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A Field Test to Estimate Efficiency of Rewound Induction Motor

Arumugapandi P.M.[1]

[1] Thiagarajar College of Engineering

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Abstract

When the cost of energy increases it is important to increase the activities to reduce the energy consumption of the system up to the maximum possible limits. This proposal establishes a very low cost and time saving method to determine efficiency of induction motor at onsite for achieving above mentioned goal. Reduction in energy consumption is achieved by replacing energy efficient motor in the place of old less efficient motor. For auditing purpose pulling out the device from its working environment may cause losses in production in case of industries. On site estimations are helps To resolve such problems this paper describes an onsite method which can capable to estimate the efficiency of new as well as rewound induction motors. Motor?s efficiency computed by this method closely approaches the exact value this thing makes a greater confidence to estimate the saving potential.

Index terms— efficiency, energy audit, energy efficient motor, induction motor, onsite test.

1 Introduction

here are several techniques available to solve the problem of gap between supply and demand. One among such techniques is using energy efficient devices instead of old less efficient devices. The proposed work focus on induction motor, which is the popular prime movers, consumes a larger portion of electrical energy in industries. A one percentage improvement in efficiency reduce drastically considerable amount of power consumption (700mw national whole) in India [1]. The proposed work helps to identify the inefficient motor and replaced with an efficient one.

This action can reduces burden to power system and save the cost of power of the industries. Induction Motors are commonly used prime mover and consume 60% of total power generated. 98% of industries uses induction motors as their drive in that 90% of induction motors are squirrel cage type less than 15 kW [1]. There are good savings potential is available to take audit and technical effort for reducing energy consumption of motor without negatively affecting the products, such think makes considerable amount of reduction in power consumption in the unit. The majority of motors in the field are induction motors. There are many methods relevant to field efficiency evaluation in the literature and new methods are appearing every year. As the cost of energy is growing at a high rate, the industries can save a considerable amount of money by replacing inefficient motors with new more energyefficient ones. In the past, many methods were used to calculate the efficiency of induction motors, one common method is to test the motor under load conditions and then monitor the input and output at different load points using a dynamometer and torque transducer [2]. This is the most straightforward method to measure the output power directly from the shaft without any need to calculate losses. Conventionally, the shaft torque method offers the most accurate field efficiency evaluation method, however, this is not suitable for the field evaluation because this process involves the removal of motor from service to place it on a test stand and couple it to the dynamometer. It can be seen that this method is impractical and costly. Another accurate method for field efficiency evaluation relies on using the no-load and blocked-rotor test results to estimate the motor equivalent circuit parameters. The blocked-rotor test procedures require reduced voltage and frequency in addition to preventing the rotor from rotating which is a difficult task [2]. Comparison of actual motor efficiencies is certainly a valid tool to justify the use of one motor over another motor. In the field, one may estimate the efficiency based on information from the name plate and input measurements, such as the slip method(SM) and current method (CM) [2]. The slip method presumes that the per unit (p. u) of load is closely proportional to the p. u. of the ratio of measured slip to full-load slip and The current method presumes that the p. u. of load is also closely proportional to the p. u of the ratio of measured current to full-load current. Using SM and CM methods, a few problems may occur. First the nameplate efficiencies of a given motor can be evaluated according to different standards. The motor may have been rewound. Hence, the error in estimated efficiency could be very high. Numerical and genetic algorithm based efficiency determination via equivalent circuit model is discussed. Exact representation for all losses in equivalent circuit is not available predetermination perhaps closely compute motor T XIII Issue XV Version I 65 ( ) Year parameter and not efficiency [3]. Similarly in [4] they additionally recognized stray load loss with respect to load and motor capacity as suggested by IEEE standard 112-1996 [5]. For predetermining the motor parameter we need sophisticated skill in evolutionary algorithm [4]. This proposed method simply based on motors torque slip relation as explained below.

2 II.

3 Torque Slip Method

The torque exerted by the motor as a function of slip is given by a torque curve. Over a motor's normal load range, the torque line is close to a straight line, so the torque is proportional to slip. As the load increases above the rated load, increases in slip provide less additional torque, so the torque line begins to curve over. Finally at a slip of around 20% the motor reaches its maximum torque, called the "breakdown torque". If the load torque reaches this value, the motor will stall. At values of slip above this, the torque decreases. In 3phase motors the torque drops but still remains high at a slip of 100% (stationary rotor), so these motors are self-starting.

A typical torque slip characteristic is shown in figure ??1. The amount of torque can be produced by induction motor increases linearly as the slip increases [6], [7]. Beyond the full load operating point this relation become reverses. For small value of slip rotor reactance is negligible compared to rotor resistance. So torque is proportional to the slip when slip approaches unity or large values of slip, rotor reactance is large compared to rotor resistance so it is negligible compared to rotor reactance. Now torque is approximately inversely proportional to the slip as shown by hyperbola. Using this plot it is possible to predict induction motor the mechanical power output torque which is directly proportional to output power. The rotor reactance should be kept as low as possible otherwise torque developed is reduced. The maximum torque is independent of rotor resistance, but the value of slip at which maximum torque occurs is directly proportional to rotor resistance.

Figure ?? : Torque-slip characteristics of induction motor Practically motor can be operate up to full load torque point beyond that no longer it can operate as motor and torque slip relation is common for all kind of induction motor. The main difference is only in altitude of full load torque. These inferences are reveals the way of simple on site measurement, the required data for estimating efficiency of induction motor via this test are operating speed, input power and name plate data of the motor. For constructing torque slip plot of test machine requires no load and full load speed of motor and full load power output, which are avail in the motor's data sheet. By knowing input power it is possible to compute the efficiency. Input power and operating speed of the motor can be measured using portable meters at the operating range. This proposal deals difficulties during efficiency estimation of induction motor in its operating environment. This method can be related to direct load test because the output of this method is torque output of motor then using equation (3) efficiency can be measured.

4 III.

5 Formula Used a) Slip

The rotating field revolves with the speed of synchronism, and if the rotor conductors were to revolve at the same speed there would not be any torque. Hence, there is a difference between rotor and rotating field speeds. The rotor speed is less than the rotating field speed and the difference in speed is known as the slip of motor. Generally, slip lies between 0 to 1.

6 b) Torque

The shaft of an ac induction motor rotates because of force created by the interaction between magnetic field of stator and the rotor of motor. The torque developed by the rotor is proportional to the product of rotor current and fundamental magnetic flux cutting the rotor. The total operating torque is the torque to produce the rated power at operating speed of the motor.

7 c) Power

The torque produced by an induction motor is a function of the shaft power and the shaft speed where the torque reduces with speed for constant power.

8 Test Procedure

In this section procedure of proposed method is explained. Initially we need to develop torque slip curve of the motor then for efficiency determination we measure input power and shaft speed of motor at its output terminal. Data required to construct the torque slip curve are full load power output in kW, Full load speed, No load speed in rpm.

The main steps involved in the field test are explained Choose the machine based on preliminary audit report, select suitable portable meters with greater accuracy, and allow the test machine to operate under normal operating range. Measure the power input to the motor and operating speed of motor using portable meters. With the help of data sheet given by manufacturer, construct the Torque Slip characteristics of the motor using no-load speed, full load speed and capacity with the equations (**??**), (2). Find out the slip of motor under operating condition using (1). With the aid of calculated slip value, compute the output torque by projecting the slip value towards curve and spot corresponding torque in torque plane. Using operating speed and computed output torque, calculate actual mechanical power output by using (3). By knowing power input of motor, it is possible to determine the efficiency of motor.

V.

9 Results and Discussions

The parameter of importance in a motor is efficiency. The efficiencies of induction motors remain almost constant between 50 to 100 percentages of loading [4]. With motors designed to perform this function efficiently; the opportunity for savings with motors rests primarily in their selection and use. When a motor has a higher rating than that required by the equipment, motor operates at part load. In this state, the efficiency of the motor is reduced. Replacement of under loaded motors with smaller motors will allow a fully loaded smaller motor to operate at a higher efficiency. In reference test all the readings are measured directly from the motor and efficiency were calculated by using standard formula, on the other hand Torque and power output of motor was predicted from torque slip plot for proposed field test and considered different load levels. They are 60, 75, 80 and 90% of motor's full load. Table 3 Study of losses increment in induction motor with respect to rewinding count was simulated for two cases. Main variable parameter is motor's impedance. Of course motor impedance are direct responsible for losses each rewinding practice increase 18-25%of its actual losses. Main reason of losses increment due to rewinding practice are extra inactive copper, poor quality material unskilled labour etc, motor impedance increment rate per rewinding count is 25% of actual impedance.

10 Rewound Loss Correction Factor

We cannot directly apply proposed Torque-Slip method to rewound induction motor because rewinding process may increase the losses and alter the capacity of motor as mentioned in the name plate and new capacity of motor is unknown. Such case we need some special calculation to incorporate that changes in motor, that incorporating all the losses in calculation is described as Rewound loss Correction Factor (RLCF) Suppose, One time rewound motor 30 hp motor its normal operating speed at full load is 2970 rpm after rewound its operating speed at full load is 2960 rpm. Speed reduction is 10 rpm. RLCF=Î?"N r /Î?"N s (4)

Î?"N r -Change in speed of rotor with respect to normal rotor speed(rpm)

Î?"N s -Change in speed of stator with respect to normal stator speed(rpm)

For this case RLCF=1.33

Actual full load efficiency at normal condition is 92.2% remaining 7.8% goes as losses. In that 5.07% is copper loss and 2.73% other losses (constant, stray, mechanical losses) multiplying this factor with old losses we can estimate actual losses at rewound condition. Only witness parameter to indicate the changes in motor performance is speed of motor. When we know the actual losses it is possible to estimate efficiency of motor.

VII.

11 Tools Description

Name and descriptions of tools are explained, which were used for measuring motor parameters. VIII.

12 Conclusion

A simple low-cost and accurate method for determining induction motors efficiency at field has been described. The method relies on measuring the input power, and motor shaft speed. The motors' torque and power output are identified using the measured variables, name plate data. The efficiency is then determined using the calculated power output to input power measured. The new method has the potential of quickly estimating the motors' efficiencies on site. The information can then be used to guide future decisions regarding the investment in higher efficiency motors using payback period or present value analysis. [1]

Figure 1:

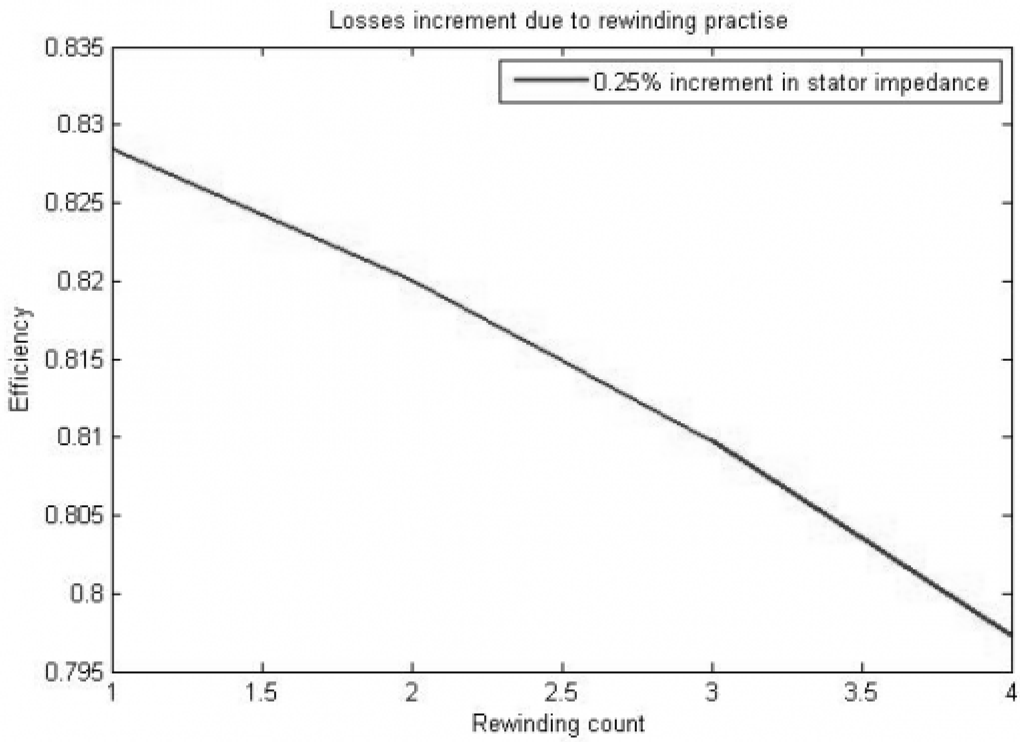

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Figure 2: Figure 2 :

1

Power input (kW)	Torque (Nm)	Slip (%)	Efficiency (%)
2.45	12.19	2.60	76.00
3.28	16.60	3.26	76.90
3.48	18.79	3.46	81.80
4.15	22.88	3.90	83.00

Figure 3: Table 1 :

2

Power input (kW)	Torque (Nm)	Slip (%)	Efficiency (%)
2.45	12.00	2.60	74.00
3.28	17.00	3.26	77.98
3.48	19.20	3.46	81.00
4.15	22.95	3.90	82.78

Figure 4: Table 2 :

3

Load (%)	T.R (Nm)	T.C (Nm)	Error (%)
60	12.19	12.00	1.59
75	16.60	17.00	2.40
80	18.79	19.20	2.10
90	22.88	22.95	0.87

Figure 5: Table 3 :

4

Load (%)	E.R (%)	E.C (%)	Error (%)
60	76.00	74.00	1.44
75	76.90	77.98	1.40
80	81.80	81.00	0.98
90	83.00	82.78	0.24

Table 1 & 2 are shows results obtained by direct load test and on site efficiency estimation techniques respectively.

Figure 6: Table 4 :

Where,
P -Power output of motor in kW
Ns -Synchronous speed of motor in RPM
N -Actual rotor rotating speed in RPM
RPM-Operating speed in RPM

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The deviations in onsite method were computed by comparing results with reference test. Error in calculations also tabulated in corresponding table, the maximum obtained results in onsite test 0 to ± 1.5% only(test was repeated for 5 times on same machine at

same above mentioned load levels), this deviation in calculation of efficiency is tolerable. Commonly replacement policy is recommended only when measured motor efficiency is lesser than the efficient motor efficiency in the tune of 4% and more. inference provided by table is deviation in calculated result is maximum of ±1.5% ,it is tolerable, how means the effect of small deviation is just extent or minimize the payback period by one or two months.

Figure 7:

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