

DYNAMICS OF INDUCTION MOTORS WITH ROTOR IMPEDANCE

AND VARIABLE-FREQUENCY CONTROL MODES

by

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Dedicated to:

MY LORD JESUS !

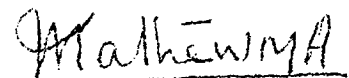
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ABSTRACT

This thesis investigates in detail steady-state and dynamic operations of a wound-rotor induction motor with rotor impedance control mode, when operating from a constant-frequency supply source. It also examines transient and steady-state performances of an induction motor operating from a variable frequency source with external inductors connected to the rotor circuit (or stator leads). Besides, a switching transient analysis of the induction machine is also carried out with and without the external control network connected to the rotor circuit.

Some efforts^{28,29} have been made in the past to obtain different types of torque-speed characteristics for wound-rotor induction motors by the use of static rotor networks consisting of resistance, inductance, and capacitance. It has been demonstrated that any desired torque-speed characteristic may be obtained with suitable rotor impedance control (RIC) of a wound-rotor induction motor on a constant-voltage, constant-frequency supply. However, the methods of analysis and synthesis used in the past were based upon the equivalent circuit approach and graphical trial and error methods which are quite involved and cumbersome. Only steady-state performances were studied and in the absence of any dynamic model the stability and transient response aspects of induction motors with RIC mode of operation could not be reported. One of the

significant contributions of the present work is the development of dynamic models on different reference frames for wound-rotor induction motors with RIC mode in order to study their comparative applicability and suitability for both steady-state and dynamic analyses. Dynamic performance of the machine under small-perturbations with R,L,C parameters connected to the rotor circuit is studied in the present work using the model based on rotor reference frame (RRF). The characteristic equation is developed and the stability is checked from the characteristic roots. The transient response is analysed qualitatively by determining the degree of stability which is indicated by the distance of the nearest characteristic root from the imaginary axis.

Speed control of wound-rotor induction motor through RIC mode is discussed for three different schemes. For each scheme suitable values of the R, X_C, X_L parameters are synthesised easily on a digital computer to obtain any desired torque-slip (T-s) condition making use of the steady-state model based on synchronously rotating reference frame (SRRF). Since a given T-s condition can be achieved with several combinations of (R, X_C, X_L) parameters, attempt has been made to optimize these parameters by analytical techniques in order to provide best performance under both steady-state and dynamic conditions. Experimental results are obtained for a test machine in support of the analytical results obtained on the digital computer.

Shepherd et.al²⁸ and Yu²⁹ have demonstrated that constant starting torque characteristics can be achieved by insertion of an external network of fixed resistances and inductive reactances in the rotor circuit of a wound-rotor induction motor. However, for the synthesis of the required rotor external control parameters they have adopted graphical trial and error methods. Sastry et. al³⁰ have tried to solve the same problem on a digital computer using an optimization algorithm but their iterative optimization technique starting from an equivalent circuit approach is also found to be involved and inexact. Another significant contribution of the present work is the development of a novel analytical method for direct and exact evaluation on a digital computer of the required external network parameters in order to achieve any desired constant-starting torque. Sensitivity analysis has also been carried out to highlight the sensitivity of torque to variations in the external network parameters, applied voltage, and frequency.

Many works^{15-23,34,46} have been reported in the literature for speed control of induction motors using variable-frequency (V-F) mode of control. With such a mode of control, it has already been established that an induction machine is inherently lightly damped and is susceptible to instability during low-frequency operations particularly for machines having low-inertia constants. In view of this, the present work explores a special mode of control under variable-frequency operation

for avoiding the inherent low-frequency instability regions for machines having low-inertia constants. A comparison of the V-F and RIC modes of operation has also been brought out with a view to highlight the feasibility of the RIC mode for industrial application.

Besides, the present work also examines the constant-horsepower and constant-torque modes of operation of induction machines supplied from an inverter-fed V-F supply source. These modes of operations are discussed under different control schemes based on either constant ratio of supply voltage to supply frequency, or constant fractional slip, or constant slip-frequency conditions etc. Making use of the SRRF model, the steady-state performances for these different schemes have been compared in order to establish the best mode of control scheme.

Finally, a suitable state-space model has been developed for studying the switching transients of a wound-rotor induction motor with and without the rotor control network.

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