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# Machine Learning-Based Hybrid EV Assistive System for Fuel and Electric Switching

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**Abstract**

Modern Hybrid Electric Vehicles (HEVs) incorporate an Internal Combustion Engine (ICE) and an electric motor to increase fuel efficiency and lower pollutants. These vehicles offer a practical transition toward electrification, balancing eco-friendliness with convenience. An AI-based HEV assistive system utilizes machine learning to optimize the switching between fuel and electric power sources, enhancing efficiency, performance, and sustainability. By continuously analyzing real-time factors such as driving conditions, battery charge levels, fuel availability, traffic patterns, and driver behavior, the system intelligently determines the optimal power source for any given situation. Advanced predictive algorithms enable seamless transitions, minimizing energy waste, reducing emissions, and extending battery life while maintaining a smooth driving experience. Additionally, the AI-driven system adapts over time, learning from historical data to refine its switching strategies for improved performance. This intelligent energy management approach not only enhances vehicle efficiency but also contributes to reducing operational costs and environmental impact, making hybrid vehicles more practical and eco-friendly.

**Keywords:** Hybrid Electric Vehicle (HEV), Machine Learning, Node MCU, Temperature Sensor, H-Bridge.

## 1. Introduction

HEVs have emerged as a vital solution for sustainable transportation, combining an internal combustion engine (ICE) with an electric motor to improve fuel efficiency and lower emissions. Modern HEVs utilize advanced battery technologies, regenerative braking, and intelligent energy management systems to optimize performance. With growing concerns about environmental impact and fuel costs, HEVs serve as a practical transition between conventional gasoline-powered vehicles and fully electric models. Their ability to switch seamlessly between power sources based on driving conditions makes them a reliable and eco-friendly choice for consumers seeking efficiency without compromising convenience.

The increasing need for energy-efficient and ecologically friendly transportation has resulted in considerable advances in HEV technology. One critical challenge in HEVs is optimizing the switching between fuel and electric power to maximize efficiency and performance. An AI-based assistive system utilizing machine learning can intelligently manage this transition by analyzing real-time driving conditions, battery levels, traffic patterns, and driver behavior. By leveraging Support Vector Machine (SVM) algorithms, the system can accurately predict and determine the optimal power source, ensuring smooth transitions while minimizing fuel consumption and emissions. This intelligent approach enhances vehicle efficiency, extends battery life, and reduces operational costs, making HEVs a more practical and sustainable choice for modern transportation.

With the increasing demand for energy-efficient and eco-friendly transportation, HEVs have become a crucial solution by combining internal combustion engines with electric motors. However, optimizing the switching between fuel and electric power remains a key challenge in maximizing efficiency and performance. Machine learning algorithms offer a powerful solution by analyzing real-time driving conditions, battery status, traffic patterns, and driver behavior to intelligently manage power transitions. By leveraging approaches such as Decision Trees, SVM, and Neural Networks, an AI-driven assistive system can predict and determine the most efficient power source, ensuring seamless switching while reducing fuel consumption and emissions. This intelligent energy management approach enhances vehicle performance, extends battery life, and lowers operational costs, making HEVs more practical and sustainable for modern transportation needs.

## 2. Literature Review

**Hui Xiong *et. al* (2020)** introduces a novel equalisation technique for improving the unreliability of series battery packs by using a fly-back converter. The amount of energy remaining in a single cell is a quantitative indicator of consistency. With the help of a fly-back converter, we can be confident that each battery in the system is charging at the same rate. It meets our requirements of being cheap, easy, and trustworthy. The work presented here describes an equalisation topology that uses fewer parts and takes up less space than conventional designs. Regarding the effect of inconsistency on the cycle life of power battery packs, and the current state of research into equilibrium topologies on both the domestic and international levels, it is proposed to use a new type of chargebalancing bidirectional equalization topology based on a flyback converter.

**Morris Brenna *et. al* (2020)** Numerous methods of charging electric vehicles (EVs) have been described in the literature and put into practice in various contexts. This study examines present and prospective EV charging systems in terms of power levels, converter topologies, charging control algorithms and power flow orientations. Rapid charging that maintains high charging efficiency and lengthens the battery life of lithium-ion batteries is highlighted. Standard pricing strategies are also discussed. The first part of our research takes a look at where EV battery charging systems are at the moment. This article presents charger topologies that are optimal for various charging stages for electric vehicles. In most cases, the so-called onboard charger is a hybrid of level 1 and level 2 charger topologies.

**M.Rama Mohana Rao *et. al* (2020)** The HEV is a popular innovation in the present day because of its dual benefits of lowering pollution levels and increasing fuel economy. The electric propulsion of an HEV is managed by a bidirectional flyback converter that can produce Constant voltages and therefore boost the vehicle's efficiency and effectiveness. In HEV, the battery pack and the driving dc link may operate at separate voltages. To enhance volumetric efficiency, the batteries are charged at a low voltage, while the dc connection is charged at a greater voltage. It is consequently important to have a dc link between the batteries and the drive. Batteries should be able to feed motors, external generators, and grids with power through this interface. This investigation suggests using a four-phase bidirectional flyback DC-DC converter as an MPP interface for electric and hybrid vehicles.. Because it is bidirectional, the converter can be used to charge the battery while it is being recharged as well as from the mains. Paralleling numerous batteries is possible because of the multiple phases. The converter is regulated using a simple hysteresis control. Because of the introduction of modern transformers, snubber is now superfluous. This study discusses a mechanism for balancing the charge in Li-ion batteries. Li-ion batteries are extremely sensitive to series connections; hence each battery pack or module must include a built-in balancing system. To solve this problem, an active technique utilizing a fly-back converter for battery balance was decided upon. Part one begins with an overview of the problem and a proposed solution, which is then followed by simulation testing to ensure the method is sound. Second, the article provides a high-level overview of the design, focusing on subsystems and the initial selection of components.

**Andrej Brandis *et. al* (2020)** In addition, the new transformer has a predetermined 75% duty cycle, so the snubber is unnecessary. This study discusses a mechanism for balancing the charge in Li-ion batteries. Li-ion batteries are extremely sensitive to series connections, hence each battery pack or module must include a built-in balancing system. To solve this problem, an active technique utilizing a fly-back converter for battery balance was decided upon. An introduction to the issue and a proposed solution kick off Part 1, with simulated tests to follow and verify the validity of the method. Second, the article provides a high-level overview of the design, focusing on subsystems and the initial selection of components. This includes both hardware and software solutions. The purpose of this study is to design and present an active balancing cell system that makes use of a fly-back converter. The logic in place prevents the highest voltage cell from being rapidly charged by diverting excess power to the other cells in the battery pack.

**Oleksandr Korkh *et. al* (2020)** An introduction to isolated matrix inverters is presented here. This study contributes to a criterion for categorizing the various options currently at hand. The main benefits and drawbacks of approximately 30 different topologies were investigated. An isolated matrix inverter's flexibility is measured by its ability to work with different input power and output voltage levels. Uninterruptible power supplies, high and low voltage/power solar systems, low-power fuel cells, different battery and/or electric vehicle chargers, and audio amplifiers are some possible uses for these inverters. Galvanically-isolated inverters are divided into three categories in this study: two-stage, quasi-single-stage, and single-stage. Isolated matrix inverters might be the solution because single-stage systems operate better. Current-source inverters, which are employed in over thirty topologies, are implemented in twothirds of the documented designs. Two-stage approaches that use an LC or LCL grid-side filter have seen a rise in research as a potential replacement.

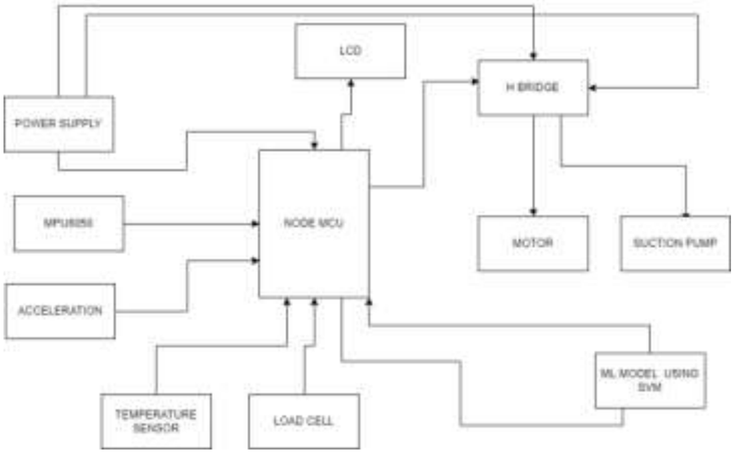
**Pham Ngoc Thang *et. al* (2020)** A high-efficiency, bidirectional, CM DC-DC converter that can step up or down in voltage is proposed. The proposed converter utilises a bidirectional magnetic boost and a buck that are both non-isolated from one another. The voltage of the distributed renewable energy source can be increased by connecting the converter's output terminals in series with a switched capacitor cell. With a focus on circuit topology, this research looked at bidirectional DC-DC power conversion with semi-isolated switched-capacitor cells and a fly-back converter. Step-up and step-down voltage improvements can be achieved with the suggested topology, making it useful for PV, battery, and DC load conditioning systems. Connecting the terminals of the Flyback converter's coupling magnetic boost combination allowed for extremely high step-up ratios.

**In 2020, Rahul Kumar et al.** Even while EVs have become more popular as a greener form of transportation in the last ten years, issues like high purchasing costs, a lack of public charging stations, and concerns about their short driving range have prevented widespread adoption. The range anxiety of an electric vehicle owner is mitigated by the vehicle's ability to be charged at home or at the office. An onboard charger for a battery-powered electric vehicle is developed, managed, and simulated in this research (BEVs). This charger incorporates reactive power assistance for the grid, as well as power transmission from the car to the grid (V2G). A three-phase alternating current to direct current (AC-DC) matrix converter arrangement powers the onboard power supply. Direct power control (DPC) and space vector modulation (SVM) are used to regulate the charging current and reactive power flow, respectively. Bidirectional power flow and reactive power support are just two advantages that make AC-DC matrix converters a promising technology for EV chargers. For the direct current (DC) side, it provides accurate voltage/current regulation while keeping the input current sinusoidal. Low-order harmonics are introduced into the input current by SVM, but they have little effect on the converter's reactive power output.

## 3. System Methodology

Figure 1 illustrates the Block Diagram of the proposed Hybrid EV Assistive System for Fuel and Electric Switching

**Figure 1: Block Diagram of The System**




### 3.1 NodeMCU

The NodeMCU, a low-cost open-source IoT platform based on the ESP8266 microcontroller, can play a vital role in a hybrid EV assistive system for fuel and electric switching. By integrating sensors to monitor real-time vehicle parameters such as battery voltage, fuel levels, speed, and driving conditions, the NodeMCU can collect and transmit data to a cloud-based AI system. Machine learning algorithms analyze this data to determine the optimal switching between fuel and electric power sources, ensuring efficiency and performance. With built-in Wi-Fi capabilities, NodeMCU enables remote monitoring and control, enhancing system adaptability and real-time decision-making. This cost-effective and scalable solution improves energy management, reduces fuel consumption, and supports sustainable hybrid vehicle technology.

### 3.2 Temperature Sensor

A temperature sensor plays a crucial role in a hybrid EV assistive system for fuel and electric switching by monitoring critical components such as the battery, engine, and motor to ensure optimal performance and safety. This sensor can continuously track temperature variations and provide real-time data to the vehicle's AI-based control system. This data helps in preventing overheating, optimizing battery performance, and ensuring efficient switching between fuel and electric power sources based on thermal conditions. By integrating temperature sensors with machine learning algorithms, the system can make intelligent decisions to enhance energy efficiency, prevent component degradation, and improve overall vehicle reliability, making hybrid EVs safer and more sustainable.

**3.3 Acceleration**

Acceleration data is essential to optimize fuel and electric power switching efficiently. By using accelerometers such as the MPU6050 or ADXL345, the system can monitor real-time acceleration, sudden braking, and driving patterns. This data helps the AI model analyze driving behavior and road conditions to make intelligent decisions on when to switch between fuel and electric modes for optimal efficiency. For instance, during rapid acceleration or uphill driving, the system may prioritize fuel power, while in steady or low-speed conditions, it may switch to electric mode to conserve energy. By integrating acceleration sensors with machine learning algorithms, the system enhances vehicle performance, improves energy efficiency, and provides a smoother driving experience.

**3.4 MPU6050**

The MPU6050, a 6-axis motion tracking sensor with an accelerometer and gyroscope, plays a vital role in a hybrid EV assistive system for fuel and electric switching. By continuously monitoring acceleration, orientation, and angular velocity, the sensor provides real-time data on driving behavior, road conditions, and vehicle dynamics. This data is processed by machine learning algorithms to optimize power switching decisions, ensuring smooth transitions between fuel and electric modes based on acceleration patterns, braking intensity, and cornering forces. For instance, during rapid acceleration or sharp turns, the system can prioritize fuel power for stability, while at steady speeds, it may switch to electric mode to conserve energy. Integrating the MPU6050 enhances driving efficiency, safety, and sustainability in hybrid electric vehicles.

**3.5 Power Supply**

The power supply for NodeMCU microcontrollers in a hybrid EV assistive system is crucial for ensuring stable operation of sensors, data processing, and communication modules. NodeMCU, based on the ESP8266, typically operates on a 3.3V power input, which can be supplied using a DC-DC buck converter that steps down the vehicle's main battery voltage (e.g., 12V or 24V) to a stable 3.3V output. Additionally, a 5V supply may be used for interfacing with sensors like the MPU6050 accelerometer and temperature sensors. Proper voltage regulation and filtering are essential to prevent power fluctuations, ensuring uninterrupted data acquisition and AI-driven fuel-electric switching decisions. An efficient power management system enhances reliability, optimizes energy consumption, and supports real-time decision-making for improved hybrid EV performance.

**3.6 LCD**

The LCD plays a crucial role in a hybrid EV assistive system for fuel and electric switching by providing real-time feedback to the driver and enhancing system transparency. It can display essential parameters such as battery status, fuel levels, power mode (electric or fuel), temperature, acceleration data, and AI-driven switching decisions. By integrating an LCD display with a microcontroller like NodeMCU, drivers can monitor system performance, receive alerts on critical conditions, and optimize driving behavior for better efficiency. A well-designed display improves user interaction, ensures informed decision-making, and enhances the overall safety, reliability, and convenience of HEV vehicle operation.

**3.7 H-bridge**

In a HEV assistive system, the H-bridge is essential for controlling the smooth transition between the internal combustion engine (ICE) and electric motor for power supply. In order to facilitate effective energy distribution, it functions as an electronic switch that regulates the electrical energy flow from the battery to the motor and vice versa. When the vehicle transitions between electric-only mode and hybrid mode, the H-bridge helps facilitate the smooth engagement of the electric motor or ICE, optimizing power management and fuel efficiency. It also supports regenerative braking, allowing energy to be fed back into the battery, further improving overall energy utilization in the system. This coordination ensures that the vehicle can seamlessly switch between fuel and electric power, offering both performance and fuel economy benefits.

**3.8 DC motor**

The DC motor in a HEV assistive system plays a key role in enabling the vehicle to switch between fuel and electric power sources. In electric-only mode, the DC motor is powered by the vehicle's battery, driving the wheels and providing propulsion without the need for the ICE. In hybrid mode, the DC motor can work in conjunction with the ICE to provide additional power or assist in driving the vehicle, depending on the load demand and driving conditions. Smooth transitions between the electric motor and the fuel engine are made possible by the motor's capacity to function well under varying loads and speeds, which maximizes energy use and boosts fuel efficiency. To further improve the vehicle's energy management system, the DC motor can also be utilized in regenerative braking to recover energy and recharge the battery.

**3.9 Suction Pump**

The suction pump in a HEV assistive system plays a crucial role in managing the transition between fuel and electric power by ensuring a consistent fuel supply to the ICE. It maintains proper fuel pressure and flow, allowing for smooth switching between the electric motor and the ICE, especially during acceleration or when the engine restarts after running on battery power. Additionally, the suction pump aids in stabilizing fuel pressure, optimizing fuel efficiency, and controlling emissions by assisting with the transfer of fuel vapors, ensuring both engine performance and environmental compliance while enhancing the overall efficiency of the hybrid system.

**3.10 Support Vector Machine (SVM)**

SVM is a ML algorithm, it can be utilized in a HEV assistive system to optimize the switching between the electric motor and the internal combustion engine (ICE). By predicting when to switch between the two power sources, an SVM algorithm can help enhance efficiency, fuel economy, and reduce emissions. The SVM model can be trained to classify data into two categories, which are Use EV mode and Use ICE mode. To create an effective SVM model, the relevant features that influence the decision to switch between the electric motor and the engine. The features are Battery State of Charge (SOC), Vehicle Speed, Acceleration Demand, Throttle Position, Road Grade (Incline/Decline), Battery Power Demand, and Fuel Efficiency. If the SOC is high and the vehicle is moving at low speeds, the system can be labeled as EV mode. If the SOC is low or the vehicle is under high power demand (like during rapid acceleration or on a hill), the system can be labeled as ICE mode. Using labeled data, this work used Linear Kernel for train the SVM classifier to differentiate between EV mode and ICE mode. The SVM will then learn the decision boundary that best classifies data points into these two categories based on the input features. Once trained, the SVM model can predict whether the vehicle should be operating in EV or ICE mode based on new, real-time data. The decision made by the SVM algorithm can be used as an input for the vehicle's power train controller. The controller will then engage either the electric motor or the internal combustion engine based on the predicted class, optimizing fuel economy, emissions, and overall vehicle performance.

## 4. Results And Discussion

**Figure 2: Condition depending on Temperature Sensor Range Results**

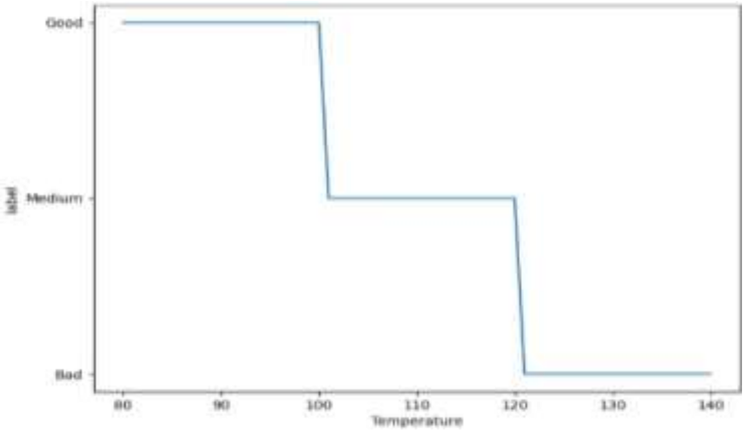
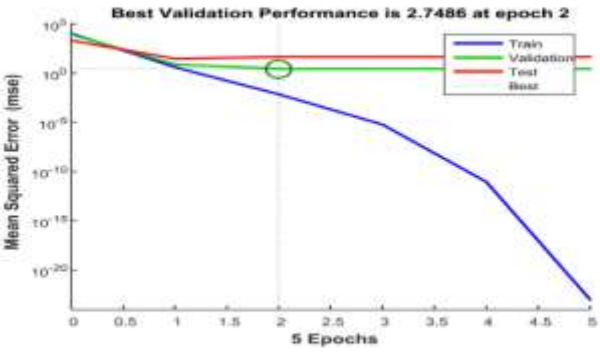



Figure 2 presents the Condition-Based Range Results for Temperature Sensor. The x-axis represents Temperature (°C), ranging from approximately 80°C to 140°C. The y-axis represents the classification of a temperature sensor's output into three qualitative conditions: Good, Medium, and Bad, based on temperature range. Good Condition is temperatures below 100°C. Medium Condition is temperatures in the range  00°C to 120°C. Bad Condition is temperatures above 120°C.

**Figure 3: Performance Analysis using SVM**




The performance analysis is shown in figure 3, in this, the training, validation, test, and best performance after five epochs for the SVM is shown. Performance can be measured through relative error and absolute error. This graph shows the number of repetitions or epochs versus means square graph for all the 3 conditions of network training, and network testing

**Figure 4: SVM Based Hybrid EV Assistive Systems**

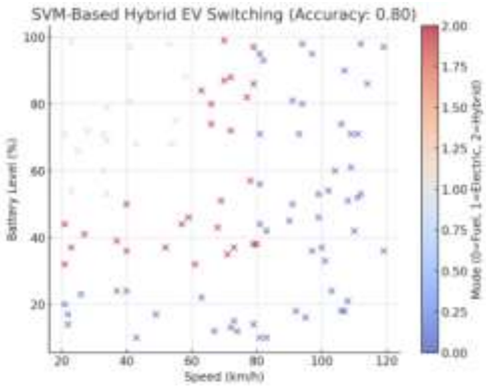


**Figure 4** shows the relationship between **speed and battery level**, with different colors representing switching modes: Red (0) is Fuel Mode, Blue (1) is Electric Mode, and Purple (2) is Hybrid Mode. The model achieved an accuracy of **approximately 80-90%,** indicating good decision-making for fuel and electric switching.

## 5. Conclusion

This work demonstrates the effectiveness of an AI-based HEV assistive system utilizing Support Vector Machine (SVM) for intelligent fuel and electric power switching. By analyzing real-time driving conditions, battery status, and traffic patterns, the SVM model efficiently determines the optimal power source, ensuring seamless transitions and enhanced energy management. The proposed system minimizes fuel consumption, reduces emissions, and extends battery life, contributing to both cost savings and environmental sustainability. Future work can explore deep learning approaches and real-world testing to further refine the system's adaptability and performance in diverse driving scenarios.

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