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Rewinding of the Single Phase Induction Motor

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ABSTRACT

The efficiency of an single phase induction motor can reduce due to the age of the motor. Therefore, the old induction motor have a less efficiency compare to the new ones. Some methods can be apply to increase the efficiency of the old induction motor. In this research, one of the methods is applied in the small single-phase induction motor. This efficiency can be improve with reducing the losses of the induction motor. The low-power single-phase induction motors are repaired by manually rewinding. The results showed that the efficiency of low power single phase induction motors that was repaired with manually rewinding is increasing with average + 16.93% and ranges between +2.42% to +20.11%.

KEY WORDS: *Losses, Efficiency, Single Phase Induction Motor, Rewinding*

1.0 INTRODUCTION

Today, electric motor is important component in the operation of the industry, business sector, transportation, and in public sector. In some countries, the total cost of electric motor operation was two-thirds of the total energy used. In Europe and America, the total energy consumption of the electric motors was around $ 100 million (U.S) per year [1]. Furthermore, the electric motor fault causes the increasing of the production cost, including the downtime of the production processes and delivery schedules problem. Therefore, the electric motor must be maintenance regularly. A rewinding or repairing the electric motor is two methods of the maintenance the electric motor. The cost of maintenance is the important aspect to choose the two methods of the electric motor maintenance [2]. However, the rewinding of the motor can improve the efficiency of the motor. The results of a study that was be done by the Electrical Apparatus Service Association and the Association of Electrical and Mechanical Trades (EASA / AEMT) on large electric motors 100- 150 hp (75 - 112 kW) with a one-time manualy rewind process, show that the average efficiency improve around 0.6% with range 0.3 to 0.5% and for 100-200 hp (75 to 150 kW) electric motors with the process of two to three times using the rewinding machine, the average efficiency improve 0.1% with a range of 0.7 to - 0.6%.

Some researchers work with this area [4]-[10]. According to [5], the rewinding of large motor were reasonable. A high Efficiency MV motor can be rewinding with a good result with proper services company [6]. With Finite Element Method and simulation software, the rewinding motor can improve the efficiency of the electric motor [7]-[8]. The other researcher shows that the improving the energy efficiency is not currently exactly truth. This happen due to the rewind companies that do not have the expertise to redesign the failed large motor, and they will be constrained to copy the winding to limit their legal liability [9]-[10]. As for low power electric motors, especially single phase induction motors in the study has not been done.

The redesign and rewinding the industrial electric motor can refer to IEEE standard 1068 TM, 2015 about IEEE Standard for the Repair and Rewinding of AC Electric Motors in the Petroleum, Chemical, and Process Industries [11] and the testing of the motor can refer to IEEE std. 43 about IEEE Recommended Practice for Testing Insulation Resistance of Electric Machinery [12].

Efficiency in an electric motor is the ratio of the output mechanical power to the input electrical power. The input electrical power is equal to the output mechanical power plus the losses in motor.

The losses of induction motor consist of four components such as copper losses, iron losses, mechanical losses, and stray losses [13]. The copper losses are the losses due to the heating of the winding in stator and rotor. This loss depends on current and copper material. The iron loss is loss due to the magnetic circuit. Normally this loss consists of hysteresis and eddy current losses. The mechanical loss is loss due to the drag on the motor movement. The other losses that are not cover in previous losses are stray losses. In this paper, it is only the copper and core losses used in calculation.

The paper is organized as follows: In the next section, a Methodology of rewinding is presented. Section III presents results of rewinding and discussion of the results. Finally, the conclusions are made in section IV.

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2.0 METHODOLOGY

The rewinding method of the industrial electric motor that was used in this study is using duplicate or copy method with manually rewinding technique without using rolling machine. The duplicate or copy method is a rewinding method that duplicate all physical characteristics of the electric motors such as copper wire size, number of turns, and winding configuration. The nameplate of induction motor evaluates the parameter of the induction motor. Besides that, the no-load and locked rotor test also can calculate the induction motor parameter.

The rewinding of the single-phase induction motor have six steps as shown in Figure 1 such as preparation, process of rewinding, testing, and evaluation. Figure 1 shows a flow chart of rewinding process of low power single-phase induction motor.

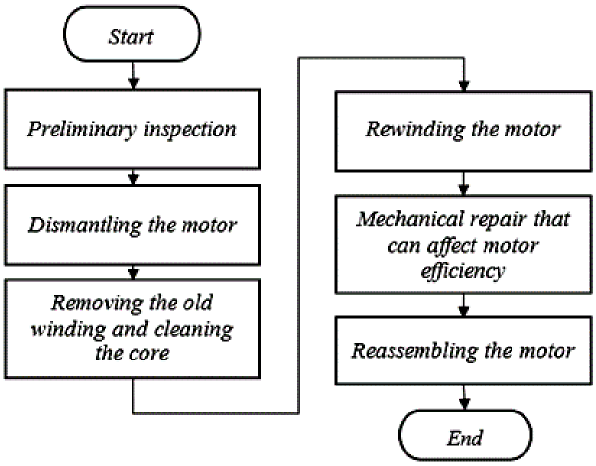

Figure 1: Flow chart of rewinding process [1]

As shown in Figure 1, the method of rewinding will begin from the preliminary inspection of the single-phase electric motor until reassembling the motor.

A. Preliminary Inspection

The preliminary inspection is an examination of the induction motor conditions before rewinding. This examination includes visual inspection, physical examination, documentation of technical data, and etc. Table 1 shows a summary of technical data of the three motors that was used as objects of research.

TABLE I. SUMMARY OF TECHNICAL DATA OF MOTORS

No	Motor Id	No. Phase	Voltage	F (Hz)	Pole	RPM	Po (W)	Pin (kW)	Eff (%)
1	PH 100 ANB	1ϕ	220V	50	2	-	100	0.26	38.4
2	PS-121BIT	1ϕ	220V	50	2	2850	125	0.35	35.71
3	Fujian DB 125	1ϕ	220V	50	2	2850	125	0.25	50

This data based on nameplate of the motor and measurement the electrical parameter of electric motor. From this table, the efficiency of the motor before rewinding is very low, around 35 % until 50% and only have two pole. This motor can categorized as small single-phase induction motor.

B. Dismantling

The next stage is the dismantling of the motor. Figure 2 is a snippet of the dismantling motor of the research object.

Figure 2: Rotor configuration after dismantling

In dismantling stage, the component of the single-phase induction motor takes part by part. In step of dismantling can be done by Split the Casing Apart and Remove the Front End Cap, Remove the Rear End, the Wiring and the Rotor. Remove and Clean Up the Switch Contact Board, Check the Operation of the Centrifugal Weights, Electrical Resistance Readings, and Clean Up and Reverse the Steps.

C. Removing the old winding

There are three points at this stage. Firstly, the technician recorded the information of the old motor such as coil winding information. After this step, we can release the old coil. Finally, the stator of motor must be clean and prepare for the process of re-twisting. Table 2 shows the result of recording coil winding motors of research objects.

TABLE II. DETAIL RECORD OF THE WINDING MOTOR

No	Id Motor	No. Pole	Winding Configuration	Group -ing	Coil pitch	Turn/coil	Size of Wire
1	PH 100 ANB	2	Konsentris, 1 layer	4	6, 8, 10	Main: 47, 64,75,80 Auxiliary: 67,84,99,109	Main 0,45 mm Auxiliary 0,4 mm
2	PS-121 BIT	2	Konsentris, 1 layer	4	6, 8, 10	Main: 47, 77,106,115 Auxiliary: 47,64,146,150	Main 0,45 mm Auxiliary 0,4 mm
3	Fujian DB 125	2	Konsentris 1 layer	4	6, 8, 10; 10, 12	Main: 100, 110, 120, 130 Auxiliary: 90, 100	Main 0,45 mm Auxiliary 0,4 mm

The releasing of the old coil can be accomplished by cutting the winding out of the stator. In cutting the winding of the motor coil is made as close as possible to the stator with no harm to the stator core. Cutting is not done by machine but is done manually

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using a hacksaw. The avoiding iron edge nicks in pulling the top and subsequent coils out of the armature iron slots. When the armature is made the wire is passed over a U bent copper extension of each commutator bar. At the end of a coil winding the wire is passed over the next U extension, While the last extension is mechanically pressed flat and spot welded.

The stator core is made of layers of thin steel and between layers are isolated. Cleaning is done carefully so as not to damage the stator core. The damaged stator core layer can cause the stator core to rapidly heat up and reduce motor efficiency. The remove the varnishing winding can heated by fire and then clean up the slot winding.

D. Rewinding

The copy method technique used to rewind the induction motor. The copy method duplicate the motor windings based on the original form of the manufacturer. The motor is recycled with a configuration of concentric windings, two poles, and four groups (grouping) entanglement. Figure 3 is one example of motor rewinding result from motor of research object.

Fig 3. Sample of rewinding the motor (PH 100 ANB)

New coils wound manually by hand on a coil-winding machine. The technician controls the wire tension, layering, and number of turns on the coil. The winding based on winding diagram that can be seen in Figure 4.

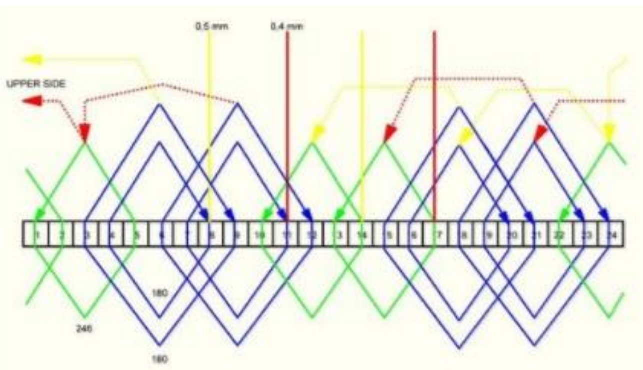

Fig 4. Winding diagram

The newly rewound coil warmed in an oven, immersed in an epoxy varnish and baked in an oven at a temperature of 300 degrees Fahrenheit for at least four hours. This procedure is dip and bake technique.

E. Testing the Electric Motor

This testing based on the IEEE 112 TM- 2004 about IEEE Standard Test Procedure for Polyphase Induction Motors and Generators [14] and IEEE std. 43 about IEEE Recommended Practice for Testing Insulation Resistance of Electric Machinery [12]. Some tests performed include testing of anchor wind resistance, no load testing, and load testing.

1) Resistance winding measurement

The measurement method used to measure stator winding resistance based on IEEE 118 std-1978 and 119 std 1974. This measurement use the volt-ampere test method. Stator winding resistance in each motor was measured 10 times. The average value of stator winding test result of each motor is shown as in Table 3.

TABLE III. STATOR WINDING RESISTANCE

No	Id Motor	Average resistance (Ohm)	
		Main winding	Sub winding
1	PH 100 ANB	17,63	31,59
2	PS-121BIT	27,6	40,9
3	Fujian DB 125	29,5	17,95

2) No load test

No load testing is done by running the motor at its working voltage according to the nameplate motor without giving the load coupling to the shaft and observing some electrical parameters such as voltage, current, power, power factor, and motor rpm.

No-load testing on the object of research is intended to determine the losses that occur in the motor that includes stator-winding losses, core losses, friction or friction, and wind pressure. The results of the load-free testing of the object motors in this study are shown in Table 4.

TABLE IV. NO LOAD TEST MEASUREMENT

Id Motor	Voltage (Volt)	Speed (RPM)	I (A)	Cos phi	P in (Watt)
PH 100 ANB	220	2973	1,13	0,75	186
PS-121BIT	220	2960	0,85	0.58	85
Fujian DB 125	220	2960	0,45	0,85	79

3) Load test

The purpose of load test on the motors is determining the efficiency motor that was be repaired (rewinding). Load testing is done by running the motor at its nominal voltage and braking by coupling loads with different loads. Each test is done five times with different loads. Table 5 is the result of loaded motor testing.

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TABLE V. LOAD TEST MEASUREMENT

Id	Load	Speed (RPM)	I (A)	Cos phi	P in (Watt)
PH 100 ANB	a	2960	0,8	0,77	97
	b	2956	0,82	0,8	100
	c	2930	0,83	0,85	105
	d	2919	0,83	0,87	114
	e	2876	0,87	0,92	128
PS-121BIT	a’	2956	0,89	0,65	97
	b’	2953	0,92	0,65	100
	c’	2947	0,94	0,7	105
	d’	2923	0,97	0,73	114
	e’	2914	1,2	0,75	149
Fujian DB 125	a”	2887	0,47	0,87	82
	b”	2863	0,51	0,92	95
	c”	2798	0,52	0,94	101
	d”	2680	0,56	0,97	114
	e”	2658	0,63	0,98	139

3.0 RESULT AND DISCUSSION

A. *Stator windings (Pcu) and rotational losses*

According to the stator winding resistance, the voltage, and the current at the no-load test in Table 3 and Table 4. The power losses at the stator windings, friction losses, and rotational losses of the motor calculated. According to (1) and (2), winding losses on the stator and rotational losses of each motor can be determined.

$$P_{cu1} = I^2 R_1 \tag{1}$$

The result of this calculation can be seen in Table 6.

TABLE VI. STATOR WINDING AND ROTATIONAL LOSSES

Id Motor	P_{in} (Watt)	P_{cu} (Watt)	$P_{rotlosses}$ (Watt)
PH 100 ANB	186	62,85	123,15
PS-121BIT	85	49,49	35,51
Fujian DB 125	79	9,61	69,39

Table 6 shows the greatest power losses are on the PH 100 ANB motor. These power losses are both power losses at stator windings and power losses due to rotational losses. The bad condition of the stator core and the bearing can increase the stator winding resistance losses.

B. *Efficiency*

The efficiency of single-phase induction motor less than 1 HP could not done by direct measurement method (mechanical measurement). This is because the initial torque or locked rotor torque (LRT) produced by a single low-power motor is relatively small. Therefore, it is unable to overcome the losses during the starting period.

According to that condition, the motor efficiency can be calculated by the nameplate motor method [6]. The method evaluates the efficiency by nameplate data such as nominal power, nominal speed, and some measurement activities such as actual motor speed, stator current, etc.

The efficiency can be calculated by knowing two of the three components. Through the nameplate approach to the motor, the output power and the efficiency of the research object motor can be determined.

The motor output power is the multiplication of motor torque T to the speed of its shaft ω [3], or (4) can mathematically express it.

$$P_{out} = T\omega, \qquad T < T_d \tag{2}$$

With the T value smaller than the torque developed by the T_d motor (due to friction losses and wind pressure), using (5) torque can be determined [6], ie:

$$T = \frac{I}{I_r}\frac{\omega_r}{\omega}T_r \tag{3}$$

With Tr, Ir, and ωr respectively are the torque, current, and nominal speed of the motor, whereas I and ω are respectively motor-absorbed currents and motor rotor shaft speeds.

Nominal speed, current, and torque of motors for three-phase electric motors or large power-electric motors can generally be observed through motor nameplate technical data. However, in low-voltage motor, especially single-phase motor are less than 1 HP in general the information is rarely included. Therefore, the approach to determining the current and nominal torque on the motors is done through mathematical calculations. Using (4), the nominal Tr torque of each motor can be determined [6].

$$T_r = \frac{P_r}{N_r}. \tag{4}$$

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With Pr and Nr respectively are the output power and nominal speed of the motor, therefore the nominal torque of each motor is:

$$T_{r1} = \frac{100\ W}{2900\ Rpm} = 0.034\ Nm$$

$$T_{r2} = T_{r2} = \frac{125\ W}{2850\ Rpm} = 0.044\ Nm$$

Referring to the motor nameplate in Table 1 and using (5), the nominal current can be determined. In this case, the approximation for the power factor value used is 0.85.

$$P_{in} = VI\ Cos\ \theta \quad (5)$$

With Pin is the motor-absorbed power, the motor voltage V current, and cos θ is the power factor value.

TABLE VII. TORSI OUTPUT MOTOR HASIL PENGUJIAN BERBEBAN

Motor	load	speed (RPM)	I (A)	T (Nm)
PH 100 ANB	a	2960	0.8	0.196
	b	2956	0.82	0.202
	c	2930	0.83	0.206
	d	2919	0.83	0.207
	e	2876	0.87	0.220

Using (2), the output power and efficiency can be calculated. Table 8 is the result of the efficiency after rewinding.

TABLE VIII. EFFICIENCY EVALUATION

Motor	Load	P in Measurement (Watt)	T (Nm)	Po (Watt)	eff (%)
PH 100 ANB	a	97	0.58	60.90	62.8%
	b	100	0.61	62.42	62.4%
	c	105	0.63	63.19	60.2%
	d	114	0.64	63.19	55.4%
	e	128	0.64	66.23	51.7%
Average					58.5%
PS-121BIT	a'	97	0.4	64.85	66.9%
	b'	100	0.42	67.04	67.0%
	c'	105	0.44	68.49	65.2%
	d'	114	0.45	70.68	62.0%
	e'	149	0.47	87.44	58.7%
Average					64.0%
Fujian DB 125	a"	82	0.29	47.94	58.5%
	b"	95	0.32	52.03	54.8%
	c"	101	0.33	53.05	52.5%
	d"	114	0.37	57.13	50.1%
	e"	139	0.42	64.27	46.2%
Average					52.4%

Table 7 shows that the efficiency of single-phase induction motor with manually rewinding process still have relatively good value. The tests carried out by varying load values show that the mean value of the three motor efficiency is still above 50%.

Compared to the efficiency value before the rewinding process is done in Table 1, the efficiency value of the repair motor is less than 1 Hp with manually rewinding process Table 9 also shows a relatively better value, an increase with an average value of + 16.93% .

TABLE IX. EFFICIENCY COMPARISON

No	Id Motor	Eff Rated (%) Before	Eff Rated (%) After	Δ Eff (%)
1	PH 100 ANB	38.4	58.51	+20.11
2	PS-121BIT	35.71	63.96	+28.25
3	Fujian DB 125	50	52.42	+2.42
Average				+16.93

4.0 CONCLUSION

The result shows that the efficiency of rewinding low power single-phase induction motor have a much better efficiency. The results showed the efficiency of single-phase induction motor was an average increase of +16.93% with range +2.42% s.d. +20.11%. From this study also obtained information that the initial torque or locked rotor torque low power induction motor is

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relatively small. Therefore, the direct power output testing cannot be done. Another approach that can be done in evaluating the efficiency of low-power induction motors is with no load test and short-circuit locked test.

During the process of repairing low-powered motor by manually rewinding can affect the efficiency of the motor, therefore the repair process in the correct and careful way can improve motor efficiency.

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