Feasiblestudy of modifier induction motor for low speed renewable energy generator

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Abstract

This research presents a study on value added of used induction motors. The induction motor utilization and the efficiency of motor are typically decreased according to operating time. The efficiency reduction affects to the higher energy consumption to maintain the normal operating conditions. The structure of the used induction motor cannot apply due to deterioration or low efficiency used to modifier for low speed renewable energy generator; however it has a potential for renewable resource generator that mostly requires low prime mover speed. In remote rural area, the electricity from grid is not sufficient to the economic reason. This research proposes the structural change to the used induction motor to rebuild the low speed renewable resource generator by rewiring the new coil in the motor stator and adding permanent magnets embedded in the rotor of the induction motor. In addition, the preliminary test of the induced electric production and efficiency in turns coils between single phase and three phases show the proposed generator that can produce expected voltage at low speed with acceptable designed power. Moreover, the efficiency of three phase generator is higher than the single phase generator with the same rating. Finally, the parameter of propose generator will be discussed to enhance the performance of the low speed renewable resource generator.

Keywords: induction motor, generator, renewable energy

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Introduction

In recent, Thailand has the potential demand for the energy increasing with advances in other developing economies. Evidenced by the country's energy development plans are expected to increase as energy while the power energy is limited and, resulting in higher energy prices. The current estimates arethe electrical energy demanded growth in Thailand averagely 4-5%. Thailand must find the power energy increasedevery year to find and rely on the energy from neighboring countries to back up. The energy development in the country of what it is worrisome concern to the energy policy with environmental impacts. The renewable energy can become the major energy supply option in low- carbon energy economies. Disruptive transformations in all energy systems are necessary for tapping widely available renewable energy resources (Verbruggen *et al*., 2010). Therefore, supporting the electrical energy produced from renewable energy suchwind, small hydro, solar energy, biomass and biogas energy is both sustainable energy developments in the future. However, the problem of the cost power generation from renewable energy remains expensive per unit of production, which currently has a research interest in this issue (Leijon *et al*., 2010; Skoglund *et al*., 2010). Application or modification for the production of electricity from renewable energy produced at the low cost is interesting. Currently, the industry had the AC induction motorsingle and three phases which has been used extensively in bothmanufacturing industry appliances and equipment of using in the household including water systems, fan blowing, air compressors and air conditioning systems etc. The most users generally think that the motor is strong resistance not need much care. Therefore, when installation is completed, it will be activated until have the problem such as coil and circuit damage from the motor. Sometimes, the protective equipment is cutting off the motor when the motor is not running problem. The users will focus on the over-current relay or will control of the motor cut out (trip). Generally, the cause of what if you do not know the cause of problems when cut the system off and then usually further recurrence. Sometimes, the operator ignored the problem by keeping equipment running (Mistry *et al*., 2010). Until it causes serious damage to the motor used. While motor is corrupted, and have been negligible,the repair is used again. Although the performance of any motor down, the old motor of large industry used in the small industries or the Small and Medium Enterprises (SMEs) to the low cost of equipment.

The induction motor utilization and the efficiency motor are typically decreased according to operating time. The efficiency reduction affects to the higher energy consumption in order to maintain the normal operating conditions. Therefore, the recommended preventive maintenance plan with time-based and condition-based is the most common to generally perform for satisfying the efficiency of induction motor in the acceptable condition.

The researchers have thought that the guidelines would increase the value addedthe induction motor that may be reused in the small industries with unacceptable efficiency motor. The feasible study of the low speed renewable resource generator development is considered in term of engineering, economic and environment. The modifying of structural induction motor for the low speed generator will be diseased. In this paper, the researchers will find the basic performance suitable for implementation of the generators including the patterns of winding coils between a single phase and three phases winding. Finally, the parameter of propose generator will be discussed to enhance the performance of the low speed renewable resource generator.

Induction motor as generator

Using induction motors as generators is a very cost effective way of providing a generator for a turbine system. It especially works well with the single phase or three phase systems that are interconnected to the utility, as an induction system requires no governor controls. The induction motor, instead of consuming energy, is driven at over its rated 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 totheinterconnect utility applications (Verbruggen *et al*., 2010). 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 (Leijon *et al*., 2010). In the 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 legs of the motor. The machine selection either a three-phase squirrel cage induction motor or a capacitor type motor may be used. Of 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. The size machine for using depends on the rating you need from the generator but generally should not exceed about 10 HP for a three-phase machine or 3 HP for a single-phase machine show in (Figure 1). Poor results can be expected below about ½ HP for three phase or 1/6 HP for single phase. The best generators are machines rated at 700 rpm or higher. Lower speed machines can be used, but will require larger capacitors. The theory of operation for either types of machine, capacitors will be used to provide excitation to the machine (Muravleva and Muravlev, 2003). The excitation magnetizes the machine's rotor. The magnetized rotor moving past the windings generates vo1tage in the windings. The machine voltage and frequency are determined by how many turns are in the windings, how fast the rotor turns and how much load is applied to the generator.

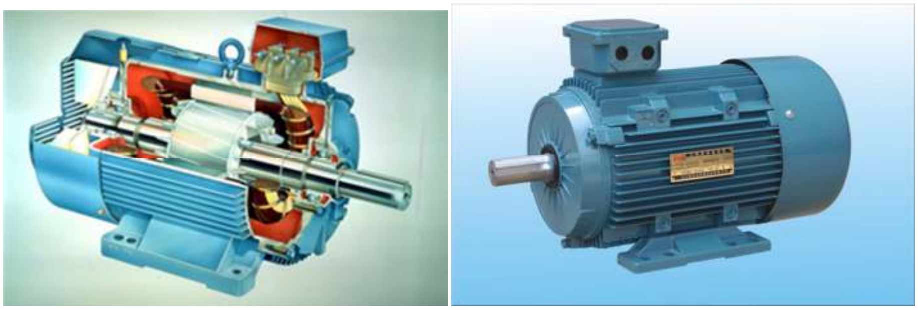


Figure 1 Typical squirrel cage induction motors.

The cost of electricity energy savings was realization from the preventive maintenance of that equipment. Here by the induction motor, the saving came from maintaining optimum efficiency and avoided energy consumption, as different to energy reductions. An accurately estimate of savings would require determining what would be consumed if good preventive maintenance were not practiced. This saving is difficult to quantify. The following equations provide a method for determining demand reduction and energy savings (Skoglund *et al*., 2010). The energy saving can determine by equation (1) and equation (2).

$$kW_{saving} = 0.746 \times HP \times \left[LF \times \frac{\eta_n - \eta_o}{\eta_o} \right] \quad (1)$$

$$kWh_{saving} = kW_{saving} \times h \quad (2)$$

where: HP is the motor rated horsepower

LF is the load factor

η_n is the new efficiency obtained by implementing the strategy

η_o is the old efficiency prior to implementing the strategy

h is the annual operating hours

IEEE standard 112 efficiency test method

According to the international motor efficiency test method, the control variable factor in the experiment cannot cover all. However some input control variables are selected to maintain in the accepted limit by various test methods (Cummings *et al*., 1981). The standard tests have been developed to evaluate the errors from the determination of the motor efficiency. There exist a number of international standards that are used to test efficiency (Skoglund *et al*., 2010). The important ones are:

- IEEE 112
- IEC 60034-2
- CSA 390
- JEC
- SANS IEC 60034-2
- AS 1 359. 1 02

The major difference between those standards are in the treatment of stray losses, see (Table 1) below.

Table 1 Electricmotor standard test.

standard	method	stray loss	temperature correction
IEEE 112	method B	loss segregation method (direct)	yes
IEC 60034-2	direct	loss segregation method (direct)	yes
CSA 390	method 1	loss segregation method (direct)	yes
JEC 37	method 1	ignores stray loss	yes
SANS IEC 60034-2	indirect method	assigns 0.5%	no
AS	direct	loss segregation method (direct)	yes

IEEE Standard 112, in addition to other types of tests, currently including five methods for the determination of motor efficiency (Sawetsakulanond *et al*., 2008). These may be divided into two parts.

Part1: Direct measurement of output

Method A (brake)

Method B (dynamometer)

Method C (duplicate machines)

Part2: Determination of losses without output measurement

Method E (input measurements)

Method F (equivalent circuit)

The dynamometer provides the motor designer with a flexible tool for evaluating motor performance in multiple conditions of operation. It is relatively easy to use and, when used properly, it is accurate. For these reasons, it has been adopted by National Electric Manufacturing Association (NEMA) as the preferred means of measuring motor efficiency for ratings 1 through 125 HP (Gray and Martiny, 1996). Where equipment is available, it is also used for much larger motors as well. The dynamometer provides a controlled load for the temperature rise testing: it also can be used for measuring torque and current throughout the entire speed range and can be operated to duplicate many duty cycles other that continuous operation at a steady load.

The principal concern with the dynamometer in this paper is its use for the efficiency determination. The dynamometer has many attractive aspects in this regard. The testing is close to actual operating conditions; therefore, the quantities being measured are as they would be in service. The test is relatively easy to understand and the analysis of the test data is fairly straightforward.

Induced voltage of generator

The basic principles of the induced voltage (Hahn *et al.*, 2002) of the generator caused by two main components include the rotor and stator winding show in (Figure 2). These coils are more than one turn and a coil is turned by a full-pitch coil. The field coils on the rotor will produce waves of flux density *B* as a sine wave form on the surface of a stator (Bakshi and Bakshi, 2008).

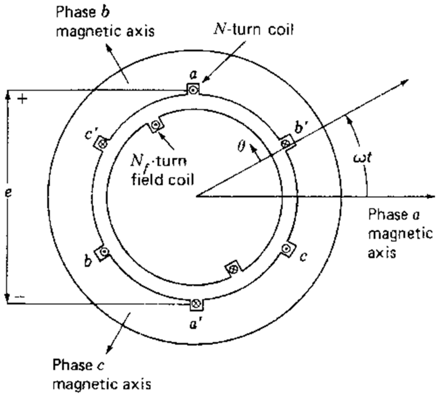


Figure 2 Show cross section of three phase generators.

If the electric currents into the coil field in the rotor will be assumed that the flux density *B* as a sine wave shown in equation 1.

$$B = B_m \sin\theta \quad (1)$$

The Air-Gap Flux that occurs in the air gap. It will form a sine wave with the same equation 2.

$$\phi = \phi_m \sin\theta \quad (2)$$

While rotating rotor the Air-Gap Flux rotates in the air cut through the stator coil of three phases. The Flux Linkage with each phase winding as a coil is *N* turns follow the Farady Laws. The voltage induced in the coil state purpose of *e* phase can be obtained from equation 3.

$$e(t) = N\frac{d\phi(t)}{dt} \quad (3)$$

From the equation 3, the flux was changed by the time as a sine form so that will be.

$$\phi(t) = \phi_m \sin\omega t \quad (4)$$

Then,

$$e(t) = N\frac{d\phi}{dt} = \omega N\phi_m \cos\omega t \quad (5)$$

The maximum induced voltage (E_{max}) and the root mean square (E_{rms}) as follows.

$$E_{max} = \omega N\phi_m = 2\pi f N\phi_m \quad (6)$$

$$E_{rms} = \frac{E_{max}}{\sqrt{2}} = \frac{2\pi f N\phi_m}{\sqrt{2}} = 4.44 f N\phi_m \quad (7)$$

In equations 6 and 7, the same equation voltage induced in the transformer. In particular, the relative motion of the coil and flux density waves. This is the amplitude constant in the rotating machinery. At the same time, voltage induced due to flux variation with time winding in the transformer. The rotation causes the time element and changes the distribution of flux density in space a voltage that varies with time. The voltage induced by equation 7 is the voltage per phase. Assuming that the phase voltage of the coil a,-a, and coil b,-b and c,-c of the two phases in three phase machines. These coils are placed far apart; each coil is the electrical angle 120 degrees show that in (Figure 2).

The AC machines in general, there are many winding coils in series in each phase and may be distributed or the fractional pitch. The voltage induced in the coil, each coil in the same phase angle and phase difference phase sum of the pressure in the coil, each coil is less than the sum of the pressure of algebra. Thus reducing the multiplier factor, also called k_w is the winding factor the equation 7. The new E_{rms} is following

$$E_{rms} = 4.44 f k_w N\phi_m \quad (8)$$

where: N is the turns of the series of coils in one phase;

k_w is the winding factor

ϕ_m is the flux per pole

f is frequency.

Modification the induction motor as the low speed generator

Design and prototype the low speed generator 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. The details are as follows:

1. Parts 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 magnetshown in (Figure 3). The permanent bar magnets used in generators trapezoid shape, which contributed directly to the rotor size,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 5000 gauss.

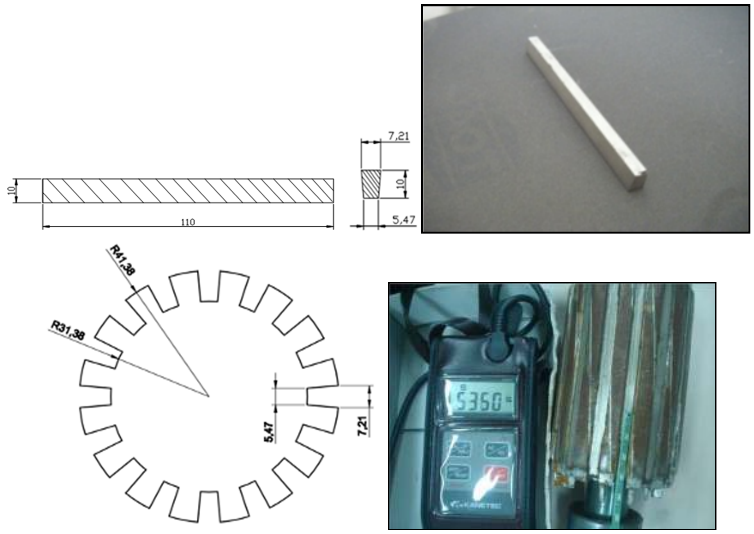
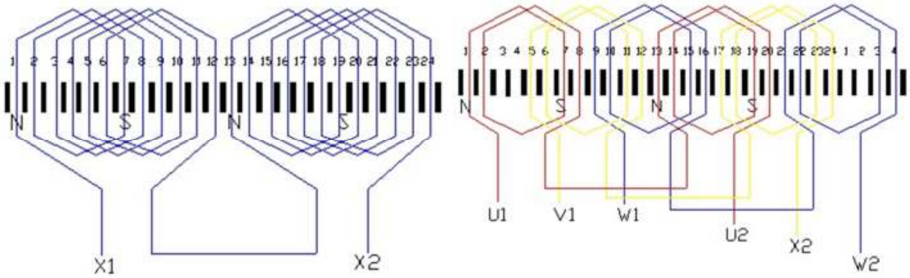


Figure 3 Modified rotor of induction motors by the permanent magnet.

2. Part of stator

In a modification of the stator of induction motor as the 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 (Sawetsakulanond *et al*., 2008). There is the distributed turn of coils because the depth of the original slot is limited. The number turns to refer to the equation 8.

A stator has 24 slots for turn's coils of single and three phases. The design single phase 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 increased shown in (Figure 4a). The turn coils of the three phases similar to the single phase characteristics, but the three phases separate the each phase are independent (Leijon *et al*., 2010). The induced voltage had two levels depended on the types of the connection to be a star or delta, which each has different property. The schematic diagram of turn coils three phases shown in (Figure 4b).



(a) (b)

(c)

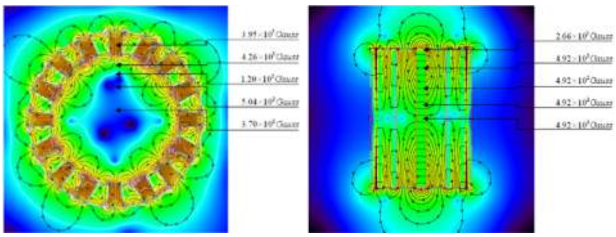
Figure 4 Improved the stator of the used induction motor for the low speed generator (a) single phase winding, (b) three phases winding and (c) the modifier stator and rotor of generator.

Methodology

1. Simulation of flux density of the new generator

The simulation results from the magnet fields in the rotor by Visimag 319 program (Visimag.com, 2016) shown the front and side view of rotor magnetic as illustrated in (Figure 5).

This simulation is only a preliminary test in the path field in the rotor core that is not how the analysis of more than this. In thefuture research simulates and analyze the suitability of various parameters affecting the induced voltage of generator (Schwartz *et al.*, 2005).



(a) (b)

Figure 5 Simulation results from the magnet fields in the rotor by Visimag 319 program (a) front rotor (b) side rotor.

Figure 6 Testing of the low speed generatorwith the AC-load.

2.The experimental process in the laboratory

The experimental results on the low speed generator can generate electric power to supply AC-load (lamp) as shown in (Figure 6).

The prototype generator to connect the mechanical as a 1.5 kW DC motor is and connect the voltmeter for measuring the induce voltage of the generator. The adjustment speed of the mechanical power for recording 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. Every step of adjusting the recording speed, torque and speed of the motor driver for the generator used to calculate the performance of various speed. To change the generator, the three phases retry for the experimental results.

Results and discussion

The experiment of a generator for generating the induced voltage waveform of the low speed generator (Figure 7) that constant speed without electricity load. The power of single phase is more than the three phases shown in (Figure 8) because each coil of the single phase is the turns of same series. Whenthe electrical lad contested with the generator, the results are the three phases winding of the generator had the efficiency at 62.03%, the speed at 300 rpm. There is the 49.19% of the single phase at the same speed shown in (Figure 9). However, the high efficiency is the 52.09% of the single phase, while the speed is at 500 rpm. To adjust the speed of the generator, the power energy produced has increased; while the performance of generators, both lower. This is caused by increasing speed with caused the mechanical and electrical loss of generator, the resulting in the lower efficiency shown in (Table 2). Therefore, the use of generators should find that the appropriate speed optimization.

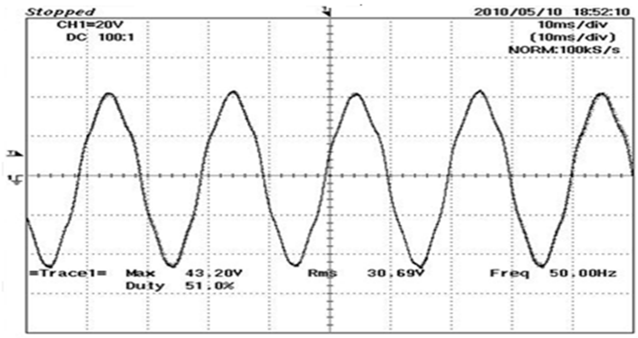


Figure 7 The induce voltage waveform of the low speed generator.

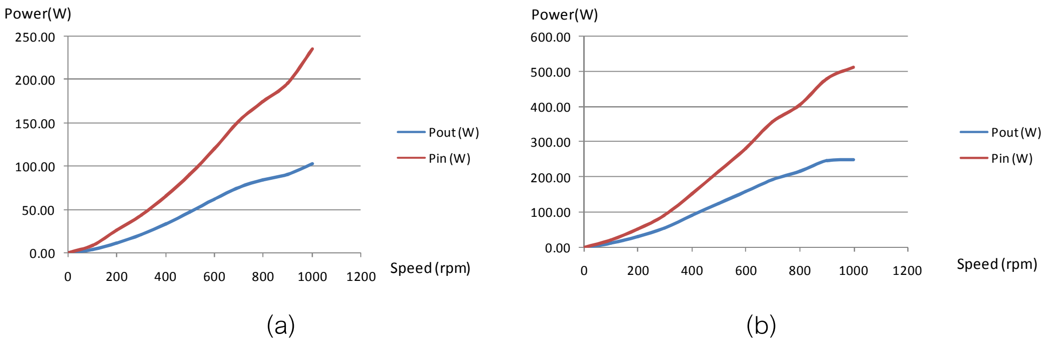


Figure 8 Thegenerator input and output; (a) single phase and (b) the three phase winding.

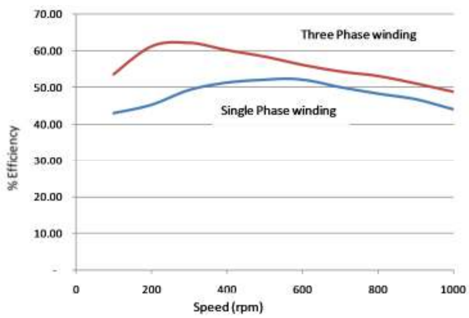


Figure 9 The efficiency between the single phase and the three phase winding.

Table 2 Numericalexperiment results of the bolt generator at the low speed.

generator speed (rpm)	single phase				three phase			
	V load	P out	P in	Eff	V load	P out	P in	Eff
	(V)	(W)	(W)	%	(V)	(W)	(W)	%
0	0.00	0.00	0.00		0.00	0.00	0.00	
100	6.00	3.75	8.73	42.96	5.20	10.50	19.63	53.49
200	10.50	11.85	26.24	45.16	9.24	31.50	51.52	61.14
300	14.30	21.30	43.30	49.19	13.86	56.00	90.28	62.03
400	20.10	33.40	65.25	51.19	17.32	91.00	151.77	59.96
500	22.50	47.00	90.23	52.09	20.21	126.00	216.35	58.24
600	24.50	62.50	120.00	52.08	22.52	157.50	280.35	56.18
700	27.30	76.25	152.23	50.09	24.25	192.50	355.25	54.19
800	30.50	84.30	174.50	48.31	25.83	215.20	405.25	53.10
900	33.40	91.25	195.60	46.65	27.55	245.50	480.24	51.12
1000	35.60	103.40	235.20	43.96	29.30	250.30	512.30	48.86

Conclusions

The result of this study show that the used induction motor can modify to build the low speed renewable resource generator with the acceptable efficiency and the investment cost. The efficiency of the three phase generator is higher than the single phase generator with the same rating. The system used the generator should be the stand alone by charging the electric current into the battery stored because the induce voltage is suitable. Then, the efficiency is the good quality when the generator is low speed derived. The possibility use the prototype of generator in the renewable energy such as wind, micro hydro for the low speed generate the electrical energy.

When the used induction motor is not reused in the market, it means that the new 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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