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Embedded Based Power Flow Control of Regenerative Braking Energy in Electric Rail

Dr.R.Rajagopal[1], Sakthi Rajesh.J[2], Arumuga Nainar.G[3], Muthu Raj.V[4], Philiph.J[5]

Associate Professor, Department of EEE, Francis Xavier Engineering College, Tirunelveli, India[1]

Student, Department of EEE, Francis Xavier Engineering College, Tirunelveli, India[2]

Student, Department of EEE, Francis Xavier Engineering College, Tirunelveli, India[3]

Student, Department of EEE, Francis Xavier Engineering College, Tirunelveli, India[4]

Student, Department of EEE, Francis Xavier Engineering College, Tirunelveli, India[5]

ABSTRACT: This study investigates the application of embedded controllers to optimize power flow during regenerative braking in electric rail systems. These embedded systems capture the kinetic energy converted into electricity during braking and manage its conversion and redirection back into the power grid. This approach not only reduces overall energy consumption but also enhances the efficiency of the railway network. Furthermore, by reusing regenerative energy, the system contributes to a cleaner environment by minimizing the reliance on traditional power sources.

KEYWORDS: Regenerative braking energy, energy efficiency, electrified railways, power flow control

I. INTRODUCTION

Electric railways are becoming increasingly eco-friendly due to regenerative braking, which captures energy during deceleration. However, effectively reusing this energy requires intelligent power flow control strategies. This paper delves into embedded-based control systems specifically designed for managing regenerative braking energy. By seamlessly integrating these embedded systems with railway power converters, we aim to achieve a multi-pronged approach. Optimizing energy recapture during braking is a primary goal, but this solution will also improve the stability of the railway's power supply and contribute to a significant enhancement in the overall efficiency of the electric rail system.

1.1 PROBLEM STATEMENT

- Integrating DC braking energy into the AC grid.
- Managing fluctuations in power fed back during braking events.
- Limited storage capacity for excess regenerated power.
- Traditional control systems' bulkiness for space-constrained rail vehicles.

1.2 OBJECTIVE

- Slash the energy bill for electric railways.
- Boost overall efficiency - less energy wasted, more for everyone!
- Help the environment by reducing the reliance on new energy generation.
- The reintegration of regenerative energy can help stabilize the power grid, reducing strain on traditional energy sources.
- Improved System Performance to The embedded control system can optimize power flow, potentially leading to improved system performance and reduced operational costs.

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1.3 SCOPE AND STUDY

The scope of the project involves will investigate the application of embedded-based power flow control systems to manage regenerative braking energy (RBE) in electric rail networks. The focus will be on utilizing embedded controllers to optimize the flow of RBE back into the power grid or for internal railway use. Analyze the potential of RBE for improving energy efficiency in electric rail systems. Evaluate different embedded-based power flow control strategies for RBE management. Design and simulate an embedded controller system for real-time power flow control of RBE. Investigate the integration of energy storage devices (e.g., batteries, supercapacitors) with the embedded control system for enhanced RBE utilization. Analyze the economic and environmental benefits of implementing embedded-based power flow control for RBE. Identify technical challenges and limitations associated with the proposed system.

II. COMPONENTS

2.1 COMPONENTS AND SPECIFICATIONS:

- Step-down Transformer
- AC/DC Converter
- Inverter
- Motor
- DC Generator
- Optocoupler
- Microcontroller (PIC 16F877A)
- Battery

2.1.1 STEP-DOWN TRANSFORMER

Reduces the high voltage from the overhead catenary wires to a lower voltage suitable for distribution within the train or railway system. Transformer has 240 V primary winding and center tapped secondary winding. The transformer has flying colored insulated connecting leads (Approx 100 mm long). The Transformer act as step down transformer reducing AC – 240V to AC – 12V

2.1.2 AC/DC Converter

Converts the AC voltage from the step-down transformer into DC voltage, which is utilized by various onboard systems. AC/DC converters are electrical circuits that transform alternating current (AC) input into direct current (DC) output. AC/DC Converters are also called “rectifiers”; they convert the input AC voltage to variable DC voltage, then optimize it through a filter to obtain an unregulated DC voltage.

2.1.3 INVERTER

Converts the DC voltage from the AC/DC converter into AC voltage for powering traction motors during acceleration or propulsion. It is the most important circuit in the “Pv-system”, because it’s the major process, converts Dc-voltage to Ac-voltage and the most industrial load and house loads are operating under Ac-voltage. This type converts the low voltage DC into a low voltage AC first and then converts the low-voltage AC into the wanted AC voltage. The advantages are the low-voltage (=safe) operation, the insulation from the grid after the inverter, the ease with which it makes sine-wave which feeds into the transformer and the most important in many aspects: reliability due to the low number of semiconductors in the power path. Disadvantage is the slightly lower efficiency of the inverter, typically 92%. Also some hum can be generated by the transformer under load.

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2.1.4 MOTOR

The DC motor is the motor which converts the direct current into the mechanical work. It works on the principle of Lorentz Law, which states that "the current carrying conductor placed in a magnetic and electric field experience a force". And that force is the Lorentz force DC motor is powered, a magnetic field is created in its stator. The field attracts and repels magnets on the rotor; this causes the rotor to rotate. To keep the rotor continually rotating, the commutator that is attached to brushes connected to the power source supply current to the motors wire windings.

- Operating Voltage(V): 12
- Rated Speed (RPM): 200
- Rated Torque(kg-cm): 1.5
- Stall Torque(kg-cm): 5.4
- Load Current (A): 0.3
- No Load Current (A): 0.06

2.1.5 DC GENERATOR

When the train decelerates or brakes, the regenerative braking system activates the DC generator, which converts kinetic energy into electrical energy. It depends on how much current coil of rotor can carry. If the gauge of coil is more then it can carry more current. 12v DC motor with maximum 1.5A capacity can generate 18W of power. 12v DC motor with maximum 3A capacity can generate 36W of power.

DC generator works by rotating a coil of wire, called an armature, between the poles of a permanent magnet. As the armature rotates, it cuts through the magnetic field, which induces a current in the wire. This current is then collected by brushes and sent out as DC electricity

- Operating Voltage: 6V-12V DC.
- No Load Current: 0.28A.
- Rated Current: ≤0.5A.
- Rated Power: 28W.
- Rated Speed: 10000RPM.
- Shaft Length: 5mm.
- Shaft Diameter: 2mm.
- Motor Total Length: 42mm.

2.1.6 OPTOCOUPLER

Provides isolation between the microcontroller and the regenerative braking system, enhancing safety and reliability. Optocoupler types are determined by the type of detector used, as described below. Certain types have different characteristics and are therefore better suited to specific applications. Optocouplers are often referred to by their "output type"; for example, a phototransistor device might be called an optocoupler "with phototransistor output."

Optocoupler has a one-way transmission, and the input and output to achieve electrical isolation, so that the output signal has no effect on the input, so it is widely used in a variety of isolation circuits, for power electronics, in the AC load application is more, through the composition of a strong anti-interference ability isolation circuit together with the thyristor, as follows, note that to increase the current limiting resistor, in addition to the output load to increase the RC absorption circuit or parallel a varistor, which helps to protect the load.

2.1.7 MICROCONTROLLER (PIC 16F877A)

Controls the operation of the regenerative braking system. The PIC 1677A manages the activation of the DC generator, monitors system parameters, and implements control algorithms to optimize energy utilization. The

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PIC16F877A features 256 bytes of EEPROM data memory, self programming, an ICD, 2 comparators, 8 channels of 10-bit Analogue-to-digital (A/D) converter, 2 capture/compare/PWM functions, the synchronous serial port can be configured as either 3-wire Serial Peripheral Interface (SPI™) or the 2-wire Inter-Integrated Circuit (I²C™) bus and a Universal Asynchronous Receiver Transmitter (USART). The data EEPROM and flash program memory is readable and writable during normal operation (over the full VDD range)

- High-performance RISC CPU
- Analogue comparator module with programmable on-chip voltage reference (VREF) module
- Single-supply 5V In-Circuit Serial Programming
- Watchdog timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code protection
- Power saving sleep mode
- In-Circuit Debug (ICD) via two pins
- Low-power consumption

2.1.8 BATTERY

Stores the electrical energy generated during regenerative braking for later use. The battery can be charged during braking and discharged during acceleration or when additional power is required. There are many different types of 12v batteries, including lead-acid, flooded lead-acid, sealed maintenance-free (SMF) lead-acid, gel cell, absorbed glass mat (AGM), and lithium-ion. Each type of battery has its own advantages and disadvantages.

- Voltage Per Unit: 12 V
- Nominal Capacity: 150Ah at a 10-hour rate to EOD of 1.8V per cell at 25°C
- Maximum Discharge Current: 1500A (5 sec)
- Recommended Max Charging Current: 45A
- End of discharge voltage: Varies from 10.5V to 10.8V

III.DESIGN OF A FIRE FIGHTING DRONE

3.1 WORKING

Regenerative Braking and DC Power Generation During braking, the electric motors on the train leitourgoun as generators, converting the train's kinetic energy into DC electrical energy. This DC power is fed into the system through a DC generator. Power Conversion and Control An AC/DC converter transforms the incoming DC electricity from the generator into AC electricity. An inverter then regulates the AC voltage to ensure it meets the grid's requirements. This conversion process allows for the seamless integration of the regenerated power into the AC power grid. Embedded Microcontroller for Intelligent Power Flow Management An embedded microcontroller unit (MCU) serves as the intelligent core of the system. It gathers data about the train's operating condition, including speed, acceleration, and braking events, via an optocoupler. This real-time information enables the MCU to optimize the power flow process effectively. By strategically controlling the converter and inverter, the MCU regulates the conversion and ensures the efficient reintegration of the regenerative braking energy back into the power grid. In essence, this embedded-based power flow control system plays a critical role in maximizing energy efficiency within the electric rail network by capturing, converting, and intelligently reusing the braking energy.

3.2 APPLICATION

- It is used in self regulating power supplies
- It has consumer electronics

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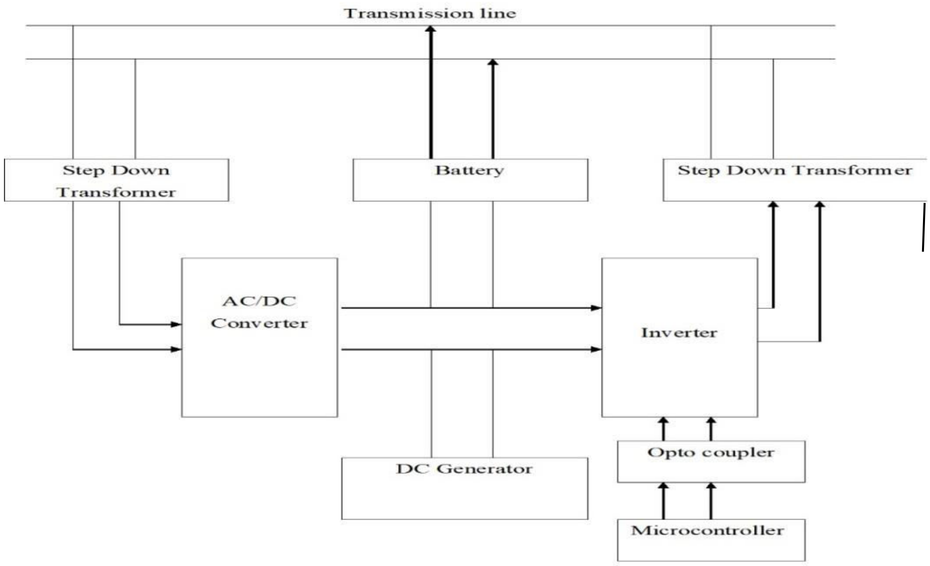
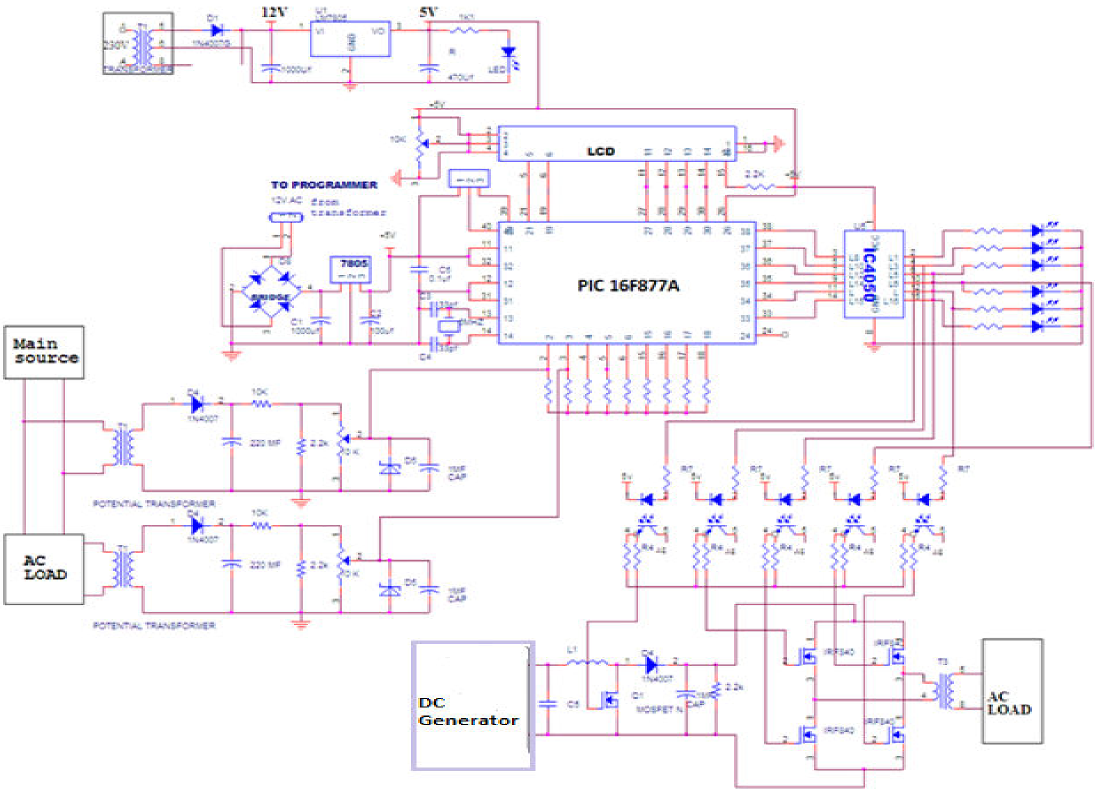
- It is used in Battery power system
- Power amplifier application

3.3 BLOCK DIAGRAM



3.4 CIRCUIT DIAGRAM



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3.5 ADVANTAGES

- This work is based on embedded platform; hence the power management is fully automatic here.
- The changes can be accurately found out by the embedded system and hence the system can achieve high degree of accuracy.
- Higher output voltage and Low operating duty cycle.

IV. RESULT AND DISCUSSION

The embedded control system, comprised of the microcontroller, optocoupler, inverter, and associated components, could manage the captured RBE in several ways Direct Feed-In The inverter converts the DC braking energy captured from the DC generator (motor acting as a generator during braking) into AC current that can be directly fed back into the AC power grid via the transformer. Battery Storage. The DC braking energy can be stored in a battery for later use by the train or fed back into the mainline grid during off-peak hours when electricity demand is lower. Power Grid Support The system could inject reactive power into the grid to improve voltage regulation and stability. Real-Time Control The embedded microcontroller can rapidly respond to changes in braking energy generation and grid conditions, optimizing power flow in real-time. This enables for a more dynamic and efficient response to varying system demands. Scalability The system can be adapted for use on various scales of electric rail networks, from single train deployments to large multi-line systems. This scalability makes the technology applicable to a wide range of electric railway applications. Efficiency Embedded systems are designed for efficient operation with low power consumption. This translates to lower overall system operating costs.

V. CONCLUSION

This paper proposes an embedded-based power flow control system for managing regenerative braking energy (RBE) in electric rail networks. The system utilizes an embedded controller, inverter, and DC-DC converter to capture the DC energy generated during braking, convert it to AC, and feed it back into the grid or store it for later use. The simulation results demonstrate the effectiveness of the proposed system in optimizing RBE utilization. The embedded controller efficiently regulates the power flow between the traction network, RBE generator, and the grid/storage system. This reduces energy consumption, improves overall system efficiency, and minimizes environmental impact. Further research can explore more advanced control algorithms to optimize RBE management under various operating conditions. Additionally, integrating energy storage devices with the system can further enhance RBE utilization and grid stability.

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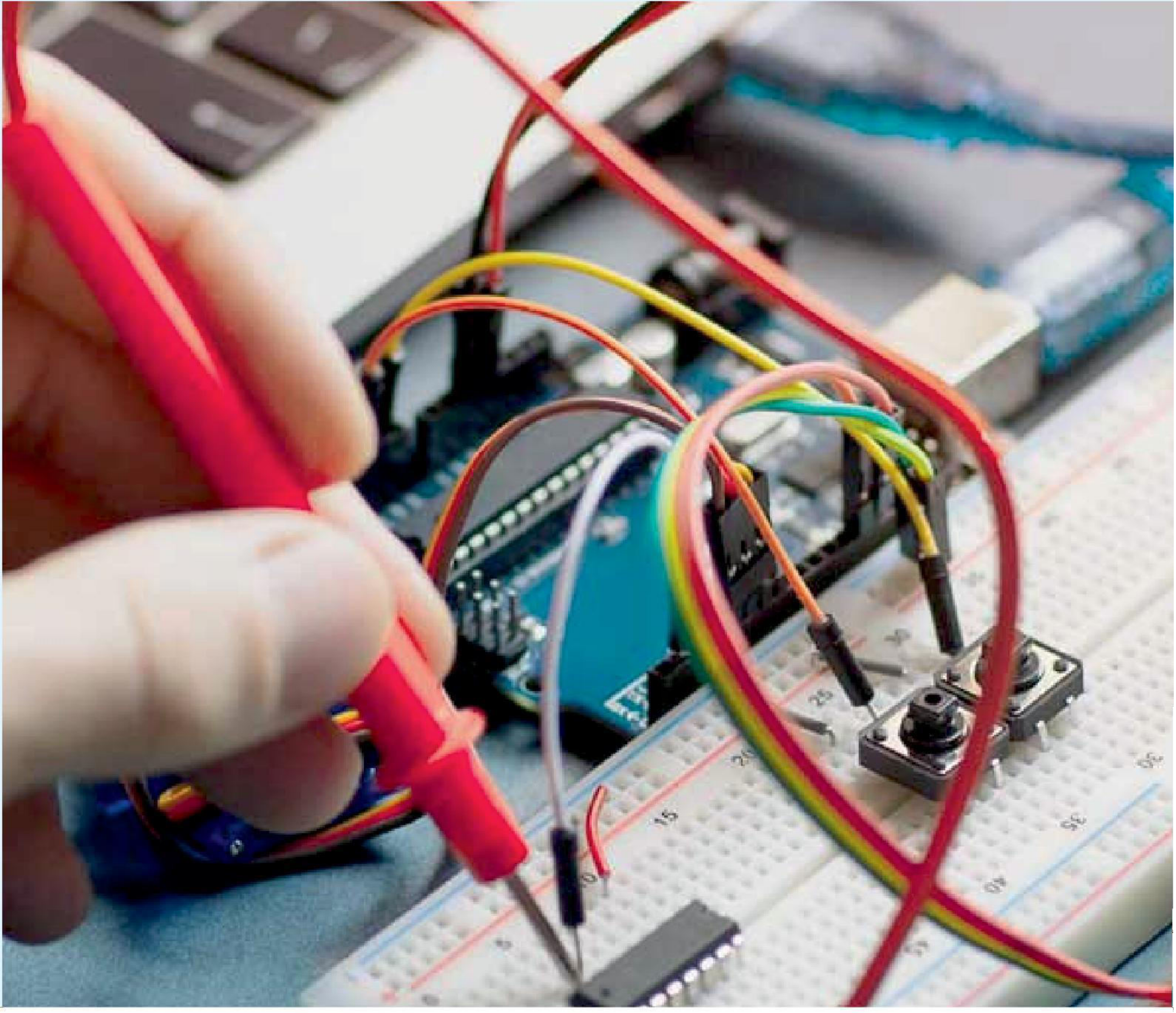

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