Design of Multifunctional Induction Machine

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Abstract- With the need for increased versatility of industrial equipment, the industries are leaning towards the multifunctioning of a single unit for various applications. In view of this, two of the most widely used industrial equipment's i.e. Induction motor and Welding Transformer can be made to work simultaneously as a single unit and hence the name "Multifunction Operation of Induction Motor". Multifunctioning induction motor aims at running the machine as a three-phase motor, welding transformer, single phase motor, and a phase converter. This not only reduces the cost and space but also performs better when made to run as a single-phase induction motor. In the past, several works have been published on achieving this through the redesigning of the stator three-phase winding. In addition, two single-phase windings have been incorporated in the stator to serve the purpose of transformer secondary winding and the tap changer. The same set of single phase windings also serve as starting and running windings of single-phase induction motor when made to run on a single-phase supply. On the basis of the above works, it is clear that induction occurs from three phase to single phase winding, creating harmonics in single phase winding and limiting the duration of the motor's operation. Our current work aims at redesigning the stator and rectifying the above problem, which has been overlooked in previous works.

Index Terms— **Three-phase motor, Welding transformer, Single-phase motor and phase converter.**

I. INTRODUCTION

Induction motors finds extensive application in industries which involves metal cutting, heavy fabrication, electric traction...etc. Between the slip ring (wound) and squirrel cage rotor designs, the latter one is popular for its ruggedness, robustness and maintenance free nature. Slip ring induction motors require more maintenance because of the wear associated with the brushes and slip rings. Hence wound motors are seldom used.[1] Apart from Induction motors, Welding Transformers are commonly used in the industries for arc welding purposes such as TIG and MIG welds. Welding Transformers work on the principle of static induction whereas the induction motors work on the principle of dynamic induction i.e. both, the machines work on the same underlying principle of electromagnetic induction.

The fact that the induction motor is nothing but a generalized rotating transformer can be taken advantage for integrating both devices into a single unit. This can be achieved by redesigning the stator winding on a three phase induction motor without affecting any other parts of the machine. The proposed design does not need any kind of special arrangement and can be constructed with small modifications to any three phase induction motor.

The stator windings need to be modified to accommodate two single phase windings in the same slots. The two single-phase windings have been incorporated in the stator to serve the purpose of transformer secondary winding and the tap changer. Moreover, multi-layer arrangement is required because the conductors must handle high currents, which is ideal for welding applications.

II. SCOPE OF THE PROJECT

With the upcoming modernization of the industries, the industrial setup demands multifunctioning and efficient machinery units. Given this, a multifunctional induction motor has proven to be an appropriate option since induction motor is well known as the workhorse of the industry. This finds several applications in commercial units and mega workshops.

The redesigned motor requires less space, less weight in comparison with the separate units of induction motors and welding transformers. Further, usage of such a unit in industries reduces the installation cost. At the same time when operated as a single phase induction motor, the machine shows better efficiency compared to that of a standard single phase induction motor which reduces operating cost. Thus, the distinct winding proposed for the stator, makes the machine cost-efficient. This machine also finds its application in the industries such as metal cutting workshops, heavy fabrication industry, electric traction system.etc. Thus commercialization of this distinctly wound motor proves to be a viable option.

III. OBJECTIVE

The objective of this project is to make the induction machine multifunctional i.e. to run the machine as,

• Three phase Induction Motor • Single phase Induction Motor • Welding Transformer • Rotatory Phase Converter.

In order to make the motor multifunctional, the stator has to be redesigned to accommodate two single phase windings. The considered motor and the redesigned motor can be subjected to standard induction motor tests like blocked rotor test, phase shift test by operating the machine on both single phase and three phase supply. Hence obtained results can be analyzed and compared for efficiency and regulation. The block diagram is as shown in fig. 1.

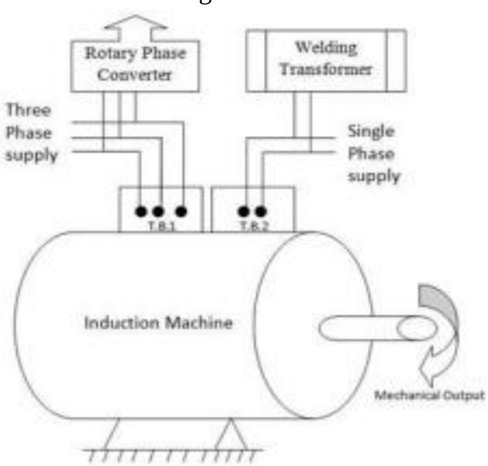

Figure 1.1: Block Diagram[6]

IV. METHODOLOGY

The following steps are to be carried out to arrive at the required results as per the objective.

•Choosing the machine: An induction machine of suitable rating is chosen and parameters of that machine are tabulated.

•Conduction of standard tests: Chosen induction motor is subjected to standard induction motor test and parameters like efficiency and regulation are calculated. • Redesigning of stator winding: The redesigning of stator three phase winding is developed on any software platform and then hardware implementation is employed. Further, parameters of the redesigned winding are tabulated.

• Conduction of standard tests on redesigned motor: The redesigned induction motor is subjected to standard induction motor test and parameters like efficiency and regulation are calculated.

• Comparison and Analysis: The test results obtained from step 2 and step 4 are compared, analyzed, and evaluated for various performance parameters.

• Fabrication: The unit is fabricated as a hermetically enclosed unit for robustness and protection with some machine terminals available externally to operate and conduct tests.

V. PROPOSED SYSTEM

To redesign the stator winding, the original specification and design of the chosen motor must be carefully examined. The winding is divided into three parts, with one set of windings having the same gauge wire and half the number of turns. [6] Since the number of stator windings has been reduced by half, the power rating of the machine, when run as a three phase induction motor, also gets reduced to its former value. The other two windings are the single phase windings which serve as secondary and tap changer of Welding Transformer. If the motor is made to run on a single phase supply as a single phase induction motor, the same set of single phase windings act as starting(auxiliary) and running(main) windings. Further, as we know the welding application requires high current rating, the triple layer winding is used to improve the current rating. The new winding distribution accommodates the same frame size as the baseline three-phase motor.

VI. WINDING SCHEME FOR MULTIFUNCTIONAL INDUCTION MACHINE

[A] Winding Scheme of the Conventional Motor.

The winding parameters of the chosen induction motor is tabulated in table 1

Parameter	Value
Speed	1430 rpm
Connection	Delta
Insulation	Class B
No. of slots	36
No. of poles	4
Slot pitch	1 to 8
No. of conductors per slot	72
Total no. of coils	36
Name plate rating	3.7 kW(5 HP)
Voltage, Current, Frequency	400V, 3.8A, 50Hz
Power Factor	0.8 lagging

Table 1: Winding parameters of the conventional motor

The chosen induction motor is of 5 HP having 36 slots in the stator as shown in fig 2.

$$Slot\,pitch = \frac{No.\,of\,slots}{No.\,of\,poles} = \frac{36}{4} = 9$$

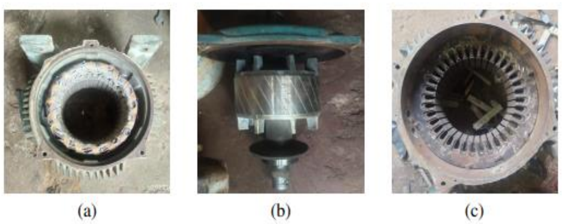

Fig 2. Images showing (a) Conventional Winding (b) Rotor of the considered motor and (c) Stator slots

Since double layer winding has been incorporated, the number of coils is equal to the number of stator slots i.e. the motor has 36 coils. Hence the number of conductors in each slot is 72. The line and phase current can be calculated as shown below.

$$P = \sqrt{3} V_L I_L cos\phi$$

$$3730 = \sqrt{3} \times 400 \times I_L \times 0.8$$

$$I_L = 6.72A \; and \; I_{ph} = 3.88A$$

[B]Winding Scheme of the Redesigned Motor

The redesigned motor has three set of windings, with one set of windings having the same gauge wire and half the number of turns. Hence the power of the three phase induction motor gets reduced by half of its original value. The other two windings are the single phase windings which serve as starting and running winding of single phase motor. If the motor is made to run on a single phase supply as a single phase induction motor, the same set of single phase windings act as starting and running windings.

[C]Three Phase Winding Design

The parameters of the redesigned winding is tabulated in table 2.

Parameter	Value
Speed	1440 RPM
Connection	Delta
Insulation	Class B
No. of slots	36
No. of poles	4
Slot pitch	1 to 8
Turns per slot	17
Total no. of coils	36
Total no. of turns	$36 \times 17 = 612$
Power rating	1865 kW(2.5 HP)
Voltage, Current, Frequency	400V, 1.94A, 50Hz

Table 2: Winding parameters of the redesigned motor

Following calculations help us to arrive at the number of turns per slot.

$$\phi_m = B_{av}\tau l = \frac{B_{av}\pi dl}{P}$$

where,

ϕ_m = Maximum Flux

B_{av} = Average Flux Density

d = Diameter of the slot

l = Length of the slot

P = Number of Poles

$$\phi_m = 0.34 \times \pi \times 0.1412 \times 0.1665/4$$

$$\phi_m = 0.06380\ Tesla$$

$$V = 4.44\phi_m f T K_w$$

where,

$\phi_m = Maximum\ Flux$

$T = Number\ of\ turns$

$K_w = Winding\ Factor(0.955)$

$$230 = 4.44 \times 0.0638 \times 50 \times T \times 0.955$$

$$T = 17 turns/slot$$

$$P = \sqrt{3} V_L I_L cos\phi$$

$$1865 = \sqrt{3} \times 400 \times I_L \times 0.8$$

$$I_L = 3.36A$$

$$I_{ph} = \frac{3.36}{\sqrt{3}} = 1.94A$$

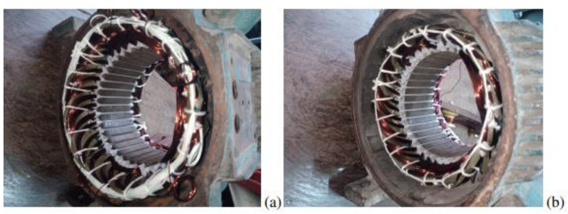

Figure 3: Images showing 3 ph redesigned winding

Single Phase Winding Design:

$$P = V_{ph} I_{ph} cos\Phi$$

$$1865 = 230 \times I_{ph} \times 0.8$$

$$I_{ph} = 10.13A$$

Starting and running winding turns are 75 and 67 turns respectively. Windings of 21 and 25 gauge are used for starting and running winding respectively. The starting winding turns are less and the current flowing through the starting winding is high.

Welding Transformer Design:

$$\frac{N_1}{N_2} = \frac{I_2}{I_1}$$

$$\frac{612}{75} = \frac{I_2}{1.94}$$

$$I_2 = 15.83A$$

Hence by connecting four such coils in parallel, currents get added and hence the welding transformer gets nearly 60 A (15.83 x 4) current for the welding purpose. The single phase windings are placed above the three phase winding as shown in fig. 4.

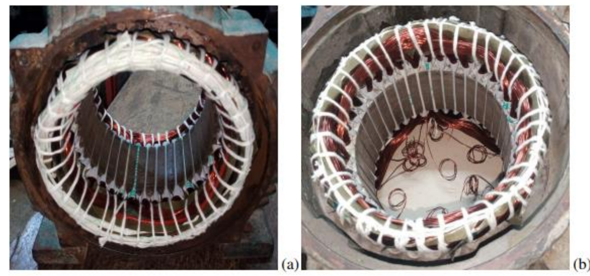

Figure 4: Images showing complete redesigned winding

VII. RESULTS AND DISCUSSION

The first objective of this work was to run the machine as a three phase induction motor with a reduced power rating as compared to the original motor of 5HP power rating. This objective has been achieved successfully by running the motor on a three phase supply delivering half of the original power i.e. 2.5HP.

The second objective was to utilize the same machine as a welding transformer when it is made to run as three phase induction motor. To measure the welding current, the secondary of the welding transformer is subjected to lamp load and with the help of the clamp meter the current is measured. The setup and the clamp meter reading are shown in fig. 5 respectively.

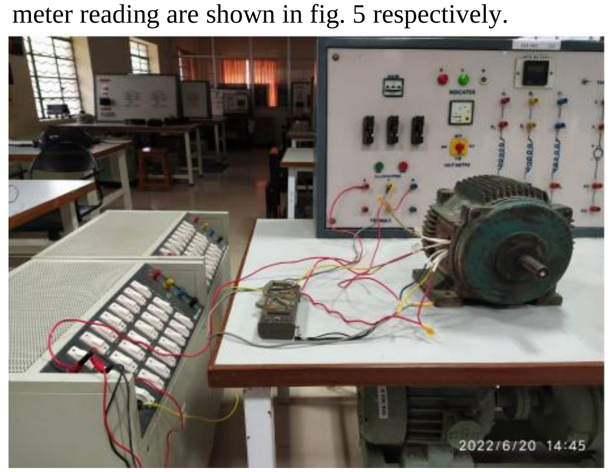

Figure 5: Setup used to measure the welding current

The final objective was to utilize the same machine as a rotatory phase converter performing phase conversion from single phase to three phase power. This has been achieved partially. Phase conversion occurs when the motor is made to run on a single phase supply. As the reliable operation of the single phase motor cannot be ensured for a longer period, the three phase power which is available as a result of phase conversion cannot be utilized to power any machine or device.

VIII. ANALYSIS OF THE RESULTS

The intention to run the machine on a single phase supply did not turn out as a feasible option for the following reasons: • The number of starting and the running winding turns are 75 and 67 turns respectively. The starting winding turns are less and the current flowing through the starting winding is high. A lesser number of turns were employed due to the less space available in the stator slot. • Having less number of turns and high current, the machine demands conductors of larger gauge. The gauge used for starting winding is 21 and for running winding is 25. The gauge of starting winding had to be compromised due to the minimum space available in the stator slot. Hence the starting winding cannot sustain a large current flowing through it. • Since the conductors carry a large current, it results in huge heat production due to which the conductors demand insulation of higher class i.e class F which is capable of withstanding temperature rise upto 155 degrees Celsius. But the class of insulation that has been deployed is class B due to the space constraints.

IX. CONCLUSION

A three phase motor of 5HP power rating can run at 2.5HP power if the stator turns are reduced and with no modifications being made to rotor. • The machine works as welding transformer with a current sufficient for welding purpose. But to control the welding current to weld metal rods of different thickness and material, tap changer is required. • The machine develops huge torque when made to run on single phase supply due to reduced number of windings resulting in high current. • The induction machine which is known to run on low current can be modified to handle huge current by choosing windings of proper gauge and accommodating sufficient number of turns, This demands an increased slot size and hence the motor size.

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