

THE OPERATION AND CONTROL OF INDUCTION MOTORS  
WITH SPECIAL CHARACTERISTICS

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C E R T I F I C A T E

Certified that the dissertation entitled " The Operation and Control of Induction Motors with Special Characteristics" which is being submitted by Shree Bishwambhar Prasad Singh in partial fulfilment for the award of the Degree of Doctor of Philosophy in Electrical Engineering of the Indian Institute of Technology, Delhi is a record of the student's own work carried out by him under our joint supervision and guidance. The matter embodied in this dissertation has not been submitted for the award of any other Degree or Diploma.

  
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Dated May 30, 1974


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S U M M A R Y

Ever since its development, the induction motor has remained a major source of all electrical drives and numerous references are available in the literature to the effort of design, applications, and control engineers in adapting the characteristics of the induction motor to satisfy the diverse requirements of individual drive systems. Recent advances in solid-state technology leading to the easy commercial availability of variable-frequency sources of large power rating have so considerably widened the scope of application of the induction machine, that almost any desired speed-torque characteristic could now be economically synthesised with the help of suitable control elements and excitation systems. The investigation reported in this thesis seeks to establish the generalised criteria for the choice of the excitation system and/or the control elements to give the induction machine some of the special torque-speed characteristics normally encountered in industrial drives.

The first part of the investigation deals with the variable-frequency mode of operation. A novel method of expressing the required machine characteristics at any operating frequency as a fraction of the corresponding characteristics at the base frequency leads to the establishment of performance equations which contain only dimensionless parameters and hence are applicable to machines of any rating. A detailed analysis of these equations shows that the conventional constant volt/Hertz

type of excitation control leads to very poor performance in the low frequency region. The required criteria for operation in the constant-torque and the constant-horsepower modes are separately established. It is shown that a given control of the variation of the slip and the excitation voltage with frequency makes the performance equations of the machine independent of the frequency of operation, and leads to a constant-torque operation. Since both the flux-density  $B$  and the winding current density  $J$  remain constant in this mode of operation over the entire frequency range, an optimum utilisation of the material takes place. The control suggested is very similar to the one reported by Nelson et al.\*, but unlike the latter, it is not empirical in nature and leads to identical performance at all frequencies of operation.

A number of possible schemes for constant horsepower operation from a variable-frequency source is next examined in detail and a speed range of operation larger than any reported earlier is shown to be feasible. The investigation in the variable-frequency mode is wound up after establishing the criteria for minimising the losses under variable-frequency operation and studying the variation of power factor with frequency.

The second part of the investigation deals with the synthesis of control elements for a wound-rotor induction

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\* Nelson, R.H., Lipo, T.A. and Krause, P.C., "Stability analysis of symmetrical induction machine" IEEE Trans. (Power Apparatus & System), Vol PAS-88, pp 1710-1717, 1969.

motor to give the desired speed-torque characteristics under fixed-frequency operation. The works of Shepherd & Slemon\*\* and Yu\*\*\* on 'Rotor-impedance control' are critically examined. It is shown that computer optimisation of the control network elements is far superior to the graphical techniques advocated by the previous workers and for constant-torque starting, it is found possible to keep the deviation of the torque developed during the starting and the run-up period within  $\pm 3$  to 10% of the desired constant starting value. It is further shown that for obtaining different values for the constant-torque the parameters of the control elements need multiplication by a readily-obtainable dimensionless constant. An attempt is next made to synthesise an external passive network in the rotor circuit to give shunt characteristics and it is shown that approximately constant speed operation at several values of speed is possible. In conclusion, the use of thyristors in the rotor circuit is examined and it is found that almost any desired torque-speed characteristic is possible with the help of sophisticated electronic controls.

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\*\* Shepherd, W. and Slemon, G.R., "Rotor impedance control of wound rotor induction motor", A.I.E.E. Trans. (Power Apparatus & Systems), Vol 78, pp.807-14, 1959.

\*\*\* Yu, L.Y.M., "Constant starting torque control of wound rotor induction motor", IEEE Trans. (Power Apparatus and Systems), Vol.PAS-89, pp.646-51, 1970.

Extensive tests have been carried out in the laboratory to test the validity of the theoretical and computer prediction of characteristics. It is shown that the experimental evidence in all cases is in close agreement with the theory developed.

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