

IX. THREE PHASE INDUCTION MOTOR

A. PREPARATION

1. Introduction

Galileo Ferraris was perhaps the first person to demonstrate a motor of the induction type (1). He made a machine with two pairs of electromagnets as shown in Figure 1 and drove the two windings with two AC voltages 90° out of time phase. The rotor was made of solid copper. Since the machine had a very large effective air gap, it could only develop a very small torque; enough only to cause the copper rotor to rotate at no load.

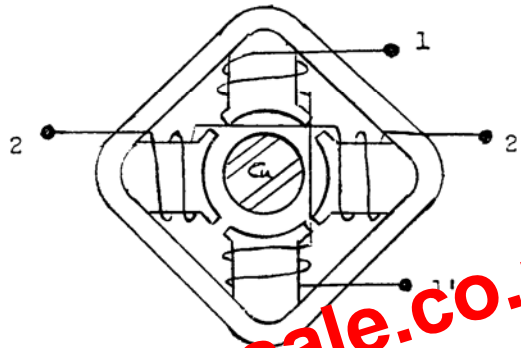


Figure 1.

Nikola Tesla is generally credited with the 'invention' of the induction motor for which he was issued a patent in the United States on 1 May 1888. The validity of the patent was hotly contested in the courts but it was upheld, even though Ferraris could document prior disclosure of substantially similar ideas. Tesla's patent was upheld primarily because he was the first to recognize the commercial importance of the principle of the induction motor and also the first to construct a useful machine. Tesla's invention of the induction motor in 1888, along with the development of the transformer, were two important reasons why the initial use of DC generation and distribution, as espoused by Thomas A. Edison, was superseded by AC generation and distribution, which in the United States was pioneered by George Westinghouse and Co. (2).

Westinghouse immediately realized the commercial possibilities of Tesla's invention and within a few months time in 1888 had acquired the patent rights from Tesla and employed him to develop the motor. A number of people at Westinghouse contributed to improvements in the induction motor. These included C.F. Scott, who helped Tesla substitute slot-embedded coils and a ring wound stator for the original salient pole structure; O.B. Shallenberger, who, also in 1888, invented the AC watt-hour meter, a variant of the induction motor principle; and B.G. Lamme, longtime chief engineer at Westinghouse, who added a completely distributed two-phase stator winding and a distributed rotor winding. Working together, these men achieved a practical induction motor at Westinghouse by 1892.

Figure 12. Although a star connection is shown, the same effect occurs with the delta connection. The DC excitation produces a stationary field relative to the stator, while the rotor experiences a field rotating at approximately synchronous speed. A torque on the rotor approximately equal to the starting torque is developed in a direction to slow the motor; and the rotating kinetic energy of the rotor and connected load is partially converted to heat in the rotor and electrical power supplied to the DC source.

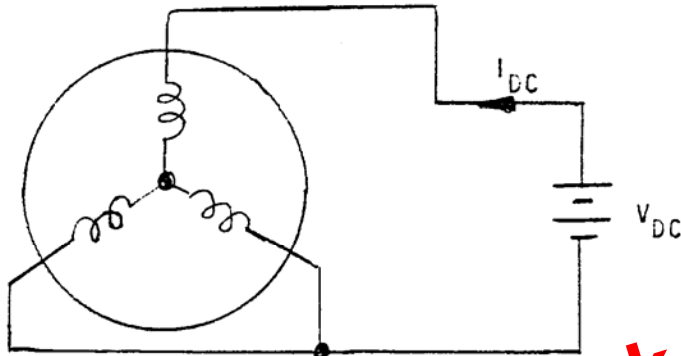


Figure 12

7. Determination of Motor Constants (4)

The major operating constants of the equivalent circuit of an induction motor can be found in much the same way as with a transformer, which is not surprising considering the general similarity of the two devices. Two tests are made.

The first is a no-load test in which voltage is applied to a motor running with no connected shaft load. A series of voltages is applied ranging from about 25 percent above rated value, down to the point where the motor speed drops perceptibly. For each value of the applied voltage, readings are taken of the motor line current and the power input to the motor.

The second is a blocked-rotor test in which the rotor is mechanically constrained so that it cannot turn. A series of reduced voltages is applied to the motor such that line currents ranging from zero to about 125 percent of full load value are produced. Power input to the motor is simultaneously monitored in this test.

Also, a measurement is made of the DC stator resistance.

Rather than the equivalent circuit of Fig. 10, we choose one more akin to Fig. 9 to yield the result shown in Fig. 13. Based on past experience, the following simplifying assumptions can be made for this model:

C. REPORT

(a) Based on your data from the no-load and locked-rotor tests, do the following. Plot graphs similar to those described in Figure 14 and find the power lost due to friction and windage. Compute the following: (1) the stator winding phase resistance R_1 from your line-to-line measurement, (2) numerical values of the exciting path elements R_o and X_o at rated voltage, and (3) numerical values of R_2 and X_1 and X_2 at rated current. Assume that X_1 is equal to X_2 . Show your final equivalent circuit (Figure 13) for the induction motor using these values,

(b) Use your *equivalent circuit* to calculate the expected starting current of the motor assuming 120 $V_{rms, \text{ line-line}}$ and no load. Is your calculated value close to the observed value? Comment. [Note: You will have to study Fig. 13 and Section 7 with care to answer this question successfully.]

(c) Use your equivalent circuit to generate smooth theoretical curves of slip (%), torque (ft-lbs), power in (watts), power out (Hp), efficiency (%), line current (Amp), and power factor versus motor speed (rpm). All of these parameters are to be computed at 120 $V_{rms, \text{ line-line}}$ and six separate graphs are to be made using the same motor speed scale. Next, overlay the experimental points onto these graphs and comment cogently.

(d) Using your equivalent circuit, compute the motor horsepower at rated line-to-line voltage of 208V and rated speed. Compare your result with the 0.75 Hp given as the rated output on the motor nameplate. Is 0.75 Hp a conservative value for this motor?