DEVELOPMENT OF A MICROCONTROLLER BASED AUTOMATED OZONE GAS MANAGEMENT SYSTEM FOR ENVIRONMENT CONTROL IN PERISHABLE FOOD STORAGE SPACES

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Abstract - *It is important to increase the income generated from agricultural activities and allied occupations like fisheries, poultry etc. in order to sustain economic growth. These occupations generate large scale employment and contribute in the fight against poverty and malnourishment. Hence it is important to reduce volatility in the prices of perishable agricultural produce. This can be achieved by increasing storability of the produce. Hence the produce should be treated with substances with germicidal properties. The storability is severely degraded by use of pesticides and other chemicals which are sprayed in the farm. Hence it is necessary to effectively remove these chemicals from the produce. Moreover these chemicals can be poisonous and detrimental to the consumers.*

Ozone can be used to effectively oxidize these chemicals. It is not feasible to store ozone hence it is generated locally using ultraviolet radiation or electrical corona discharge. In the past ozone has been used effectively to clean the produce in many households. This method effectively neutralizes the toxic chemicals. It is important to treat the produce an earlier time in order to increase storability. Moreover ozone acts against any microbe and pests.

Cold storages have a low humidity and low temperature environment. Hence cold storages provide ideal environment to treat the produce with ozone using corona discharge method and hence increase storability. Hence these systems can be used to increase storability and ultimately have a positive effect on farmer's income by reducing losses and wastages. Since these storage spaces are spread over large areas it is difficult to equip these spaces with ozone generator. Moreover using traditional ozone generating systems create areas with higher than prescribed concentration of ozone. This may have detrimental effects on the produce. Hence it is necessary to build ozone generating systems which can facilitate equal distribution of ozone throughout the storage area. Moreover these systems should be affordable and economically feasible for widespread adoption.

Miniaturized ozone generating modules mounted on mobile platforms can be used as an effective alternative to traditional systems. Voltage multipliers can be used instead of transformers to miniaturize these systems and reduce weight. Such systems can traverse large areas if sufficient onboard energy storage and tractive systems are provided. Moreover a closed loop control system can be used in order the maintain ozone concentrations in prescribed concentration limits.

Key Words: Ozone, Mobile, Perishables, Preservation,

1. INTRODUCTION

Biological processes do not always produce satisfactory results. As early in 19th century, ozone has been reviewed for its safety towards food products and had since be declared as GRAS for food contact application. Later in 1990's ozone was declared safe to be used in Japan, France and Australia. In 2003, ozone had received formal approval from U.S FDA to be used as food addictive. Ozone gases are easily detectable by distinct smell, it has a detectable pungent smell when the concentration is high but it is already detectable by human at concentration as low as 0.01 μL/L. In term of oxidizing power, it has been reported that ozone is 1.5 times more potent oxidizing agent compared to chlorine and 3000 times of hypochlorus acid. Since ozone will naturally decompose onto oxygen, there is actually no harmful effect of using ozone towards food products.

Towards organic substances ozone is strikingly active. Organic coloring matters are bleached; for example, indigo is oxidized to isatin. Turpentine rapidly absorbs the gas, and if the liquid is exposed on filter paper in an atmosphere of ozone, inflammation may occur. India-rubber is rapidly attacked and so is of little value for connections in ozone apparatus. Alcohol is oxidized into acetaldehyde and even cellulose is oxidized, giving an indefinite peroxide compound. The oxidation of an alcoholic solution of tetraethyl-p-di-amino diphenyl-methane by ozone produces a violet color; this solution, applied conveniently on absorbent paper (as "tetraethyl base paper"), supplies a delicate test for ozone, possessing the additional advantage of distinguishing this gas from nitrogen dioxide, with which a yellow color is formed, and from hydrogen peroxide, with which no color is obtained.

Ozone in postharvest application is currently growing. Lots of research on ozone application had been done especially on major exported fruits. It is reported that a right dose of ozone application can delay the ripening of certain kind of fruits and vegetables. Ethylene sensitive commodity such as broccoli and seedless cucumber shelf life were extended in application of ozone at 0.04 μL/L with 3 o C (Skog and Chu, 2001) while 10 μL/L ozone concentration can dramatically decrease mango (Mangiferaindica L.) respiration a rate (Tran et al., 2013). The reduction in respiration rate indirectly indicates that ozone can also prolong the shelf life of mango.

Cold storages and warehouses provide excellent opportunities for post harvest treatment of the produce. The challenges associated with the use of such systems in warehouses and cold storages include low potency due to generation of ozone pockets and hence inefficient use of generated ozone. Traditional methods of generation and delivery of ozone are either not feasible in industrial environments or demand large resources like energy, maintenance resources etc. It is possible to use more efficient utilization of the generated ozone if the requirement of ozone and availability of resources can be defined. Hence ozone generators should be mounted on mobile platforms to ensure delivery of ozone in different regions in the right concentration.

2. METHODS

The ozone generating module generates a strong non uniform electric field in order to ionize the feed oxygen and hence create oxygen. The electrodes are made up of 2mm thick aluminum sheet and are mounted on a pine wood frame. The distance between the two legs of the wooden frame can be adjusted using a screw mounted on both sides of the frame. The module is connected to the HV module which is necessary to generate a high voltage discharge. The module has a capacity to generate 1gm of ozone in 1 hour when operated in standard conditions. A fan is placed at the feeder end in order to generate sufficient airflow for cooling of electrodes and adequate supply of diatomic oxygen.

The most typical corona configuration (both pulsed and continuous) is created around a sharp edge (this maximizes the active discharge volume). In corona, a non-homogeneous electric field is used to stabilize the discharge via the buildup of space charge around a corona wire or point. Silent discharges use charge buildup on a capacitive barrier to achieve a similar end result. Corona discharges are best suited for VOC destruction and a number of sterilization applications.

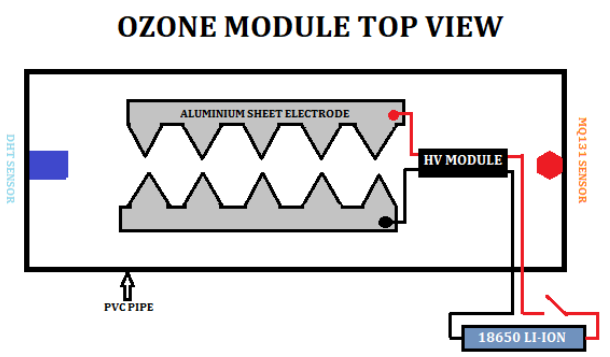

Fig -1: Miniature ozone generation module

A timer chip (NE555) is configured as astable multivibrator (oscillator), or square wave generator. This square wave generator is used as a trigger pulse for the switching device. The gate terminal of the static switching device is connected to pin3 of the NE555 which provides a square pulses at a frequency of 25 kHz. Passive components connected to NE555 are selected according to required output frequency (25Hz) and required duty cycle (50%). A series resistance is connected between pin3 and base terminal to dampen the amplitude of the square wave and make it suitable for triggering the static switch. The TIP3055 NPN power transistor is designed for general purpose switching. The power transistor is connected to a heat sink to prevent overheating. It is used as a switching device for conversion of 6V DC supply into 6V 25 kHz AC supply and drives primary winding of the step up transformer at 25 KHz and as a result a high voltage will be induced across its secondary winding. This unit forms the HV Module used to generate high voltage corona discharge.

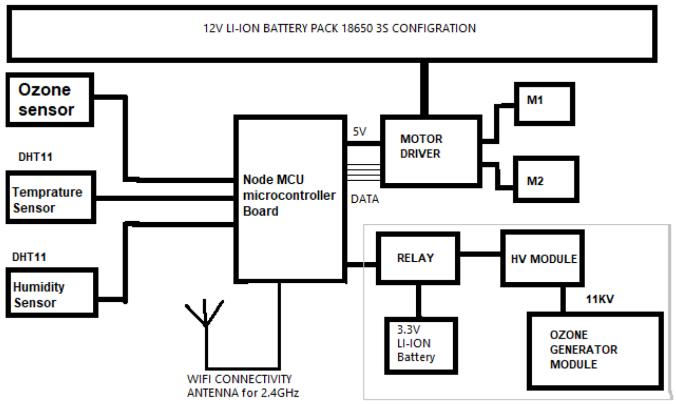

Fig -2: Block Diagram

The block diagram illustrates the connections implemented in the product in order to develop a closed loop control system. Real time data is acquired from the DHT11 sensor as well as the MQ131 sensor. The DHT11 provides real time temperature and humidity values. The MQ131 sensor provides concentration of ozone in ambient air in g/cm2 and PPB. These values are analyzed by the microcontroller to make a prediction about the ozone generator efficiency as well as the required ozone to reach set point concentration. This data is shared using a secured Wi-Fi network to a Personal Computer which acts as a server. The server creates a database, stores the data, displays the data and analyses it to improve the mathematical model and enable more predictability based on learning tools.

Based on this prediction the duty cycle of the ozone sensor is calculated. The switching of the ozone module is achieved by switching the high voltage generating module using a mechanical relay. This mechanical relay receives control signals from the microcontroller. It is necessary for the ozone module to produce a harmonic motion over the designated path. This is done by controlling the motors for direction of rotation. An H Bridge motor driver is used to control the center shaft DC motors which are utilized in the traction system. The motor drive receives the control signal from the microcontroller. Moreover it supplies a 5V regulated supply to the microcontroller. This ensures that the ozone generator is mobile and hence can deliver ozone gas in the right concentration in the different parts of the allocated area. The power supply unit consists of a battery pack of three 18650 Lithium Ion batteries connected in series. Hence the battery provides the a 11.1Vvoltage output and has a capacity of 7.5Ah

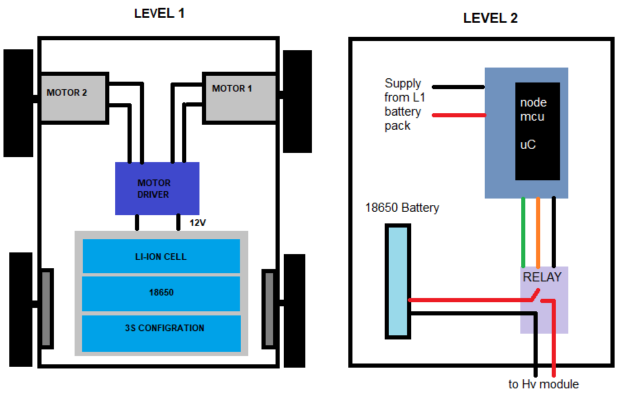

Fig -3: Organization of the Multilevel Mobile Platform

The project is realized in the form of a multistage rover. Heavy components are placed at the lowermost levels to ensure dynamic mechanical stability of the rover. A separate battery is provided for the ozone generating system for redundancy as well as to reduce risk of explosion of battery due to over discharge.

The rover is organized in three levels. A large of electromagnetic noise is created by the corona discharge generated I the ozone generator. As most of the control system components are embedded systems, they may be influenced due to electromagnetic interferences. Hence the two levels are separated by metallic acrylic sheets to deflect the noise. This also acts as a deck to mount components for the next level. Connections on the two levels are made through the holes drilled on the chassis. This enables internal cable routing. All components are mounted using a nut and bolt assembly on the chassis.

4. Testing Performance Characteristics and Indices

4.1 Testing of High Voltage Module

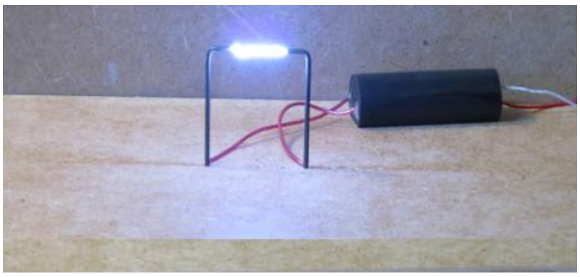

Fig 4. Generation of corona Discharge using HV module

A corona discharge is generated using the high voltage module. The module generated has a maximum arc length of 5cm during pulsed operation. For maintaining the arc the gap length has to be maintained for a length less than 4mm.

The design of voltage multiplier utilizes lot of contact points. These contact points induce contact resistances, and hence there is a large variation in the output voltage of the multiplier from the calculated value. Hence the high voltage is measured by air gap method. As the breakdown voltage gradient of air 3kV/mm it can be concluded that the generated voltage is 12kV.

4.2 Testing of Automated Guided Vehicle

The automated guided vehicle utilizes two motors. These motors utilize 9 Watts of power in an hour. The torque delivered to the wheels form of mechanical force is 2.975 Watts per wheel. Hence the traction system operates at an efficiency of 85% when loaded to75% of the loading capacity. Further the control system, peripherals and the ozone generator consume 20 watts per hour when the duty cycle of ozone generator is considered to be 50%.Hence the up time of the system can be calculated to be 3.1 hours.

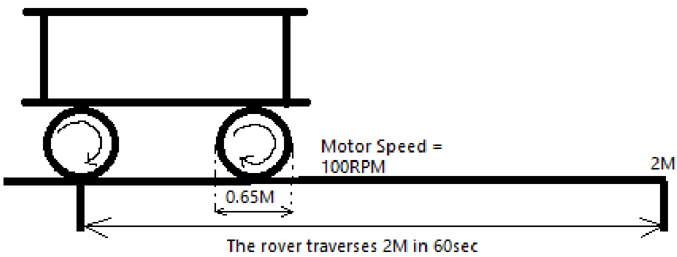

Fig 5. Distance covered in one rotation

Hence the range of the rover can be calculated to be 387m.Thiscan be further extended by using devices with higher energy density and higher capacity.

4.3 Testing of Ozone Generator

The ozone generator generates ozone at the rate of 1000 part per million as sensed by the MQ131 sensor when placed very close to the generating module. Hence the output of the ozone generator can be calculated to be 1 kg/m3. Considering that the oxygen in feed gas is 20 percent we can calculate the efficiency of the ozone generating module. This efficiency can be calculated to be 2 percent.

The corona discharge is sensed using a super cooled CCD camera from HORIBA. Such devices are usually used to conduct spectroscopic studies of stellar entities. A CCD or Charge Coupled Device is a highly sensitive photon detector. It is divided up into a large number of light-sensitive small areas known as pixels, which can be used to assemble an image of the area of interest. A CCD is a silicon-based multi-channel array detector of UV, visible and near-infra light. These are used for spectroscopy, since they are extremely sensitive to light. That makes these detectors suitable for analysis of the inherently weak Raman signal. It also allows multi-channel operation, meaning the entire spectrum can be detected in a single acquisition.

CCDs are widely used beyond sensors in digital cameras. Versions that are used for scientific spectroscopy are of a considerably higher grade, to give the best possible sensitivity, uniformity, and noise characteristics. Coupling this sensor with an IR pass filter inbuilt in the filter wheel the corona discharge can be analyzed. Following images are of the spectroscopic analysis of corona discharge in still air. From the images by the spectroscopic signature presence of large quantities of ozone and nitrogen dioxide can be sensed. The device has a superior signal to noise ratio hence detection of streamers as well as disintegration of streams can be detected.

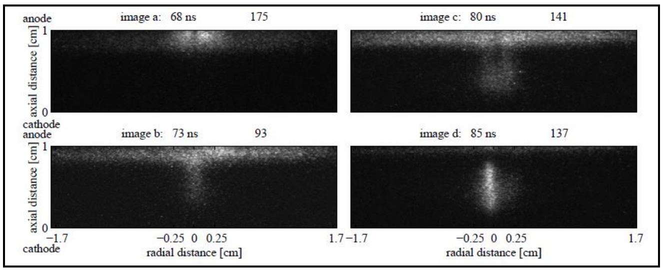

Fig 6.Streamers in Visible Wavelengths

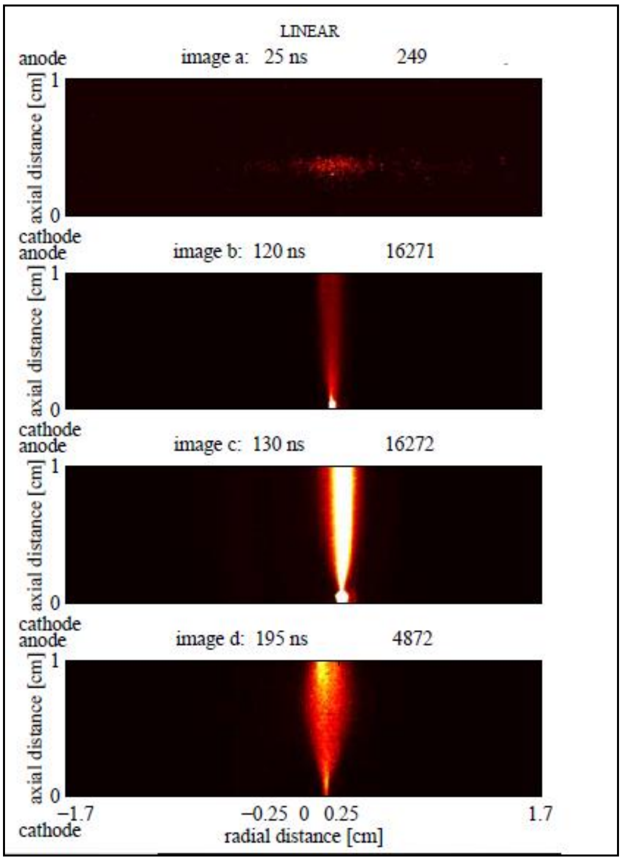

Fig 7.Generation of Streamers in Infrared

5. Conclusion and Future Scope

The system consists of a Personal computer acting as a server while the rover acts as the client. The rover transfers the data to the server via a secured wifi link. The system ensures an increase in shelf life of perishables by up to 50 percent.

5.1 Advantages

1. Significant increase in shelf life of perishable goods.
2. Effective against Bacteria and viruses.
3. Effective against large number of pesticides and chemicals commonly found on perishables
4. Wide spread of ozone ensures treatment produce in the entire designated area
5. Closed loop control system ensures that the negative effects of ozone like discoloration can be completely avoided.

5.2 Limitations

1. Such systems should be implemented in areas with a high level of automation in. Ozone has detrimental effects on soft tissues found in eyes, mouth, lungs in the bodies of warehouse managing personnel. Continuous inhalation and contact in ozone rich environment by humans should be avoided.
2. The system has a limited range because of low energy density in the energy storing device.

5.3 Future Scope

1. Such systems can be useful in smog prone areas to make cities habitable. This can be done because of oxidation of Carbon Monoxide gas which is the polluting constituent of smog.
2. Such systems can be used in poultry farms, chemical plants, breweries, restaurants, food selling joints for deodorant for the surroundings using ozone.
3. The system can be upgraded to include ceramic based ozone generating plates as these plates have five times the efficiency of the current unit. Moreover such systems are less prone to damage by accidents or incorrect operation.
4. The server can be used to guide the rover to move into areas deficient in ozone. The server can also utilize learning algorithms for smooth and efficient implementation. Multiple rovers connected to a single server can be used in large areas. As these rovers also measure ambient temperature and humidity, airflow patterns can be studied using intelligent systems. Depending on the airflow patterns and ozone densities the movement of these rovers can be altered.
5. Such systems can be used in hospitals and healthcare related areas to sanitize surroundings. Such systems would be more useful as ozone gas can reach even the most inaccessible areas and sanitize the areas. This can be particularly useful during epidemics and pandemics where the disease is highly communicable in nature.

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