very little investment [21-22]. An induction motor may function as a generator if it is driven by a torque at greater than 100% of the synchronous speed show in Fig. 1. [23]. This is corresponding to a few % of "negative" slip, say -1% slip. This means that as we are rotating the motor faster than the synchronous speed, the rotor is advancing 1% faster than the stator rotating magnetic field. It normally lags by 1% in a motor. Since the rotor is cutting the stator magnetic field in the opposite direction (leading), the rotor induces a voltage into the stator feeding electrical energy back into the power line.

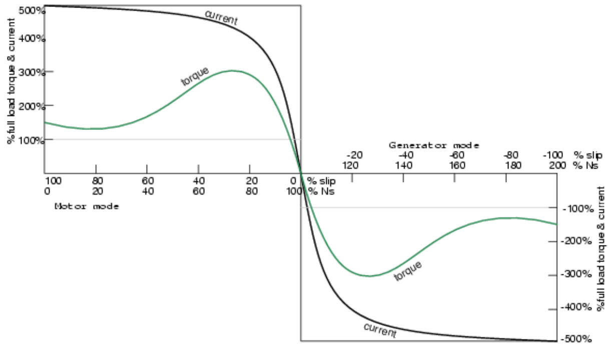
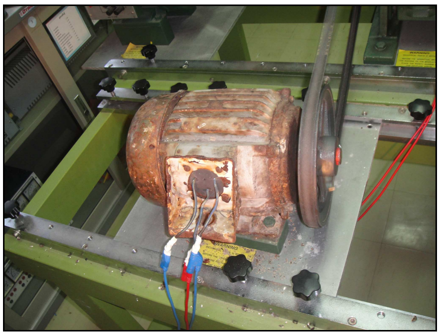


Fig. 1. Negative torque makes induction motor into generator.

The size of machine is selected to use for low speed induction generator, is depending on the rating of your need from the generator but generally should not exceed 10 HP for a three-phase machine or 3 HP for a single-phase machine. The worst generators can be expected generate electrical power output below 1/2HP for three phase or 1/6 HP for single phase. Which the different age of the typical electric squirrel cage induction motors show in Fig. 2. The best generators are motor speed at l700 rpm or higher rate. The lower speed machines can be used, but will require larger capacitors. The theory of operation for either type of machine, capacitors will be used to provide excitation to the machine. The excitation magnetizes at the machine's rotor. The magnetized rotors are moving past and the coil windings are generates output voltage in the terminal poles. The output voltage and frequency are determined by how many turns are in the windings and how fast the rotor speed and how much load is applied to the generator.



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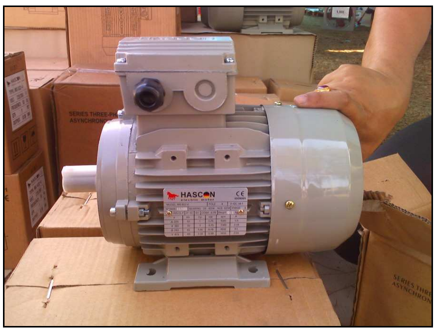


(b)

Fig. 2. Typical electric squirrel cage induction motors (a) Induction motor with 10 years of used (b) New induction motor.

There are numerous applications where induction generator is offer distinct advantages over conventional synchronous machines, resulting in simple design and installation at lower initial cost and substantial saving in O&M expenses. However, the induction generators have some disadvantages which need to be evaluated before practical use [24]. The majority of limitation being the need for an external source to supply the magnetizing current required to establish the sufficient magnetic field across the air gap.

2.1 The advantages of induction generator

The simple design of induction generator is less expensive cost. The construction is that of squirrel cage induction motor. The field windings, provisions for rotating excitation supply to the field or separated field excitation equipment (exciters) and slip rings as well as voltage regulation equipment (automatic voltage regulators) are not required. It always assumes the same output voltage and frequency as that of the power system which connected to irrespective of motor seed, so synchronizing equipment is not necessary. The protective relaying is the same as that would be provided for an induction motor of compatible size. It does not hunt or drop out-of-synchronism. When short-circuited, the machine delivers little or no sustained power output because its excitation quickly becomes zero. The machine does not have a definite speed for a given frequency as the operation of synchronous generator, but the speed with constant frequency varies with the load.

2.2 The disadvantages of induction generator

The majority limitation of an induction generator is that it cannot operate as an isolated power source. It must be connected to a power system which sufficiency to supply the magnetizing current required to establish the magnetic field across the air gap. This tends to lower the power factor of the system, and usually compensated by shunt capacitors installed at the generator. A load requiring lagging current cannot be supplied by the induction generator. Theoretically, the induction generator could operated an isolated system with the magnetizing current supplied by capacitors connected to the system, but there is no economical way to vary the reactive power from the capacitors in order to maintain the generator terminal voltage constant with changing load. In general, the induction generator has a lower efficiency than the comparably rated synchronous generator.

3. MODIFICATION THE INDUCTION MOTOR AS LOW SPEED GENERATOR

2.1 Analytical of a PM Synchronous Generator

The low speed generator is design same as the (PMSG) is considered in this section. The model relates the mechanical design specifications of the machine to the performance and equivalent circuit parameters. It neglects magnetic saturation, which is no considerable in face-mounted permanent magnet machine (PM) [25-26]. The machine has radiate magnetized NdFeB PMs mounted on the surface of a solid mild steel rotor core. The resulting air-gap flux density is approximately rectangular in shape. The machine stator has a fully pitched, distributed, double-layer three-phase winding accommodated in semi closed oval slots.

The root-mean-square (rms) value of the fundamental component of the excitation voltage induced in phase winding of the machine can be expressed in Eq. (1):

$$E_f = \frac{2\pi}{\sqrt{2}} f N_{ph} K_{w1} \phi_p \quad (1)$$

where f is electrical frequency, N_{ph} is the number of turns per coil, K_{w1} is factor of the fundamental harmonic winding and ϕ_p is the flux per pole. The flux per pole can be expressed as Eq. 2:

$$\phi_p = B_{1\max} lD / p \quad (2)$$

where, $B_{1\max}$ is the peak value of the fundamental space harmonic component of the excitation flux density, l is length of wire and D is diameter of each wire of conductor. The $B_{1\max}$ can be related to the plateau value of the rectangular air-gap flux density distribution, as follows:

$$B_{1\max} = k_f B_g \quad (3)$$

where k_f is the factor of the excitation field, B_g is the rectangular air-gap flux density distribution. The k_f can be expressed as:

$$k_f = \frac{4}{\pi} \sin\left(\frac{\alpha\pi}{2}\right) \quad (4)$$

The plateau value of the excitation flux density distribution can be related to the remnant flux density and the relative permeability of the PMs by the following expression:

$$B_g = \frac{l_m / \mu_r}{l_m / \mu_r .1/C_\phi + K_c I_g \left(1 + p_{r1}\right)} .B_r \quad (5)$$

where l_m is magnet length, l_g is air-gap length, C_ϕ is the flux focusing factor, μ_r is air magnetic permeability, μ_r is PM relative permeability, K_c is Carter's coefficient, and p_{r1} is the normalized rotor leakage permanence.

The effective air gap in a PMSG with magnets mounted on the rotor surface can be considered constant and relatively large. This is due to the relative permeability of the PM material being close to unity. The *d* and *q-axis* asynchronous reactance are consequently identical in this machine. The synchronous reactance is related to the magnetizing (X_m) and leakage (X_t) reactance as $X_s = X_m + X_t$. The magnetizing reactance can be expressed as:

$$X_m = \frac{6\mu_0 lDfK_{\omega 1}^2 N_{ph}^2}{p^2\left(K_c l_g + l_m / \mu_r\right)} \quad (6)$$

where the term $K_c l_g + l_m / \mu_r$ represents the effective air-gap length in the path of the magnetizing flux. This includes the mechanical air-gap clearance modified by Carter's coefficient to account for slotting.

The leakage reactance can be written in terms of the specific permanence coefficients associated with the dominant leakage flux paths of the stator (i.e., the slot, tooth-top, and winding overhang leakage flux paths, as:

$$X_t = 4\pi\mu_0 f \frac{N_{ph}^2 l}{pq}\left(\lambda_{slot} + \lambda_{tooth-top} + \lambda_{overhang}\right) \quad (7)$$

The per-phase resistance of the stator winding, neglecting the skin effect, can be expressed as:

$$R_a = \frac{l_{ph-winding}}{a.\sigma_{cu}.A_{cond}} \quad (8)$$

where $l_{ph-winding}$ is the total length of a phase winding. The efficiency of the PMSG can be expressed as

$$\eta = \frac{P_L}{P_{shaft}} \quad (9)$$

where P_{shaft} is the input mechanical power and P_L is the total real power delivered to its load. The input and load power can further be related by: $P_{shaft} = P_L + P_{Cu} + P_{rot} + P_{core}$ where P_{Cu} is the total stator copper loss, P_{rot} is the total rotational losses, and P_{core} is the total core losses. The total real power delivered to a load on the generator can be expressed as:

$$P_L = 3V_a I_a \cos\phi \quad (10)$$

The total stator copper losses can be expressed as:

$$P_{Cu} = 3I_a^2 R_a \quad (11)$$

The total rotational losses consist of friction losses in the bearings $P_{friction}$ and windage losses $P_{windage}$. The total rotational losses can therefore be written in terms of its component losses as $P_{rot} = P_{friction} + P_{windage}$.

The total core losses in the machine can be estimated on the basis of the hysteresis loss densities in the stator teeth and yoke $\left(P_{ht}, P_{hy}\right)$, and the average eddy current loss densities in the stator teeth and yoke $\left(\overline{P_{et}}, \overline{P_{ey}}\right)$. The total core losses can therefore be expressed as:

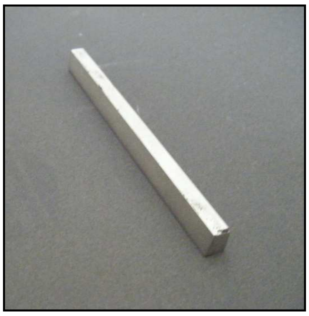
$$P_{core} = V_{teeth}\left(P_{ht} + \overline{P_{et}}\right) + V_{yoke}\left(P_{hy} + \overline{P}_{ey}\right) \quad (12)$$

where V_{teeth} and V_{yoke} are the volumes of the stator teeth and yoke, respectively.

3.2 Design Prototype of Low Speed Generator

The prototype of low speed induction generator is designed by using the squirrel cage induction motor that poor performance for the improvement. To match the theoretical electrical mechanical is a way to improve the two parts: the rotor and the stationary.

Part of Rotor: In this part, the rotor of used induction motor is modified to put the bar permanent magnet which the design size of slot for permanent magnet is shown in Fig. 3. The permanent bar magnets used in generators trapezoid shape, which contributed directly to the rotor size , which has a width 7.21 and 5.47 mm, length 110 mm and height 10 mm. The core rotor consists of all 16 bars magnetic alternating north pole-south. The flux density per bar magnet magnetic approximately 5,000 gauss.



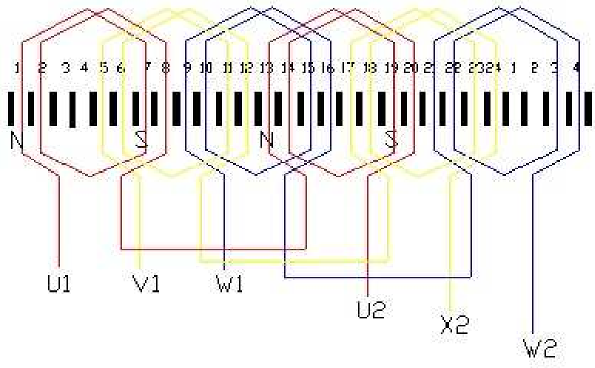
(a)

(b)

Fig. 3. Rotor of low speed generator (a) Permanent magnet bar (b) Modified rotor of induction motors.

Part of Stator: In a modification of the stator of induction motor as generator was designed and built the single phase and three phase winding, with turns of copper coils to provide a full pitch of the two sides of the coil in the center pole. There is the distributed turn of coils because the depth of the original slot is limited. The number turns to refer to the Eq. (1).

A stator has 24 slots for turn's coils of three phases. The design three phases of the turn coil as single layer and the turn coil is distributed in 6 slots which is full pitch. The connection coils in series so that the induction voltage is increasing show in Fig.4. (a). The turn coils of three phase characteristics, separate the each phase is independent. The induced voltage had two levels depend on the type of the connection to be a star or delta, which each have different properties. The Fig. 4 (b) is show the overall composition of the generator to be adapted from the induction motor.



(a)

(b)

Fig. 4. Improved the stator of used induction motor for low speed generator (a) three phase winding and (b) the new stator and rotor of generator.

4. METHODOLOGY

This research will test the steps by a split in two experiments. First, experimental determines the efficiency in the used induction motor and new induction motor. Second, experiments also to determine the efficiency in the induction generator is modify or rebuild construction by old induction motor as PMSG.

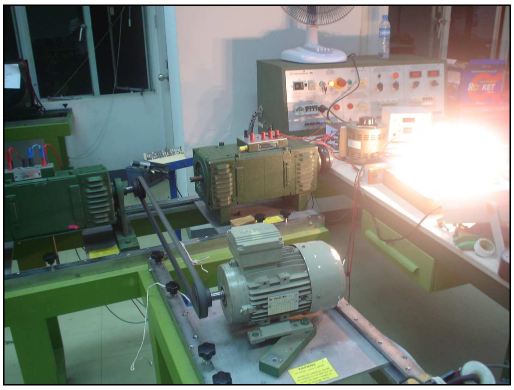
4.1 Experimental I

This part uses a dynamometer test to measure of the input and output, to determine the performance in IEEE Standard 112-Method B [27]. In North America, the prevailing testing method is based on direct efficiency measurement methods as described in IEEE 112-B and in Canadian CSA 390 standards. Those standards require to measurement of the mechanical power output and the electric input. In Europe, the prevailing testing method is based on an indirect efficiency measurement as defined in IEC 34-2 standard. This standard is different mainly by the method used to take into account the additional load losses. Many papers have been published IEC 34 – 2 was found to be unrealistic and a recent IEC Standard introduces fixed losses depending of the motor rating [28-31]. In 2007, IEC published a revised standard no. 60034-2-1 which includes a test procedure similar to IEEE 112-B. In Standard IEEE 112-B the losses are segregated and the efficiency is estimated by the following formula:

$$\Delta P_{st} = P_{in} - P_{out} - \left(\Delta P_{le1} + \Delta P_{le2} + \Delta P_{mec} + \Delta P_{fe}\right) \quad (13)$$

where the electric input power, P_{in}, is measured with a power analyser and the output power, P_{out}, with a torque meter. With the improved accuracy of recent power analysers and torque meters, this method can be considered accurate and reliable. The overall precision of efficiency assessment mainly depends on the torque estimation.

The sample of the used induction motor for the testing is past using in industry; which last for 3 years and 10 years usage rates 12 hours per day, the size is 2 HP, 3 phase, 1450 rpm and 380 volts at rated. To comparison with the new induction motor the same rating. The testing was tested in the case of a motor operator that the performance of each state as to how for to analysis for economics. The experimental can be seen in Fig. 5.



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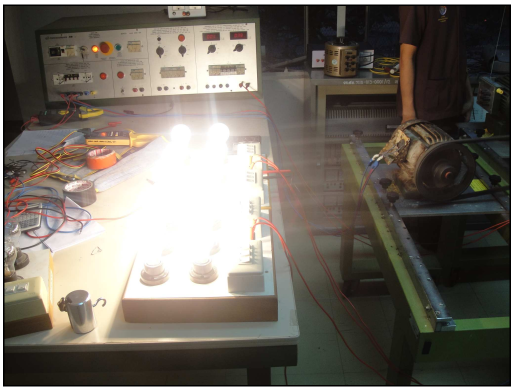


(b)

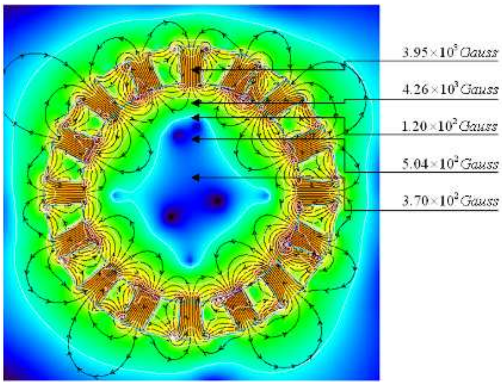
Fig. 5. Test station of used and new induction motor (a) Testing of new indution motor (b) Testing of 3 and 10 years indution motor.

4.2 Experimental II

This experiment II will trial to find the features of the low-speed generator prototype has already designed; that is, a generator adapted the structure of the induction motor is old or used for many years and poor performance. With the experiment was divided into two sections as the following. First section is to simulate the magnetic field of force of permanent magnets embedded in the rotor that looks how a computer program. Second section is to be tested in the modified induction motor as the prototype induction generator.

4.2.1 Simulation Magnet field by Software

The simulation results of the magnet fields in the rotor by Visimag 319 program [32]. A dynamic simulation was performed to study the electromagnetic field in the prototype generator. The result from this simulation can be seen in Fig. 6. show the front and side view of rotor magnetic as illustrated in Fig.6. The electromagnetic field in the prototype generator is uniformity following the research design. The simulated results will be analysis the suitability of various parameters affecting the induced voltage of generator.



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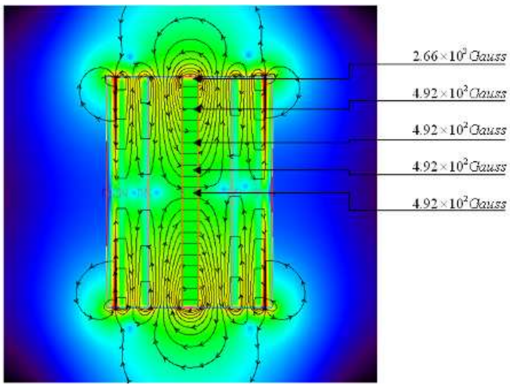

(b)

Fig. 6. Simulation results of the magnet fields in the rotor by Visimag 319 program (a) front rotor (b) side rotor.

4.2.2 Testing of low-speed generator prototype

The test process of the generator prototype is same as the experimental I. The low speed generator prototype could generate electric power to supply electrical load (Lamp) as shown in Fig.7. The testing is divided into two parts consisting of the No-load and On-load test generator. The No-load for a feature of the induce voltage is correlated with speed of rotation of the generator. The On-load test had to find the performance of the generator.

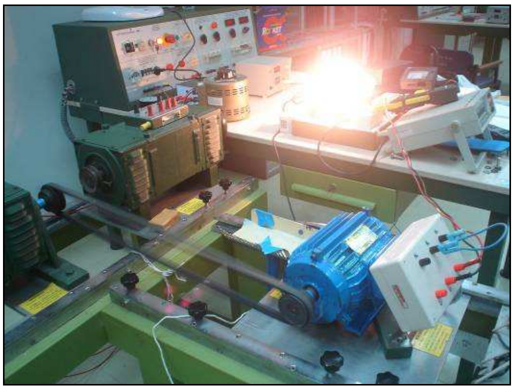

Fig. 7. Testing station of low speed generator prototype with the electrical load.

The low-speed generator prototype is connect to the mechanical as a DC motor size is 1.5kW and connect the voltmeter for measuring the induce voltage of the generator. The adjustment speed of the mechanical power for record the induce voltage while no load. The connection of the electrical load (12 lamp size is 24 V, 60 W that can open-close separate independent) to the generator then record the electric power.

5. EXPERIMENT RESULTS

The testing results of the induction motors in the *experiment I* was showing the significant lower performance for used induction motor comparison to new induction motor at higher speed and worst performance with 10 years motor as show in Fig.8. The performance comparison of induction motors at different ages at 60% load condition is showing in Fig.9. The longer usage time of motor made the performance of the motor are lower as show in Fig.9 performance 10 years motor is worst than 3 years motor and same as 3 years motor is worst than new motor at the same load, the output performance will be 62%, 78% and 87% respectively.

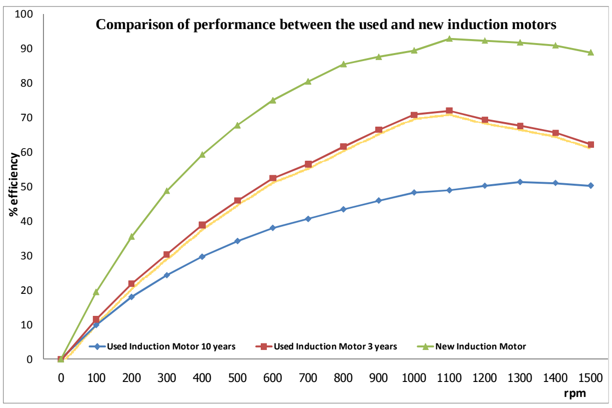

Fig. 8. Performances of the used and new induction motor.

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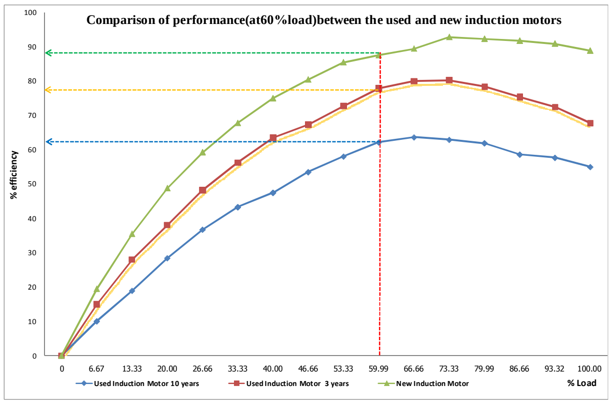


Fig. 9. Performances of the used and new induction motor at 60 % load.

If consider the power consumption of the induction motors per year of age differences are shown in Table1. Notice that the induction motor has been used 10 years to use electrical power energy more than three years, and new induction motors, if the percentage compared to that of 40%, 32% and 28% respectively. For the cost of electricity of the motor each age group and each usage is reflected as shown in Fig.10. When analyzed by simulating the use of the induction motors in the sample to determine the energy cost, that oldest induction motor is valid for high energy cost. If the use of the motor 12 hours per day in the new induction motor and induction motor age 10 years, or if look at Fig.10, approximately 4,500 hours per year. This represents the energy cost comparison of the induction motors 10 years have free energy cost than a new induction motor to 40.32%. Therefore, if considered the optimum period of using induction motors with energy costs, it is interesting In compared as a percentage of the induction motor age of 10 years, 3 years and the new motor the operating cost are 140.3%, 111.5% and 100% respectively; if set up the new induction motor as 100% for energy consumption, is shown in Fig.11.

Table 1. Numerical results of energy consumption

hr/year	New Induction Motor		Induction Motor 3 Years		Induction Motor 10 Years	
	Wh/year	$/year	Wh/year	$/year	Wh/year	$/year
500	514.48	53.63	573.85	59.82	721.94	75.26
1000	1028.97	107.26	1147.69	119.64	1443.87	150.51
1500	1543.45	160.89	1721.54	179.46	2165.81	225.77
2000	2057.93	214.52	2295.38	239.28	2887.74	301.03
2500	2572.41	268.15	2869.23	299.10	3609.68	376.28
3000	3086.90	321.79	3443.08	358.91	4331.61	451.54
3500	3601.38	375.42	4016.92	418.73	5053.55	526.79
4000	4115.86	429.05	4590.77	478.55	5775.48	602.05
4500	4630.34	482.68	5164.62	538.37	6497.42	677.31
5000	5144.83	536.31	5738.46	598.19	7219.35	752.56
5500	5659.31	589.94	6312.31	658.01	7941.29	827.82
6000	6173.79	643.57	6886.15	717.83	8663.23	903.08
6500	6688.28	697.20	7460.00	777.65	9385.16	978.33
7000	7202.76	750.83	8033.85	837.47	10107.10	1053.59
7500	7717.24	804.46	8607.69	897.29	10829.03	1128.84
8000	8231.72	858.09	9181.54	957.11	11550.97	1204.10
Avg	**4373.10**	**455.86**	**4877.69**	**508.46**	**6136.45**	**639.68**

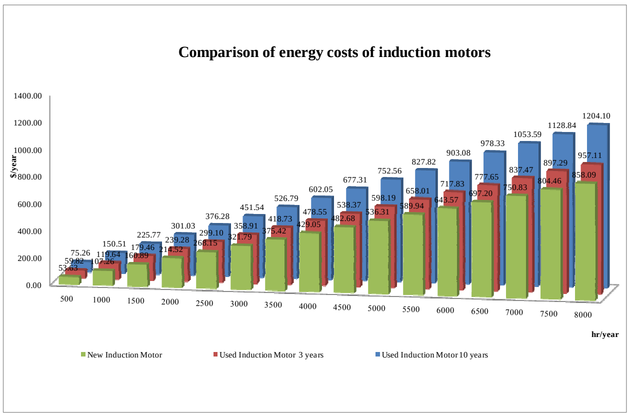


Fig. 10. Energy cost of induction motors per year.

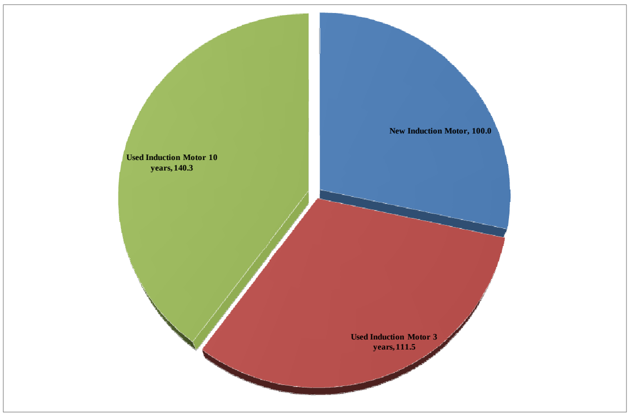
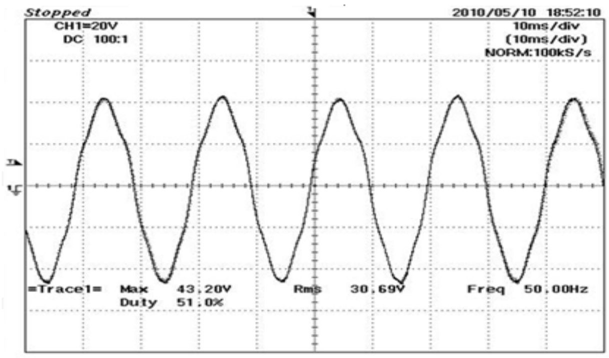


Fig. 11. Percentage of energy consumption of induction motor per year.

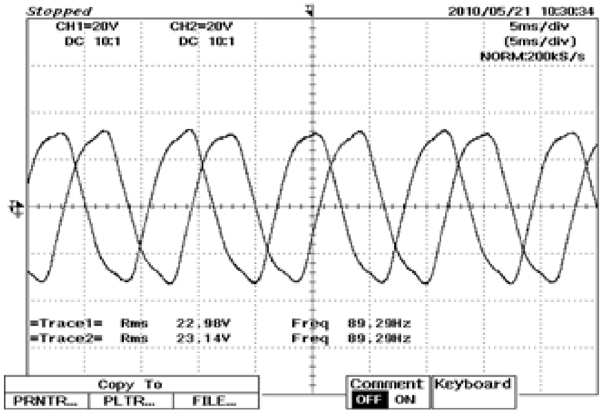
The simulation results of energy consumption by various cases show that the energy consumption is increased by nonlinear relationship with life time. In the other words, the incremental years of life time will consume more energy when compare to the first age. According to the optimization schema, the induction motor may consume more energy than the new motor re-investment, which the optimal life time should be investigated by various annual running time. The *experiment I* has the idea resulted to try the oldest induction motors of the experiment (approximately 10 years), PMSG has updated the previous design, which will display the captive in the *experiment II* of the research.

The *experiment II* of the PMSG is modify by the construction of the oldest induction motor. The resuts will be proposes the induced voltage between the single phase and three phase winding that constant speed at same without electricity load shows waveform in Fig 12. When compared with the standard of quality electric voltage was considered to be acceptable for use [33-35].

The induce voltage of the three phases winding show in Fig.13. The results are the three phases winding generator had the efficient 62.03% the speed at 300 rpm show in Fig.14.



(a)



(b)

Fig. 12. Induce voltage waveform of low speed generator (a) Waveform of single phase winding (b) Waveform of three phases winding, phase A, B.

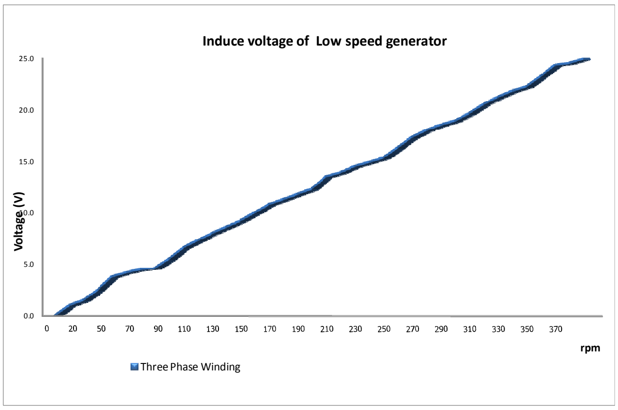


Fig. 13. Induce voltage of armature winding.

However, the highest efficiency is the 62.03% , while the speed at 300 rpm. To adjust the speed of the generator up to see that the power energy produced has increased; while the performance of generators is dropped. The increasing speed will cause of the mechanical and electrical loss of generator, the resulting in decrease efficiency, as shown in Table 2. Therefore, to use the induction generators should find that the appropriate speed to optimization output performance and efficiency.

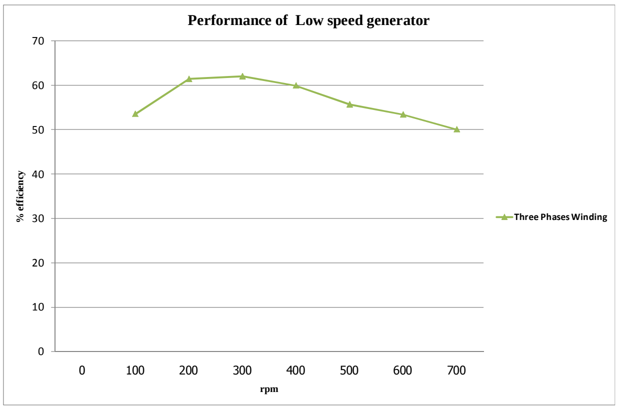


Fig. 14. The efficiency of the low speed generator.

Table 2. Numerical experiment results of generators.

Load Test				
Gen. Speed (rpm)	Vload (V)	Pout (W)	Pin (W)	Eff %
100	5.20	10.50	19.63	53.50
200	9.24	31.50	51.29	61.42
300	13.86	56.00	90.28	62.03
400	17.32	91.00	151.77	59.96
500	20.21	126.00	226.34	55.67
600	22.52	157.50	295.16	53.36
700	24.25	192.50	384.65	50.05

6. CONCLUSIONS

The results of the first experiment, the testing of the induction motors efficiency will see the long life cycle of used motor had significant drop in output efficiency comparison to new motor. The induction motor, 2 hp tested be obtained a difference of power to 220 watts of rated power, 80 percent of the induction motor. This means that if we have induction motors with rated old age and use similar in many factories will have consumption of energy is wasted, it will rise to as much as. Therefore, we can bring to the concept of motivation to reduce the energy consumption in industry by changing the new induction motors with comparing the rate of investment return on the value of the new induction motor power consumption.

The second experiment of the results, is extend the ways to bring it back induction motor; this study show that the used induction motor can modify to build the low speed renewable resource generator with the acceptable efficiency and investment cost. The results of this test; the efficiency of three phase generator is high. The system uses the generator should be the stand alone by charging the electric current into the battery stored because the induce voltage is suitable. Then, the efficacy is good quality when the generator is low speed derived. The possibility use the prototype of generator in renewable energy such ac wind, micro hydro for low speed generate the electrical energy.

When the used induction motor is not reused in the market it means that the new induction motor will be used. The energy efficiency will be increased by two reasons; first from the used of new induction motor and second from the additional energy from the proposed low speed renewable resource generator. The challenge of the economic analysis will be then be in the future to determine.

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