INNOVATIONS IN ENERGY MANAGEMENT OF INDUCTION MACHINE BASED INDUSTRIAL PLANTS

A THESIS

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Declaration by the Research Scholar

This is to certify that thesis entitled "**INNOVATIONS IN ENERGY MANAGEMENT OF INDUCTION MACHINE BASED INDUSTRIAL PLANTS**", submitted by me to the Indian Institute of Technology Mandi for the award of the degree of Doctor of Philosophy is a bonafide record of research work carried out by me under the supervision of **Dr. Bharat Singh Rajpurohit**. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

Place: Kamand
Date: 25 Sept 2017

Signature of Research Scholar

THESIS CERTIFICATE

This is to certify that the thesis titled **INNOVATIONS IN ENERGY MANAGEMENT OF INDUCTION MACHINE BASED INDUSTRIAL PLANTS**, submitted by **Gurinderbir Singh Grewal**, to the Indian Institute of Technology Mandi, for the award of the degree of Doctor of Philosophy, is a bonafide record of the research work done by him under my supervision. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

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ABSTRACT

The non-intrusive *in-situ* efficiency estimation of induction machines (IMs) in real industrial environment is given due consideration and its possibilities are thoroughly investigated. The non-intrusiveness refers to measurement of electrical input voltages and currents at IM terminals only. This thesis develops the techniques for estimating the efficiency of IM in a non-intrusive manner for balanced/unbalanced power supplies. Also, energy auditing case studies of two industrial plants is undertaken to reduce consumption of electrical power and enhance savings. Overall work has been completed in three sections.

First section is the study of numerous methods of efficiency estimation of IM and different standards applied so far. In this section, the mathematical modeling of IM is done in D-Q reference frame. Efficiency calculation of IM is done in stationary reference frame. The efficiency estimation of in-situ IM is accomplished through the development of low cost non-intrusive air-gap torque method by doing modifications to original air-gap torque method based on air-gap torque equations employing line-to-line voltages and two phase currents with sufficient accuracy and least intrusion level. Speed estimation of IM rotor is accomplished by model reference adaptive mechanism which utilizes rotor flux error vector as tuning signal for speed estimation for IM drives in the speed adaptation mechanism. Efficiency estimation is performed for both balanced and unbalanced conditions.

In the second section, population based algorithm i.e. cuckoo search algorithm (CSA) is proposed for efficiency estimation of *in-situ* IM which is capable of dealing with balanced/unbalanced voltages. The proposed technique is non-intrusive in nature and needs least measurements like two line voltages and currents along with nameplate data of IM. Also, gravitational search based algorithm (GSA) is proposed for efficiency estimation of in-service IMs which handles unbalanced/unbalanced voltages and gives better results than CSA. These proposed techniques don't alter any operating condition of IM.

In the third section analysis for energy auditing performed for two industrial plants i.e. Jindal Steel Plant (JSP) and Sohna Woolen Mill (SWM) to reduce their energy consumption is presented. This task is accomplished by analyzing the replacement of IMs giving poor efficiencies by energy efficient IMs of suitable ratings. In JSP, rescheduling of loads on power transformers is done to reduce the losses and burden on insulation of over-loaded transformer. This enhances energy savings as well. Also, power factor improvement is suggested for JSP. During the process of energy auditing, the need of device for efficiency estimation of IM for any loading condition is felt since lot of time is consumed in measurements of electrical input quantities. Conventional methods of efficiency estimation need de-coupling of IM from drive. Therefore, a low cost non-intrusive handheld device is fabricated for evaluating IM efficiency. This device has PIC 18F4520 micro-controller which is programmed as per non-intrusive air-gap torque method. This handheld device is implemented for efficiency estimation of IM in balanced/unbalanced voltages.

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