ABSTRACT of PhD Thesis

"Design and Development of High Efficiency Three Phase Induction Motors for Solar Water Pumping and Other Applications"

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This thesis deals with an efficiency optimization method of the induction motor (IM) through the variation of the different design parameters. To achieve this goal, the flux in the airgap, in the yoke, in the teeth is modified according to an optimal flux table computed off-line for all possible operating points. The design of this motor is achieved through a combined approach of design of experiments (DOE) with one of the optimization algorithms. The design and parameter constraints are function of the geometry of the motor. The proposed optimization method is implemented, and optimized motor then tested for the field-oriented control, to show the genericity of the proposed approach. The validation is carried on an experimental test bench for six induction motors of different power ratings. The results obtained show the reduction of the losses in the motor, thus an improvement of the overall efficiency while preserving a satisfactory dynamic behavior. Consequently, the optimization of the energy efficiency is validated for the six developed motors for different low power applications i.e., fan application, pump application and electric vehicle application. In addition to the validation of the simulation results, the proposed approach is compared to existing conventional standard motors to assess its improvement. The performance of the induction motor is changed by changing its core length, shape of stator slots, shape of rotor slots or the diameter of the core, material of the stampings, material of the casting i.e., aluminum or copper in the rotor, skew angle, and air gap length. In the variable frequency drive, the first two requirement of high starting torque and low starting current are taken care by voltage source inverter (VSI). Therefore, this work focuses on the efficiency improvement of the motor. In this case, the design and construction of induction motors are based on standard motors with standardized frame sizes and dimensions, however, with modifications for converter operation.

The utilization of solar photovoltaic (PV) energy in water pumping is conservative particularly in isolated regions where the transmission of power is either impractical or exorbitant. In this research work, various topologies for solar PV array fed water pumping are developed using an induction motor drive. A high efficiency induction motor substantially reduces the size of PV array and hence its installation cost. Moreover, its high-power factor results in a reduced capacity of the used voltage source inverter (VSI). Therefore, in this work, mechanical sensorless control of an induction motor drive is investigated with fast speed control and better stability. The motor flux is optimized, and the total losses are minimized in partial loading condition. The system is made simplified and cost-effective by reducing the number of voltage and current sensors and all parameters are estimated through the sensed DC link voltage and DC link current. The system possesses a maximum power point tracking (MPPT) of the PV array by introducing a DC-DC boost converter between the PV array and a VSI, feeding the motor. The work is extended towards an elimination of a DC-DC converter and a single stage PV array fed induction motor drive is also investigated for water pumping.

A promising case of interruption in the water pumping due to the intermittency of PV power generation is resolved by using a single-phase utility grid as an external power backup. A grid interacted PV array and its control are demonstrated to get a reliable and fully utilized water pumping with an induction motor such that the pumping is not affected by an intermittency of solar PV array generation. The power is drawn from the grid in case the PV array is unable to meet the required power demand. Both unidirectional and bidirectional power flow controls are implemented for a grid interfaced PV array fed induction motor driven water pump. The bidirectional power flow control-based topology offers an additional merit of feeding power to the utility grid by the installed PV array, in case the water pumping is not required. This practice leads to a full utilization of installed resources. Moreover, it emerges as a source of earning by sale of electricity to the utility. The maximum power point (MPP) operation of a PV array, and power quality (PQ) standards such as power factor and total harmonic distortion (THD) of the grid current as per IEEE-519 standard, are met by this system.

A single-phase grid fed fan type load profile system operated by a mechanical sensorless induction motor drive suitable to work in complete speed range is developed and a unidirectional power flow control for the same is developed and realized through a power factor corrected (PFC) boost converter. This research work also aims on the power factor correction in the induction motor drive for fan application with the speed control. A power factor corrected (PFC) boost converter is utilized for the development of the system. A full speed range of a fan with enhanced power quality during normal and abnormal grid voltage conditions is achieved by using this system. The system is simulated and analyzed under variable speed and load conditions, during both the normal and weak grid, for a fan type load profile.

Hike in price due to limited and rapidly exhausting oil deposition have forced the automobile industry to find economically feasible alternative sources of energy to drive them forward. In this context, the use of a battery operated EV's becomes poignantly significant all over the world. Not much effort has been taken to counter this crisis, especially in developing countries such as India due to the non-availability of technology and expert knowledge in this domain. This research work elaborates the design and development of EV drive motors using die-cast copper rotor technology and regulating it with an economic and efficient drive controller.

All the proposed configurations are modeled and simulated using MATLAB/Simulink platform to demonstrate their performance during starting, dynamics and steady state conditions. Simulated results are verified through test results obtained from hardware implementation using a developed prototype in the laboratory. The applicability and commercial potential of proposed systems are justified by their in-depth analysis based on efficiency, cost, simplicity, and performance.