Energy-Efficient Smart Farming with IoT-Fog-Based Dual Power Management System

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Abstract

Agricultural use of alternative energy has become more prevalent. Utilizing the alternative source when it is widely accessible is economical and prudent. Drip irrigation may be even more effective when alleviated with renewable energy via a power grid link. Fog computing is a cutting-edgemethod for extending cloud services to the network's edge. With compute and storage capabilities, it offers a widely dispersed, virtualized platform. Fog could analyze vast volumes of data before sending it to the cloud. This work proposes an innovative agricultural system with integrated hydropower management and its functional blocks. For processing and decision- making in this system, the fog router received field data from the aggregator. To use the data for analysis in the future, it will be stored in the cloud. Wehave constructed an intelligent irrigation and power management system based on the IoT in our suggesteddesign with IIPMS. This prototype model detects heat and light using temperature and light sensors. If this dual parameter is discovered to be sufficient, the intelligent switch automates the switchover to solar power. The gadget and motor operate on a regular power supply from the power plant. Through GSM technology, the cloud informs the farmer about the type of electricity being used and information linked to power, such as voltage. To inform the farmer of the availability of solar power, a built-in prediction module was also proposed with the Time Series Analysis based forecasting to carry out forecastingduties (TSA). Based on the simulation study, we claimed that the proposed approach performs better in various real-world agricultural scenarios. We also compared our energy consumption model with the existing models and claimed the efficacies of the proposed approach.

Keywords: Smart Farming; IoT; Fog Computing; Dual Power management

I. Introduction

Water and food are two unbreakablenecessities that allow people to live on Earth. Water usage will treble over the next three decades, in line with a survey conducted by the International Water Association (IWA) [1]. This emergency, which resultsin a water fight, is imminent since Day Zero has already had an impact Considerable impact on many wealthy nations. Ourdaily lives depend heavily on agriculture. The first conventional irrigation technique, bucket irrigation,involved farmers manually pumping water to fieldcrops while using buckets to collect the water. As theneed for improved productivity (field extension foradditional crops) and water conservation has expanded, many irrigation systems have beenintroduced into fields.

Drip irrigation was more effective despite various irrigation techniques because it conserves water, retains soil moisture, requires less human interaction, and is simpler to integrate various technologies [2][3]. These days, there are numerous renewable energy sources available, including thermal, nuclear, and other renewable sources like solar and hydropower [4]. The original method of powering pumps used to irrigate fields was through fossil fuels. The techniques utilized to generate electricity evolved along with technology. Back then, fossil fuels (diesel, gasoline) were used using electricity generators or transferring power to the pump using a drive belt and vertical shaft. To power motorized pumps. Additionally, some

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flushes for submersibles utilize directly moving technology.

An electric pump can be directly powered by renewable energy via a power grid link. However, the supply's dependability, expense, availability, and quality affect how this energy source is used.
The easiest way farmers can get electricity is through solar energy. Farmers generally have several large structures with excellent solar system placements and roofs that are entirely exposed to the light without being blocked by trees. Because of this, agricultural use of alternative energy is becoming more and more popular. The force produced by this sustainable resource can be both on and off the farm.

The Web of Things is made possible by conventional fields such embedded systems, wireless sensor networks, control systems, automation (including home and building automation), and more. IoT technology is most closely linked to the concept of the "smart home" in the consumer market, which comprises of gadgets and appliances that can be used to support one or more common ecosystems and are controlled by ecosystem-related technologies likeSmart speakers and smartphones.

Fog computing may allow for the relocation of Cloud services closer to the edge of the network. It offers a highly decentralised platform that is virtualized and has computation and storage capabilities. Fog may analyse vast volumes of data before sending it to the cloud. This helps to reduce bandwidth usage and speeds up decision-making. There are many tiers of processing and storage, with the lowest levels being nearer higher levels and the edge spanning a larger geographic area. The cloud is the utilities' central hub for intelligence and data collection [5].

2.Literature Survey

A. The Role of Irrigation and Agriculture Using IoT Systems

Puranik et al. The approach aims to automate crop monitoring, water management, insecticide and pesticide control, and maintenance. They have used a variety of field-based sensors to determine temperature, pH, and moisture levels to irrigate the area [6]. The model was also created to assess the water's availability inside the tank or well**.**
Over the previous five years, the fog computing method has handled many applications. Unfortunately, fog can only be used in a limited number of applications. However, Bellavista et al. conducted a study Regarding fog computing and proposed numerous fog technology-based solutions [7]. The study's goal was to thoroughly analyze the many fog computing solutions available to fulfill the needs of IoT applications, outlining how they could beused separately and in combination to serve different objectives.

It was advised to provide a general introduction to the IoT-based agriculture monitoring system [8]. They described a strategy to reduce humaninvolvement in the sphere and managed the automatic irrigation of different crops. Farmers are aware of howto properly analyze changing moisture, temperature, and humidity levels to decide when to irrigate their crops and carry out all other necessary tasks for optimal growth. This study offers a generative federated learning framework for semi-supervised threat detection in an IoT-assisted smart grid system. We refer to this framework as FSEI-Net. A unique semi-supervised edge intelligence network (SEI-Net) is presented in the FSEI-Net to enable semi-supervised training using labeled and unlabeled data in the edge tier. The design of SEI-Net is based on with bidirectional generative convolutional network that can intelligently capture the patterns of threat data from partially labeled smart grid data [14].

Drip irrigation is an option to reduce backwater usage, yet it does not happen automatically.Anushreet al. proposed using a drip irrigation system to control plant irrigation automatically and manually [9]. The technology set up a live stream of the finisheddripping irrigation on a website so buyers could observe the sphere from a distance. Additionally, human intervention is minimized, and overall water waste is decreased. It has been demonstrated that IoT can be usedin agriculture as a decision-making tool [10]. Here, a concept is put out in which The Penman-Monteithalgorithm is used to gather data from the sphere, store it on a server, and analyze it to estimate how much water a crop requires. The method offers fertilisers based on the nitrogen, phosphorus, and potassium (NPK) values of the soil to achieve optimal crop yield. Additionally, it generates an irrigation schedule based on inputs such as the date of sowing, the percentage of soil moisture, and the standard waterrequirement for the crop. Considering the farmer's ease of access toinformation and combining to give one system management over all deployed systems, a techniquefor achieving precision in agriculture was developedby Kumar and Ramudu. [11].

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Mekala and Visvanathan found that several well-documented uses of IoT Sensor Monitoring Networks and cloud technologies approaches, such asa black bone or skeleton in agricultural areas, are available in their study on a cloud-based, IoT-based smart agricultural solution. The significant contributions that mobile phones have made to enhancing communication and data delivery for agricultural growth are highlighted by Masuki et al. findings. .'s where it was also considered how to connect farmers with market outlets and service suppliers. [13]. It is merely an overview of the numerous functions that a mobile device might perform to boost productivity. They found that farmers were considerably more enthusiastic about using their mobile devices to get information about markets, resource management, andland.

B. Agriculture Using Sensor Networks and Fog Computing

The development and research in the highly sought-after domains of sensor networks and fog computing served as the foundation for this survey.

For smart farming, Fog computing was used by Malik et al. to develop a distributed simulation [15]. They proposed a collection of technologies offering a full farming ecosystem with sensors and foglocations. As a result of concurrent communication, their study shows that the suggested toolkit is hardware-based and provides a platform for computing sensor energy, packet delivery ratio, and transmission latency.

Considering the simplicity of data availabilityfor farmers, Kumar and Ramu created a method to achieve agricultural precision, allowing them to control the system [11]. The system's user interface is straightforward, making it easy for farmers to operate. Additionally, the technology will keep farmers well-informed of every second-by-second occurrence in thefield.
Mekala and Viswanathan of Research wasdone using Cloud Computing and Smart Agricultural IoT. and compiled a list of typical uses for Agri technologies for IoT sensor monitoring networks are based on cloud computing [12]. The key goal is to create the ideal architecture for the Agri-IoT, which should have gadgets with low power consumption, improved decision-making procedures, quality of service offerings, affordable pricing, idealperformance, and farmer-friendliness.

Farmers, marketing companies, and their suppliers must register via a mobile app for the agro cloud module, according to Hema lata et al. (2015).'s [11] research on a transdisciplinary paradigm using IoT sensors, the cloud, and mobile computing. In addition to other data that will be analyzed, it offers analysis for the most productive crop sequence that might be employed, overall crop production in theinterest region, total fertilizer needs for each sector, and other information.

Crop growth may be significantly impacted by soil hydration. The projection of production can benefit from advanced environmental understanding—better water utilization and irrigation scheduling. In November 2014, Liu et al. studied combining weather data with statistics on soil moisture and forecasting of soil moisture assisted by an extreme learning machine.[10]

Mother Nature is full of solar energy. You can collect it and utilize it to irrigate farmland. For this, see Khiareddine et al. suggestions.'s in [15]. Theywere in charge of a pumping system run by batteries and solar panels. The focus of this essay is energy management and dynamic modeling. A lead acid battery, an induction motor, and a pump are all connected. This acts as a burden. The simulation'sfindings indicate that any excess power will be kept inthe battery for backup.

Raulter et al. evaluated the effectiveness of the sensor network in managing energy, the numerous demands made on the strategic analysis, and the powermanagement system utilized to define the various variables influencing the power management system based on field research [12].

Mani et al. perform power management, device monitoring, and control using a machine-to- machine communication system. This automated approach is effective in saving energy [10].

Applications for power distribution and management using fog computing have resulted in developing a new method known as the Internet of Energy using a layered architectural approach (IoE). [13] Despite the numerous techniques and technologies employed in agriculture, an intelligentsystem that will effectively use and store essential and in-demand resources is still required for future demands. The proposed architecture is made toaddress this need.

3.Smart Irrigation and Power Management Architecture With Iot- Fog Support

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The recommended design attempts to typically manage hydropower and electric resources. Managing floods, power, and irrigation are all incorporated into the system. The IoT-based agriculture system that is now in use is shown in Figure 1 below.

The current agricultural monitoring system extends the workflow that enables autonomous systems to thrive without human intervention by automating the process of fixing any issue that occurs at any node of the current automation system.Workflows that tend to raise the system's level of automation were also included.

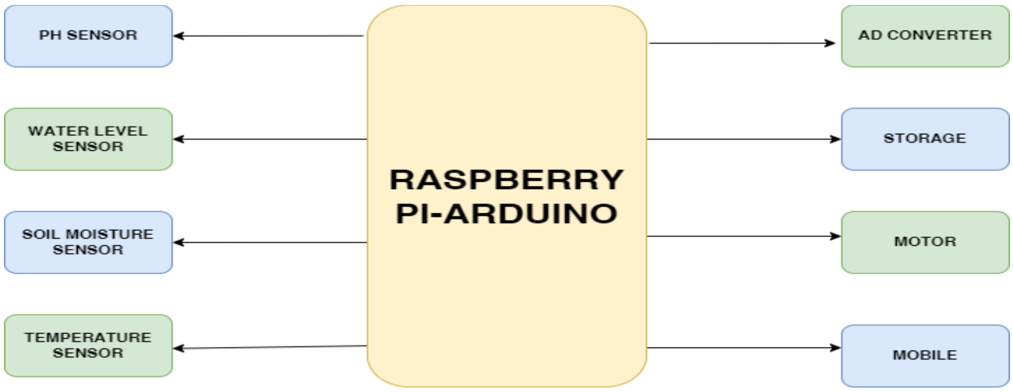

Figure 1: Existing IoT Based Agriculture System

Electricity is produced using various renewable resources, including solar, nuclear, and thermal. Solar energy is a plentiful and convenient energy source. It is available virtually year-round in the majority of Asian nations. Figure 2 shows a prototype model of an intelligent agriculture system and its functional blocks.

The functional architecture of IIPMS is constructed using a variety of agricultural andhydraulic sensors, including humidity, temperature, and water level sensors, etc., to sense the environmental conditions. The temperature sensor calculates the ambient temperature, and the amount of solar energy transformed into the voltage required to power a motor pump is determined by intelligent voltage meters.

Hazardous compounds that are detrimental to plant growth can be detected using a TDS meter to assess the water's quality. The amount of water in the field is determined by a soil moisture sensor and a water level indicator, which helps the system decide whether to pump or reverse pump. Thepower-switching action is based on the light intensity determined via the LDR. To generateelectricity for free, artificial light intensity is produced using reflectors. In this system, the aggregator collects various field data and sends it to the fog router for analysis and decision-making. To use the data for analysis in the future, it is stored in the cloud.

A. Functional Overview of Smart AgriculturalSystem

We are constructing an intelligent irrigation and power management system based on the Internet of Things in our suggested design (IIPMS). This architecture uses a DHT11 sensor to measure the temperature and humidity of a field of crops.

Therefore, we may turn the motor ON or OFF using a soil moisture detector by examining the soil's conditions. Additionally, the amount of water in the field is determined using a water level indicator. For the water pumps to suction the water outwardly toward the filter bed or the drainage. The LDR is utilized to indicate daytime. Ordarksoit can notify the appropriate person via email alert that the product uses renewable energy sources and to take precautions (e.g., Solar energy, Wind Power, Hydro Power). We can activate the plant's reflector nutrition from any location and use the reflector to provide plants with synthetic sunlight. This ensures that the climate is favorable for plant development. The Blynk app is used to keep track of all of these statistics. Data about temperature, humidity, moisturecontent of the soil, elevation, and LDR condition are displayed via the app. These indicators are visible by LED and are switched on and off.

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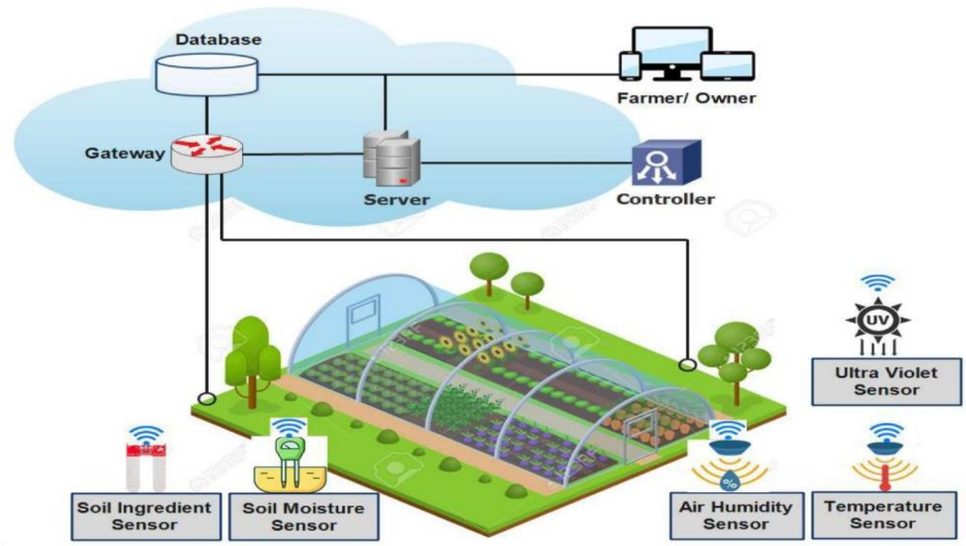

Figure 2: Functional Overview Of Smart Agricultural System

B. Running of IIPMS

The IIPMS consists of four functional modules for smart power management, field monitoring, and enhancing crop growth.

1. System for Monitoring Crops

The farmers can now remotely monitor the activity intheir fields thanks to this device. This module prevents harvesting heaps and monitors the crops already sown.
The burglar alarms The infrared sensor is placedat different heights above the ground. In order toproduce a high-frequency sound that will dissuade animals and birds from destroying the priceless crop, the hummer will be activated whenever the system detects a suspect entry.

2. System of Two Pumps

Currently, the IIPMS prototype model has a dual pumping motor. The irrigation system is powered by Motor M1, which pumps water from a borehole to thefields following the crop's requirements. Crop-based water and moisture demand data from a cloud data source are used to control the Arduino unit, enabling water loss conveyance [l kJ WCC] via intelligent pipes. The second pump, M2, is a flood prevention and groundwater booster. During dry seasons, it removes additional water from the field and returns it to the groundwater top-up pit, reducing the water

deficit and safeguarding the crops from flooding.Figure 3 below illustrates the conceptual flow.

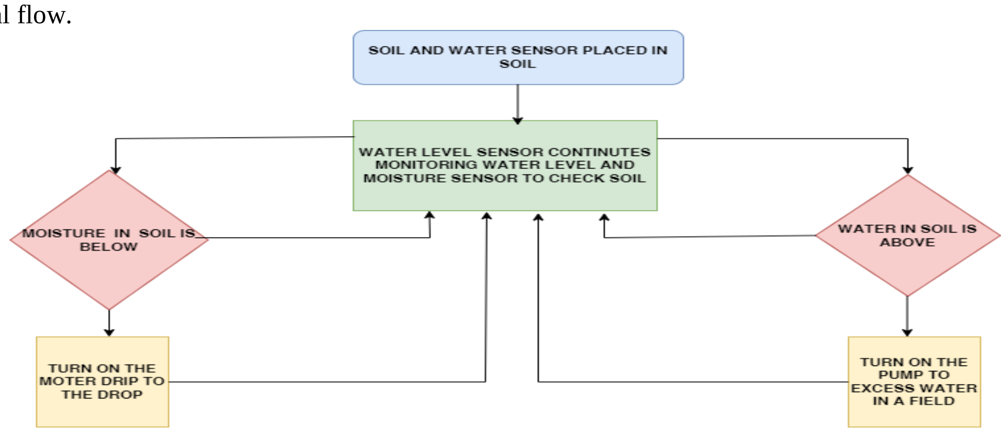

Figure 3: Dual Pumping System

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SMS messages tell recipients of the amount of water pumped IN and OUT. The formula below is a diagram of hydraulic flow. [14].

$CylinderArea{:}(Sq.\ In.) = \pi \times (inch)2/4)$ (1)
$CylinderForce{:}(Pounds) = Pressure(psi) \times Area(sq.\ in.) = Pressure \times Area/2000(Tons)$ (2)
$PumpOutputFlow{:}\ GPM = ((Speed(rpm) \times disp.\ (cu.\ in.)))/231 GallonsperMinute$ (3)
$CylinderRamSpeed{:}(Inches/sec.) = (((0.3208 \times gpm))/Area) \times 12 \times efficiencyrate 85\%$(4)

$MotorHorsepowerrequi{:}(Horsepower) = gpmxpsix 0.000583$(5)

3. Smart Power Switching

Utilizing the alternative source when it is widely accessible is economical and prudent. Thisprototype model detects heat and light using temperature and light sensors. If this dual parameteris discovered to be sufficient, the intelligent switch automates the switchover to solar power. The gadget and motor operate on a regular power supply from the power plant. Figure 4 shows the functional block in more detail.

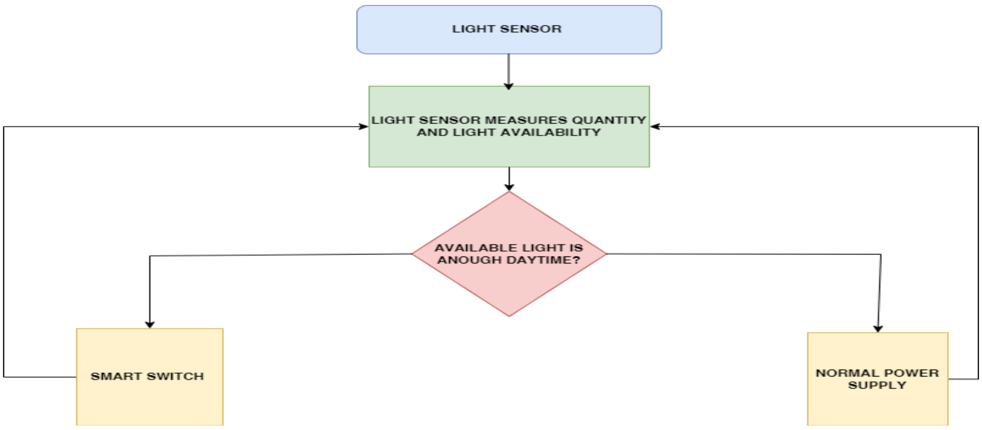

Figure 4: Smart Power Switching

Through GSM technology,the cloud informs the farmer of the type of electricity being used and information linked to power, such as voltage.

4. Reflector System

The field's corners are marked with dual-purpose reflectors. The field-installed temperature sensor determines if the environment's temperature.

suits the crop. It also refreshes the data via an aggregator to the cloud for additional usage analysis. The controller turns on the reflectors with lasers if thecrop's temperature is insufficiently placed throughout the field to provide the crop with the necessary temperature. On the other hand, the technology can create artificial solar electricity that contributes to

solar energy production in the off-season. At regular periods, the cloud is updated with all of this data. Figure 5 shows the functional ability in action.

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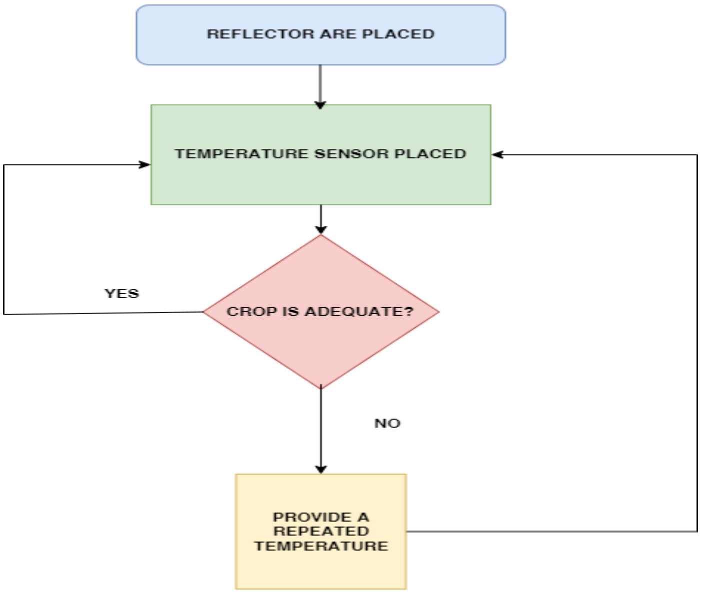

Figure 5: Reflector System

5) Solar Energy Forecasting

An integrated forecast module uses the TimeSeries Analysis forecasting approach to perform forecasting tasks (TSA) in order to inform the systemand the farmer about the availability of solar energy.

The relevant dataset, which spans 1900 January to December 2017 & offers details on solar energy use by season, is available to all (gata.gov.in).The structure of the set of available data is described in Table 1 below.

The forecast model was trained using 80% of the data, meaning data up to season 4 in 1990. The forecast is prepared from Season 1 in January 1991until Season 4 in 2012
The calculation formula for inaccuracy and accuracy

$percentageerror = actualvalue - predictedvaluea$
$ctualvalue * 100(\%)$ (6)
$Percentageaccuracy = 100 - percentageerror$ (7) Table 1 represents the monthly weather obtainedfrom the open-source dataset provider Kaggle.
Table 1 describes the dataset about the weather recorded from 1901 to 2017, which is described and trained and the same was tested using a random sampling method (80% training and 20% testing).

Table 1: Dataset of India

Year	Jan-Feb	Mar-May	Jun-Sep	Oct-Dec
1901	23.27	31.46	31.27	27.25

Table 2 : weather forecast analysis (Part 1)

1902	25.75	31.76	31.09	26.49
1903	24.24	30.71	30.92	26.26
1904	23.62	30.95	30.66	26.4
1905	22.25	30	31.33	26.57
….	….	….	….	….
2012	25.03	32.33	31.77	27.88

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2013	25.58	32.58	31.33	27.83
2014	24.9	31.82	32	27.81
2015	25.74	31.68	31.87	28.27
2016	28.33	34.57	32.28	30.03
2017	27.95	34.13	32.41	29.69

Table 3: weather forecast analysis (Part 2)

	Jan-Feb	**prediction (Jan-Feb)**	**Mar-May**	**prediction (Mar-May)**	**Jun-Sep**	**prediction(Jun-Sep)**	**Oct-Dec**	**prediction (Oct-Dec)**
1901	23.27	24.04	31.46	32	31.27	32.01	27.25	28.14
1902	25.75	24.62	31.76	30.65	31.09	30.1	26.49	28.56
1903	24.24	25.66	30.71	32.12	30.92	31.74	26.26	24.66
1904	23.62	25.74	30.95	31.99	30.66	31.66	26.4	28.65
1905	22.25	23.96	30	31	31.33	30.48	26.57	25.12
….	….		….		….		….	
2012	25.03	26.87	32.33	33.55	31.77	35.12	27.88	29.77
2013	25.58	26.45	32.58	31.78	31.33	36.47	27.83	28.25
2014	24.9	25.63	31.82	33.65	32	35.45	27.81	26.44
2015	25.74	26.45	31.68	29.45	31.87	38.78	28.27	25.44
2016	28.33	27.44	34.57	30.55	32.28	29.45	30.03	34.89
2017	27.95	26.98	34.13	39.45	32.41	29.65	29.69	30

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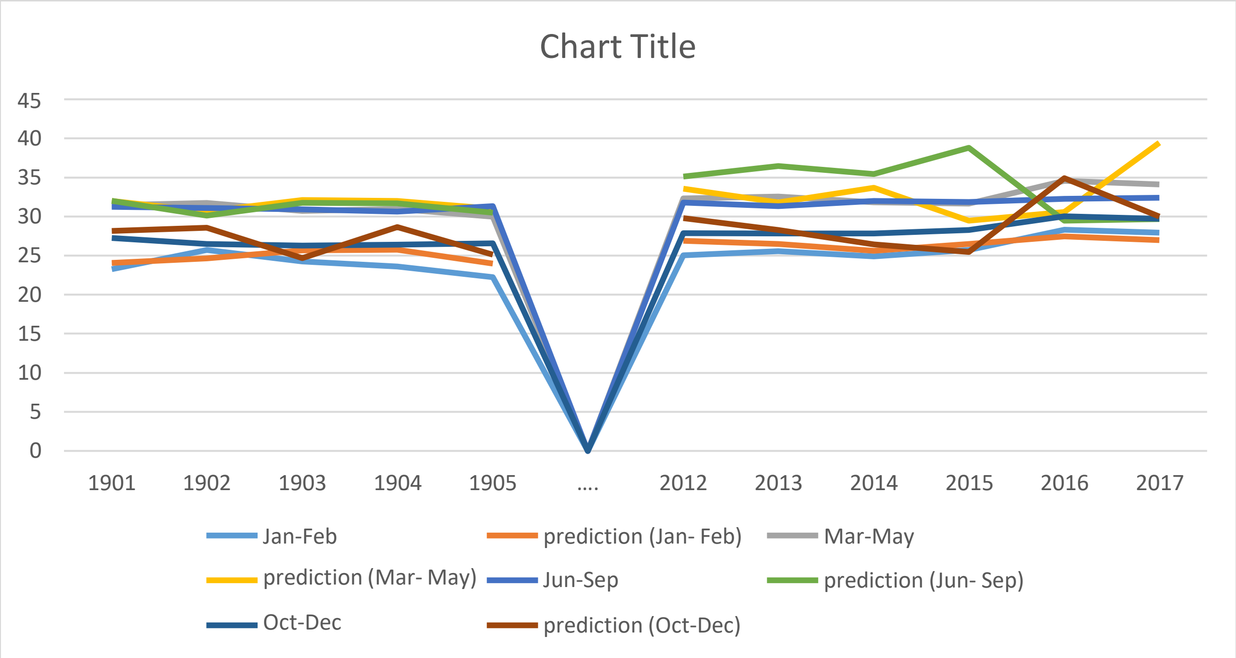

Figure 6: Actual vs prediction chart

Figure 6 illustrates the efficiency of Time series- based ARIMA in predicting the weather concerning the actual recording.

5. Conclusion

The world of today is an innovative place. Much research is still being done on agriculture automation. This effort primarily focuses on the need of the hour intelligent automation of irrigation and power management. The suggested method manages power utilizing solar energy, which is plentiful. Instead of solar energy. we can utilize solar, wind, or any other renewable energy source. With the help of this project, it will be possible to quickly recharge the groundwater and prevent flooding of fields during therainy season. Reflectors are used to manage crop temperature, which is more affordable than building agreenhouse. For comparison, the manual thresholdlevel in the model is fixed. Additionally, wireless internet access is an option. The cloud saves data sheets on the many types of soil and their characteristics and details on every sort of soil with a different crop that can be cultivated there. Using this functionality, we may choose threshold values based on the soil types of various crops.

7. Future Scope

Future system updates will be possible thanks to modern technologies, increasing productivity. Wire connections are used in theprototype model's construction. The temperatureprediction will also facilitate the innovative dual. power system to forecast possible power generation, which enhances the cultivator's decision on how much power can be sold via the power grid. Using data analytics in fog technology, we may add extra functions like a camera to monitor field intrusions, pest management methods, soil type detection, etc.

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