

COORDINATED STRATEGIES FOR ELECTRIC VEHICLES CHARGING INFRASTRUCTURE

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**DEPARTMENT OF ELECTRICAL ENGINEERING
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COORDINATED STRATEGIES FOR ELECTRIC VEHICLES CHARGING INFRASTRUCTURE

by

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Submitted

**in fulfilment of the requirements of the degree of Doctor of Philosophy
to the**



INDIAN INSTITUTE OF TECHNOLOGY DELHI

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In memory of my loving father ...

Certificate

This is to certify that the dissertation entitled ”**Coordinated Strategies for Electric Vehicles Charging Infrastructure**”, being submitted by **Ms. Rubi Rana** for the award of the degree of **Doctor of Philosophy** is a record of bonafide research work carried out by her in the Department of Electrical Engineering at Indian Institute of Technology Delhi, New Delhi.

Ms. Rubi Rana has worked under my supervision and has fulfilled the requirements for the submission of this dissertation, which to our knowledge has reached the requisite standard. The results obtained here have not been submitted to any other University or Institute for the award of any degree.

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Abstract

Commutation topology worldwide is transitioning to all-electric systems. Electrification of all forms of transportation increases the load on the transforming power grid and can potentially negatively impact the grid. However, the sustainable integration of Electric Vehicles (EVs) into the grid could alleviate these potential problems and make EVs a vital resource for providing grid services. There is a need for an outline infrastructure and operating protocols that can integrate these highly volatile loads with existing power grids and facilitate a seamless experience. Furthermore, there are numerous infrastructure needs and operational strategies to analyze with the electric utilities, stakeholders, officials, and engineers to ensure a synchronous operation between all the participating units.

This Thesis aims to develop a holistic approach for EVs charging schedules by utilizing a web application to provide insights into upcoming demand and supply needs. This work is extended to incorporate any uncertainties in EVs pre-planned schedules using a multi-level optimization strategy. The optimization strategies are further validated in the internet of things infrastructure to corroborate its effectiveness.

The Thesis also explores a decentralized framework for EVs operation in a bidirectional setup where it acts as a load as well as an energy source for the grid. The work targets the EVs connected at charging stations along with EVs connected at individual EV owner houses.

Many modern economies are thought to be economies backed by energy surplus. EVs can act as small powerhouses when standing ideal for a more extended period. This Thesis

explored a possibility of an energy trading system where the energy can be traded amongst EVs or at charging station levels using Assignment Matching Theory. Furthermore, the Thesis also validates GB/T EV communication protocol, which is another critical aspect of EV charging infrastructure.

सार

दुनिया भर में कम्प्यूटेशन टोपोलॉजी ऑल-इलेक्ट्रिक सिस्टम में संक्रमण कर रही है। परिवहन के सभी रूपों के विद्युतीकरण से ट्रांसफॉर्मिंग पावर ग्रिड पर भार बढ़ जाता है और संभावित रूप से ग्रिड पर नकारात्मक प्रभाव पड़ सकता है। हालांकि, इलेक्ट्रिक का सतत एकीकरण ग्रिड में वाहन (ईवी) इन संभावित समस्याओं को कम कर सकते हैं और ईवीएस को ग्रिड सेवाएं प्रदान करने के लिए एक महत्वपूर्ण संसाधन बना सकते हैं। एक रूपरेखा बुनियादी ढांचे और ऑपरेटिंग प्रोटोकॉल की आवश्यकता है जो मौजूदा पावर ग्रिड के साथ इन अत्यधिक अस्थिर भार को एकीकृत कर सके और एक निर्बाध अनुभव की सुविधा प्रदान करता है। इसके अलावा, सभी भाग लेने वाली इकाइयों के बीच एक समकालिक संचालन सुनिश्चित करने के लिए विद्युत उपयोगिताओं, हितधारकों, अधिकारियों और इंजीनियरों के साथ विश्लेषण करने के लिए कई बुनियादी ढांचे की जरूरतें और परिचालन रणनीतियां हैं।

इस थीसिस का उद्देश्य आगामी मांग और आपूर्ति की जरूरतों में अंतर्दृष्टि प्रदान करने के लिए एक वेब एप्लिकेशन का उपयोग करके ईवीएस चार्जिंग शेड्यूल के लिए एक समग्र दृष्टिकोण विकसित करना है। बहु-स्तरीय अनुकूलन रणनीति का उपयोग करते हुए ईवीएस पूर्व-नियोजित शेड्यूल में किसी भी अनिश्चितता को शामिल करने के लिए इस कार्य को बढ़ाया गया है। ऑप्टिमाइज़ेशन रणनीतियों को इंटरनेट ऑफ थिंग्स इन्फ्रास्ट्रक्चर में इसकी प्रभावशीलता की पुष्टि करने के लिए और अधिक मान्य किया गया है।

थीसिस एक द्विदिश सेटअप में ईवीएस संचालन के लिए एक विकेन्द्रीकृत ढांचे की भी खोज करती है जहां यह ग्रिड के लिए भार के साथ-साथ ऊर्जा स्रोत के रूप में कार्य करता है। कार्य व्यक्तिगत ईवी मालिक के घरों से जुड़े ईवी के साथ चार्जिंग स्टेशनों से जुड़े ईवी को लक्षित करता है।

कई आधुनिक अर्थव्यवस्थाओं को ऊर्जा अधिशेष द्वारा समर्थित अर्थव्यवस्थाओं के रूप में माना जाता है। अधिक विस्तारित अवधि के लिए आदर्श खड़े रहने पर ईवीएस छोटे पावरहाउस के

रूप में कार्य कर सकते हैं। इस थीसिस ने एक ऊर्जा व्यापार प्रणाली की संभावना का पता लगाया जहां ऊर्जा का व्यापार किया जा सकता है असाइनमेंट मैचिंग थ्योरी का उपयोग करते हुए ईवी या चार्जिंग स्टेशन स्तर पर। इसके अलावा, थीसिस जीबी/टी ईवी संचार प्रोटोकॉल को भी मान्य करता है, जो ईवी चार्जिंग इंफ्रास्ट्रक्चर का एक और महत्वपूर्ण पहलू है।

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Nomenclature

BCL	Battery Charging Demand
BCP	Battery Charging Parameter
BCS	Battery charging total status
BHM	BMS Handshake Message
BMS	battery management system
BSD	Battery statistical data
CC	Central Controller
CCS	Charger charging state
CEV	Charging EV
CHM	Charger Handshake Message
CPs	charging points
CS	Charging station
CSD	Charger statistical data
CTS	Charger send-time synchronization

DEV	Discharging EV
DGs	distributed generation resources
DLMP	Distribution Location Marginal Pricing
DSO	Distribution system operators
EMS	Energy management system
EV	Electric vehicle
FC	Fuel Cell
FND	fictitious nodal demand
GPRS	General Packet Radio Services
GSM	Global system for mobile communication
IoT	Internet of Things
JADE	JAVA Agent Development framework
LMP	locational marginal price
MT	Micro Turbine
OPF	optimal power flow
PV	Photo Voltaic
RBTS	Roy Billinton Test System
SB	Sub-block
SoC	state of charge

TOD	Time of Day
TOU	time of use
UB	user base
V2G	Vehicle to grid
VSC	Voltage Source Converter vehicle
VSL	Vehicle Smart Link
WT	Wind Turbine