ON APPLICATION OF STEP - B EQUIPMENT: INVESTIGATION OF THE PERFORMANCE CHARACTERISTICS OF A SPLIT – PHASE MOTOR

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Paper Presented At the 1st International Conference on Sustainable Development Strategies

Held at the Cross River University of Technology, Calabar, Nigeria

Paper No: DECEMBERCON/2012/067

ABSTRACT

The research work has been an investigation into the performance characteristics of the split-phase induction motor. The ease and comfort at which the research was carried out is attributed to the recent upgrading of laboratory facilities in the Electrical Department of the Federal polytechnic, Ilaro courtesy of the World Bank through the STEP - B Project. The result obtained from the experiment conducted confirmed the almost constant speed performance of the split-phase motor under varying load conditions – a remarkable feature justifying its wide application in household electrical appliances.

INTRODUCTION

Generally, in Nigeria and other developing countries, the bulk of students specialize in non – science disciplines while the few who choose science and technology-based courses are poorly trained. The deficiency in training hinges on the ill – equipped science laboratories and workshops in the various educational institutions. To stem the tide of drift of students from science based courses, the World Bank in 2006 initiated a project in Nigeria named; Science and Technology Education for Post – Basic (STEP – B) institutions. Post – Basic institutions include - all Tertiary Institutions and Senior Secondary Schools. The STEP – B project is aimed at producing better qualified Science and Technology graduates that are globally competitive and of higher quality, who will be relevant to research institutes and for firms to utilize these outputs to improve productivity and enhance economic growth.

The Federal Polytechnic Ilaro (FPI) amongst some other institutions benefited from the STEP –B project. Three departments of the FPI namely: **(i)** Electrical Engineering Department **(ii)** Food Technology Department and **(iii)** Computer Engineering Department had their laboratories upgraded to enhance conduct of practicals, research works, paper publication and the teaching of Science and Engineering. In the Electrical Engineering Department, the Electrical Machine Laboratory has been supplied with new sets of bench-top equipment that cover a wide range of experiments on D. C machines, 3 - Ø A. C machines and 1 - Ø machines. This paper has focused on investigation of the load characteristics of a single-phase motor that has a wide application – the split-phase induction motor.

The split-phase induction motor is the most commonly used type of ac motors. It is simple, with rugged construction and costs relatively little to manufacture. It has a rotor that is not connected to an external source of voltage like every other type of induction motors. The loads are generally belt driven or small direct-drive loads. The main feature of the split-phase motor is that it can be used in areas of the plant where three-phase has not been distributed, or on small loads on the plant floor where fractional-horsepower motors can handle the load. This motor does not provide a lot of starting torque, so the load must be rather small or belt driven. (Rajput, 2008). Once running, however, the single phase split-phase motor works just like three phase motor except that it does so without the advantages of the other two additional phases. This motor is available in a variety of frame sizes (1/20 to 1.5 HP), which allows it to be mounted easily in most machinery. The split-phase motor uses the difference of its coils size to create a phase difference along with physically locating the start winding out of phase with the run winding to cause a magnetic phase shift that is large enough to cause the rotor to start revolving.

LITERATURE REVIEW

An induction motor is an electric motor driven by an alternating current which consists of two basic parts: the stationary part (stator) having coils supplied with alternating current to produce a rotating magnetic field, and a movable part (rotor) attached to the output shaft that is given a torque by the rotating field whose principle of operation was rooted in Michael Faraday’s 1831 discovery of a changing magnetic field that is capable of inducing an electric current in a circuit without electrical connections (Theraja, 2006). This type of motor gains more popularity due to the advancement in electrical power engineering which leads to widespread of AC power.

In the late 19th century in the United States and Europe, many inventors spring up, trying to develop workable AC motors (Jill, 2003) and in June 28, 1879 Walter Baily gave a workable demonstration of his battery-operated polyphase motor aided by a Commutator to the Physical Society of London. Nearly identical to Baily’s apparatus is the French electrical engineer, Marcel Deprez 1880 publication that identified the rotating magnetic field principle and that of a two-phase AC system of currents to produce it. In 1886, English engineer Elihu Thomson built an AC motor by expanding upon the induction-repulsion principle and his wattmeter. As technology advances, an alternating current commutatorless induction motor was invented. This invention was independently done by Galileo Ferraris and NikolaTesla. Ferraris demonstrated a working model of his single phase induction motor in 1885 and Tesla built his working two phase induction motor in 1887 and demonstrated it at the *American Institute of Electrical Engineers* in 1888 (Franklin, 2012). Also, in 1888, Ferraris published his research to the Royal Academy of Sciences in Turin, where he detailed the foundations of motor operation. In the same year, Tesla, was granted a United States patent for his own motor. Borrowing from Ferraris's experiments, Mikhail Dolivo-Dobrovolsky introduced the first three-phase induction motor in 1890, a much more capable design that became the prototype used in Europe and the U.S (Galileo, 2012).

Most common AC motors use the squirrel cage rotor of which split-phase motor is one - which will be found in virtually all domestic and light industrial alternating current motors. The squirrel cage motor takes its name from the shape of its rotor windings. It is typically cast aluminium or copper poured between the iron laminates of the rotor and usually only the end rings will be visible. The vast majority of the rotor currents will flow through the bars rather than the higher-resistance and usually varnished laminates. Very low voltages at very high currents are typical in the bars and end rings; high efficiency motors will often use cast copper to reduce the resistance in the rotor. Moreover, in order to prevent the currents induced in the squirrel cage from superimposing itself back onto the supply, the squirrel cage is generally constructed with a prime number of bars, or at least a small multiple of a prime number (rarely more than 2). The split-phase induction motors have two windings from a single phase arranged in the stator (Fig 1). One is the main winding and other is starting winding which is used only for starting purpose. The main winding has characteristics of low resistance but high reactance while the starting winding has high resistance but low reactance. When voltage is first applied to the motor's stator, both the running winding and starting winding are energized. Since the rotor is not turning, the windings will draw maximum current. This current is called inrush current or locked-rotor amperage (LRA) (Theraja, 2008). This current produces magnetic field in both start and run windings and because of their different electrical characteristics, the running winding current lags behind the starting winding current in time (Fig2). This produces a phase difference between the two windings and a rotating magnetic field is developed because the two windings are out of phase. This causes the rotor to rotate with the revolving magnetic fields. The Phase angle between I_s and I_m is made as large as possible, because the starting torque of a split-phase motor is proportional to sin α.

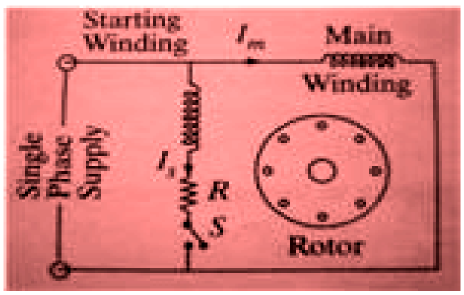

Fig.1: Split-phase induction Motor

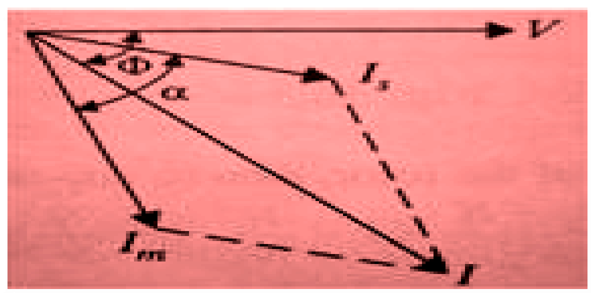

Fig.2: Phasor diagram of a Split-phase Motor

APPLICATIONS

These motors have high starting current and low starting torque. They are used for easily started loads like fans, blowers, grinders, centrifugal pumps, washing machines, oil burners, refrigerator compressors, Air-conditioning, bench grinders, table saws, small belt-driven conveyors, etc

METHODOLOGY

An experiment was conducted using the new equipment supplied in carrying out the investigation. Readings were taken of the parameters of the split-phase motor, the parameters include motor speed, current, supply voltage and input power for varying values of load torque. Other parameters like the power factor, output power and efficiency were computed from the readings obtained. Thereafter, using Microsoft excel, graphs were plotted to present a visual display of the various characteristics of a split-phase motor. Finally, a comparison was made between the obtained curves and the standard curves.

APPARATUS

- Test – Bed FH2
- Split-phase motor FH70
- Wattmeter 0 – 500W range W1
- Voltmeter 0 – 250V range V3
- Ammeter 0 – 6A range A30

PROCEDURE
The experiment was set up as shown in the connection diagram of Fig.4 and the readings of current, speed and supply voltage were obtained by varying the load torque in steps shown in the table of results.

CIRCUIT DIAGRAM

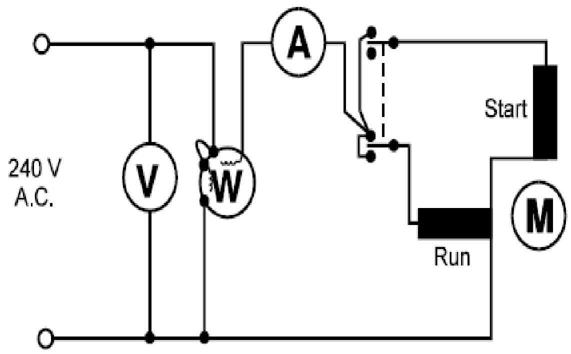

Fig.3: Split-phase Motor Circuit Diagram

CONNECTION DIAGRAM

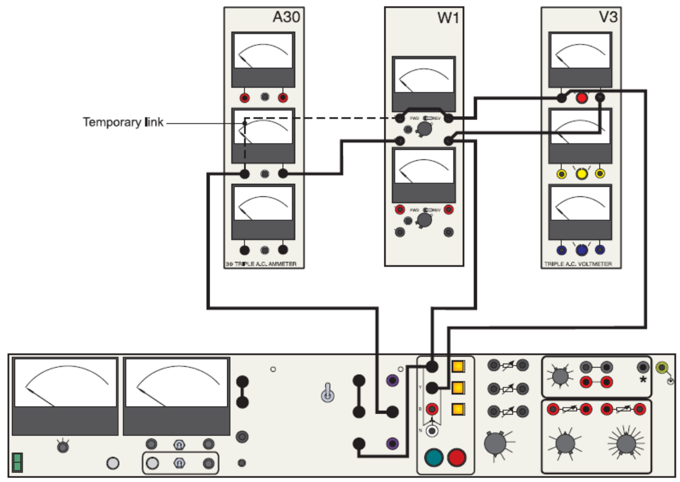

Fig.4: Split-phase Motor Connection Diagram

SOURCE: TechQuipment Electrical Machines Teaching System: Student Guide

PRECAUTION
The load torque is set to a value above zero to absorb the shock of high impact torque of starting on the motor coupler.

RESULTS
Table 1: Split-phase motor measured and calculated parameters

Torque (Nm)	Speed (r.p.m)	Output Power (W)	Supply Voltage (V)	Supply Current (A)	Volt–Ampere (VA)	Input Power (W)	Power Factor	Efficiency (p.u.)
0.1	1490	15.61	230	1.2	276	120	0.43	0.13
0.2	1470	30.78	230	1.2	276	140	0.51	0.22
0.3	1460	45.86	230	1.2	276	150	0.54	0.31
0.4	1460	61.10	230	1.2	276	170	0.62	0.36
0.5	1450	75.90	230	1.2	276	190	0.69	0.40
0.6	1450	91.10	230	1.25	287.50	210	0.73	0.43
0.7	1440	105.50	230	1.3	299	240	0.80	0.44
0.8	1420	118.90	230	1.4	322	260	0.81	0.46
0.9	1400	131.90	230	1.5	345	290	0.84	0.45
1.0	1390	145.50	225	1.6	360	320	0.89	0.45
1.1	1350	155.40	225	1.75	393.8	365	0.93	0.43

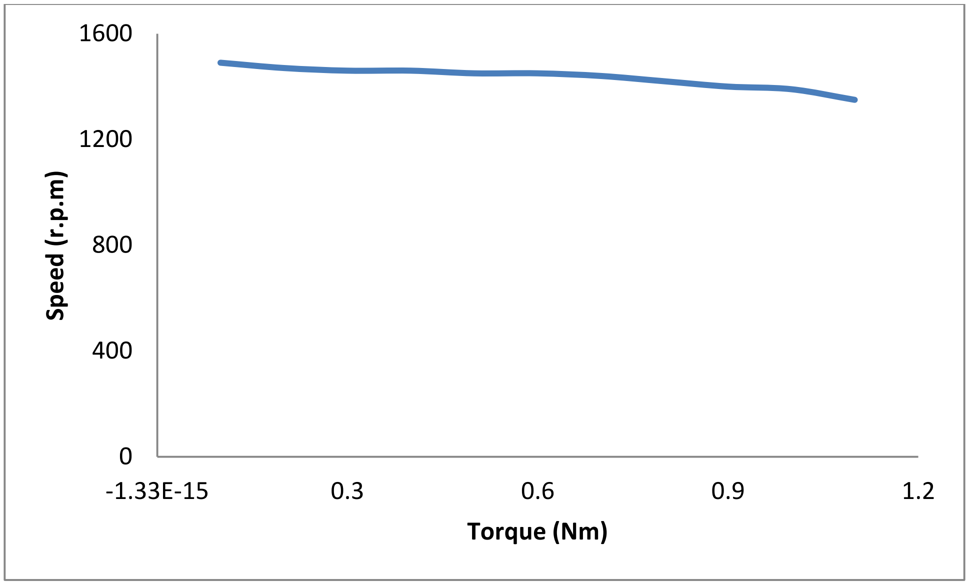

Fig.5: Speed / Torque Characteristic

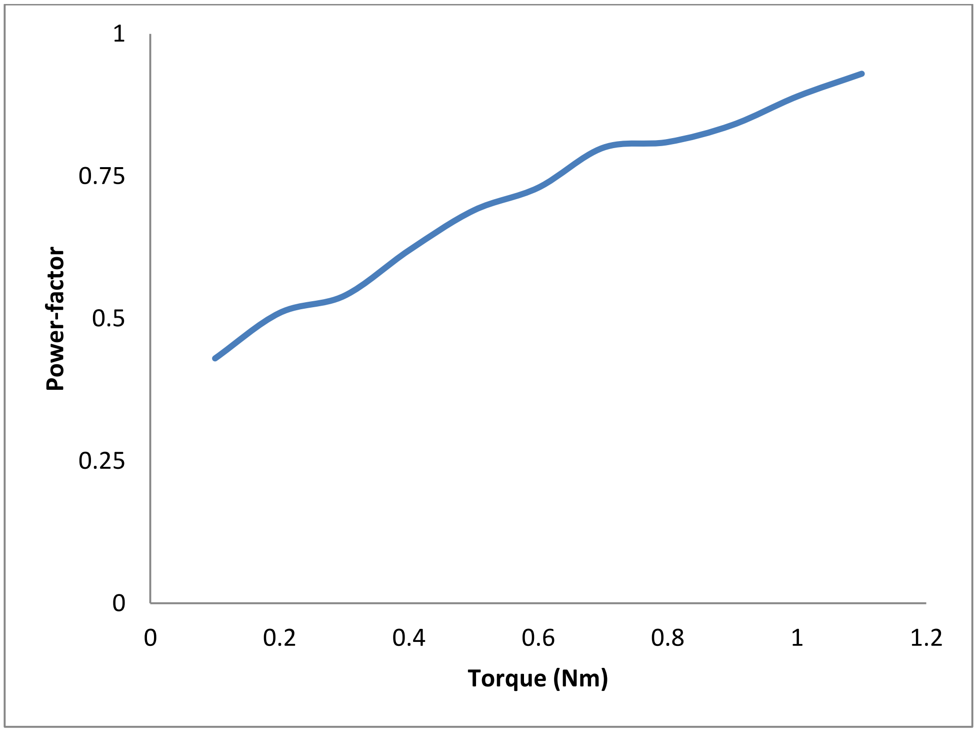

Fig. 6: Power-factor / Torque Characteristic

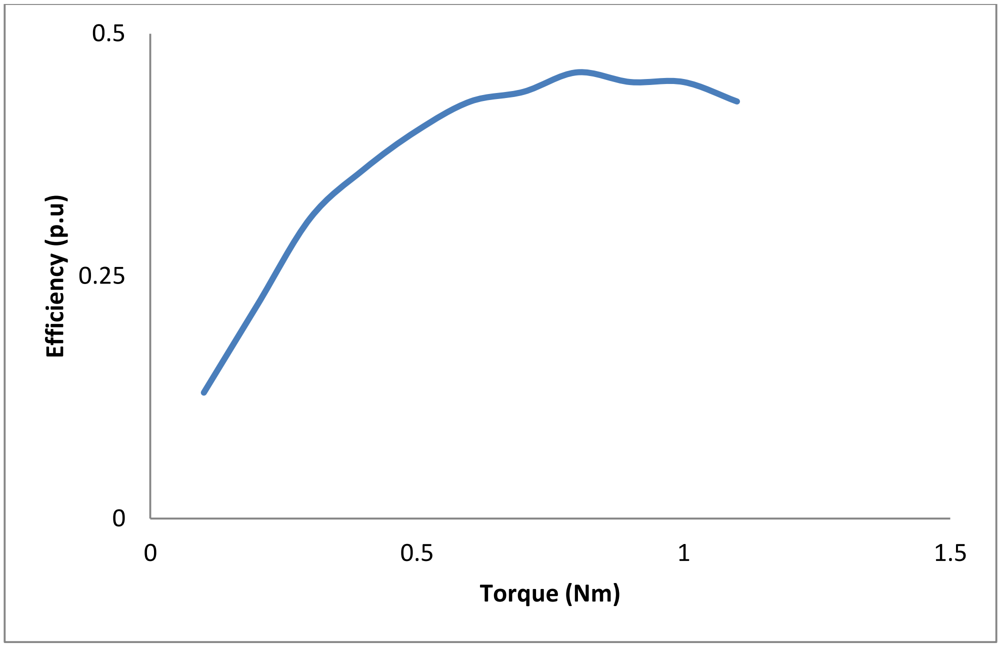

Fig. 7: Efficiency / Torque Characteristic

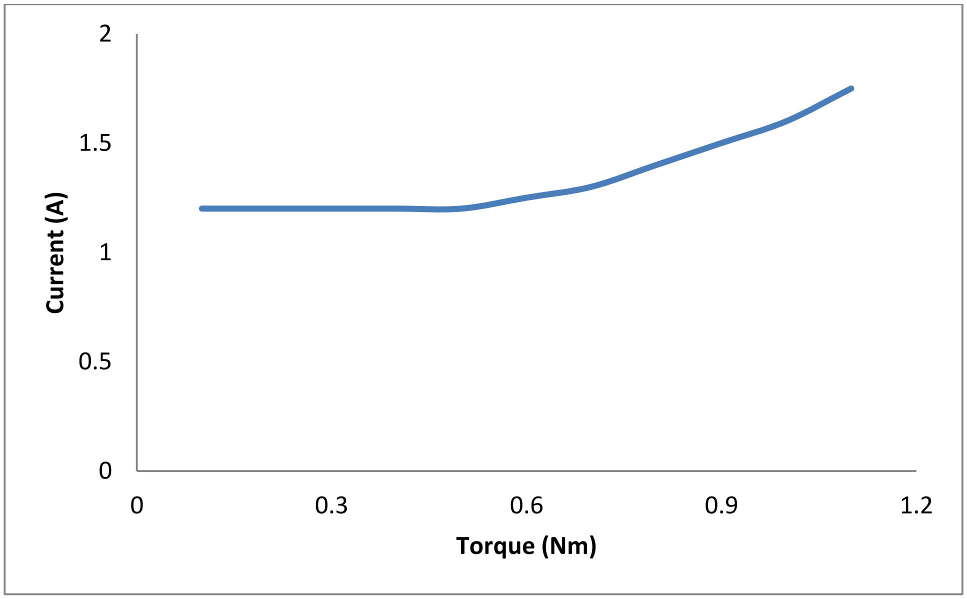

Fig. 8: Current / Torque characteristic

DISCUSSION OF RESULTS

(i) **Speed - Torque Graph**

In fig. 5, the shape of the curve portrays a fairly constant speed drive despite the changing values of load torque. This characteristic of the split-phase motor has made its application useful in devices requiring constant speed drive like refrigerator, vacuum cleaners etc.

(ii) **Power Factor Versus Load Torque**

The shape of the curve agrees with the theory of machine operations, the higher the load the more the useful power required to drive it which also causes an improvement of the power-factor.

(iii) **Efficiency versus Load Torque**

The efficiency versus load torque curve conforms with the expected performance of electrical machines. The efficiency increases with loading until the breakdown or maximum load torque is attained and this occurs at a torque of 1.0Nm.

(iv) **Current versus Load Torque**

The curved obtained here corresponds with the expected theory of performance of the split-phase motor. The current is constant until the centrifugal switch opens. Then it increases as the load torque increases.

CONCLUSION

The experimental investigation has invariably turned out to be a quality control test on the specifications and performance operations of the supplied equipment under the Step – B project. Additionally, the learning and teaching of electric machine courses has been enhanced and made true-to-life when laboratories are well equipped and upgraded with modern equipment. A striking difference noticed about the implementation of the STEP – B project has been the ability to allow inputs from the end user – the beneficiary. The institution was involved in the collation of the list of equipment, contract awards and other procurement procedures. An additional feature of the STEP – B project is the training of staff on the use of the equipment, thus averting an ugly situation whereby supplied equipment are left unused in crates, a misfortune that has bedevilled similar World-Bank sponsored projects.

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