Nat.Volatiles&Essent.Oils,2021;8(5):5411-5421

NVEO
Natural Volatiles &
Essential Oils

IoT-Fog Integrated Voice of the Plant Based Smart Irrigation and Power Management System for Smart Farming

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Abstract
Human survival on Earth will be solely dependent on agricultural products from the past to the present and also in the future. With the integration of IoT-Fog based technologies in agricultural applications, we can make better use of the fundamental and vital resources of water and power. This method enables a better approach to agriculture by focusing these two valuable resources using a variety of sensor-based agricultural practises (SBAP) to monitor characteristics like as moisture, humidity, on-field water level, temperature, and so on. This proposed model has a 360-degree reflector system, which is critical in increasing the light source or adjusting the temperature as needed by the plant during peak hours. It is proposed to develop a unique IoT-Fog-based automated agriculture monitoring system. Using Arduino and several on-field monitoring sensors, this architecture is emulated as a prototype model. This prototype model incorporates machine learning to give a crop-based decision-making mechanism. This system is equipped with a clever changeover mechanism that switches over to the renewable power resource when it is sufficiently available, allowing it to be used as a source of energy. This approach also recommends the use of a ground-level water top-up device to raise the water table during floods and wet seasons.

***Index Terms** - Internet of Things, On-field Sensors, Smart irrigation, Smart Power Changeover Mechanism, Sensor Based Agricultural Practice.*

I. Introduction

Food and water are the two indivisible necessities that allow humans to survive on Earth. According to a poll done by the International Water Association (IWA), water consumption will double in the next three decades [1]. Since the Day-Zero effect has already had a significant influence on many affluent countries, this crisis situation, which could lead to a water war, is not far away. Agriculture plays an important role in our daily lives. Bucket irrigation was the first traditional irrigation system, in which farmers used a manual way of water pumping to the field crops, utilising buckets to draw water. Various irrigation technologies have been implemented into fields as the need for water conservation and enhanced productivity (field extension for more crops) has grown. Table 1.1 is a list of some of them.

Despite the range of irrigation systems available, drip irrigation has been determined to be more efficient due to water conservation, soil moisture, reduced human engagement, and ease of integration of multiple technologies [2][3]. Various renewable energy sources, such as thermal, nuclear, and other renewable energy sources, such as solar and hydro, are available these days[4]. Pumps driven by fossil fuels were the first source of electricity for irrigation fields. As technology progressed, so did the methods used to create electricity.

Motorized pumps were powered by fossil fuels (diesel, gasoline) at the time, either by electricity-generating generators or by delivering power to the pump via a drive belt and vertical shaft. Furthermore, certain submersible pumps work with direct displacement.

A power grid connection can directly power an electric pump with renewable energy. However, the use of this energy source is determined by the reliability, cost, availability, and quality of supply.

Solar energy may be one of the most straightforward ways for farmers to obtain electricity. Farmers frequently have multiple big buildings with roofs that are directly exposed to the sun without being obstructed by tree shadows, making them a good location for installing a solar system. As a result, the use of alternative energy in agriculture is growing in popularity, and the energy generated from this renewable resource will be used either on or off the farm.

The web of Things is enabled by traditional domains such as embedded systems, wireless sensor networks, control systems, automation (including home and building automation), and so on. Within the consumer market, IoT technology is most closely associated with products that fall under the "smart home" concept, which encompasses devices and appliances that support one or more common ecosystems and can be controlled by ecosystem-related devices such as smart phones and smart speakers.

Fog Computing could be a new approach to bringing Cloud services closer to the network's edge. It provides a highly virtualized and distributed platform with storage and compute capabilities. Before the data reaches the Cloud, Fog may analyse massive amounts of data. This saves a lot of bandwidth and allows for faster decision-making. Different degrees of storage and processing are available, with lower levels being closer to the edge and higher levels covering a greater geographical area. The cloud serves as the utilities' overarching intelligence centre and data collector [5].

II. LITERATURE REVIEW

A. IoT In Agriculture And Irrigation System

The model proposed by Puranik et al., aims to automate the upkeep, insecticides and pesticides control, water management and crop monitoring. They have made use of varied sensors that are placed in field to work out moisture, pH, and temperature so as to irrigate the sector [6]. They have also designed the model to test availability of water within the well or tank.

In the past five years, huge numbers of applications are handled by fog computing technique. Unfortunately there were only few applications that can be handled using fog. But Bellavista *et al.*, made a survey on fog computing and put forth a large number of solution using fog technology [7]. The paper aimed at the in-depth analysis of the different solutionsusing fog computing which supports the requirements of IoT applications, detailing how they can be integrated and applied to meet specific requirements.

A general introduction about agriculture monitoring system using IoT was suggested[8]. They explained a way to scale back the human intervention into the sphere and irrigation of assorted crops automatically within the controlled manner. Here proper analysis about changing conditions of moisture, temperature and humidity level are made conscious to the farmers so he is ready to choose proper timing for irrigation and perform all other necessary things that required for correct growth of crops.

Drip irrigation is obtainable to cut back water usage, but it's not automated. Anushree et al., proposed the event of drip irrigation system that controls plant irrigation in manual as well as in automatic fashion[9]. The system established a live streaming of the complete drip irrigated land on a Web-page in order that user can monitor the sphere remotely. Also the general water wastage is reduced and human intervention is minimised.

IoT can be utilized as deciding tool for agriculture and this is proved[10]. Here a model is proposed where data from the sphere is collected, stored in server and analysis is completed to calculate the water requirement of a crop based on the algorithm called Penman Monteith algorithm. The system recommends fertilizers based upon the soil nitrogen, phosphorous and potassium (NPK) values inorder to realize optimum crop production. It also generates an irrigation schedule based upon input parameters like date of sowing, soil moisture percent and calculated water need for the crop.

Kumar and Ramudu designed a system to realize precision in agriculture while keeping farmer's simple access to the information in mind along with integrating to possess control on all deployed systems in a single system [11].

A survey was conducted by Mekala and Viswanathan on IoT based Smart Agriculture system with Cloud Computing and recorded some typical applications of IoT Sensor Monitoring Network technologies combined with Cloud techniques as balckbone or skeleton in agricultural fields [12].

The findings of Masuki et al., furnishes the main points of mobile phones in improving communication and data delivery for agricultural development and added the dynamics of linking farmer with market outlet and service providers[13]. It's simply a glimpse into various roles that a mobile could play in improving productivity. From their observations, farmers were much more excited for using the mobile to access data on land, resources management and markets.

B. Sensor Networks And Fog Computing In Agriculture

This survey is based developments and researches in sensor networks and in the field of fog computing which is in high demand for today's trend.

Malik *et al.,* made a distributed simulation on fog computing for smart farming [14]. They proposed a toolkit which provides a whole farming eco-system that has sensors and fog locations. Their evaluation shows that the proposed toolkit works on hardware while providing a platform to compute sensor energy, packet delivery ratio, and transmission delay due to simultaneous communication.

Kumar and Ramudu designed a system to realize precision in agriculture while keeping farmer's ease of access to the data in mind and so integrating them to have control on the system [11]. The farmers can use the system conveniently as it has a simple user interface. Also the system will keep the farmers well notified about event each second that happens within the field.

A survey was conducted by Mekala and Viswanathan Smart Agriculture IoT with Cloud Computing and recorded some typical applications of Agriculture IoT Sensor Monitoring Network technologies using Cloud computing as the backbone [12]. The main theme is to develop an optimal Agri-IoT architecture which is enclosed with low power consumption of devices, better deciding process, QoS service, low cost, optimal performance and it's easy for the farmers to know without knowledge.

Hemalata et al., (2015)[15] , in their work on multi-disciplinary model using IoT sensors, cloud and mobile computing and massive data analysis said that farmers, marketing agencies and their vendors must be registered to the agro cloud module through mobile app. It provide analysis for best crop sequence that can be carried out , total crop production within the area of interest, total fertilizer requirements for each sector and other data that will be analysed.

Soil moisture may be a significant indicator affecting crop growth. Advanced knowledge about the surroundings can help in irrigation scheduling, water utilization improvement, and yield forecasting .Liu et al., (2014, November) analyzed prediction of soil moisture supported extreme learning machine and integration of weather factors with statistic of soil moisture and its prediction[16].

Solar energy is found abundantly in Mother Nature. It may be harvested for irrigating the fields. This was proposed by Khiareddine *et al*., [17].They did Power management in a photovoltaic/battery operated pumping system. This paper aims on dynamic modeling and energy management. Lead Acid battery and an induction motor are coupled to a pump. This serves as a load. The simulation results show that if any excess power is found; it will be stored within the battery later on which it can be used as backup.

The efficiency of the sensor network in energy management and the various requirements of the power management system were analyzed and the strategic analysis is carried out in determining the various aspects that affects the power management system by Raulter et al., on the basis of a field survey [18].

A machine to machine communication technique is adopted by Mani et al., in order to perform power management and device monitoring and control. This automated system is proven efficient in power saving [19].

The advent of using Fog computing in power distribution and management applications draws a new technique called as Internet of Energy (IoE) through a layered architectural approach[20].

Although there are various systems and technologies that are implemented in the field of agriculture there is still a need of smart system that will save the essential and high demand resource in terms of efficient usage and storage for the future needs the proposed architecture is made.

III. IoT-Fog Assisted Smart Irrigation And Power Management Architecture

The proposed architecture aims in conventional management of electric and hydro resource. The system is integrated with irrigation, power and flood management. The following figure 1 describes the IoT based agriculture system which is in practice.

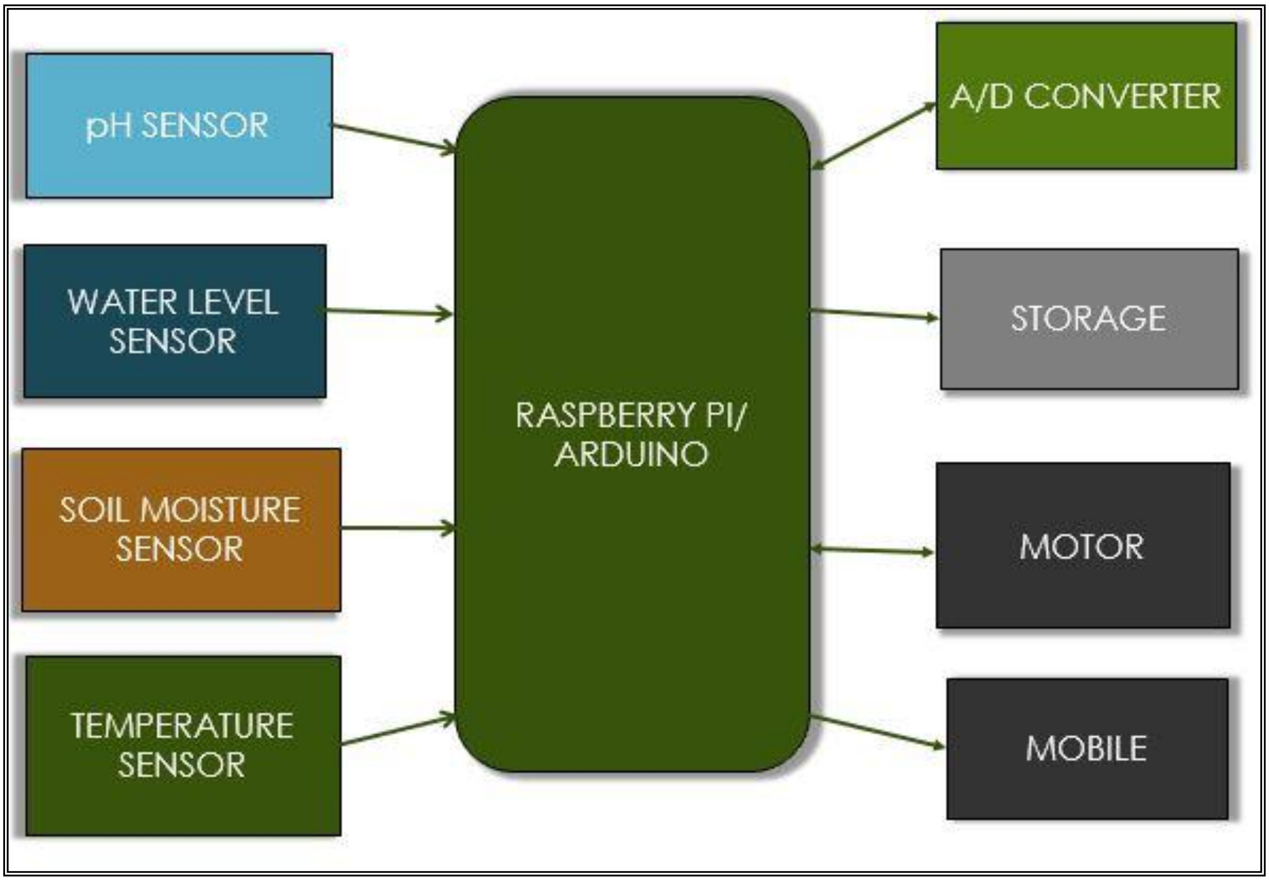

Figure1. Existing IoT Based Agriculture System

The current agricultural monitoring system automates the rectification process of any error occurring at any node of the prevailing automation system by extending the workflow which helps standalone systems to thrive with no human intervention. It also implemented workflows that tend to extend the extent of automation within the system.

Various renewable sources are used for generating electric power such as solar, thermal, nuclear etc. Solar energy is an abundant energy source and easy to access too. In most of the Asian countries it is available almost in all the seasons of a year. The prototype model smart agriculture system and its functional block is illustrated in the figure 2.

The functional architecture of IIPMS is designed with variety of agricultural and hydraulic sensors like humidity, temperature and water level sensors etc. for determining the environmental conditions. The temperature sensor computes the environmental temperature, Smart voltage meters determine the conversion of sunlight energy into voltage that is sufficient to operate a motor pump. TDS meter is used to determine the quality of water in order to determine the presence of harmful substances which is harmful for the growth of the plants. Soil moisture sensor and Water level indicator is employed to quantify the extent of water within the field, which helps the system to come to a decision on pumping and reverse pumping. LDR is used for determining the light intensity, based on which the power switching operation takes place. Reflector is used for creating artificial light intensity for zero cost power generation. In this architecture the aggregator is used for collecting various field information and uploads it to the fog router for further processing and decision making. The cloud is used for storing of data which in terms can be utilized for the future analytical needs.

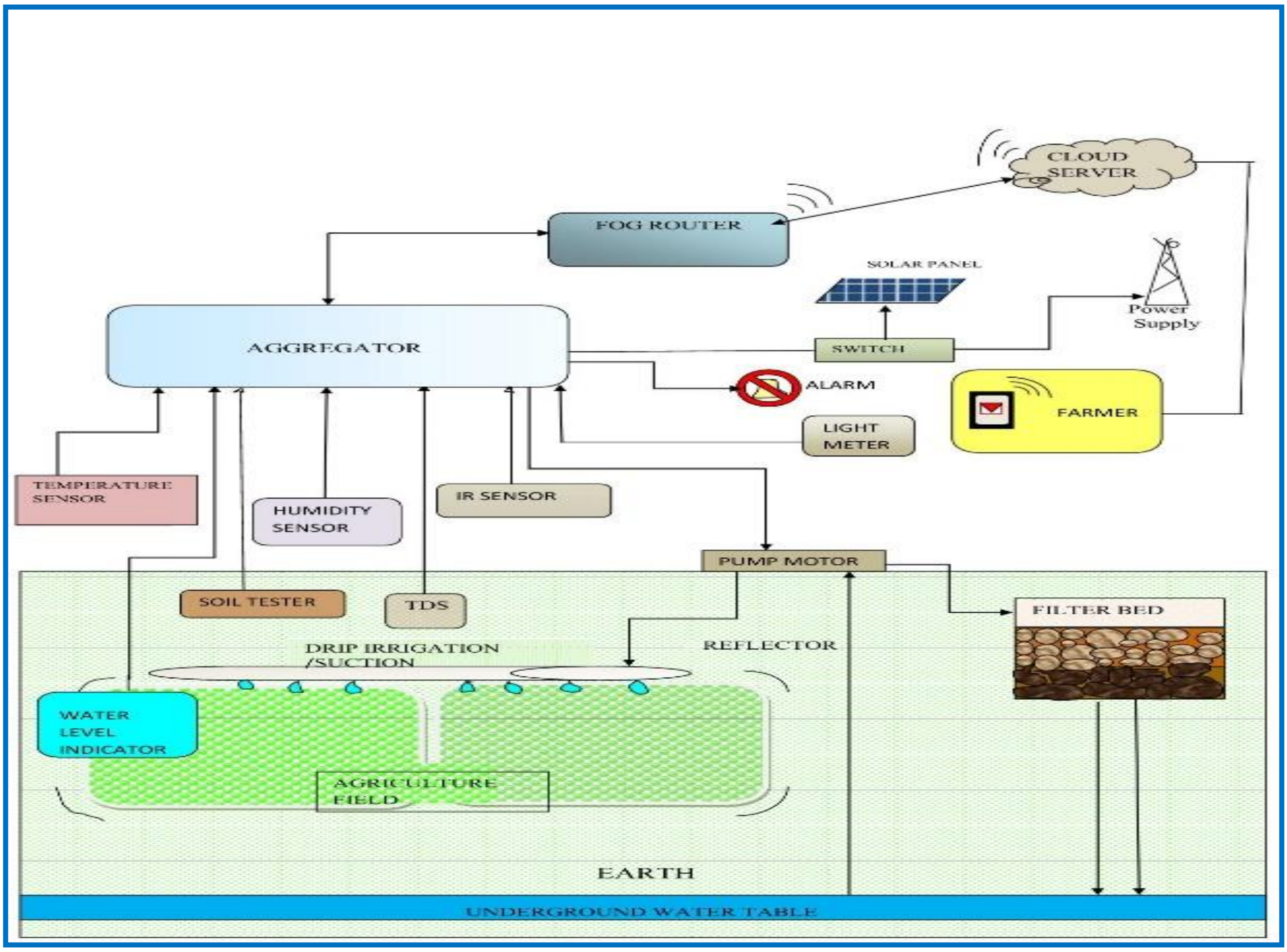

Figure 2. IoT-Fog Assisted Smart Agriculture System

A. Functional Overview Of Smart Agricultural System

In this proposed architecture we are implementing IoT based intelligent irrigation and power management system (IIPMS). DHT11 sensor is employed in this architecture, which can sense the temperature and humidity of the area of crop field. And so by using soil moisture sensor we can turn ON and OFF the motor by analyzing the conditions of the soil. And additionally water level indicator is employed for the detection of water content available in the field. So that the water pumps can suck the water outwards towards the drainage or to the filter bed. The LDR is employed for the indication of day time or dark so it can send an email alert to the respective person and gives an alert message that the product is operating under renewable energy resources (e.g. Solar energy, Wind Power, Hydro Power). From anywhere we can trigger the reflector for the plant nourishment and by using reflector we can get artificial sunlight to the plants. This ensures the adequate temperature for plant growth. All these data's are monitored via Blynk app. The app shows the values of temperature, humidity, soil moisture, water level, LDR status which may be viewed by LED and a switch to trigger the reflectors.

B) Operation Of Iipms

The IIPMS is divided into four functional modules for field monitoring, crop growth enhancement and smart power management.

1) Crop Monitoring System

This system facilitates the farmers to remotely monitor the activities of field. This module is not only used for monitoring the planted crops but also helps to prevent the harvested heaps.

The intruder detector Infrared based sensor is positioned at various levels from the ground level. If the system finds a suspicious entry it will activate the hummer in order to produce a high frequency sound that can keep the birds and animal away from the priceless crop.

2) Dual Pumping System

This IIPMS prototype model is enhanced with a dual pumping motor. Here Motor M1 is used for irrigation i.e. pumping water from bore-well to the fields based on the requirement of the crop which is controlled by the Arduino unit based on the crop based water and moisture requirement data fed from the cloud data source which facilitates transportation water loss [l kJ WCC] using smart pipes. The other pump M2 act as a ground water booster and also a flood saving system which draws the excess water in the field back to the ground water top up pit, which plays a vital role during dry seasons in avoiding scarcity of water and also prevents the crops from flood. The functional flow is illustrated in the following figure 3.

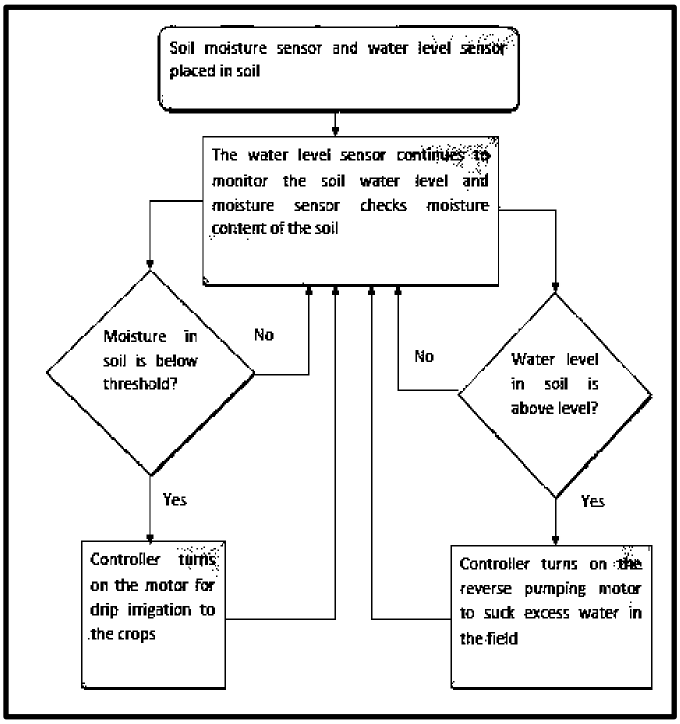

Figure 3. Flow diagram for Motor Function

The information about the quantity of water pumped in and out is intimated through SMS.

Hydraulic flow formula is showcased below [20].

$$Cylinder\ Area:\ (Sq.In.) = \pi \times Diameter\ (inch)^{2\,/\,4}\ ) \quad (1)$$

$$Cylinder\ Force:\ (Pounds) = Pressure\ (psi)\ \times Area\ (sq.in.) = Pressure \times Area\ /\ 2000\ (Tons) \quad (2)$$

$$Pump\ Output\ Flow:\ GPM\ = ((Speed\ (rpm) \times\ disp.(cu.in.)))/\ 231 Gallons\ per\ Minute \quad (3)$$

$$Cylinder\ Ram\ Speed:\ (Inches\ /\ sec.) =\ (((0.3208\ \times\ gpm))/\ Area)\ \times\ 12\ \times\ efficiency\ rate\ 85\% \quad (4)$$

$$Motor\ Horsepower\ required:\ (Horsepower)\ =\ gpm\ x\ psi\ x\ 0.000583 \quad (5)$$

3) Smart Power Switching

It is cost effective and wise to use the alternate source when it is abundantly available. Here in this prototype model light detecting sensor and temperature sensor is used for the detection of light and heat. If this dual parameter is found enough, the smart switch automates the change of power source to solar. Normal power supply from power station is utilized for the device and motor operation. The functional block is illustrated in figure 4.

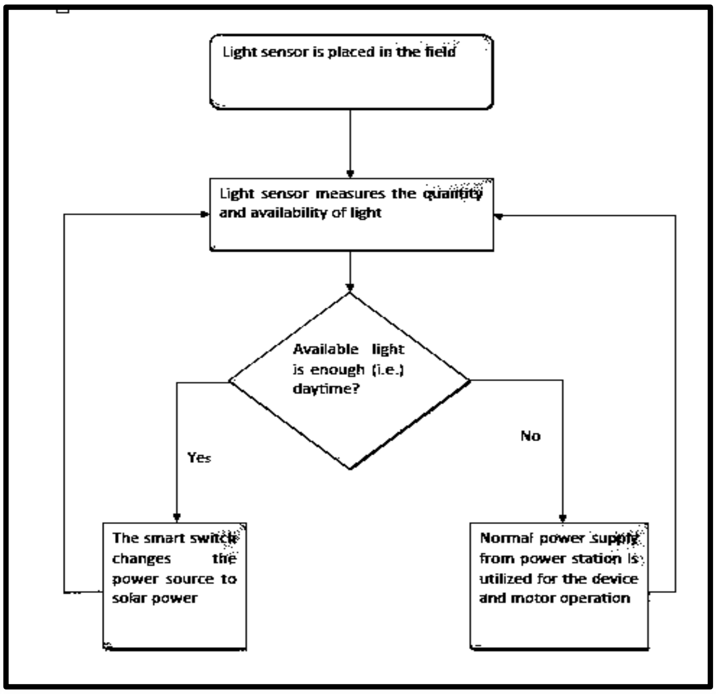

Figure 4.Flow diagram for Smart Power Switching

The mode of power in usage and the power related information such as voltage is intimated to the farmer by cloud through GSM technology.

4) Reflector System

Dual purpose reflectors are placed around the corners of the field. If the temperature for the crop is adequate, the temperature sensor placed in field detects ambient temperature of the environment and updates the data to the cloud through aggregator for future reference and analysis. If Temperature for the crop is not adequate, Controller turns on the reflectors provided with laser around the field to provide required temperature to the crop. On the other hand the system can be used as an artificial solar power generator which play its part in solar power generation during off seasons. All these information's are updated to the cloud at regular intervals. The functional ability is demonstrated in figure 5.

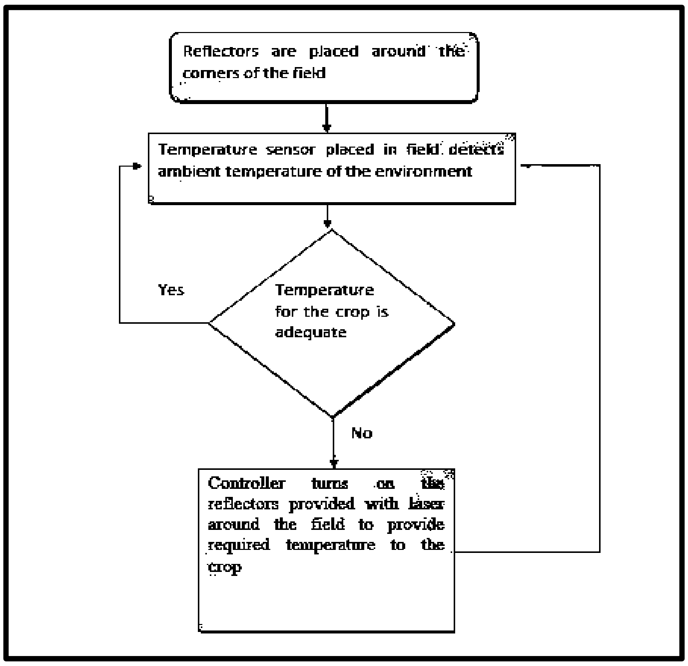

Figure 5. Flow diagram for Reflector System

5) Solar Energy Forecasting

In order to keep the system and the farmer posted about the availability of solar energy is made by an inbuilt prediction module that performs forecasting task using the traditional forecast analysis model called Time Series Analysis (TSA).

Here the dataset is availed from the public domain (gata.gov.in) which contains the data of season wise solar energy availed from 1900 January till 2012 December. The following Table 1 describes the structure of data set availed.

The forecast model is trained with 80 percent of data i.e. till 1990 season - 4. The forecast is made from Jan 1991 Season 1 till season 4 of 2012.

Equation for error and accuracy calculation

$$percentage\ error = \frac{actual\ value - predicted\ value}{actual} value * 100(\%) \quad (6)$$

$$percentage\ accuracy = 100 - percentage\ error \quad (7)$$

Table 1. Forecast Data vs Actual Data

Year	Jan-Feb	Predicted (Jan-Feb)	Mar-May	Predicted (Mar-May)	Jun-Sep	Predicted (Jun-Sep)	Oct-Dec	Predicted (Oct-Dec)
1990	19.44	18.71	25.55	26.06	27.18	27.3	22.11	21.92
1991	19.21	19.7	26.02	26.44	27.32	27.18	21.87	22.49
1992	19.06	19.05	25.64	25.47	27.15	27.17	22.05	22.27
1993	19.61	19.66	25.98	25.84	27.34	27.83	22.21	22.43
1994	19.76	19.58	26.3	26.99	27.3	27.37	21.97	21.48
1995	20.33	19.37	26.94	26.93	28.07	28.45	23.19	22.68

1996	20.79	20.75	26.49	26.89	27.22	26.89	21.76	21.76
1997	18.87	19.04	25.68	26.02	27.6	26.95	21.89	21.87
1998	19.72	19.42	26.41	26.71	27.69	27.93	22.42	22.75
1999	19.75	18.93	26.66	27.04	27.38	27.81	22.29	22.66
2000	19.33	20.15	26.47	26.53	27.23	27.18	22.68	22.47
2001	19.75	19.72	26.82	26.01	27.47	27.13	22.52	22.29
2002	19.65	19.09	27.22	26.96	27.71	27.93	22.58	22.32
2003	19.82	19.31	26.52	26.03	27.64	27.45	22.23	22.52
2004	19.93	18.47	27.06	27.83	27.33	27.6	22.24	22.01
2005	19.79	19.1	26.33	26.41	27.64	27.01	21.93	22.27
2006	21.36	21.05	26.52	26.89	27.4	26.95	22.66	22.01
2007	20.1	19.4	26.69	25.39	27.49	27.57	22.32	22.54
2008	19.16	18.96	26.46	25.85	27.26	27.06	22.86	22.48
2009	20.72	18.72	26.86	25.27	27.89	27.45	22.58	22.85
2010	20.2	21.06	27.83	27.6	27.5	27.99	22.6	22.39
2011	19.54	19.4	26.38	26.88	27.54	27.47	22.71	22.37
2012	19.34	18.8	26.55	26.12	27.71	27.81	22.35	22.4

The following graphical representation in figure (6) shows the year wise seasonal forecast.

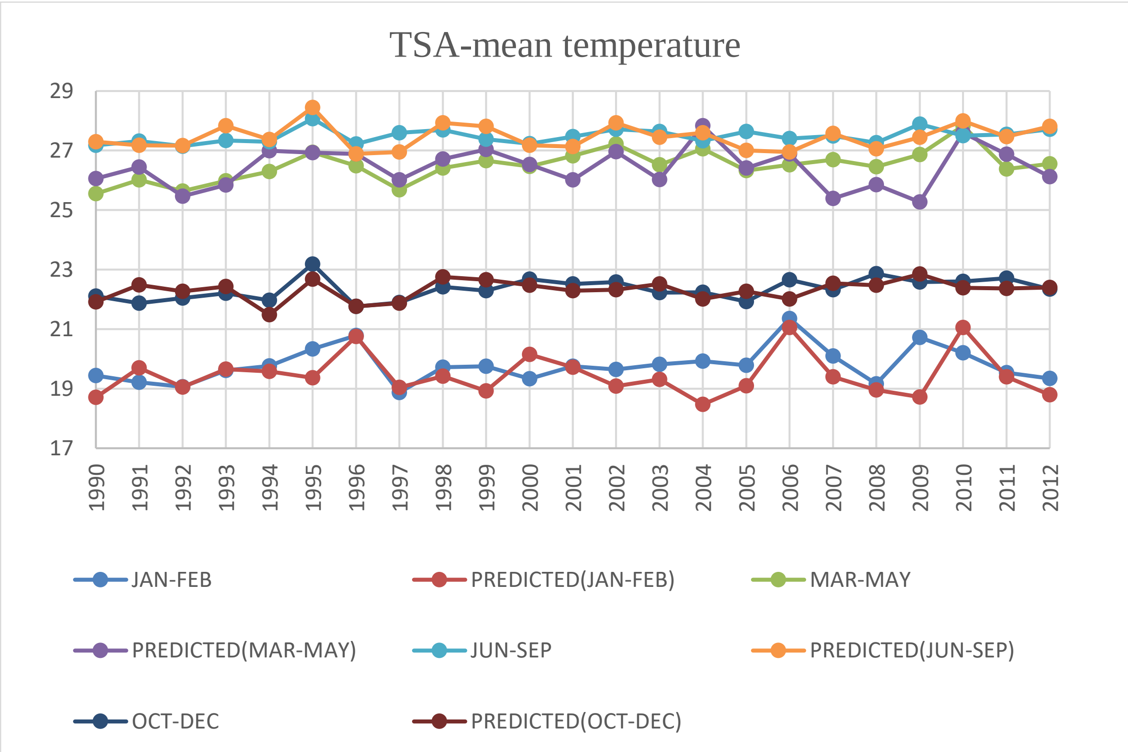

Figure 6. Year wise seasonal forecast

The seasonal wise forecast has resulted in a forecast accuracy of 97.259%, 98.222%, 98.989%, 98.709% and error of 2.741%, 1.778%, 1.011% and 1.291% for January-February, March-May, June-September and October-December respectively.

IV. CONCLUSION

Today's world is filled with many innovations. Lot of researches are still going on to automate agriculture. This work mainly focusses on the automation of irrigation and power management which is in need. The proposed system provides power management using solar energy which is abundant in nature. We can also use wind or any sort of renewable energy instead of solar. Flooding of fields during rainy season can be prevented and also easy recharge of ground water is attained by this project. Temperature for crops is maintained using reflector which is cost effective than constructing a green house. In the model, manual threshold level is fixed for comparison. We can also use wireless data connectivity where cloud holds data sheets of various types of soil and its properties and also data about different crops that can be grown in a particular soil. This feature helps us to select threshold values that suit different crops based on their soil type.

V. FUTURE SCOPE

In future, system can be updated using advanced technologies for attaining higher rate of productivity

The prototype model is built using wired connection. The project aims to implement the system using wireless connection. We can add additional features like camera for monitoring intruders into the field, pest control measures, soil type detection etc. using data analytics in fog technology.

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