IoT (INTERNET OF THINGS) BASED EFFICIENCY MONITORING SYSTEM FOR BIO-GAS PLANTS

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***Abstract*— In a world where people are talking about increase in the usage of non-polluting and renewable sources of energy, monitoring and controlling such biogas plants remotely becomes very important. Monitoring the properties like pH, temperature, pressure and total amount of gas produced and consumed will help in understanding the health of the biogas plant. The whole process of offline monitoring has to be replaced with an online automation system. To overcome the barrier of data connectivity issues in the rural area, GSM based data transfer has to be used. In this paper, an IoT based efficiency monitoring system for biogas plants is proposed. An Arduino micro-controller system is deployed and tested to measure the gas production and consumption. Android based application is designed to act as an SMS gateway which is a free replacement for commercial solution. A dashboard plotting the usage statistics is designed to help the plant administrator to monitor the parameters.**

Keywords – IoT; BioGas Monitoring; Arduino; GSM; Android; Sustainable energy

I. INTRODUCTION

Nine out of every 10 households in rural India rely on firewood and other biomass for cooking. In total, around 144 Million households do not have access to clean cooking fuel in India. For their cooking, people use firewood, crop residue and dung cakes, which emit hazardous smoke. This alone results in about 1 Million deaths annually. Apart from being a major health hazard, these fuels leads to widespread deforestation and environmental damage via emission of greenhouse gases. On the other hand, LPG gas provided by Govt agencies is yet to reach widespread penetration in rural areas and is expensive for most of the rural population. Around 80 million families in rural India own cattle and at least 40 million families have sufficient space and animal manure to generate Biogas as an affordable solution for their cooking needs. All that they need is a reliable, safe and affordable system to generate Biogas. But this is NOT a new discovery. The Government of India has implemented rigorous Biogas programmes over the last 30 years. However, they have achieved limited impact due to limited awareness of the end user, no after-sales support, and difficulties in repair and maintenance of Biogas plants.

The opportunity With a track record of technical and market failures, biogas is waiting to be re-imagined. Apart from offering superior technology which is cost effective, there is a need to provide reliable support and service on the ground.

Via effective real-time engagement with customers via ICT, the barriers to adoption and maintenance of biogas can be removed. This could help achieve a hassle-free experience for the rural user, and set the way forward for clean energy proliferation in rural areas [1].

Information and communication technology (ICT) consumes energy, but is also an important means of conserving energy. Conventionally, it has done so by optimizing the performance of energy-using systems and processes in industry and commerce. In the near future, ICT will also play a critical role in supporting the necessary paradigm shifts within the energy sector towards more sustainable energy generation [2].

IoT on the other hand is connecting all the previously unconnected and dumb physical devices. Giving the intelligence to think and act on a command or situation. IoT uses RFID devices, infrared sensor, laser-scanner, GPS, GIS and other information sensor devices to connect any things to Internet, changing information and communicating, to realize intelligent identification, location, tracing, monitoring and management [3]. IoT technology has been widely used in environment protection, industry monitoring, food tracing source, logistic trading and other fields [4] In this paper we present a system which leverages this capability of IoT to monitor the efficiency of the BioGas plants.

II. RELATED WORK

ICT is a tool for enabling energy efficiency (typically as a side effect of process or infrastructure optimization). ICT can play an important role here because it can assist individuals in making more informed decisions and reward socially desirable behavior in daily life. In fact, getting users into the loop can not only help to guide individuals when using energy consuming devices, but also encourage them to make favorable decisions. Also, achieves energy savings on top of the efficiency gains resulting from automated systems.

Applications aiming at inducing behavioral change by providing direct feedback on household electricity consumption has been proposed in the paper [2].

A monitoring system using electronic devices in order to maintain the biogas installation to its optimal function is poposed in paper [5]. Arduino Uno board is used to interface the sensors to measure Temperature, pH and pressure. The readings are later displayed on an LCD.

An architecture which not only collects the data, displays it on an LCD, but also uses a GSM module attached to the controller to push the data to a mobile phone as an alert is proposed in the paper [6]. It also uses an in house server to log all the values. The draw back of both the systems is that, it does not push the usage logs, or the parameters log to the server for further analysis or initiation of an action.

III. PROPOSED SYSTEM

The basic idea here is to monitor the usage of biogas generated in the biogas digester and update the remote DB. The next set of actions would be to interface all the sensors required to measure the pH, temperature and pressure as mentioned in [5]. The test setup we have used here is a biogas digester provided by SustainEarth Energy Soultions, a biogas burner, an analog gas flow meter for calibration and a step up pump. Figure 1, shows the overall architecture of the system proposed. The digester is fed with cow dung as the primary ingredient in a specific ratio. Biogas produced in the digester is pulled by a step up pump beside the biogas burner.

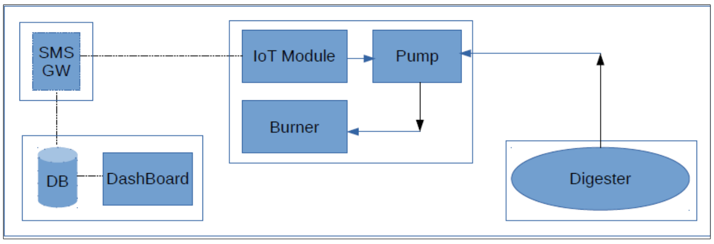

Figure 1: Overall System Architecture

The IoT module is placed along with each biogas burner near the biogas plant. The IoT module measures the biogas usage and sends as a text message with authentication code to the Android application which acts as an SMS gateway through a GSM module.
After validating the authentication code, the Android application pushes the usage statistics into the web database. The Android application pushes the data only when the Internet is available. An interactive web dashboard reflects the change of data in the database and it also displays per user usage logs and it also generates a bill invoice.
The IoT module also facilitates the controlling of plant remotely, where the administrator can lock the module when user fails to pay the bill, the administrator can also unlock the IoT module. Both locking and unlocking the IoT module is achieved by sending SMS to the GSM module in the IoT module.

The IoT Module: Measuring the gas usage is done using the following logic. There is a step up pump which helps in increasing the pressure of the biogas from the digester at the burner.

Figure 2: BioGas Digester at JIT

It runs at a constant speed, which helps us in measuring the amount of gas passing the pump per unit time.
We correlated the values to measure the gas pumped with the help of an analog gas flow meter. Figure 3, shows the architecture of the IoT module.

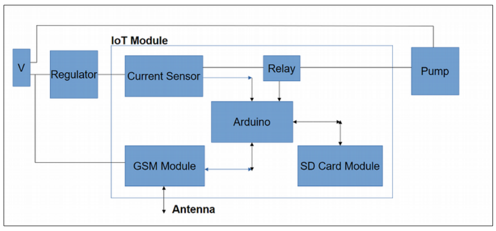

Figure 3: Architecture of IoT module

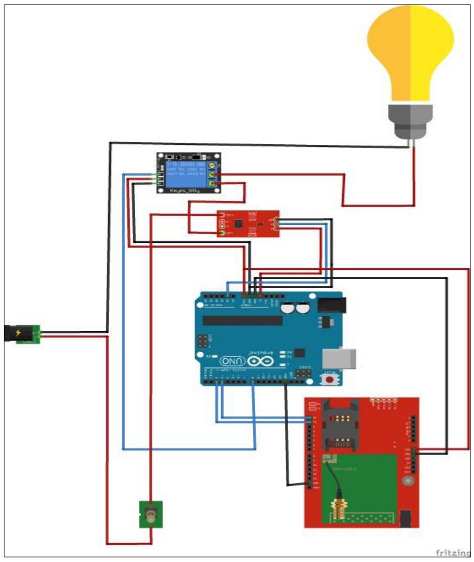

Figure 4: IoT module circuit diagram

Indirect Gas Volume Measurement: The Arduino board in the IoT module is interface with a current sensor, ACS712 which measures the current which regulates the power to the pump. Start time and the end time of the pumping is noted and the total duration is calculated. Till the pump is on, the gas is flowing and the burner can be lit. Once the pump is switched off the gas flow stops and the total duration is sent as an SMS to the registered mobile number immediately. GSM module SIM800A is interfaced to Ardunio to send and receive the SMS. Figure 4, shows the circuit connections inside the IoT module. A dimmer regulator was provided to switch on and off the pump at the gas stove. To test the module in the lab, instead of the pump, we used a zero candle bulb.

The Calibration process: We had to calibrate the measurements made by the Arduino. The process followed was tabulated. Three iterations of calibration tests were run to make sure that the measurements are correct, according to our calculations. An analog flow gas meter was used to manually note down the readings. The pump was run for 60s, 300s and 600s to note the amount of gas in CC.

According to the inferences made in the calibration tests, the web application calculates the amount of gas used by each user and shows the readings in cubic centimeters (CC).

Security: The system is designed to handle the security issues like eavesdropping or impersonation. Even before the usage statistics in the SMS is updated to the DB by the Android application, the SMS is parsed for an *AuthCode* which is hard coded in Arduino. If AuthCode is either missing or wrong, the SMS is considered as invalid.
In the future we can have a dynamic AuthCode which changes every time the usage stats are sent to the SMS gateway.

Android Application as SMS Gateway: Instead of a commercial SMS gateway, which provides a reply number and APIs, we developed an Android Application which receives the SMS and validates it with the help of an AuthCode and updates the usage statistics to web DB. It parses the SMS for, a) AuthCode b) UserID c) Number of Seconds the Pump ran in three different modes. Figure 5, shows the snapshot of the SMSs received by the application which were parsed and updated to a remote web DB. The remote DB will authenticate the request and update the DB for the UserID specified in the SMS.

Figure 5: Android SMS Gateway Application Snapshot

Remote Control of IoT Module: We need to be able to actuate an action at the biogas plant based on the learning or the administrators command in the future. We have tested this feature of locking the IoT module remotely. If we send message "LOCK" to an IoT module for the plant we want to lock, the IoT module gets locked and will not pump the gas. If we want to unlock then, we can send message "UNLOCK", which unlocks the module.

The Remote WebDB: A dashboard is designed to show the usage statistics of all the biogas plants installed. The dashboard will provide the information of individual user, ID, Location, total bio gas used on a daily basis, etc. We can also search a particular user based on ID and get the details. The usage is provided in two units, CC (Cubic Centimeters) and Minutes (Total amount of time the pump ran). It is hosted in our domain www.gaugas.vadiedu.com. Figure 6, shows the usage statistics of one of the current users.

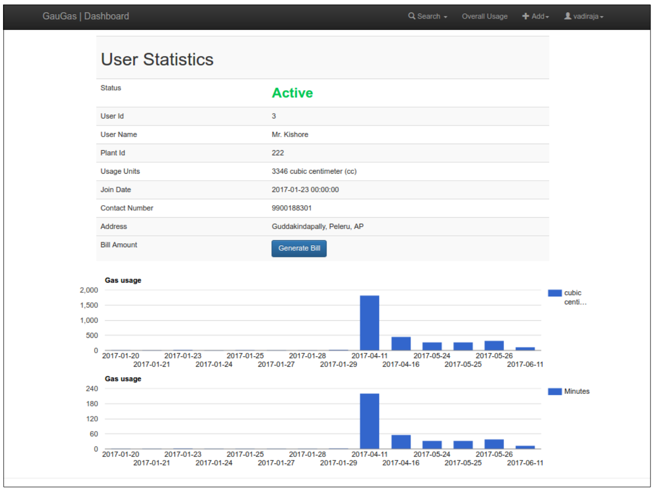

Figure 6: The Dashboard, hosted at www.gaugas.vadiedu.com

Prototype: The IoT module prototype is built and deployed in two places currently. One at our college campus, Jyothy Institute of Technology, Bengaluru and the other at a farmer's residence in Guttakindapally, Peleru, Andhrapradesh. The student team has trained the farmer to use the prototype. Since then we have been getting regular SMSs from the plants. Figure 7, shows the prototype built to test. Figure 8, shows the IoT module deployed at out college boys hostel canteen, where the biogas is used on a daily basis for cooking.

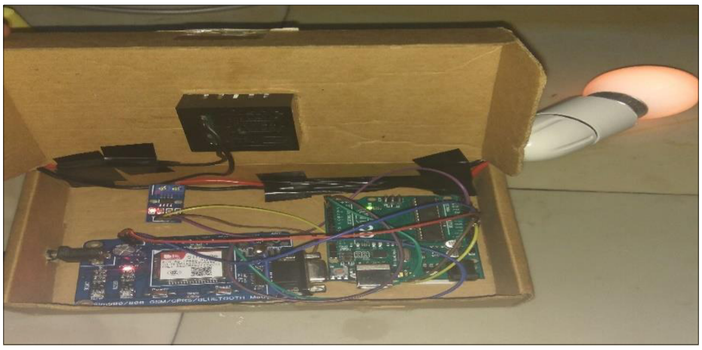

Figure 7: The IoT Module Prototype used for testing (with a bulb)

Figure 8: IoT Module deployed at boy's hostel cantten, JIT

Bill Generation: Rural mass is given an option of either owning a complete plant or use a connection to a community based biogas plant setup near the residence. In the later case, the user is billed every month for the exact amount of gas he/she has used. The dashboard gives the administrator to set the unit price per CC. Automatically the bill is generated every month. A PDF bill is generated dynamically and can be saved for future.

III. RESULTS

Our IoT module is currently installed in two different places. We have been receiving usage statistics regularly. We could able to make out a pattern in their usage. The time they use the gas, the amount and if at all they are using it or not and others. Finally we were also able to lock the IoT module remotely with the help of "LOCK" and "UNCLOCK" messages.
The users are also happy with the overall design of the IoT module and the placement of the dimmer regulator which is placed beside the biogas burner.

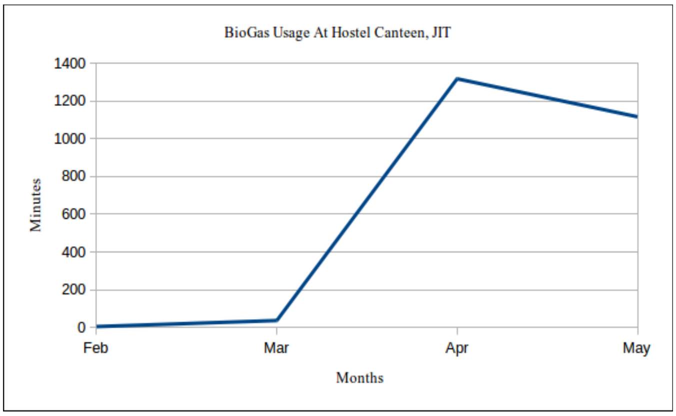

Figure 9: BioGas Consumption at Hostel Canteen, JIT

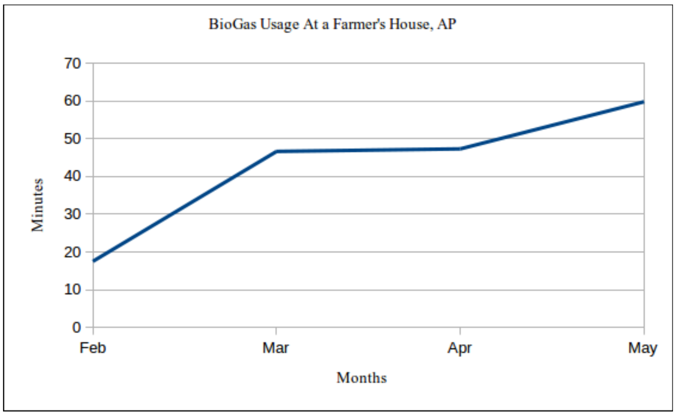

Figure 10: BioGas Consumption at a Farmer's House, AP

A constant increase in the usage of biogas was observed at both the plants. There was a specific pattern in the usage which was observed, which gave insights about the duration and quantity of the gas used. Figure 9, is the graph plotted for the boy's hostel. Its obvious that the gas consumption is very high there. Figure 10, is the graph plotted for a farmer's house at a village in AndhraPradesh, and it can be observed that the consumption is fairly less.

IV. FUTURE WORK

We are planning to interface the sensors to measure the pH, temperature and pressure to monitor the health of the biogas plant in the near future. As mentioned in [5], [6] we will be using the same Arduino controller to interface the sensors along with the GSM module. Next thing we would be working on is to initiate an action based on the learning we develop after analyzing the parameters read from the plant. Also, we plan to make the Arduino reconfigurable remotely by interfacing an SD card which can be read and rewrote. SD card could also be used to store the usage logs or parameter logs locally for an audit trail. Security is another concern, we would also work on replacing the AuthCode regularly. After two successful installations, we would check if the same architecture can be scaled up for more such plants.

V. CONCLUSIONS

The architecture proposed here is a scalable solution to monitor the usage statistics, and also crucial parameters to maintain the efficiency of the biogas plants. We have proposed and tested the capability of the system to both monitor and actuate an action on command. We have been successful in encouraging the rural mass to embrace the renewable energy solutions like biogas using ICT.

IV. ACKNOWLEDGEMENT

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REFERENCES

[1] Problem of the current BioGas systems: www.sustainearth.in, June 2017
[2] Friedemann Mattern, Thorsten Staake, Markus Weiss: ICT for Green: How Computers can help us to conserve energy:e-Energy '10 Proceedings of the 1st International Conference on Energy-Efficient Computing and Networking PP. 1-10 :ACM 2010
[3] GanZhixiang, "Research on origin and development of IOT", MORDEN ECONOMIC INFORMATION; 2010
[4] Longjun Wan, Dawei Sun, Jianhua Deng: Application of IoT in Building Energy Consumption Supervision:978-1-4244-6734-1/10 2010 IEEE
[5] Wassima Ait Ahmed, Mohammed Aggour, Fayçal Bennani: Smart System for Bio Digester Monitoring, 978-1-4673-7894-9/15 2015 IEEE
[6] Suruchi Dedgaonkar, Ankita Mohire, Ajinkya Jadhav, Sonali Pawar, Rushikesh Bane: BioGas Monitoring System for Measuring Volume using Microcontroller & GSM, PP. 1153-1557 2016 IJCET

[7] Interfacing Current Sensor with Arduino To Measure Current: www.henrysbench.capnfatz.com/henrys-bench/arduino-current-measurements/the-acs712-current-sensor-with-an-arduino/ June 2017

[8] Reading Current sensor values through Arduino uno and displaying the values on the serial monitor https:// www.electrodragon.com/acs712-current-sensor-read/ June 2017

[9] Automatic refresh of data without refreshing on web page, https://www.simplifiedcoding.net/php-mysql-insert-into-database-tutorial/, June 2017

[10] Interfacing the GSM module to begin and get connected to the network for calling and receiving sms https://www.instructables.com/id/Interfacing-SIM900A-GSM-Modem-with-Arduino/, June 2017

[11] Android tutorial for learning about how database works in the android application, https://developer.android.com/training/basics/data-storage/databases.html, June 2017

[12] To read and delete the sms based on their position in the stored messages in the sim http://www.learnerswings.com/2014/03/read-sms-message-by-at-commands-using.html, June 2017

[13] How to interdace GSM Module with Arduino http://www.circuitstoday.com/interface-gsm-module-with-arduino, June 2017

[14] Paper on Receiving the sms and displaying it in the application using a list view http://javapapers.com/android/android-receive-sms-tutorial/, June 05 2015

[15] Technical report on economics of gau gas plant by D.K.Desai GSFC Professor , IIM Ahmedabad , July 1974

[16] Online monitoring and control of the biogas process By Kanokwan Boe , Institute of Environment & Resources , Technical Univesity of Denmark , May 2006

[17] General Theory of Security and a Study Case in Internet of Things Yixian Yang, Haipeng Peng, Lixiang Li and Xinxin Niu , July 2015