# COORDINATED STRATEGIES FOR ELECTRIC VEHICLES CHARGING INFRASTRUCTURE

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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**


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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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**Date:** **Rubi Rana**

# 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 ऑफ़ 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 |