7 THE TRANSDESIGN, WINDING AND TESTING OF A DISUSED 4-POLE SQUIRREL CAGE SINGLE-PHASE INDUCTION MOTOR FOR 4-POLE, THREE-PHASE OPERATION

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1. INTRODUCTION

The rewinding of a burnt-out induction motor stator is a painstaking exercise involving mainly the faithful copying of the existing winding. To achieve this, the data of the original winding must be carefully taken. This includes:

(i) different types of coils that may be present;
(ii) the disposition of the coils;
(iii) the number of turns in each coil, and
(iv) the conductor size used in each coil type.

Faithful recording of the above requires skill and dedication on the part of the person engaged in the rewinding. The skills are acquired by proper knowledge gained from experienced personnel by using the appropriate equpments such as micrometer screw gauge and techniques. This situation is not usually readily available in Nigeria as the amateur rewinder usually picks up the technique half baked and with the use of make-shift methods from low level apprenticeship. It should be noted that any error in any of the four items of information above will result in wrong rewinding with consequent malfunction of the motor subseqently. Once this error is made, it is very difficult if not impossible to correct. The result of the above is the abundance of disused induction motors in industries and elswhere all in Nigeria.

In the work reported here, an attempt is made to put the disused motors to some form of use by redesigning the stator. Starting from the easy case, the redesign for three-phase operation is undertaken.

2. MOTOR DATA

The motor has no name-plate and hence name plate data were not available. However, physical measurements were made and the values are given below:-

Axial length of stator core	=	44.4mm
Bore diameter	=	78mm
Rotor diameter	=	76.45mm
Airgap length	=	0.78mm
Number of stator slots	=	36mm
Number of lamination in the stator core	=	70

It is known that for such motors in service, the synchronous speed is 1500 rev/min. Thus the number of magnetic poles is 4.

3. STATOR WINDING REDESIGN DATA

3.1 Slot Allocation

Since there are altogether 36 slots; thus for 4-pole operation there will be 9 slots per pole and 3 slots per pole per phase.

$$\text{Slot angle} = \frac{180^\circ}{9} = 20^\circ \text{ (electrical).}$$

For an unbifurcated concentric winding, the winding factor considering three coils per pole per phase will be - Kwl = 0.8544.

Based on the above, slots are allocated to the phases as shown below:

PHASE A	PHASE C	PHASE B
1-12	4-33	7-18
2-11	5-32	8-17
3-10	6-31	9-18
13-24	19-30	25-36
14-23	20-29	26-35
15-22	21-28	27-34

3.2 Magnetic Flux Densities

A maximum flux density of 1.55T was chosen as the starting point form the magnetization curve. This corresponds to the flux density at a stator tooth.

From this, the average tooth flux is $B_t = B_{tmax}/1.5 = 1.03T$. The corresponding airgap flux per pole $\emptyset m = 1.26mWB$.

The necessary ampere turns/m are calculated from the B.H. curve to be H = 1394.4AT/m.

3.3 Specific Electric Loading

The specific electric loading for the stator is

$$Q = \frac{2mNI}{\pi D} = \frac{2mH}{\pi D} = 34.14 \text{Amp turn/meter.}$$

3.4 Machine Output

The output of the machine is given by the expression -

$$S = 1.11Kw_1 \pi^2 BQD^2 Ln \times 10^{-3} KVA^1$$

where -

Kw_1 = winding factor
B = average airgap flux density in Teslas
Q = specific electric loading Amp-Cod/m
D = bore diameter (m)
L = axial length (m)
n = synchronous speed (rew/sec).

For the given machine, s = 0.995KVA = 1 KVA

3.5 Number of Turns

The number of turns per phase is calculated after calculating the number of turns per pole. the value is 551 turns. These are in turn subdivided into the different concentric coils to give

N_1 = 218 turns (for 1-12 in phase A)
N_2 = 191 turns (for 2-11 in phase A)
N_3 = 142 tunrs (for 3-10 in phase A)

The full load current is calculated from the rating and system voltage as follows:

$$I = \frac{S}{3Vc} = \frac{0.995 \times 10^3}{3 \times 400} = 1.44A$$

3.6 Conductor Size

This can be evaluated from any of these:

(i) current density approach; or

(ii) slot-fullness approach.

The use of method (i) gave wire size as SWG22 (d = 0.71mm) for a current density of 3.88A/mm^2. Unfortunately this size could not be accommodated in the slots. The second approach (slotfullness) was then used. This gave the size as SWG25. This was finally used as the wire could be accommodated.

4. CONSTRUCTION

4.1. Winding of the Stator

The stand hand method was used. The coils were made on a suitable former and then placed inside the appropriate slots have been appropriately insulated. The coils were labelled appropriately to facilitate connections. The coils themselves were hand made. Alternatively, they could have been machine-wound but it is better training to use the manual method as the coil winding machine is most unlikely to be available to the individual easily.

After the coils had been placed into slots the end connections were made and preliminary tests carried out. These include continuity tests and insulation tests. The stator is connected in star. The developed diagram of the winding is shown in Figure 1.

4.2 Varnishing and Baking

The stator windings were varnished and baked in a locally-made even. the baking was done twice. The first time for four hours and then left to cool till the next day by which time it was again baked for another four hours.

4.3 Assmbling of Motor

After the baking, the motor was assembled, care being taken to ensure that the end plates did not injure the end windings.

5. TESTING

The following major tests were carried out:

(i) Insulation resistance;

(ii) Temperature rise;

(iii) No-load;

(iv) Locked Rotor (short-circuit) test.

5.1 Insulation Resistance Test

This was carried out with a megger connected between the phase terminal and the earth. The results are as follows:
Phase A - 4.0 Megaohm; Phase B - 3.5 Megaohm; Phase C - 4.0 Megaohm.

5.2 Temperature Rise Test

This test can be carried out by:

(i) direct mechanical loading; or

(ii) coupled dc or a.c generator.

The objective is to load motor and observe the temperature rise, specifically note the highest temperature reached.

The monitoring of the temperature can be done in one of several ways. Thus a thermocouple can be included in the winding. A thermometer can also be used. The disadvantage of the latter method is that it will not usually monitor the hot spots. However, this second method was used in the work. The result is given below. No-load running for 15 minutes, observed temperature rise = 17 centigrade degree. The desired temperature rise is the one at full load.

5.3 No-load Test

The motor was connected to the mains, switched on and the following readings taken:

Line Voltage (Y)(V)	Line Current (A)			Power (W)		Speed (rev/min)
	IA	IB	IC	W1	W2	
400	0.4	0.4	0.4	70	0	1200

5.4 Locked rotor (Short-Circuit) Test

The rotor was mechanically prevented from rotating and a reduced voltage applied to the stator. The following results were obtained.

Line Voltage	Line Current (A)			Power (W)		
(Y)(V)	1A	1B	1C	W1	W2	W1 + W2
240V	1.1	1.2	1.3	220	80	300

5.5 Load Test

This test was not carried out by arrangements are under way to do so. It involves finding a suitable load for the motor. It could easily be used to drive a d.c. generator loaded by resistance bank.

6. ANALYSIS OF RESULTS

The test results 5.3 and 5.4 above were analysed to obtain actual performance parameters and compare same with values calculated theoretically. In addition the circle diagram was drawn for the machine. From test 5.3, the magnetising parameters were evaluated, and from test 5.4 the short circuit parameters were evaluated. Thus the equivalent circuit was fully determined and drawn as shown in Figure 2.

7. COMPARISON OF RESULTS

The predicted values of performance parameters were compared with test results and these are shown in the Table below.

PARAMETER	PREDICTED	DEDUCED FROM TESTS
Full load efficiency	63%	66%
Maximum output	677 watts	339 watts
Full load slip	0.06 p.u.	0.136 p.u.
Full load current	1.4A	0.77A
Power factor	0.68	0.77

CONCLUSION

The results obtained from the work are very encouraging, so much so that further work is going on in the project. Another disused, this time a bigger machine, is being transdesigned again from single-phase to three-phase operation. It is hoped that in the end a computer aided approach will become operation and thus motors can very quickly be rehabilitated.

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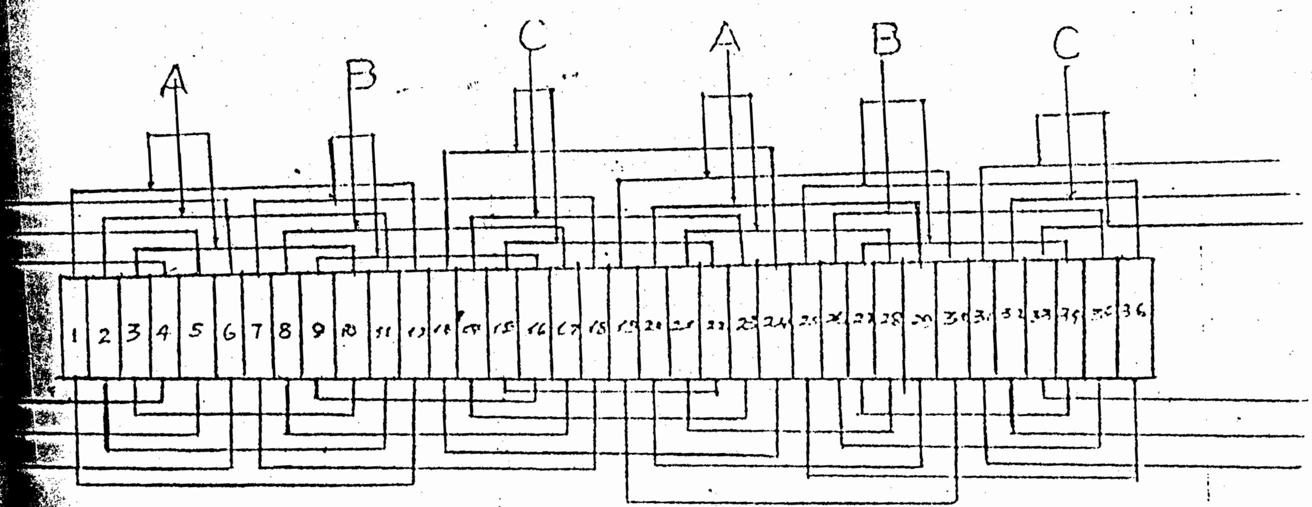

Fig-1 : Developed Diagram Of The Winding
(Concentric Type)