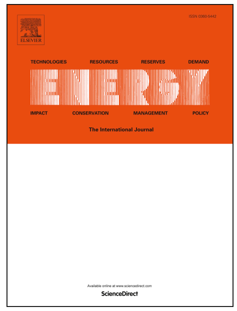

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# State of Charge Estimation for Electric Vehicle Power Battery using Advanced Machine Learning Algorithm under Diversified Drive Cycles

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**Abstract:** State of charge estimation is one of the most critical factors to solve the key issues of monitoring and safety concerns of an electric vehicle power battery. In this paper, a state of charge estimation approach using subtractive clustering based neuro-fuzzy system is presented and evaluated by the simulation experiments using advanced vehicle simulator in comparison with back propagation neural network and Elman neural networks. Input parameters to model the state of charge estimation approach using subtractive clustering based neuro-fuzzy system are current, temperature, actual power loss, available and requested power, cooling air temperature and battery thermal factor. Data collected from 10 different drive cycles are utilized for the training and testing stages of the state of charge estimation model. Experimental results illustrated that the proposed model exhibits sufficient accuracy and outperforms both neural network and Elman neural network based models. Thus, the proposed model under different drive cycles show remarkable advancement in state of charge estimation with high potential to overcome the drawbacks in traditional methods and therefore provides an alternative approach in state of charge estimation. In addition, a sensitivity analysis is also performed to determine the importance of each input parameter on output i.e. state of charge.

**Keywords:** Battery Management System, Electric Vehicle, Energy Storage, Battery State Estimation, State of Charge, Machine Learning

## 1. Introduction

Due to limited fossil fuel resources and recent environmental and energy crisis, electric vehicles (EVs) and hybrid electric vehicles (HEVs) are gaining more popularity as a promising and alternate source of transportation that is neither harmful to the green echo system nor effects the ozone layer. Many developed as well as developing countries including United states and China have taken initiatives to fight against the climate change and have announced their plan to have *5 million EVs on road by the year 2020 plan* reported by [1]. Individuals in academia, researchers, governments and automobile industries from around the world have invested a lot of resources to develop and advance the automotive industry transition to electric vehicles and hybrid electric vehicles from traditional internal combustion engine (ICE) based automotive industry due to their remarkable energy-saving capabilities and potential integration with renewable smart power grids. white et al.[2] and Silvestre et al [3] have both discussed the issues related to vehicle to grid connectivity and to optimize the charging time for electric vehicles to further reduce the charging costs for the users in order to achieve the objective of power grid peak load shifting.

A major challenge faced by existing EV and HEV automotive industry is the overall driving range that is significantly lesser compared with the traditional ICE vehicles. Adding to the problem of overall driving range is the lack of a battery management system that can estimate and predict the actual remaining power of a battery i.e. to predict the residual driving range.