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# ACCURATE POWER LOSS MEASUREMENT OF INDUCTION MOTOR USING THERMAL EQUATION

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**Abstract-** The measurement of power losses of electrical machines is the most curious aspect to manufactures & designers. This paper presents the power loss calculation technique using thermal equation and shows the limitations of the conventional input output procedure leading to loss figure. The proposed method discussed in this research work is based upon electrical machines ventilation wind temperature heat transfer equation. A 3.73 kw induction motor is tested under various load condition using proposed technique and the results show that the power loss calculated from the proposed method has an error near about 4% comparing with power losses from the experiment.
**Keywords** -Heat transfer, machines, power lossest.

## Introduction

The direct current machine, the synchronous machines and induction machines are the major electro mechanical conversion devices in industry one of the most common AC machines found industrial applications is the three-phase squirrel cage induction motor of totally enclosed fan-cooled design because of its lightness simplicity, ruggedness, robustness, less initial cost, higher torque-inertia ratio, capability of much higher speeds ease if maintains etc. [1]

These motors are often driven by variable voltage and variable-frequency inverters as a result can achieve variable speeds and torque control of particular load, but because of non-sinusoidal voltage of inverter and different switching frequency the power losses occurring. The machine losses comprise copper losses, core losses and friction and wind age losses. These losses will be transformed in to heat and increase operating temperature conditions of the motor [2].

Inside a machine the heat transfer occurs due to the thermal imbalance between two media. This transfer is by conduction, convection or radiation. Heat transfer always occurs in one direction from warmer medium towards the cold one and it will end when two temperature becomes equal [3]. The proposed method depends on the heat transferred principles of thermodynamics, free convection using ventilation fan. The assumed heat transfer modes are the thermal conduction between the inner surface and the forced convection between the housing outer surface and environment. Therefore the surrounding temperature of the machine surface increased from relation of the surrounding temperature and losses can be determined using thermal equation

This presented method could be conveniently applied to calculate the power losses of machine replacing general direct input-output method. In order to apply this method, the induction motor is needed to be removing from the process plant and installed for test. The advantage of proposed method, that when the motors are connected in their process plant, the losses can be determined easily.

## Methodology

### A) Conventional loss measurement [input-output procedure]

This is the most frequently used method for total loss measurement for electrical machines. It is based on the very simple energy conservation equation.

$$P_{loss} = P_{in} - P_{out} \qquad (1)$$

where,

$P_{loss} =$ Total power loss, (Watts)

$P_{in} =$ Power input , (watts)

$P_{out} =$ Power output,(watts)

*The motor* connected to a DC shunt generator with electrical load. Assuming the generator efficiency 80% and measuring terminal voltage and load current of DC generator the input to the generator, i. e output of induction motor calculated. The input power $P_{in}$ is usually measured by means of the two wattmeter method. The connection to a three phase supply and the $P_{in}$ is the sum of the two wattmeter reading.

The output power $P_{out}$ is calculated from,

$$\left(\frac{\text{Generator output}}{\text{Generator efficiency}(80\%)}\right) = \text{Generator input} \qquad (2)$$

$$\therefore \frac{V_{\text{Terminal}} * I_L}{80\%} = \text{Generator Input} = \text{Motoroutput}$$

**B) Power loss calculation by thermal equation**

Induction motor is when operated at various load condition there are losses in electrical machine. These losses will converter in temperature and heat is accumulating in the machine, depends on specific heat at constant volume of material used in machine. During the heat accumulation, the heat will dissipate to machine fins by air ventilation fan of the motor. The ventilation air temperature is higher than the surrounding environment temp. The change in temperature can be used to calculate the power loss with equation (3)

The equation can be written as.

$$P = \rho A V C_p (T_h - T_a) \quad (3)$$

Where

$P$ is power losses in machine.(watt)

$\rho$ is air density,(kg/m$^3$)

$A$ is cross sectional area of machine inlet air ventilation,(m$^2$)

$V$ is average ventilation wind velocity,(m/s)

$C_p$ is specific of ventilation wind at constant pressure,(J/Kg ˚C)

$T_h$ is ventilation wind temperature, (˚C)

$T_a$ is ambient temperature, (˚C)

**C) Measuring the machine temperature and wind velocity**

This method measures steady state ventilation temperature and ambient temperature, using RTD-PT-100 sensor. The temperature is to be measured at the top front of the motor be caused by its highest temperature due to fact that ventilation air flows directly to the machine top front. There are three measuring points identified at the middle of pins here the air has the temperature close the inlet air temp in fig (2) this phenomenon can be explained by the fact that the air in the middle of the channel has a higher speed than fig (2) is the cross section area of inlet air for machine ventilation. At this point the inlet air velocity measured using anemometer.

$h = 1.007T - 0.026$ For temperature between 10 ˚C to 60 ˚C, at constant pressure

(2) Air Density $\rho = \dfrac{p}{R \bullet T}$

Where,

$\rho$ =Airdensity,kg/m$^3$

$p$ = pressure, Pascal's

$R$ = Gas constant, J/(kg*degK) = 287.05 for dry air

$T$ = Temperature, deg K = deg C + 273.15

**Results and Discussion**

The results were obtained and measured with the parameters of experiment are as shown in Table-1.

All the measured and calculated parameter were placed in equation (3) and power loss of induction motor is compared with conventional method as shown in Table-1 and in Fig-5.

The graphical representation of percentage error between power loss calculation by heat transfer equation and experimental direct input-output method as shown in Fig-6.

**Conclusion**

The result of the proposed method is compared with the result from the experiment shown in fig.5 and fig. 6. It can be seen that there is an error if the power losses are calculated by conventional method. In proposed technique and the conventional technique the overall average error at different load condition is less than 4% which is considering small. Also using this proposed method the power loss can be calculated of any machine without stopping machine operation and the result is accurate as compared with conventional method.

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*Table 1 - The parameters and the result of power loss calculation of 3.73 kw Three- phase induction motor*

| Percentage load | $T_h$ ˚C | $T_a$ ˚C | $V$ m/s | $A$ m$^2$ | $\rho$ (m/s) | $C_p$ (J/Kg ˚C ) | $P_{loss}$ Thermal (Watts) | $P_{loss}$ Input–Output Method (watts) | Percentage Error |
|---|---|---|---|---|---|---|---|---|---|
| 62% | 40.73 | 30 | 3.5 | 0.015 | 1.125 | 1007 | 638.14 | 620 | 2.84% |
| 65% | 42.43 | 31 | 3.5 | 0.015 | 1.119 | 1007 | 676.09 | 656.25 | 2.93% |
| 75% | 43.27 | 31 | 3.4 | 0.015 | 1.116 | 1023 | 713.66 | 687.5 | 3.67% |
| 85% | 44 | 31 | 3.4 | 0.015 | 1.113 | 1022 | 753.92 | 716.5 | 4.96% |
| 100% | 44.83 | 31 | 3.4 | 0.015 | 1.11 | 1021 | 799.46 | 770 | 3.68% |

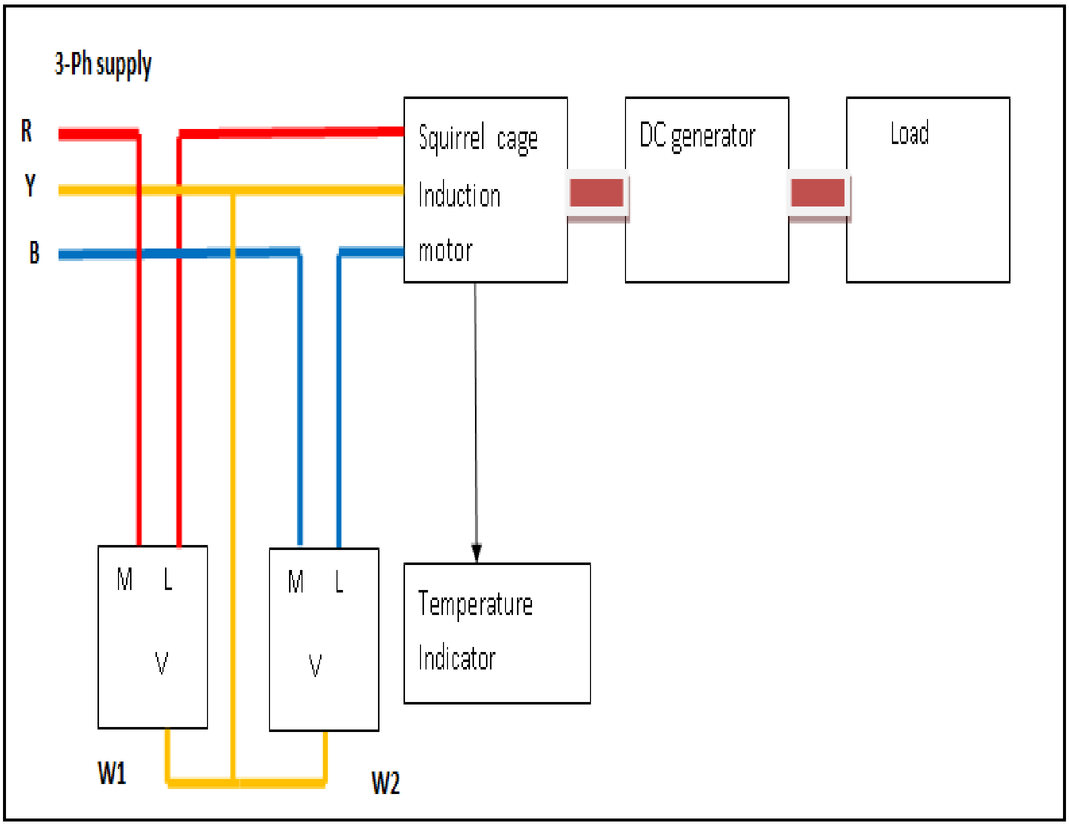


**Fig. 1-** Experimental Set-Up

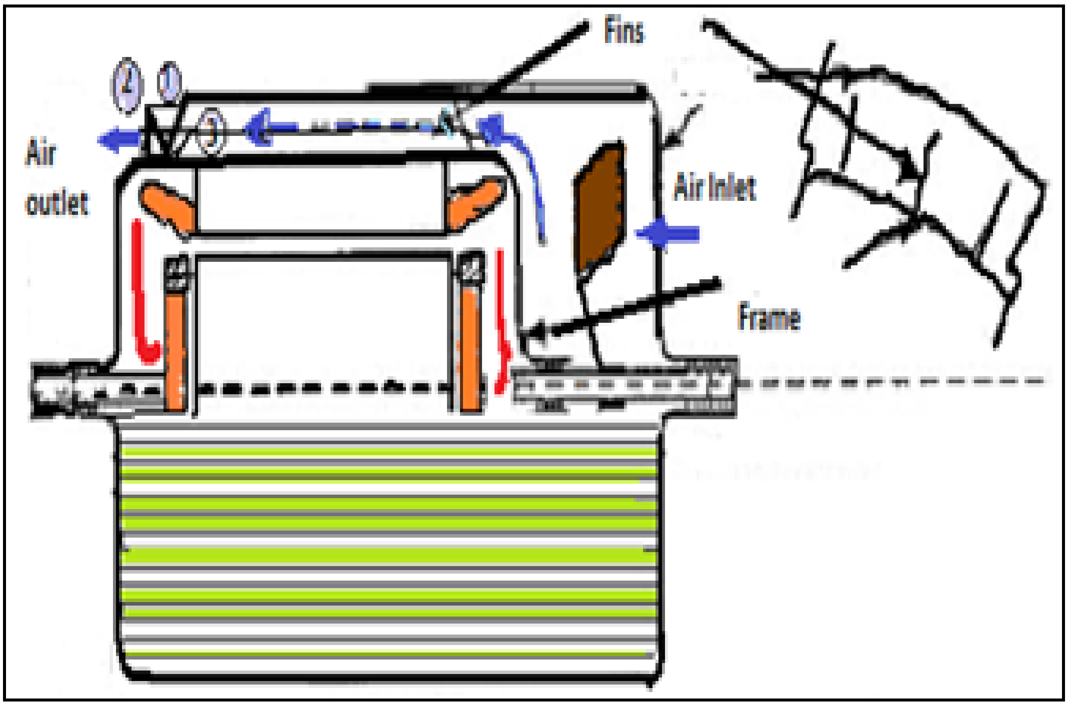


**Fig. 2-** Three points For Temperature measurement

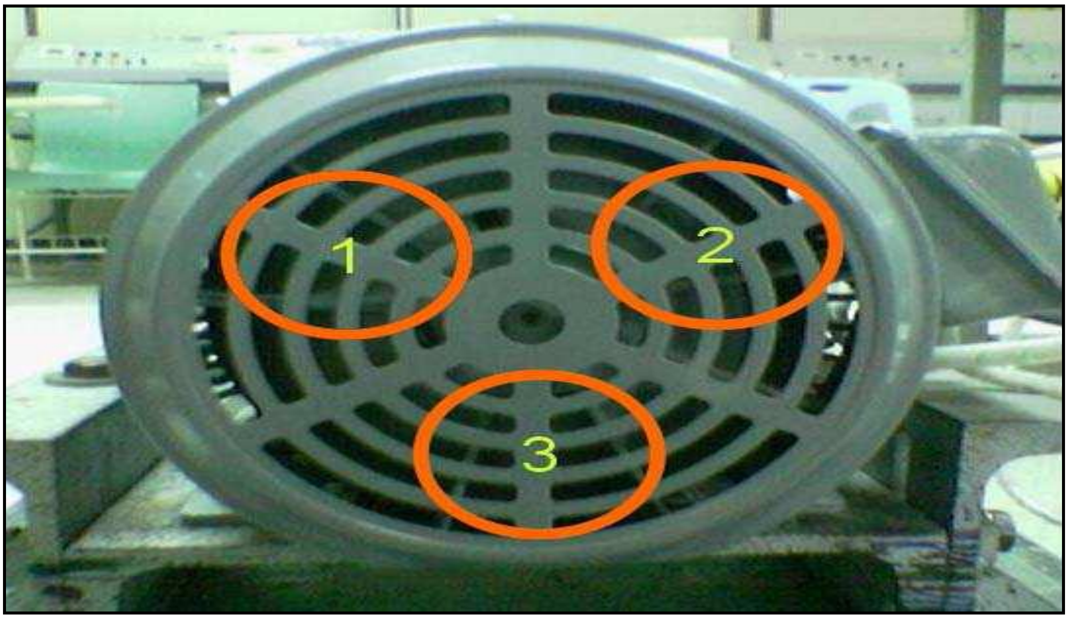

**Fig. 3-** Three point of measuring wind velocity


**Fig. 4-** Experimental Setup for Temperature measurement

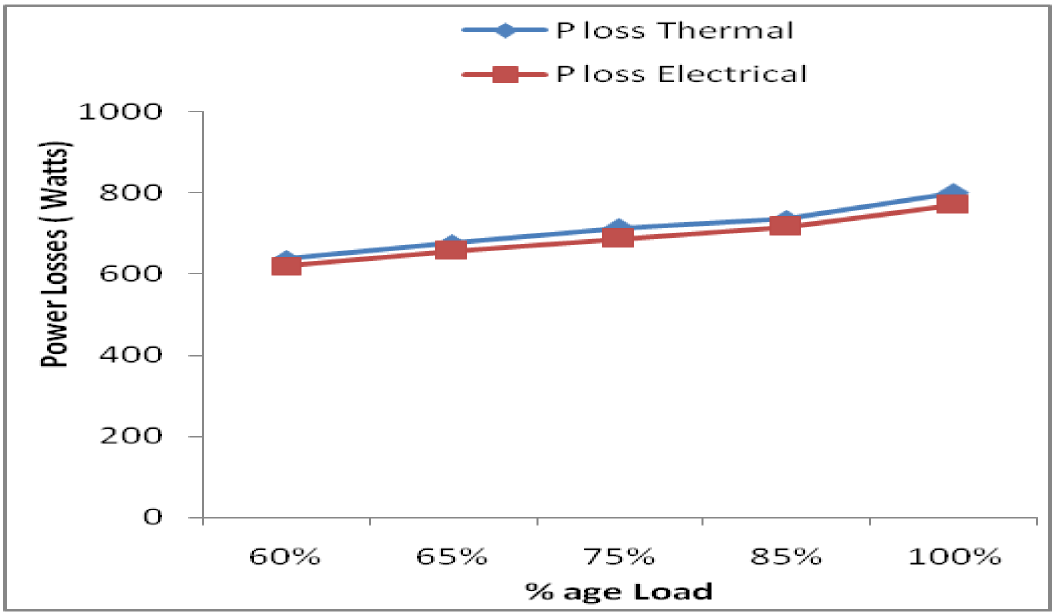


**Fig. 5-** A comparison of the result of the power losses calculation results from the heat transfer equation and the result from test.

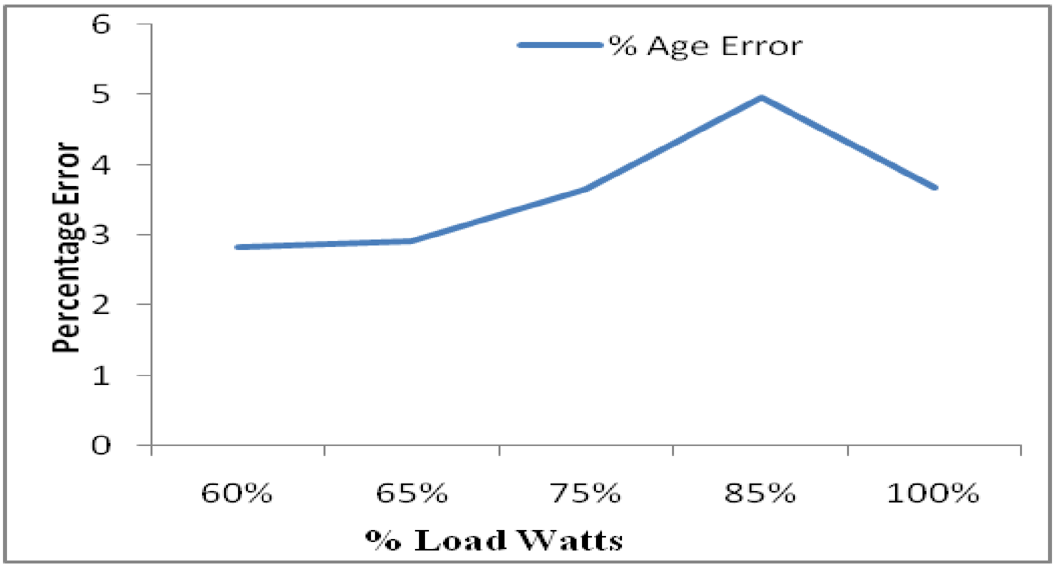


**Fig. 6-** The graphical representation of percentage error between power loss calculation by heat transfer and test