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Development of an Ai Driven Sustainable Livestock Protection System Against Insects to Improve Cattle Health for The Benefit of Cattle Growers

K. MOHANRAJ[1], K. MANOJ KUMAR[2], K. MONISH[3], G. NICKSON[4]

[1]*Assistant Professor, Department of Electrical and Electronics Engineering, Kongunadu College of Engineering and Technology (Autonomous), Thottiam, Tiruchirappalli, Tamilnadu, India.*

[2, 3, 4]*UG Scholar, Department of Electrical and Electronics Engineering, Kongunadu College of Engineering and Technology (Autonomous), Thottiam, Tiruchirappalli, Tamilnadu, India.*

Abstract- An AI-enabled insect control system for livestock protection is developed using Zero Voltage Switching (ZVS) based induction heating technology. The system operates on a 12 V DC supply where a ZVS circuit generates high- frequency AC to drive an induction coil for rapid, flameless heating. The induced heat is used to vaporize a natural-source mosquito repellent liquid without direct combustion or chemical spraying. An STM32 NUCLEO-L412KB microcontroller with an LDR sensor controls system activation through a relay for safe and energy-efficient operation. A 12 V DC air pump distributes the generated repellent vapor inside the cattle shed. The proposed system provides a safer and sustainable solution to improve cattle health and support livestock growers.

Index Terms - Induction Heating, Livestock Protection, STM32 Microcontroller, Sustainable Insect Control, ZVS Driver

I. INTRODUCTION

The infestation of Insect and mosquito infestation in cattle sheds is a major challenge that affects livestock health, milk productivity and the working conditions of cattle growers. Continuous exposure to insect bites causes irritation, stress and increases the risk of disease transmission among cattle. Commonly used protection methods such as chemical sprays, coils and direct smoke generation methods may produce harmful fumes and residues, which are not suitable for long-term use in enclosed livestock environments.

To improve safety and sustainability, controlled vaporization of natural repellent liquids using electrical heating methods is a better alternative to combustion-based approaches. Induction heating technology provides rapid and flameless heating with higher efficiency and lower switching losses. This makes it suitable for generating repellent vapor in a controlled manner without direct burning.

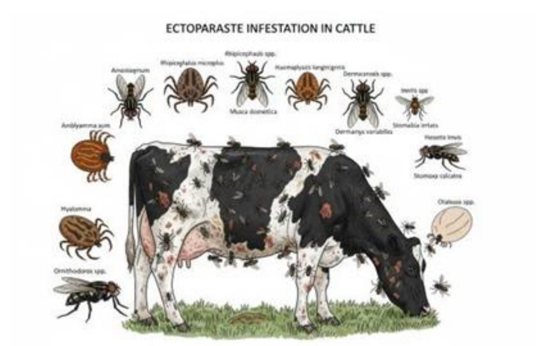

Fig.1: Illustration of ectoparasite infestation in cattle showing ticks, flies and biting insects affecting animal health and productivity in cattle farming

This work focuses on the development of an AI driven sustainable livestock protection system against insects using Zero Voltage Switching (ZVS) based induction heating. The system uses an STM32 NUCLEO-L412KB microcontroller, an LDR sensor for environmental sensing, a relay- controlled ZVS induction heating module and a DC air pump for vapor distribution. The repellent liquid formulated from natural sources is vaporized inside a heating chamber and distributed inside the cattle shed. The proposed system aims to provide a safer, energy-efficient and sustainable insect control solution to improve cattle health for the benefit of cattle growers.

II. LITERATURE REVIEW

Eyupoglu et al. described that repellents are substances used to drive away harmful and blood-feeding insects from living environments. Their work explains the classification, working mechanisms and functional properties of repellent substances, with special attention to plant-based and natural oil repellents. The study also highlights that many synthetic repellents may introduce toxic effects and therefore safer natural alternatives are increasingly preferred.

Soma et al. presented a survey on advanced insect repellent approaches using aerial and automated platforms. Their work reviews drone-assisted pest control and repellent delivery systems and discusses the importance of environmentally acceptable and automated protection methods. The study also outlines how AI-assisted data analysis can support agricultural pest monitoring and targeted repellent deployment.

J. H. Diaz et al. reviewed the growing threat of arthropod-borne diseases and emphasized that preventive protection methods are essential where vaccines are limited or unavailable. Their analysis compares chemical and plant-derived repellents in terms of safety, effectiveness and toxicity. The study underlines the importance of topical and environmental repellent barriers for both human and animal protection.

Tiwari et al. discussed multiple pest control techniques including electronic repellent devices based on frequency generation. Their work explains that traditional pesticides and chemical repellents may pose health risks, while electronic pest repellers offer a low-cost and eco-friendly alternative. Ultrasonic and electronic repellent systems are described as non-chemical solutions that disturb pests without direct poisoning.

Baskar et al. examined protected agricultural environments and reported that pest control combined with controlled cultivation improves productivity and resource efficiency. Their review explains that sensor-based and automated monitoring systems support better environmental control and pest management. Technology-assisted cultivation methods help reduce chemical usage and improve sustainability.

Udofa et al. focused on smart pest repellent and monitoring integration in precision agriculture. Their study reviews sensor systems, automated monitoring platforms and intelligent control strategies used in modern farming. The work highlights that combining monitoring and repellent mechanisms improves response efficiency and supports sustainable agricultural practices.

Wokoma et al. demonstrated the design of a low-cost electronic mosquito repellent circuit using simple timer-based architecture and compact power supply methods. Their implementation shows that effective repellent devices can be developed using minimal components and simple circuit design, making such systems affordable and accessible.

III. DESCRIPTION OF EXISTING SYSTEM

In current cattle farming practice, insect and mosquito control is mainly achieved through conventional chemical and smoke-based repellent methods. The most commonly used systems in cattle sheds include chemical spray formulations, mosquito coils, liquid vaporizer heaters, fumigation smoke methods and topical repellent applications. These systems are widely available in the market due to their low initial cost and simple usage, but they operate with limited control and often produce continuous exposure effects.

Chemical spray repellents are frequently applied inside cattle sheds and on animal surroundings to reduce insect presence. These sprays act quickly but require repeated manual application and may leave chemical residues on surfaces and in the air. Continuous usage increases exposure risk to animals and workers and may affect enclosed shed environments. Similarly, repellent coils and smoke sticks are also used to generate insect-repelling fumes. These methods depend on combustion and produce dense smoke, which may cause respiratory discomfort and uneven repellent distribution.

Electric liquid vaporizer devices using resistive heating elements are also available in the consumer market. These systems heat repellent liquid using

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direct-contact heaters and release vapor slowly into the surrounding area. However, resistive heaters operate continuously once powered and do not provide condition-based activation. Their heating efficiency is lower compared to high-frequency heating methods and the heating elements are subject to wear and scaling over time.

Fig.2: Common market-available insect repellent products including coils, sprays, vaporizers and aerosol systems used in cattle and domestic environments

In agricultural and livestock environments, some electronic pest repellent devices based on ultrasonic or frequency generation techniques are also used. These devices emit high-frequency sound waves intended to disturb insects and small pests. Their effectiveness varies depending on shed structure, pest species and coverage area and they do not provide vapor-based repellent protection.

Overall, existing systems largely depend on chemical exposure, combustion smoke or continuous heating operation. Most available solutions lack intelligent control, energy-optimized activation and controlled vapor generation mechanisms. These limitations create the need for safer, non-combustion and controlled heating-based repellent delivery systems suitable for livestock protection environments.

IV. CHALLENGES IN EXISTING SYSTEM

Existing insect repellent systems used in cattle sheds and farm environments face several operational and safety challenges. Chemical spray repellents require frequent manual application and depend heavily on user consistency. Improper dosage and uneven spraying often result in incomplete protection coverage. Continuous exposure to chemical formulations may also create health concerns for livestock and workers in enclosed shed conditions.

Combustion-based repellent methods such as coils and incense sticks generate dense smoke and particulate matter. While they provide temporary insect reduction, prolonged smoke exposure may cause respiratory discomfort and air quality degradation inside animal shelters. These methods also involve open heating sources, which introduce fire and handling risks in dry shed environments.

Electric liquid vaporizers based on resistive heating operate continuously once powered and generally lack condition-based control. Their heating elements are subject to scaling and efficiency loss over time. Vapor output control is limited and distribution depends mainly on passive air movement, which reduces effectiveness in larger shed areas.

Fig.3: Natural oil extract sources such as neem, eucalyptus, lemongrass, citronella and garlic used as organic repellent liquids for vapor-based insect control

Ultrasonic and electronic frequency-based pest repellent devices show variable performance depending on insect species and structural conditions. Their coverage range is limited and effectiveness is not uniform across different pest types commonly found in livestock environments. Overall, many existing systems lack controlled activation, energy-efficient operation and uniform vapor delivery mechanisms. Limitations in safety, consistency and environmental suitability highlight the need for

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improved repellent delivery systems designed specifically for livestock protection conditions.

V. BLOCK DIAGRAM

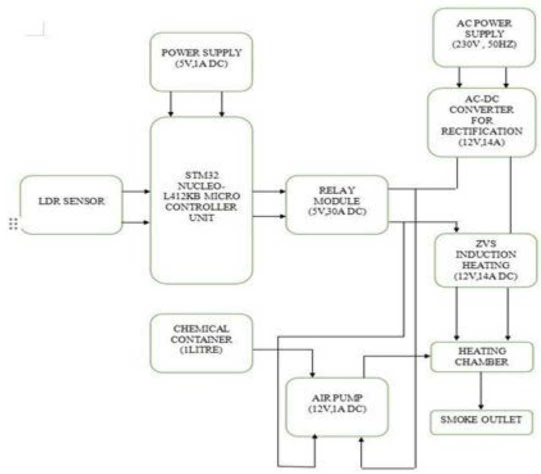

Fig.4: Block Diagram of the Proposed System

VI. FLOW CHART

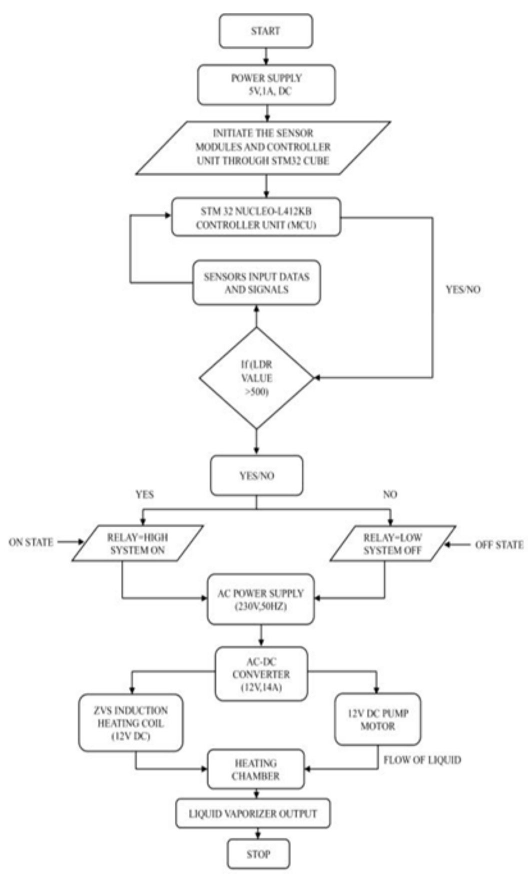

Fig.5: Flow Chart of the Proposed System

VII. HARDWARE IMPLEMENTATION

a. STM32 NUCLEO-L412KB: Used as the main controller for sensing input processing and relay control.
b. LDR Sensor: Used to detect ambient light level for activation logic.
c. Relay Module (5V, 30A): Provides isolated switching of the high-current heating and pump circuit.
d. ZVS Induction Module (12V, 14A): Generates high-frequency current to drive the induction heating coil.
e. Step-down Transformer (12V, 15A): Converts AC mains to low-voltage supply.
f. Rectifier and Filter Capacitor: Converts AC to smooth DC using metal diode and 10,000 µF capacitor.
g. 12V DC Air Pump: Distributes the generated repellent vapor.

VIII. WORKING OF PROPOSED SYSTEM

The working of the proposed AI driven sustainable livestock insect protection system is based on sensor-based activation and controlled induction heating vapor generation. When the system is powered, the regulated 5V DC supply energizes the STM32 NUCLEO-L412KB microcontroller and the sensing circuit. The controller initializes and continuously reads the signal from the LDR sensor, which measures the ambient light condition inside the cattle shed environment. The sensed input is compared with the preset threshold value stored in the controller program. Based on this decision condition, the controller generates an output control signal to the 5V relay module. When the activation condition is satisfied, the relay is energized and connects the high- current DC supply line to the ZVS induction heating module and the DC air pump unit.

The AC mains supply is stepped down and rectified to produce a 12V DC output using the transformer, metal diode rectifier and filter capacitor stage. This DC supply powers the ZVS driver, which produces high-frequency current in the induction coil. The alternating magnetic field generated by the coil causes rapid heating inside the heating chamber without direct electrical contact or flame.

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A natural oil based repellent liquid container placed inside the heating chamber undergoes controlled vaporization due to induced heating. At the same time, the 12V DC air pump operates and forces air through the chamber, carrying the generated repellent vapor to the outlet for distribution within the cattle shed. When the sensor condition is no longer satisfied, the controller deactivates the relay and both the heating and vapor distribution stages are turned OFF, thereby stopping the process.

IX. OPERATION OF THE PROPOSED SYSTEM

The operation of the proposed system follows a controlled sequence from sensing to vapor delivery. Initially, when the system is connected to the AC mains supply, the step-down transformer and rectifier stage generate regulated DC outputs required for the control and power sections. The 5V DC line powers the STM32 NUCLEO-L412KB controller and relay interface, while the 12V DC line is reserved for the heating and air pump modules. After initialization, the controller continuously monitors the LDR sensor input to observe ambient light conditions inside the cattle shed. The sensed value is evaluated with the predefined control threshold stored in the program. When the operating condition is met, the controller sends a trigger signal to the relay driver circuit.

The energized relay connects the 12V DC supply to the ZVS induction heating unit and the DC air pump. The ZVS module drives the induction coil with high-frequency current, producing a strong alternating magnetic field that heats the chamber through induction effect. The natural oil-based repellent liquid container placed inside the chamber begins to vaporize due to this controlled heating process. During this heating period, the DC air pump runs simultaneously and pushes air through the chamber, enabling continuous movement of repellent vapor toward the outlet. This ensures that the generated vapor spreads into the surrounding cattle shed area. When the sensed condition falls below the threshold level, the controller removes the relay trigger signal, disconnecting the heating and pump circuits and stopping vapor generation. This controlled ON – OFF operation ensures regulated, safe and energy-efficient system performance.

X. RESULTS AND DISCUSSIONS

The developed AI driven sustainable livestock insect protection system demonstrated effective and stable operation for controlled insect repellent vapor generation in cattle shed environments. The integrated control and heating arrangement provided an automated and non-combustion-based repellent delivery method using natural oil formulations. The STM32 NUCLEO-L412KB controller and LDR sensing unit produced consistent response behavior, enabling condition-based activation of the repellent vapor generation stage.

Fig.6: Developed Induction-Based Natural Repellent Vaporization System for Livestock Insect Protection

The sensor-driven control ensured that the heating and vapor distribution stages were activated only when the defined environmental condition was satisfied. The relay-controlled switching mechanism operated reliably and provided proper isolation between the low-power control circuit and the high- current induction heating section. The power conversion stage using the step-down transformer, rectifier and filter capacitor delivered stable DC supply for continuous system operation.

The ZVS induction heating module showed steady high-frequency performance and achieved rapid flameless heating inside the heating chamber.

The natural oil-based repellent liquid placed in the chamber was converted into vapor in a controlled manner without direct burning or smoke generation. The DC air pump enabled uniform movement of the generated vapor through the outlet path, supporting effective dispersion.

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Fig.7: Working Model of the Proposed System

The overall system operation confirmed coordinated performance of sensing, control, induction heating and vapor delivery stages with reduced need for manual intervention. Compared to coil-based smoke methods and repeated chemical spraying, the system supports controlled vapor generation and safer operating conditions. Minor practical considerations such as enclosure sealing, airflow direction and chamber insulation can further improve field performance. The obtained operational results validate the suitability of the system for sustainable livestock insect protection applications.

XI. CONCLUSION

An AI driven sustainable livestock insect protection system based on ZVS induction heating and controlled natural repellent vaporization has been designed and implemented for cattle shed environments. The system replaces combustion-based coils and uncontrolled chemical spray methods with a non-combustion, electrically controlled vapor generation approach. The STM32 NUCLEO-L412KB controller with LDR-based sensing enables condition-based activation and relay-controlled operation of the heating and vapor distribution stages. The induction heating module provides rapid and flameless heating for converting natural oil-based repellent liquids into vapor, while the air pump ensures directed vapor delivery. The integrated sensing, control and heating arrangement supports automated and energy-efficient operation with reduced manual intervention. The developed system demonstrates functional suitability for safer and more sustainable insect control in livestock protection applications. Further extended field deployment and long-duration testing can enhance performance evaluation under real cattle shed conditions.

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