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Design Hybrid EV using Supercapacitor for Long Mileage and Durability

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Abstract: The "Hybrid Vehicle Supercapacitor" system is an advanced energy management solution designed to enhance the performance, efficiency, and sustainability of hybrid vehicles by integrating high-capacity supercapacitors with traditional battery systems. This project leverages the rapid charge–discharge characteristics, high power density, and long lifecycle of supercapacitors to optimize power distribution during acceleration, regenerative braking, and varying load conditions. Supported by sensors, an Arduino Nano microcontroller, and power electronics such as MOSFET drivers and voltage regulators, the system ensures precise control, real-time monitoring, and seamless coordination between energy sources. The inclusion of an LCD interface, buzzer, and interactive controls further enhances usability and operational transparency. By improving energy efficiency, boosting vehicle responsiveness, and reducing strain on batteries, the proposed system contributes to extended component lifespan, enhanced user satisfaction, and reduced environmental impact—advancing the goal of sustainable and intelligent hybrid vehicle technology.

I. INTRODUCTION

The "Hybrid Vehicle Supercapacitor" system represents a forward-looking approach to modern automotive energy management, designed to address the limitations of conventional hybrid vehicles by integrating the superior capabilities of supercapacitors with the reliability of traditional batteries. In contemporary hybrid vehicles, energy efficiency, rapid power demand, regenerative braking, and battery lifespan remain major challenges due to the inherent limitations of chemical energy storage systems. Supercapacitors, with their exceptionally high power density, fast charging and discharging properties, and long operational life, offer an ideal complementary solution to overcome these challenges. This project focuses on developing a hybrid power system in which a supercapacitor bank works alongside a battery, while an Arduino Nano microcontroller orchestrates intelligent power flow using sensors, MOSFET drivers, voltage regulators, and rectifier circuits. Through real-time measurement of voltage, current, and load variations using voltage and current sensors, the system ensures optimal energy distribution for acceleration bursts, regenerative braking recovery, and steady-state driving conditions. The inclusion of a user-friendly interface comprising an LCD display, buzzer, and control buttons enables continuous monitoring of system performance, energy levels, diagnostics, and operational status, thereby improving overall usability and reliability. By aiming to enhance vehicle performance, minimize energy wastage, extend battery life, and support sustainable, eco-friendly transportation, the Hybrid Vehicle Supercapacitor system stands as a technologically advanced and environmentally conscious innovation that bridges the gap between modern power electronics and future mobility requirements.

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II. METHODOLOGY

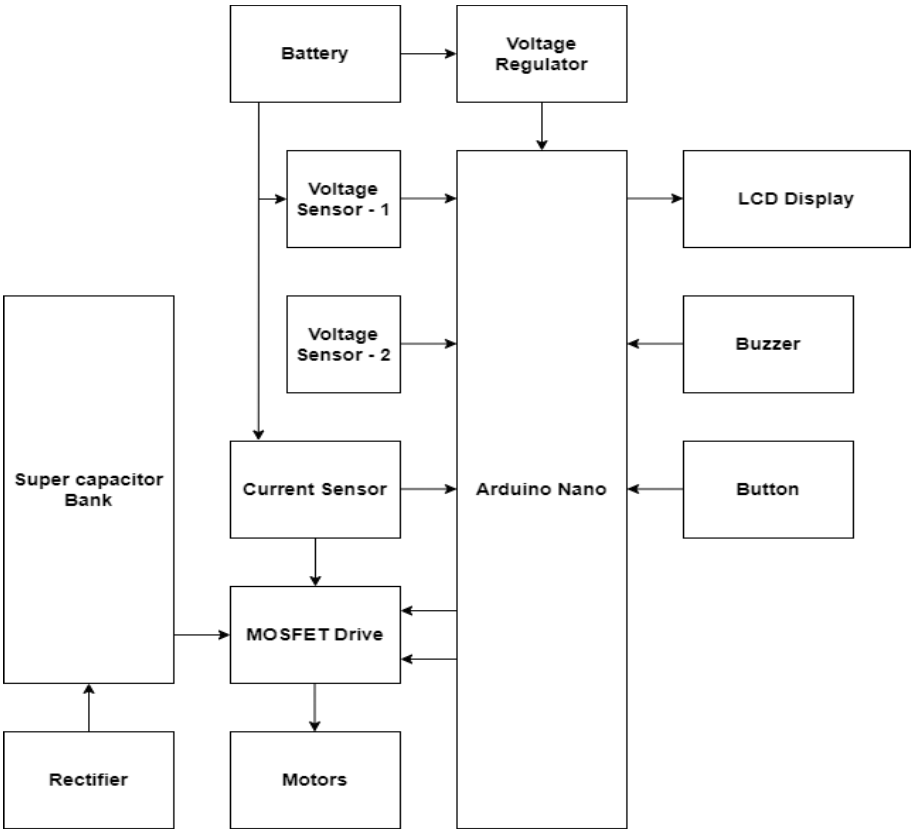

Fig: Block Diagram

The "Hybrid Vehicle Supercapacitor" system works by combining a battery with a supercapacitor bank to supply electrical energy more efficiently, especially during load peaks and regenerative braking. Below is the detailed, step-by-step working of the system:

Step 1: Power Initialization and Supply Distribution
The system starts by drawing initial power from the battery or an external generator. The power flows through a voltage regulator, which ensures that the voltage levels are within the safe operating range for each connected component. Once the appropriate voltage is achieved, the Arduino Nano, sensors, LCD, MOSFET driver, and other peripherals get powered up. This step sets the stage for real-time monitoring and control.

Step 2: Sensor Activation and Data Collection
As soon as the system powers up, voltage sensors and current sensors placed at both the battery and supercapacitor terminals begin to monitor electrical parameters. These sensors constantly measure values like:

- Battery voltage and current
- Supercapacitor voltage and charge state
- Load current
- Input from the generator (if present) This data is fed into the Arduino Nano, which is programmed to process and make decisions based on sensor readings.

Step 3: Intelligent Energy Source Selection
Once the sensor data is received, the Arduino Nano evaluates the system's current demand. Based on predefined logic:

- For low or steady loads (such as idling or cruising), battery power is supplied to the motor.
- For high loads (e.g., acceleration or climbing), the system automatically switches to or supplements power with the supercapacitor bank using MOSFET-based switching.

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The switching happens seamlessly via MOSFET drivers that act as fast, solid-state relays controlled by the Arduino Nano.

Step 4: Load Supply to Motor and Components
Power from either the battery or the supercapacitor (or both during high-demand phases) is supplied to:

- DC motors driving the vehicle
- Auxiliary components (e.g., sensors, LCD, buzzer)

This efficient load-sharing approach helps to reduce the stress on batteries and improves the overall energy efficiency of the system. Supercapacitors handle short bursts of high power, while batteries manage long-term energy needs
.

Step 5: Regenerative Braking and Energy Recovery
When the vehicle decelerates or applies brakes, kinetic energy is converted back into electrical energy via regenerative braking. This recovered energy is not wasted but is instead:

- Captured by the motor acting as a generator
- Sent through rectifiers
- Stored in the supercapacitor bank, due to its fast charging ability and high cycle life

This recovered energy is then available for the next acceleration or power spike, improving overall system efficiency and reducing reliance on battery power
.

Step 6: Real-Time Display and Alerts Throughout the operation:

- The LCD display shows live data such as:
  - Battery voltage
  - Supercapacitor voltage
  - Load current
  - Energy flow direction
- If the system detects an abnormality (e.g., overcurrent, voltage drop, overheating), the buzzer provides an audible alert.
- A manual push-button can be used to reset the system or to perform a soft start after shutdown or fault detection.

This step ensures the user is always informed and can take necessary action if needed.

Step 7: System Health Monitoring and Protection The Arduino continuously monitors:

- Temperature (if integrated)
- Load balancing between supercapacitor and battery
- Any anomalies or power surges

In case of any dangerous condition (overvoltage, deep discharge, short circuit), the system:

- Cuts off the power supply to sensitive components
- Activates an alert
- Stores the incident in memory (if EEPROM or logging system is present) This protective mechanism ensures system longevity and safety.

Step 8: Efficient Power Distribution and Load Management Based on usage patterns, the system manages when to:

- Recharge the supercapacitor bank (from the generator or braking)
- Discharge it to handle peak loads
- Preserve battery health by avoiding deep discharges or overuse

This hybrid management logic makes the vehicle more efficient, reducing energy loss, heat generation, and component fatigue.

Step 9: System Shutdown and Safe Mode Entry When the vehicle is turned off or parked:

- The Arduino sends a signal to safely disconnect the battery and supercapacitor from the load using the MOSFETs.
- Supercapacitor energy is either drained safely or maintained at a safe level.
- A soft shutdown sequence is followed to preserve data and ensure no live current remains on high-power lines.

This ensures long-term stability, safety, and readiness for the next usage cycle.
The working of the “Hybrid Vehicle Supercapacitor” system revolves around the intelligent management of energy sources, real-time monitoring, and fast response to load conditions. The integration of batteries with supercapacitors offers

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the dual benefits of energy density and power density, ensuring higher efficiency, reduced wear on batteries, and more sustainable operation of hybrid vehicles.

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