

MOVABLE ELECTRIC DESCALING UNIT FOR WATER PIPELINES

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Abstract: — Scale deposits in industrial water pipelines reduce flow efficiency, degrade heat transfer performance, and shorten pipeline service life. This paper presents a Movable Electric Descaling Unit (MEDU) that uses electromagnetic pulse technology to treat scale on the internal walls of industrial pipelines without any service interruption. A triangular chassis fitted with three rubber-wheeled geared DC motors propels the unit along the outer surface of the pipe. A copper coil wound around the pipeline generates pulsed electromagnetic fields that induce mechanical stress at the scale-wall interface, causing scale to fracture and detach. An ESP32 microcontroller manages the drive relay, coil relay, and distance tracking using a KY-040 rotary encoder. Distance data is displayed on a 16x2 LCD and transmitted wirelessly to the Blynk IoT Movable application, which also allows the operator to remotely control forward/backward movement and coil switching. The system is powered by two series-connected 6V, 4.5Ah batteries, making it fully portable and deployable without any mains supply.

Index Terms – Movable Electric Descaling Unit , Electromagnetic Pulse, Pipeline Maintenance

I. INTRODUCTION:

Scale buildup is one of the most widespread maintenance problems in industrial water pipelines. Hard water carries dissolved calcium and magnesium salts that slowly precipitate on pipe inner walls, narrowing the bore, restricting flow, and reducing heat transfer efficiency in heat exchangers and cooling circuits. Left untreated, scale growth steadily raises pumping energy requirements and eventually causes blockages that force unplanned shutdowns. For industries running continuous processes like refineries, food plants, power stations, and cooling towers, even brief downtime carries significant financial cost.

Conventional remedies include acid washing, mechanical rodding, and high-pressure water jetting. Chemical descaling generates hazardous effluents that require disposal, mechanical methods carry risk of damaging internal pipe linings, and all three techniques typically require the pipeline to be taken offline during treatment. There is a growing demand for solutions that work without stopping the process.

Electromagnetic treatment offers a non-contact, chemical-free alternative that operates entirely from outside the pipe. A time-varying electromagnetic field applied to the pipe wall alters the crystallisation behaviour of calcium carbonate promoting softer, more loosely bonded deposits and induces repetitive mechanical stress in existing scale layers sufficient to fracture and dislodge them. The present work develops this principle into a self-propelled Movable device. Mounted on a triangular chassis with three rubber-wheeled geared motors, the unit grips and traverses the pipeline outer surface while applying continuous electromagnetic pulses through a wound copper coil. An ESP32 microcontroller, relay modules, and a Blynk IoT Movable Einterface allow the operator to monitor the treated distance and control all functions remotely from a smartphone.

II. LITERATURE SURVEY

- [1] **Liang et al. (2020)** — Conducted a critical review of electromagnetic field applications for scale control in water systems, covering mechanisms, characterisation techniques, and operational parameters. The study found pulsed EM fields effective in both preventing new scale formation and loosening established deposits without chemical treatment.
- [2] **Gabrielli et al. (2001)** — Experimentally demonstrated that voltages and currents are induced when conductive solutions flow through a magnetic treatment device, establishing an electrokinetic basis for physical water treatment and confirming measurable reductions in calcium carbonate scale deposition on pipe surfaces.
- [3] **Fathi et al. (2006)** — Investigated the effect of magnetic fields on homogeneous and heterogeneous precipitation of calcium carbonate. Results confirmed that magnetically treated water produces softer aragonite crystals in suspension rather than hard calcite wall coatings, supporting the use of external EM devices as a practical scale control strategy.
- [4] **Piyadasa et al. (2017)** — Compared electromagnetic fields from two commercially available water treatment devices and found both caused measurable changes in calcium carbonate precipitation behaviour, including crystal size reduction and decreased scale adhesion in controlled pipe flow experiments.
- [5] **Xu et al. (2014)** — Tested the scale-inhibition effect of an electromagnetic field on circulating cooling water in a power plant environment. XRD and SEM analysis showed an increase in aragonite content and scale inhibition rates reaching 78.2% under optimised EM conditions.
- [6] **Gupta et al. (2025)** — Presented a comprehensive analysis of the ESP32 microcontroller for IoT applications, detailing its dual-core architecture, built-in Wi-Fi, interrupt-capable GPIO, and low-cost suitability for real-time embedded control, establishing it as a preferred platform for smart field devices.
- [7] **Krishna et al. (2025)** — Demonstrated a system for controlling and monitoring multiple motors using ESP32 and IoT, confirming that relay-based control and Wi-Fi cloud transmission via Blynk are reliable techniques for remote motor management in embedded systems.
- [8] **Baker & Judd (1996)** — Reviewed published evidence for magnetic amelioration of scale formation in water systems and concluded that physical EM treatment can reduce scaling in controlled conditions, with performance dependent on field strength, water hardness, and flow rate.

A. OVERVIEW:

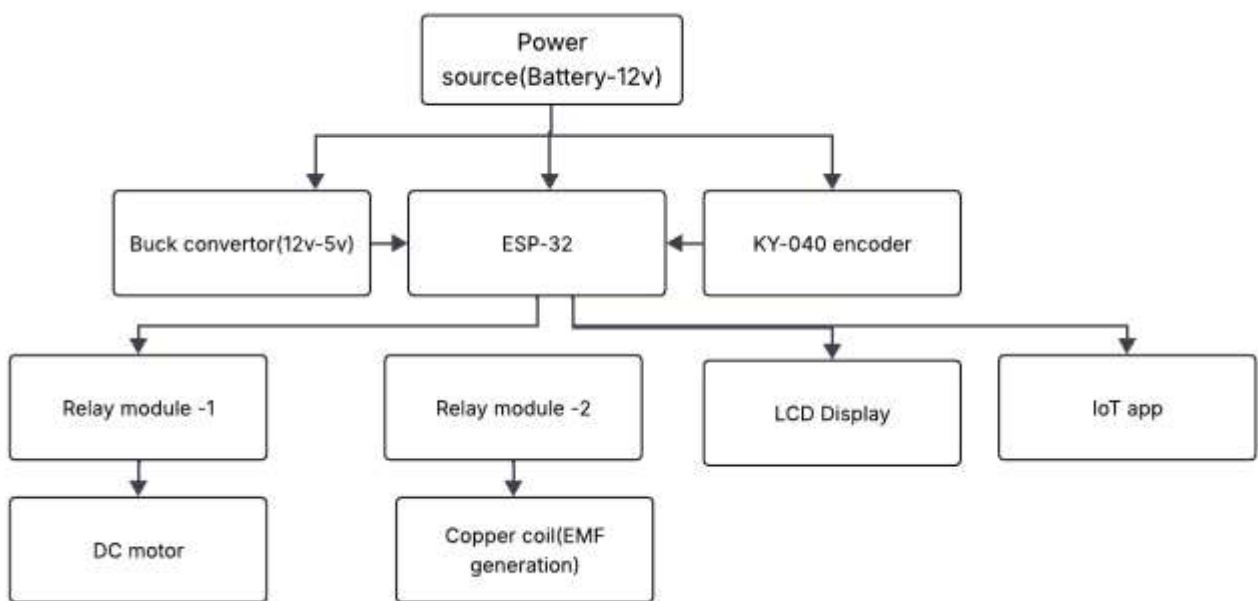
The Movable Electric Descaling Unit is a portable, externally mounted device that travels along the outer surface of an industrial pipeline while applying electromagnetic pulses through a copper coil wound around the pipe. The ESP32 at the core handles relay switching for both the drive motors and the electromagnetic coil, computes real-time distance from KY-040 encoder pulses, drives the 16x2 LCD, and maintains a live Wi-Fi connection to the Blynk cloud. This gives the operator a real-time

distance readout and full remote control forward drive, reverse, and coil on/off from a smartphone, without requiring physical access to the unit during operation.

III. OBJECTIVE

1. To develop a self-propelled Movable unit capable of traversing industrial pipelines and applying electromagnetic pulses for scale removal without pipeline shutdown.
2. To integrate real-time remote monitoring and wireless control through the Blynk IoT Movable application via the ESP32 built-in Wi-Fi interface.

IV. BLOCK DIAGRAM



Fig(4.1): Block Diagram

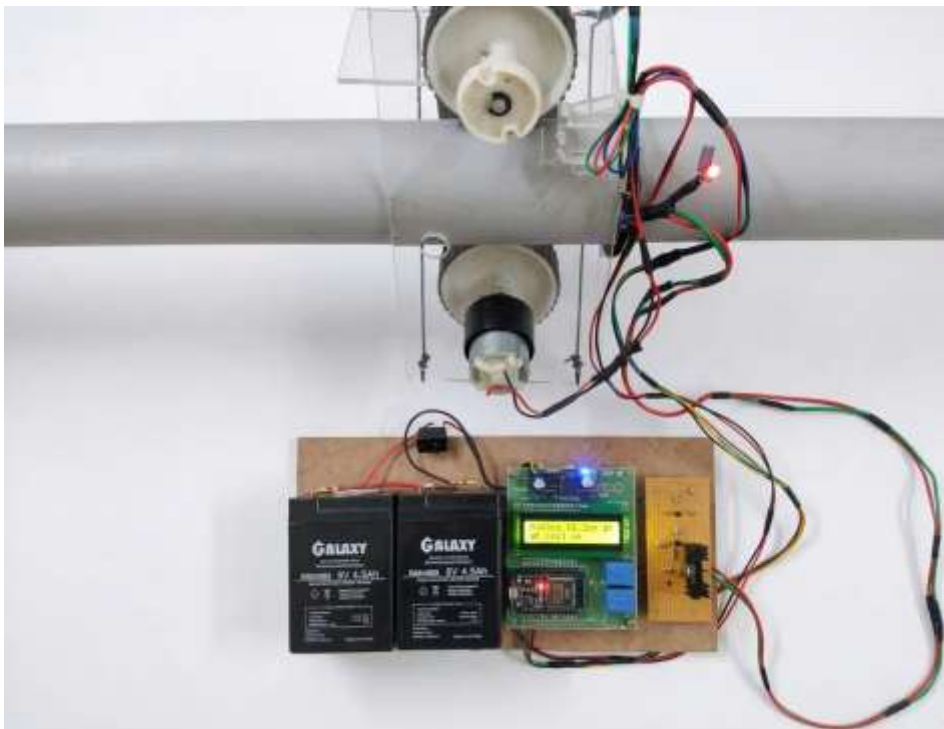
On power-up, the ESP32 initialises all peripherals and connects to the Blynk cloud over Wi-Fi. The operator issues a forward drive command from the Blynk app; Relay 1 activates and runs the geared motors, propelling the unit along the pipe surface. Relay 2 is switched on separately, energising the copper coil to generate electromagnetic pulses around the pipe. As the unit moves, the KY-040 encoder tracks wheel rotations; the ESP32 computes the traversed distance and updates both the LCD and the Blynk dashboard in real time.

WORKING PRINCIPLE

1. **Initialization:** ESP32 powers on and initialises the 16x2 LCD, encoder interrupt service routine, relay output pins, and establishes the Blynk Wi-Fi connection.
2. **Unit Placement:** The triangular chassis is mounted on the pipeline with all three rubber-wheeled motors gripping the outer pipe surface firmly.

3. **Remote Drive Command:** Operator presses Forward on the Blynk app, ESP32 activates Relay 1 to run the drive motors in the forward direction.
4. **Coil Activation:** Operator toggles the Coil button in the Blynk app, ESP32 activates Relay 2, energising the copper coil wound around the pipe.
5. **Electromagnetic Descaling:** The energised coil generates a pulsed EM field that penetrates the pipe wall, inducing mechanical stress at the scale-wall interface and causing scale to fracture and detach.
6. **Distance Tracking:** The KY-040 encoder generates pulses as the wheel turns. The ESP32 computes: $\text{Distance} = (\text{Pulse Count} \div 20) \times \text{Wheel Circumference}$.
7. **Real-Time Display:** Computed distance is updated on the 16x2 LCD and V0 on the Blynk dashboard at regular intervals.
8. **Return Traversal:** Operator presses Backward on the Blynk app to reverse motor direction for the return run.
9. **Shutdown:** Operator switches off the coil and stops the motors; total treated distance is stored on the Blynk dashboard as a maintenance record.

V. CIRCUIT DIAGRAM:



Fig(5.1): Circuit Diagram

The circuit of the Movable Electric Descaling Unit connects the power supply, control electronics, and actuators through relay-switched paths managed by the ESP32. The purpose of the circuit is to allow safe high-current switching of the motors and coil from ESP32 logic-level outputs while also integrating encoder feedback, LCD display, and Wi-Fi cloud communication from a shared portable power source.

1. **Power Supply:** Two 6V, 4.5Ah batteries are connected in series to provide a 12V DC bus to the motors and coil.

2. **Voltage Regulation:** A DC-DC buck converter steps the 12V bus down to a regulated 5V output, powering the ESP32 microcontroller and 16x2 LCD module.
3. **Relay 1 — Drive Motors:** A 10A 30V DC relay switches the 12V motor circuit under ESP32 GPIO control, responding to Forward and Backward commands from the Blynk app.
4. **Relay 2 — Electromagnetic Coil:** A second 10A 30V DC relay switches the 12V copper coil circuit via an ESP32 GPIO output, controlled by Virtual Pin from the Blynk app.
5. **Drive Motor:** 12V geared DC motor is wired to the Relay 1 output, mounted at a vertex of the triangular chassis to drive the rubber wheels along the pipe surface.
6. **KY-040 Rotary Encoder:** CLK and DT signal pins connect to ESP32 interrupt-capable GPIO pins. VCC is connected to the ESP32 3.3V rail. Counts wheel rotations for distance computation.
7. **16x2 LCD Display:** Connected to the ESP32 via I2C (SDA and SCL) through an onboard I2C adapter module. Displays the real-time distance traversed by the unit.
8. **ESP32 Wi-Fi:** The built-in Wi-Fi module connects to the Blynk cloud server using an authentication token, transmitting distance data and receiving remote control commands from the MOVABLE app.
9. **Output:** The circuit integrates ESP32, Voltage regulator, Relay modules, Rotary encoder and Drive motor to give the suitable output in the LCD Display and the Blynk Movable application.

APPLICATIONS

1. Removal of mineral scale deposits from industrial cooling water, boiler feed, and process water pipelines.
2. Maintenance of heat exchanger circuits where scale buildup reduces thermal efficiency and increases energy consumption.
3. Treatment of pipeline sections in confined or hazardous environments using remote Blynk app control, avoiding the need for physical operator access.
4. Use in food processing and pharmaceutical manufacturing plants where chemical descaling agents are not permitted.
5. Agricultural irrigation pipelines to prevent mineral clogging and maintain uniform water distribution.
6. Supports scheduled pipeline maintenance programmes with automated distance logging through the Blynk IoT dashboard.
7. Adaptable for different pipe diameters by repositioning the motor mounts on the adjustable triangular chassis frame.

TABLE I: COMPREHENSIVE REVIEW ON MEDU

FEATURE	DESCRIPTION
Name	Mobile Electric Descaling Unit
Target Application	Industrial water pipelines
Descaling Method	Electromagnetic pulse via copper coil

Chassis	Triangular frame, self-propelled, 3 geared DC motors
Controller	ESP32 Microcontroller
Distance Sensing	KY-040 Rotary Encoder (mounted on drive wheel)
User Interface	16x2 LCD + Blynk IoT mobile application
Remote Control	Forward, Backward, Coil On/Off via Wi-Fi (Blynk)
Power Supply	2 × 6V 4.5Ah batteries connected in series (12V portable)
Chemical Usage	None non-invasive and chemical-free

VII. CONCLUSIONS AND FUTURE SCOPE

The Electric Descaling Unit shows that electromagnetic pulse technology can be packaged into a compact, portable, and remotely operable maintenance device suited to industrial pipeline environments. The triangular self-propelled chassis provides stable traversal along pipe surfaces, the ESP32 handles all control and communication tasks from a single platform, and the Blynk IoT integration gives the operator real-time distance monitoring and wireless control from a smartphone without needing to be physically present at the unit. The system requires no pipeline shutdown, uses no chemicals, and records a distance log of treated pipeline through the Blynk dashboard.

Future work will focus on optimising the copper coil geometry and pulse frequency for specific pipe materials and scale compositions, adding a battery level indicator to the Blynk dashboard, integrating a small camera module for simultaneous visual pipe inspection during traversal, and refining the chassis design to handle a wider range of pipe diameters reliably. Incorporating automated traversal scheduling through the Blynk automation feature is also planned as part of the next development phase.

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