EARLY DETECTION OF LITHIUM DENDRITE RISK IN EV BATTERIES USING QUANTUM SUPPORT VECTOR MACHINES

by

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A project report submitted to the

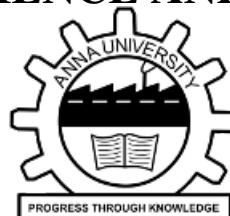**FACULTY OF INFORMATION AND**

COMMUNICATION ENGINEERING

in partial fulfillment of the requirements for

the award of the degree of

BACHELOR OF ENGINEERING

in

COMPUTER SCIENCE AND ENGINEERING

DEPARTMENT OF COMPUTER SCIENCE AND

ENGINEERING

ANNA UNIVERSITY, CHENNAI – 25

MAY 2027

BONAFIDE CERTIFICATE

Certified that this project report titled **EARLY DETECTION OF LITHIUM DENDRITE RISK IN EV BATTERIES USING QUANTUM SUPPORT VECTOR MACHINES** is the *bonafide* work of **VISHAK SENTHILKUMAR (2023103019)**, **ARAVINDHAN S (2023103034)** and **MANESH RAM (2023103037)** who carried out the project work under my supervision, for the fulfillment of the requirements for the award of the degree of Bachelor of Engineering in Computer Science and Engineering. Certified further that to the best of my knowledge, the work reported herein does not form part of any other thesis or dissertation on the basis of which a degree or an award was conferred on an earlier occasion on these or any other candidates.

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ACKNOWLEDGEMENT

This page is where you would acknowledge all those who helped you with your academic research. I would like to thank Professor Smith ...

Use your own words to express thanks. Don't forget to thank the committee and the HoD. They've been very helpful.

Vishak Senthilkumar   **Aravindhan S**   **Manesh Ram**

ABSTRACT

The overall number of electric vehicles (EVs) on the roads is increasing and the need for the safety and reliability of their batteries is becoming more important. Dendrite formation is one of the most critical issues facing an electric vehicle's battery and can cause not only safety hazards but also destruction of the battery itself. This project offers a unique procedure for spotting battery dendrite risk early, using a hybrid machine learning model that merges both classical and quantum computing methods. Quantum Support Vector Machines classify the health of the battery time-series data, which consists of voltage, current and temperature. The sensors that are placed on the battery gather continuous data for a certain period of time and this data is then divided into smaller segments using a sliding window technique of pre-processing. For each segment, various statistics including average, variance and rate of change are computed to identify potential features in the battery's behavior. Features that have been selected are subsequently provided to the hybrid model where the QSVM further pushes the feature transformation process making it easier to detect very slight abnormalities which are signs of dendrite growth. It is the objective of this model to generate real-time, very precise predictions of dendrite risk that will facilitate quick actions taken and thus better management of the overall battery. The fusion of quantum computing and traditional machine learning techniques is what marks a key milestone for the EVs battery health monitoring sector.

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LIST OF ABBREVIATIONS

QSVM Quantum Support Vector Machine

QML   Quantum Machine Learning

SVM   Support Vector Machine

EV   Electric Vehicle

QAOA Quantum Approximate Optimization Algorithm

NISQ Noisy Intermediate-Scale Quantum

CHAPTER 1

INTRODUCTION

EVs can contribute to sustainable transportation and lithium-ion batteries are the key to their operation. The charging process subjects the EV batteries to different electrical and thermal conditions, which when allowed to get out of check may lead to abnormal behavior. Thermal runaway is one of the most important safety issues since the phenomenon, which is defined as an abrupt rise in temperature, may cause battery deterioration or system malfunction. Such abnormal conditions must therefore be identified early in order to be able to ensure that operations are safe and also to guarantee reliability of the system.

Due to the growing implementation of sensor-based battery management systems, nowadays it is possible to collect a considerable amount of time-stamped battery charging data in real time. This data is usually continuous measurements, including voltage, current, temperature and state of charge, measured during the charge, which are recorded during the charging cycle. This data is usually analyzed with machine learning methods and used to identify abnormal charging conduct. Nevertheless, most of the current methods are based on classical machine learning models only, and these might not be able to depict the complicated nonlinear relationships that can exist in multivariate time-series sensor data.

The new developments in quantum computing provided quantum-inspired machine learning (QML) methods that present alternative data representation and transformation techniques. Despite the fact that mod-

ern quantum devices have not offered any computational advantage of practical datasets, hybrid learning systems with classical and quantum-inspired components have been considered, because the feature representation can be improved. Here, it is assumed that QML will not replace the classical machine learning, but it represents another processing layer that can be added to the already existing learning pipeline.

This paper suggests a hybrid classical-quantum learning model to detect anomalies in EV battery charging systems with real time stamped sensor data. It is based on the suggested procedure that combines the classical time-series preprocessing and feature extraction with a quantum-inspired processing layer that is aimed at executing nonlinear feature transformation. The resulting hybrid feature representation is then studied with a classical classifier to determine abnormal charging patterns that relate to thermal runaway.

This project will have the main goal of designing and deploying an entire learning pipeline showing the extent to which advanced machine learning techniques can be integrated in a safety-critical and real world application. Instead of prioritizing the superior performance or computational acceleration, it focuses on the architectural design, feasibility, and the systematization of evaluation of hybrid feature representations of time-series anomaly detection. The efficiency of the suggested framework is assessed with the help of the data set of time-stamped sensor readings that were recorded in EV battery charge and thermal runaway events.

CHAPTER 2

LITERATURE REVIEW

Table 2.1 Literature Review

S.No	Paper	Methodology	Limitations	Ideas for Adoption
1	Comparative Investigation of Quantum and Classical Kernel Functions Applied in Support Vector Machine Algorithms	Performs a comparative study of classical kernels (RBF, polynomial) and quantum kernels within the SVM framework. Different quantum feature maps are evaluated using QSVM on benchmark datasets.	Uses quantum simulators; high kernel computation cost; limited scalability; lacks real-world application focus.	Adopt the quantum kernel comparison framework to evaluate classical SVM versus QSVM for battery time-series features, justifying improved separability for early dendrite-risk patterns.

S.No	Paper	Methodology	Limitations	Ideas for Adoption
2	Assessment of Quantum Feature Map for Binary Forest Classification using QSVM	Evaluates multiple Pauli-based quantum feature maps for binary classification. Features are normalized, reduced, encoded, and classified using QSVM with Pareto-front analysis.	Relies on simulators; inconsistent QSVM superiority; scalability limitations in NISQ-era hardware.	Apply quantum feature map selection strategies to battery sensor data and use Pareto analysis to balance accuracy and computational cost.
3	Hybrid Quantum–Classical Framework for Urban Traffic State Classification	Implements a hybrid pipeline combining classical feature extraction with quantum encoding and QSVM-based classification.	Limited dataset; simulator-based execution; real-time scalability not addressed.	Use the hybrid classical–quantum architecture for battery monitoring by applying QSVM after classical preprocessing of voltage and temperature data.

S.No	Paper	Methodology	Limitations	Ideas for Adoption
4	AutoQML: A Framework for Automated Quantum Machine Learning	Introduces automated quantum model selection, feature encoding, and hyperparameter tuning in hybrid workflows.	High computational overhead; simulator dependence; not tailored for time-series data.	Adopt automated quantum kernel and hyperparameter tuning to reduce manual QSVM optimization for battery datasets.
5	Real-Time Quantum Machine Learning-Based Anomaly Detection for Lithium-Ion Battery Packs	Proposes quantum-enhanced K-Means clustering for real-time anomaly detection using battery sensor data.	Focuses on clustering; requires multiple qubits; real-time hardware feasibility unclear.	Extend the anomaly detection framework by replacing clustering with QSVM-based supervised dendrite-risk classification.

| 6 | Quantum Kernel-Based Support Vector Machine with QAOA Embedding for Lung Cancer Prediction | Uses QAOA-based quantum feature embedding with QSVM, achieving better results for small datasets. | Simulator execution; high cost; evaluated only on static medical data. | Adopt QAOA-based quantum embedding for capturing nonlinear patterns in reduced battery feature sets. |

CHAPTER 3

DESIGN

3.1 REQUIREMENTS

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CHAPTER 4

IMPLEMENTATION

4.1   DESIGN PRINCIPLES

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CHAPTER 5

TESTING

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CHAPTER 6

RESULTS

6.1 RESULTS

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CHAPTER 7

CONCLUSIONS

7.1   CONTRIBUTIONS

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7.2   FUTURE WORK

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