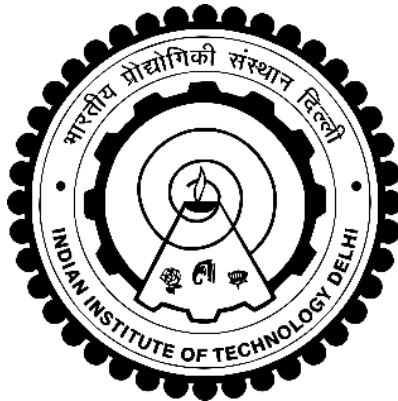


CONTROL AND IMPLEMENTATION OF INDUCTION MOTOR DRIVE FOR LIGHT ELECTRIC VEHICLE

KOUSALYA V



**DEPARTMENT OF ELECTRICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY DELHI
HAUZ KHAS, NEW DELHI-110016, INDIA
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by

KOUSALYA V

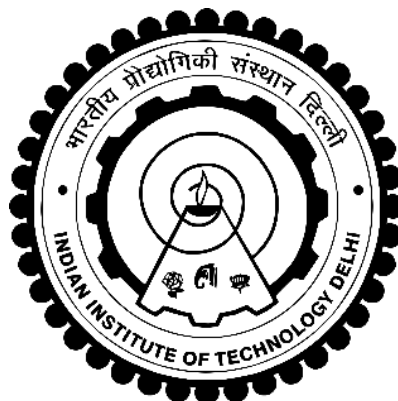
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Submitted

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CERTIFICATE

It is certified that the thesis entitled “**Control and Implementation of Induction Motor Drive for Light Electric Vehicle,**” being submitted by **Mrs. Kousalya V** for award of the degree of **Doctor of Philosophy** in the Department of Electrical Engineering, Indian Institute of Technology Delhi, is a record of the student work carried out by her under my supervision and guidance. The matter embodied in this thesis has not been submitted for award of any other degree or diploma.

Dated:

(Prof. Bhim Singh)
Electrical Engineering Department
Indian Institute of Technology Delhi
Hauz Khas, New Delhi-110016, India.

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Dated:

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ABSTRACT

This research presents control and implementation of battery fed induction motor drive based electric drive train system. In this work, five different topologies of induction motor based drivetrains are developed in which battery is used as primary energy source and solar PV array is considered as auxiliary energy source. First, to enhance the efficiency of the propulsion induction motor, optimized reference points based field oriented control is implemented. The speed of the motor is estimated using second order super twisting sliding mode observer and motor parameters like stator resistance and rotor time constant are continuously updated online with the help of model reference adaptive system (MRAS). Secondly, to improve the performance of the induction motor at various operating speeds, predictive torque control (PTC) is implemented where adaptive full order observer is used for speed estimation. Comparative analysis is made between the PTC over conventional torque control methods. Third, to improve the robustness and to reduce the dependency of model sliding model based predictive torque control and model free predictive torque control methods are implemented for induction motor. To make the speed estimation robust against DC-offset present in the measured signal, generalized integrators (GI) based speed estimation is performed. Further, to improve the robustness of the indirect field oriented control (IFOC), predictive current control is incorporated. Finally, to reduce the number of current sensors, current reconstruction is algorithm is implemented to estimate three phase current from the DC-link current. The presented works are simulated in Matlab / Simulink based software platform and verified experimentally in dSpace based hardware test bench. The comparative analysis is made between control and speed estimation algorithms to determine the suitability of control.

सारांश

यह शोध कार्य बैटरी से संचालित इंडक्शन मोटर आधारित इलेक्ट्रिक ड्राइवट्रेन प्रणाली के नियंत्रण और कार्यान्वयन को प्रस्तुत करता है। इस कार्य में इंडक्शन मोटर आधारित ड्राइवट्रेन की पाँच विभिन्न टोपोलॉजी विकसित की गई हैं, जिनमें बैटरी को मुख्य ऊर्जा स्रोत के रूप में तथा सोलर पीवी एरे को सहायक ऊर्जा स्रोत के रूप में उपयोग किया गया है। सबसे पहले, प्रोपल्शन इंडक्शन मोटर की दक्षता बढ़ाने के लिए अनुकूलित संदर्भ बिंदुओं पर आधारित फील्ड ओरिएंटेड कंट्रोल (Field Oriented Control) को लागू किया गया है। मोटर की गति का अनुमान सेकंड ऑर्डर सुपर ट्विस्टिंग स्लाइडिंग मोड ऑब्जर्वर की सहायता से किया गया है तथा मोटर के पैरामीटर जैसे स्टेटर रेसिस्टेंस और रोटर टाइम कॉन्स्टेंट को मॉडल रेफरेंस एडैप्टिव सिस्टम (Model Reference Adaptive System) की सहायता से ऑनलाइन लगातार अपडेट किया गया है। दूसरे चरण में, विभिन्न परिचालन गति (operating speeds) पर इंडक्शन मोटर के प्रदर्शन को बेहतर बनाने के लिए प्रेडिक्टिव टॉर्क कंट्रोल (Predictive Torque Control) को लागू किया गया है, जहाँ स्पीड अनुमान के लिए एडैप्टिव फुल ऑर्डर ऑब्जर्वर का उपयोग किया गया है। PTC और पारंपरिक टॉर्क कंट्रोल विधियों के बीच तुलनात्मक विश्लेषण किया गया है। तीसरे चरण में, मजबूती (robustness) बढ़ाने तथा मॉडल पर निर्भरता कम करने के लिए स्लाइडिंग मोड आधारित प्रेडिक्टिव टॉर्क कंट्रोल तथा मॉडल-फ्री प्रेडिक्टिव टॉर्क कंट्रोल विधियों को इंडक्शन मोटर के लिए लागू किया गया है। मापे गए सिग्नल में उपस्थित DC-offset के विरुद्ध स्पीड अनुमान को अधिक मजबूत बनाने के लिए जनरलाइज़्ड इंटीग्रेटर (Generalized Integrators) आधारित स्पीड अनुमान तकनीक का उपयोग किया गया है। इसके अतिरिक्त, इनडायरेक्ट फील्ड ओरिएंटेड कंट्रोल (IFOC) की मजबूती बढ़ाने के लिए प्रेडिक्टिव करंट कंट्रोल को सम्मिलित किया गया है। अंततः, करंट सेंसर की संख्या को कम करने के उद्देश्य से करंट रिकंस्ट्रक्शन एल्गोरिद्म लागू किया गया है, जिसके माध्यम से करंट से तीन-फेज करंट का अनुमान लगाया जाता है। प्रस्तुत सभी कार्यों का सिमुलेशन (MATLAB / Simulink) आधारित सॉफ्टवेयर प्लेटफॉर्म पर किया गया है तथा dSPACE आधारित हार्डवेयर टेस्ट बेंच पर प्रायोगिक रूप से सत्यापित किया गया है। विभिन्न नियंत्रण और स्पीड अनुमान एल्गोरिद्म के बीच तुलनात्मक विश्लेषण करके उनके उपयुक्तता (suitability) का निर्धारण किया गया है।

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LIST OF ABBREVIATIONS

AC	Alternating Current
ADR	Adaptive Disturbance Rejection
AFO	Adaptive Full order Observer
ARAI	Automotive Research Association Of India
ARX	Auto Regressive Exogenous
DC	Direct Current
DOD	Depth of Discharge
DSOGI	Dual Second Order Generalised Integrator
DSP	Digital Signal Processing
DTC	Direct Torque Control
EMF	Electro Motive Force
FLL	Frequency Locked Loop
FOC	Field Oriented Control
GI	Generalised Integrator
IFOC	Indirect Field Oriented Control
IGBT	Insulated Gate Bipolar Transistor
LEVs	Light Electric Vehicles
LPF	Low Pass Filter
LUT	Lookup Table
MIMO	Multi Input Multi Output
MPC	Model Predictive Control
MPPT	Maximum Power Point Tracking
MTPL	Maximum Torque per Power Loss
MVSPWM	Mixed Vector Space Vector Pulse Width Modulation
OOP	Optimized Operating Points
PCC	Predictive Current Control
PO	Perturb and Observe
PTC	Predictive Torque Control

PV	Photo voltaic
RLS	Recursive Least Square
SCFO	Sinusoidal Curve Fitting Observer
SD	Standard Deviation
SMO	Sliding Mode Observer
SOC	State of Charge
SVM	Space Vector Modulation
THD	Total Harmonic Distortions
VSI	Voltage Source Inverter