SINGLE PHASE OPERATION OF THREE-PHASE INDUCTION MOTORS

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CERTIFICATE

Certified that the dissertation entitled "The Single Phase Operation of Polyphase Induction Motors" which is being submitted by Shree Rambhawan Shivnarayan Jha in partial fulfilment for the award of the Degree of Philosophy in Electrical Engineering of the Indian Institute of Technology, Delhi is a record of student's own work carried out by him under my supervision and guidance. The matter embodied in this dissertation has not been submitted for the award of any other Degree or Diploma.

(C.S.Jha)

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S U M M A R Y

To economise the cost of transmission in low load carrying areas, many State Electricity Boards in India are resorting to the single-conductor ground-return system of transmission for rural electrification. Though the cost of transmission gets considerably reduced, problems arise in the operation of the three-phase motors most commonly used in pump-irrigation systems. Since the number of such pump installations is growing fast, a need is felt to develop a good phase conversion system to allow a proper utilisation of a three phase motor from a single-phase source. The present study was taken up to meet this need.

While the operation of a three-phase motor from a single-phase supply with a capacitor in circuit has been discussed in literature over the years, detailed analytical work has been limited either to the starting of such motors [8] or to its operation with a 2-capacitor system [6]. In the present study, the analysis has been carried out over the entire speed range of the machine with special emphasis on the magnitude of the negative-sequence voltage and the voltage unbalance factor defined as the ratio of the negative sequence voltage to the positive sequence voltage. It has been shown both analytically and experimentally that with a suitable design of the motor and a proper selection of the capacitor size, it is possible to limit the negative-sequence voltage to about 5%. A computer programme has been developed to determine the optimum size of the capacitor at all speeds. The adjustment of the capacitor size is possible through a feedback

ontrol system. However, to keep the cost of the control-gear to a minimum, an investigation has been carried out to see whether a number of discrete capacitor sizes would solve the problem. It has been found that if a three-capacitor system is used, one capacitor corresponding to the starting value, one to the running value, and one to optimise operation at 30% slip, the unbalance during the entire operation is limited to reasonable values. Both computed performance and experimental results show that Haberman's conclusions about the behaviour of the three-phase machine operatir from a single-phase supply are extremely conservative if not totally untenable. The feasibility of using a double-cage machine from a single-phase source has been investigated and it has been established that the prejudice against such a usage is indefensible he double-cage machine the performance of which was both computed from theoretical equations and tested in the laboratory showed better characteristics under single-phase operation than all the single-cage machines examined.

Next part of the investigation relates to the operation of such a machine at two speeds without any major redesign of the windings. The difficulty in operating induction machines at lower speeds is due to the considerable increase in the stator and rotor currents at the lower speed. An earlier work [11] had indicated the possibility of one-third speed operating by utilising 60° or 120° displacement between two windings. A thorough analysis has been carried out to see what would be the best method of getting one-third speed. The conventional zero-sequence connection is examined and compared with other methods. It is found that the best results are obtained when all the three

windings of the machine are utilised, one of them being divided into two parts and reconnected with the other windings to give a 60^{o} displacement between the windings. The currents taken by the windings under this connection were nearly balanced and also the smallest in value when compared to all the other possible configurations examined. Switching arrangements are evolved which necessitate only six terminals to be brought out, an economic factor worthy of consideration.

The concluding part of the investigation relates to the dynamic behaviour of a three-phase motor run from a single-phase source through a capacitor. Earlier work by Treschev [13] had indicated large variation between steady-state and dynamic torque in case of normal polyphase operation of an induction motor. An attempt has been made to estimate such variation under single-phase operation. The equations of behaviour obtained are simultaneous differential equations with complex coefficients. A computer program to calculate the behaviour could not be developed because of no known method of solving such equations. Experimental tests on a small laboratory motor however failed to show any appreciable difference between the steady-state and dynamic behaviour of the machine.

The investigation reported in this dissertation has successfully led to:-

(a) the development of a complete analysis of the behaviour of a single-phase motor operating from a polyphase supply;

(b) the laying down of useful design criteria for the successful operation of such motor;

(c) the development of a three-capacitor scheme for reducing the unbalance to a minimum over the entire speed range;

(d) the development of a new method of operating the motor at 1/3-speed with currents in the windings remaining nearly balanced and smaller in value than in all other simple methods of 1/3-speed operation; and

(e) a study of the dynamic behaviour of the single-phase

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