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Supervised Learning Algorithm for Maximizing the Productivity of IOT Enabled Smart Biogas Plant

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Abstract:
Due to the shortage of petroleum products, Biogas becomes the most important renewable energy resource which can be generated without destroying the nature. However, Biogas production in India is 2.07 billion m^3 which is very low, compare to the available potential. Biogas plants fail frequently because of the wrong ratio of input feedstock and water, poor maintenance and human error. To address these issues, the proposed system uses IoT, cloud and machine learning to improve the performance and reduces the number of failures in the biogas plant. Support Vector Machine (SVM) learning is applied to maximize the output of biogas plant. Result shows that Biogas production is increased 15 percent more compare to the traditional biogas plant and improved the life time of the biogas plant.

Keywords: *Support vector Machine, Internet of Things, Machine learning, cloud computing.*

I. INTRODUCTION

A Biogas becomes a promising renewable technology to convert Animal waste, Food waste, Agree culture waste and municipal waste into energy. Biogas development can be integrated with strategies to improve sanitation and greenhouse gases as well as reduce indoor air pollution. Municipal solid waste generation has become a global issue as it affects both the environment and public health throughout the world. It is more severe in developing countries due to rapid Industrialization and population growth. In India, MSW produces approximately 1,27,486 tons per day due to various household, industrial and commercial activities. Government of India's swacch bharat mission, waste to wealth programmes promotes to tape the potential of bio waste. Bio degradable waste (food waste, Agriculture waste, animal manure and human waste) can be converted into biogas which is used for Cooking, vehicle fuel and Electricity production [1][16]. Organic waste is converted into biogas by the four major chemical process consists of Hydrolysis, Acidogenesis, Acetogenesis and Methanogenesis. It is an eco friendly unit which reduces global warming and the waste from biogas plant can be used as organic fertilizer. Biogas is the best alternate LPG gas for domestic application. LPG gas price is increasing rapidly because of limited availability of non renewable resources. It has high market value and more advantages compare to LPG products. In the Biogas production process, methane is the most significant component. Biogas consists of methane (40-70%), CO_2 (40-50%), Nitrogen , N_2(0-10%), Hydrogen sulfide,H_2S (1%) and Oxygen during the anaerobic decomposition of organic matter [2].

Number of external and internal factors leads biogas plant failure which reduces the usage of biogas plant. Underfeeding of feedstock, wrong ratio water and input feedstock, temperature of the digester changes based on climate, poor maintenance and shortage of water are the primary factors mitigate the performance of biogas plant [3]. One of the reasons for the low use of biogas technology in dry and drought-prone areas is a large amount of water

required for the proper functioning of biogas plants [4]. Water and feed stock ratio should 1:1 to maximize the methane production which can be achieved by using sewage water. Sewage water increases methane production which indirectly reduces the water pollution and sanitation [6]. Anaerobic decomposition requires the digester temperature between 40^0 C to 65^0C to produce maximum amount of methane from biogas plant [5]. India's climate condition is suitable for biogas production and also need of biogas is huge in India. Biogas production decreases significantly during winters in cold areas due to low temperatures which affects methanogenesis [6]. Former President and scientist Dr APJ Abdul Kalam said that India has got a huge potential of tapping energy from biomass and it will help to reduce Global warming. However, the shortage of skilled manpower to fix technical faults during biogas operations acts as another obstacle to the penetration of biogas technologies in rural areas .These are the barriers to biogas plant dissemination in the society, even though it has huge advantages in terms of finance and availability of resources. In adequate knowledge of biogas plant and social-cultural issues also affects the penetration of biogas plants in India. These challenges have been dealt well in the proposed Intelligent Biogas production system[7] [13],[14],[15].

The Proposed Intelligent biogas plant consists of IoT based health care monitoring system, automation unit and purifier unit. Proposed system uses a collection of sensor nodes to monitor digester health and maximize the life time of the biogas unit. IOT processor (Raspberry Pi) collects all necessary data and sends to cloud database. Biogas units are connected via cellular / Wi-Fi Network with the cloud. Self automotive methodology uses machine learning algorithms to monitor and maximize the biogas production. Even we can train them to handle risks of biogas plant without human intervention. User can get all updates about the biogas plant through the Mobile APP. Human intervention is removed almost zero and maintenance fee system will have wide market in India. Proposed system is suitable for community or single family biogas production plants and also suitable for urban and rural areas.

The rest of the sections organized as follows: In section II & III , discussed the Design of biogas plant and Proposed Intelligent Biogas plant. In Section IV & V presented the implementation and results and conclusion.

II. DESIGN OF COMMUNITY BIOGAS PLANT

Solar energy, different thermal, wind energy and hydro sources, biogas are all renewable energy resources. But, the biogas is different from other renewable resources because of its characteristics and preserves natural balance. Biogas production and lifetime are improved by introducing IoT based monitoring system and machine learning algorithms.

A. Types of Digester

Digester selection is the important factor influence the biogas production unit. Organic matter decomposes with the help of bacteria's (acidogens and methanogens) in the absence of oxygen to generate biogas is called anaerobic digestion. Based on the temperature digester, biogas plant classified into psychrophilic plant (< 25°C), mesophilic plant (25-40°C) and thermophilic plant (45-60°C). The optimal digester temperature is 37 - 57°C to produce maximum methane from the plant. The type of gas holder and amount of input feedstock divides biogas plant into different category Fixed Dome Biogas Plants, Floating Drum Plants, Balloon Plants, Horizontal Plants, Earth pit plants and Low-Cost Polyethylene Tube Digester etc.,[8].

B. Input feedstocks

The amount of Methane content available in the biogas depends on the type of feed stocks. All biodegradable Solid wastes like plants, leaves , Agricultural waste, human waste, Animal manure and food waste can be converted into biogas. Table 2.1 gives the amount of methane available and

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amount biogas produced from each kg of materials.

Table 2.1 Methane production from various feedstock's

Input feedstock's	Yield of Biogas M3/kg TS	Methane content in percentage
Animal Manure	0.260 – 0.280	50-60
Leaves	0.210 - 0.294	58
Food waste	0.950	50
Pig manure	0.561	42
Sludge	0.640	50
Green Grass	0.630	70
Liquid	1.440	72

As India is an agriculture county, million tons of Agricultural waste is burnt after harvesting which produces air pollution. In the developing countries, Municipal solid waste management is a tough task which mitigates the economy and sanitation. These wastes can be converted into useful energy without disturbing the nature. In Fig1.1 Elephant grass, Rice straw and Ipomoea carnea are found in abundance in walayar region. Ipomoea carnea grows 10 to 12 feet tall in water bodies causing water-logging problems. The plant is not useful to human beings and animals. It can be given as input feed stock with cow dung to the biogas plant.

Figure 4. Ipomoea cornea leaves a) Elephant grass b)

C. Design of Plant size and volume

It is necessary to calculate the digester volume, storage volume and Total plant volume to design a biogas plant. The Total plant volume (Vp) is calculated as the sum of the gas storage volume (Vg), and the digester volume (Vd) where these are calculated as follows:

Digester volume $Vd = \pi (D/2)^2 H$ …….(1)

Gas storage volume $Vg = 3/7 * Vd$ …… (2)

Total plant volume $Vp = Vd + Vg$ …….(3)

It is a calculation for floating drum plants are cylindrical size. so that the gas storage and digester volumes are in the ratio of 3/7 [10].

D. Storage and purifier

The quality of biogas is measured by the amount of CO_2 (carbon dioxide) and H_2S (hydrogen sulfide) presence. An acid gas impurities such as CO_2 (carbon dioxide) and H_2S (hydrogen sulfide) has to be removed from biogas to use biogas as fuel. Methane is the combustible substance in the biogas. Biogas purification is done with the help of scrubber unit which removes H_2S content. Carbon dioxide is removed by sending the biogas to Calcium hydroxide $Ca(OH)_2$. The Methane and CO_2 rationing is dependent on feedstock and other factors[12].

III. PROPOSED INTELLIGENT BIOGAS PLANT

Biogas plant penetration mitigates because of the frequent failure and number of external and internal factors. Proposed system will improve the Biogas plant lifetime and efficiency by applying IoT and Support vector machine learning Algorithm. Proposed system addresses the significant problems in the Biogas production unit 1) shortage of water required by biogas production unit 2) temperature fluctuation in the digester due to climatic change 3) improper handling of biogas unit. Human intervention is completely removed and the biogas plant health care unit sensors data helps to maximize the biogas production.

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A. Implementation of IoT based health monitoring Unit

Self automated IOT based Biogas healthcare monitoring unit consists of bio waste collection chamber with moisture sensor, controlled mixer with temperature sensor , insulated digester with temperature and PH sensor , storage and biogas purifier with gas monitor sensor. Fig 3.1 shows overall bock diagram of smart biogas plant

The HMI panel in the mixer chamber helps to collect food

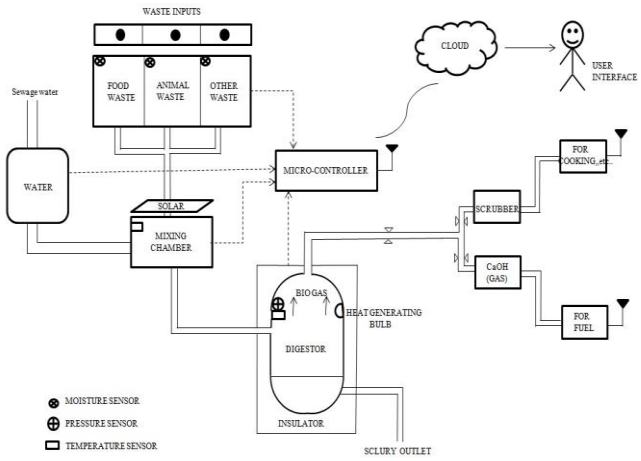

Figure 3.1. working of smart Biogas plant

waste, animal manure and other wastes and store into the respective storage areas. Feedstock moisture data is sent to microcontroller which helps to decide feedstock mixing ratio with water. The sewage water is collected in other chamber which will take care of water requirement of biogas production unit. Microcontroller controls the input feedstock and water level in the mixing unit and maintains 30-45oC based on feedstock available in the mixer. Solar panel is placed in the mixer unit to maintain prescribed temperature in the mixer with the help of microcontroller. Then the warm feedstock is sent to the insulated airtight digester for anaerobic digestion. Insulated Digester maintains adequate temperature with the help of controllable heating bulb for maximizing the biogas production.

B. Specially designed digester and mixer unit

Mixer unit mixes water and feedstock in a proper ratio to maximize biogas production. Mixer unit is connected with solar panel to heat feed stock based on temperature and pressure of digester. Microcontroller controls the input feed stock sends to the digester. Design of digester volume can be calculated based on the size and type. Temperature and pressure sensor and pressure release valves are connected with IoT processor.

C. Biogas Purifier Unit

Calorimetric micro sensor is used to measure the amount of biogas production and send the measured data to microcontroller. Scrubber unit removes H2S and water from the Biogas and used for cooking. The CO_2 is to be removed from biogas to get Pure methane with the help of CaOH. Pure Methane can be used as vehicle fuel.

D. Self automated Biogas plant Workflow

The data collected from the entire process is sent to microcontroller and forwarded to cloud database. fig 3.2 shows the entire architecture diagram of smart biogas plant. The data collected from the smart biogas plant is analyzed by the machine learning algorithm to decide the right feedstock ratio and temperature for maximizing the methane production. 80 % of slurry will be removed after extracting biogas in the digester and send to organic fertilizer unit. 20 % of remaining slurry will be used as catalyst for speedy production of biogas.

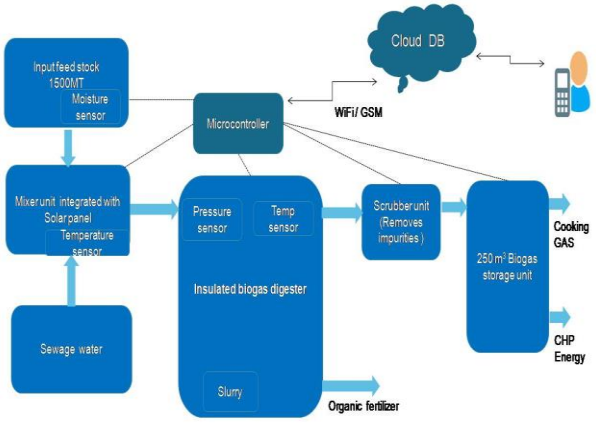

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Figure 3.2. working of smart Biogas plant architecture

If the input feedstock is empty then the notification is sent to the user through Mobile APP. A notification will be sent to user in case of any emergency. A self automated program can be trained to handle emergency situations. Human intervention is completely removed and life time, efficiency of biogas plant will be increased by applying the proposed approach.

E. Design of Unmanned Biogas Unit

Mixer Support vector machine (SVM)is a subset of Supervised machine learning used for classification and regression problems. SVM prediction is more accurate by using the trained dataset. The biogas production process contains number of stages integrated with IoT units to measure the parameters at each time. These values are recorded into the cloud database including the amount of biogas generated. These data are used as trained dataset for the Support vector Machine. Biogas plant health is monitored by the Application runs on the cloud and based on the data received from the plant takes necessary action to keep the production unit active and safe. User can view the biogas plant health condition through mobile Application.

IV. IMPLEMENTATION AND RESULTS

The proposed IoT based smart biogas system is implemented with the capacity of 1500MT. Microcontroller and sensor unit collects the data from Mixer, digester and storage chamber. Microcontroller sends the data to the cloud database where Support Vector Machine algorithm is applied to maximize the performance and efficiency of the biogas plant. Fig 4.1 shows the implementation of smart biogas unit at chinampathy near walayar valley in Coimbatore district. The Data are sent to the cloud database through GSM/GPRS module. The intelligent biogas unit decides the amount of water to be mixed and the temperature based on the knowledge from the trained dataset to maximize biogas production.

Figure 4.1. IoT based Smart Biogas plant

A. Energy Calculation

The Biogas can be converted to electrical / thermal energy based on the input feedstock type and environment. The amount of biogas produced by the plant can be varied due the different influencing parameters. The amount of biogas from Cow dung & grass production /kg = 0.075 m3.The total amount of biogas produced by 16 kg input feedstock is 16 x 0.075=1.2m^3. If 1m^3=19 MJ so 1.2 x 19=22.28MJ , In KWH 22.28/3.6= 6.33 KWH.

In conversion into electrical energy 60% of energy is lost due to heat and other mechanical loses. So the remaining energy converted into electricity is calculated as 6.33*40/100=2.58 KWH. The produced heat in the power generator can be transferred to maintain the digester temperature for the required level to maximize biogas production.

B. Compressed Bio Gas (CBG) as fuel

Biogas compression decreases storage requirements, concentrates energy content and increases pressure to the degree needed to overcome gas flow resistance. The compression is integrated with the scrubber and storage unit. The compressed biogas (CBG) properties are similar to the CNG and hence can be utilized as green renewable automotive fuel which will remove CNG usage in the industry,

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automotive and commercial areas due its enormous resource availability and low cost.

C. *Performance Comparison of biogas plants*

Biogas plant production is increased due to the automation and IoT based health care unit integrated with Support vector machine method predicted the parameters range

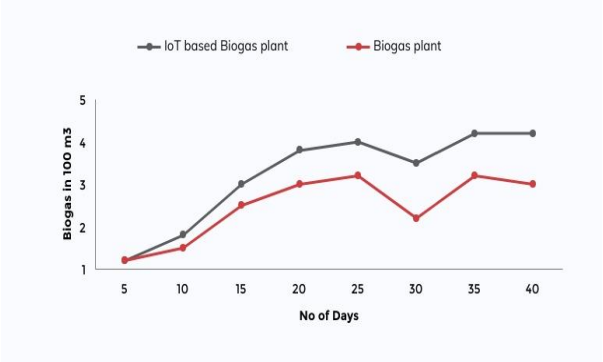

Figure 4.2. Biogas production comparison chart

required to maximize the biogas production unit. Fig 4.2 shows the comparison chart of smart biogas production unit and traditional biogas unit for the same feed stock. IoT based Support vector machine algorithm is helped to increase the production by 14.35 percentage.

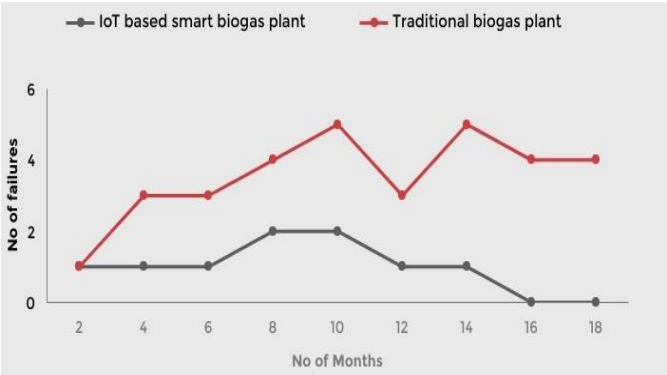

Figure 4.3. Number of failures in the biogas plant

In the biogs plant, failures occur mainly due to the wrong ratio of input feedstock and unskilled labor. It can be overcome by applying SVM prediction algorithm which predicts ambient environment to maximize the biogas production by reducing the number of failures in the biogas plant. In Fig 4.3 compares the number of failures occurred during the consecutive 18 months observation which shows number of failure becomes almost zero in the SVM based smart biogas plant. The Support vector machine prediction helps to decide the parameters value to sent ambient environment to produce maximum amount of biogas. The identified parameter values are sent to microcontroller. It controls the mixer ratio, water requirement, temperature and pressure based on digester temperature, input feedstock available slurry inside the digester.

V. CONCLUSION

Support Vector Machine algorithm applied to findout the suitable parameters values to increase biogas production and reduce number of failures in the biogas plant. The Experimental Results shows that the number of failures in the smart biogas plant is significantly reduced. Biogas penetration is very low in India because of the lack of knowledge in handing biogas plant and hard maintenance. The automation and notification to the user makes the biogas plant is completely maintenance free unit. The biogas plant production is improved irrespective of the geographical area and climate conditions by setting up ambient environment to the biogas unit. The results indicate the production of the smart biogas plant is increased 15.4 percent and removes the human requirement is almost zero with the help of Internet of things and Machine learning.

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