Conceptual View of Low-cost Sensory Evaporimeter Based on Internet of Things (IoT)

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***Abstract*— Evaporimeter, a scientific device is used to measure the rate of water evaporation into the atmosphere from a wet surface. Using this instrument, we are able to calculate irrigation scheduling, crop selection to the different geographical area and future prediction of drought. Now a day's the compressive development of wireless sensor and Internet of things (IoT) can be embedded with manually operated evaporimeter. In this paper our main intensiveness on the modernization of Class-A Pan Evaporimeter with low expenditure. By deploying different types of sensors on manually operated evaporimeter and exchange data with servers is not only reduce the manual effort but also feasible it for real-time remote area operation. Here we focus on the conceptual idea and algorithm for the design of low-cost sensory evaporimeter based on IoT.**

***Key words* –Pan Evaporimeter, Internet of things (IoT), sensors, sensory evaporimeter, ultrasonic sensor, and wireless sensor network**

I. INTRODUCTION

Water, the most precious resource with which a life can be prolong on Earth. From the availability of freshwater resource in worldwide, 85% of water is used in agriculture. Now a days due to population growth and increase in food demand needs a strategies plan for optimum use of water based on Science and technology in the field of agriculture[1].

The source of all fresh water on the land is due to precipitation. Major part of precipitation again returns back to atmosphere due to evaporation and evapotranspiration. Evaporation is the process where increase in temperature and/or pressure make a substance in liquid state to gaseous state. Evapotranspiration (ET) is the sum of evaporation and transpiration from plants. For the efficient use of water in irrigation rescheduling we need to calculate ET. A system depends on ET can save water up to 42% by time-based irrigation schedule [2]. Evapotranspiration loss generally measured by following methods are Measurement using evaporation pan, Empirical equations, Water balance methods, Energy budget methods, and Mass transfer methods. Evaporation pan method is quite often used. In this method an instrument called as Evaporimeter is used to measure the rate of evaporation of water into atmosphere. As a result in addition with evapotranspiration loss, crop selection to different geographical area and future prediction of drought can be done.

In 1965 Schooley [3] first came up with an evaporation rate meter called as evaporimeter, which has shown promise of directly measuring the rate of evaporation near the sea surface. The plainness of the instrument was the point of interest to oceanographers, meteorologists and climatologists. Bloemen [4] proposed a high accuracy instrument pan evaporimeter with some of its possibilities. A real time testing was done by Palland [5] using a new type of evaporimeter called as Evaporation brush in a field of meadow grass for measuring continuously evaporation. A comparison was also made by the measured data and the calculated data from a modified penman formula. Relationship between evaporation from different evaporimeter and metrological parameters was figured out by Iruthayaraj and Morachan [6].

The importance of Pan Evaporimeter in irrigation scheduling was first brought into picture by Reddy *et al.* [7] in 1983. It was carried out for wheat and maize grown in a semi- arid region, India. Ertek *et al.* [8] used pan evaporimeter to find the most appropriate irrigation frequency and quantity in cucumber grown in 2006 under field conditions. This instrument was also tested for tomato and cucumber grown in solar greenhouse, China [9]-[10]. For seasonal crops water requirement was also tested by Liu *et al.* [11]. The ongoing food demand with fixed water recourse needs to deploy pan evaporimeter for large scale cultivation.

For continues monitoring of pan evaporimeter was designed by Asrar *et al.* [12] by using strain gages mounted on four supporting arm. System with a high sensitivity, the evaporation measurement was 5% of manual measurement. The Modification and up gradation of evaporimeter was done by Williams *et al.* [13] by designing a simple portable evaporimeter and Boughton *et al.* [14] by reporting an automatic class A pan evaporimeter for a long-term unattended operation. Chow [15] described the design and operating characteristics of a fully automated evaporation pan with a correlation coefficient greater than 0.98 between manual and automatic reading. Modeling of pan evaporimeter was also done by linear genetic programming (LPG) in Turkey. The result indicates that modeling by LPG is better than the Fuzzy genetic, adaptive neuro-fuzzy inference system, artificial neural networks, and Stephens-Stewart models [16]. The development of wireless sensor networks based on microcontroller and current communication technologies can improve the methods of monitoring in real time [17]. Using the concept of WSN work like automated irrigation system, agriculture environment monitoring, control of an irrigation system have already done [18][19][20].

In the era of IoT we have given a little for design a low cost sensor base evaporimeter based on IoT which is not implemented yet. The main objectives behind sensory evaporimeter based on IoT are

- Connect to remote database for real time access.
- Improve accuracy
- Reduce manual effort

The paper is organized as Follows. In section II, Components of sensory evaporimeter are studied. Section III, shows the conceptual view of sensory evaporimeter. Conclusions are presented in section IV.

II. SENSORY EVAPORIMETER

A system layout of IoT based automatic sensory evaporimeter is illustrated in Fig. 1. The system mainly consists of field data station, data storage unit and remote access unit.

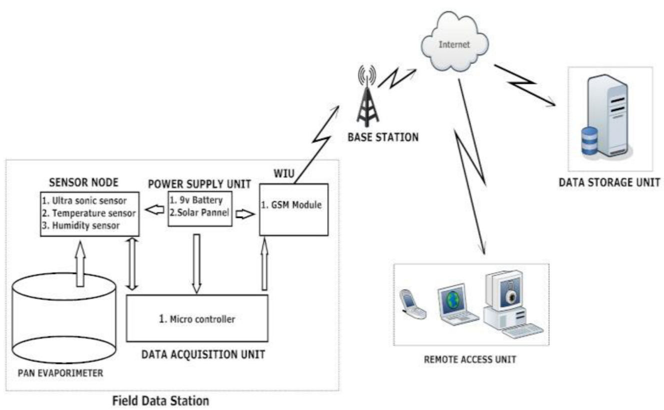


Fig. 1 System layout of IoT based sensory evaporimeter

A. *Field data station*

Field data station is comprised of five units named as manual operated Pan Evaporimeter, Sensor node, Data acquisition unit, Wireless information unit (WIU) and Power supply unit. The Field data station works include the sensing of raw data from evaporimeter to transmit meaningful data to the storage unit. Data acquisition unit is used to do some mathematical calculation taking sensing data as its input parameter and convert the raw data into user required data.

1) *Pan Evaporimeter:* Pan Evaporimeter is a manual operated scientific instrument. Pan is usually installed on a wooden platform having a fixed dimension on a grassy location. It is used to hold water during observations in order to determine the quantity of evaporation at a given location. Bureau of Indian standards has given the required specification in IS 5973(1998) draft for designing a pan evaporimeter[21]. In order to design a pan evaporimeter it requires a standard pan, wire mesh cover and wooden platform. Standard pan is only to specify that pan must be made from copper or non-rusting, non-magnetic stainless steel sheet of 1.0±0.1 mm thickness conforming to IS 1550 or IS 5522. The diameter and height of standard pan should be 1220±03 mm and 255 mm respectively. The wooden platform must have height and width of 100 mm and 1225 mm respectively. After filling water it is covered with wire mess in order to protect water from birds and animals. According to Indian Metrology Department (IMD) we have to take water level reading at 8.30 A.M. and compare the reading data of previous day to know the evaporation loss on yesterday or use to fill water by calibrated jug till the pointer of Stillwell just touch the water surface to know evaporation. The World Metrological Organization has recommended the minimum network of evaporimeters station. For Arid Zones -1 station for every 30,000sq.km, Humid temperature Zones – 1 station for every 50,000 sq.km and cold regions – 1 station for every 1,00,000 sq.km.

2) *Sensor Node:* The sensor node is consisting of four sensors. They are two ultrasonic sensors, one temperature sensor and one humidity sensor. The use of ultrasonic sensor Hc-sr04 is to measure pan evaporimeter water level in millimeter range. By deploying two ultrasonic sensors we can increase the accuracy by the method of output comparison. The ultrasonic sensors generate sound waves and speed of wave mainly depends on two parameters known as temperature and humidity. So the temperature sensor and the humidity sensor are used to improve the accuracy of ultrasonic ranging equation for outdoor environment. These two parameter temperature and humidity also required for calculation of ET. Dundar [22] has done neural network based ultrasonic level measurement of fluids. Level of fluids has been measured in interval of [0 to 30] cm at error of 10^{-8}. Here we are using this sensor for millimeter range of operation.

3) *Data acquisition unit*: In this unit we can use a microcontroller for counting the time gap form trigger the ultrasonic sensor to receive echo. For counting time gap we have to use timer operated on external input mode. To increase accuracy we can use two timers that are Timer 0 and Timer 1. TMOD is 8 bit register, used to handle timer mode of operation. For example if we use 8051 family microcontroller then Pin 3.2 (INTO) and Pin 3.3(INT1) can connect to echo pin of ultra sonic sensor. We can use DPTR 16 bit special register to store timer value for further calculation. While choosing micro controller we must keep in mind that it should be low cost.

4) WIU: In wireless information unit (WIU) we can used GSM module to get GPRS access or ZigBee wireless network based on IEEE 802.15.4 standard. Although ZigBee has low power operation and widely use for communication but it needs GPRS network to connect with internet. Only for low cost we prefer GSM module rather than other wireless communication device. In GSM module we don't need to set up a network and now a day wide range of mobile operation pushing its network limit to a greater extent. AT command is used to give command to GSM module (SIM900). AT stands for attention. These commands are used to communicate with the GSM, GPRS, CDMA, GPS modem. We can set up a HTTP, TCP or FTP connection using this modem. Here we prefer for FTP connection. To initiate GPRS connection and to make successful FTP data transfer it has to follow set of AT commands which is shown in TABLE I. After storing the file into the server one can log in by proper user name and password to fetch the evaporation reading, temperature reading and relative humidity reading.

TABLE I
USE OF AT COMMANDS FOR GPRS & FTP CONNECTION

Command type	AT commands format	Use of AT commands
Common	AT	Make attention
GPRS Connection	AT+SAPBR=3,1,"Contype","GPRS"	start GPRS connection
	AT+SAPBR=3,1,"APN","xxxxx"	set Access Point Name
	AT+SAPBR =1,1	turn on GPRS connection
	AT+SAPBR=2,1	check IP address allotted
	AT+SAPBR =0,1	close GPRS connection
FTP connection	AT+FTPCID=1	start ftp connection
	AT+FTPSERV="xxxxx"	give ftp server name
	AT+FTPUN="xxxxx"	ftp user id
	AT+FTPPW="xxxxx"	ftp user password
Store FTP file	AT+FTPPUTNAME="xxxxx"	file name to store
	AT+FTPPUTPATH="/xx"	path name to store file
	AT+FTPPUT=1	start ftp put section
	AT+FTPPUT=2,xxxxx	How many data bit send
	AT+FTPPUT=2,0	stop transferring data
Fetch FTP file	AT+FTPGETNAME="xxxxx"	file name to get/fetch
	AT+FTPGETPATH="/xxx"	path name to get file
	AT+FTPGET=1	start ftp get session
	AT+FTPGET=2,xxxxx	how many bit want to read

5) *Power supply unit:* Except GSM module all others, sensors, microcontroller need 5V DC supply. Where GSM module needs 12 V DC supply. In this unit we use solar panel which can produce 12 to 15 V and a rechargeable battery. As we need to transmit the reading data to external server once in one day or may be twice in one day so we use power saving mode of operation rest of the time to save battery power.

B. *Data storage unit*

In order to have external access of evaporation reading we have to store data in any external server data base. We take the help of a file transfer protocol (FTP) server database to store our everyday reading. We can also use Thingspeak or Sparkfun free server for better graphical view or design own website. To communicate with FTP server from our GSM modem we must have a FTP server addressed with user id and password.

C. *Remote access unit*

For future data analysis like evaporation demand, crop selection and drought prediction we have to fetch data from server data base through log in by any remote access device like laptop, personal computer, mobiles. To log in we must know the user ID and password of the server. We have also a option for public view without a password depends on web page design software.

III. CONCEPTUAL VIEW OF SENSORY EVAPORIMETER

A conceptual view of IoT based sensory evaporimeter is shown in Fig. 2. It shows a pin level configuration of whole setup. Ultrasonic sensors which are framed here used to transmit sound pulse and receive an echo to measure object distance. But speed of sound is not fixed. It varies according to the variation of temperature and humidity of the medium. So in Fig. 2 we have embedded temperature and humidity sensor with ultrasonic sensors.

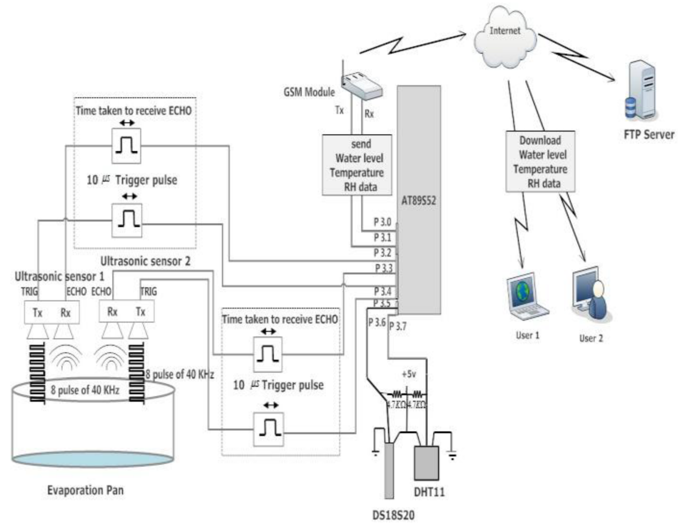


Fig. 2. Conceptual view of IoT based sensory evaporimeter.

We already have a mathematical equation to calculate speed of sound where temperature (θ℃) is only input parameter. That is

$$C_D = 331.296 + \left(0.606 \times \theta\right) m/s \qquad (1)$$

Although relative humidity will change the speed of sound maximum of 0.35% but here it has importance. In order to train ultrasonic sensor for high accuracy we must have an idea how relative humidity varies speed of sound. In TABLE II we have shown the variation of speed of sound with respect to different relative humidity.

TABLE II
SPEED OF SOUND AT DIFFERENT RELATIVE HUMIDITY

Temp(θ˚C)	RH = 0%	RH = 10%	RH = 30%	RH = 50%	RH = 70%	RH = 100%
0	331.296	331.328	331.392	331.455	331.519	331.615
5	334.314	334.360	334.452	334.545	334.637	334.775
10	337.306	337.371	337.502	337.633	337.765	337.962
20	343.210	343.337	343.592	343.847	344.103	344.489
30	349.015	349.250	349.721	350.195	350.672	351.392
40	354.725	355.140	355.977	356.821	357.674	358.970
50	360.344	361.051	362.481	363.935	365.413	367.677

By using if else condition we can add set of commands to modify the speed of sound calculated by (1) with respect to different relative humidity. Microcontroller timer which is used to measure time gap from sending sound pulse to receive echo, gives output in microsecond. But the speed of sound is in m/s. So first we have to convert second into microsecond and also meter to millimeter as water level should be measured in millimeter range. Let **x** be the time for both to and fro motion of sound, so

$$\text{Object distance } \left(\frac{X}{2}\right) = = \frac{X}{2000/C_D} \text{mm}$$

Let the denominator part as "Dividing factor = D" which is only divided with the timer count and it is varying for different speed of sound.

For $D = \dfrac{2000}{C_D}$; The Object distance $= \dfrac{X}{D}$ mm

For the calculation of dividing factor we have to consider speed of sound C_D in m/s. From (1) using mat lab we have found Fig. 3. It shows the relationship between speed of sound with respect to temperature (degree Celsius) in the primary axis and relation of Dividing Factor with respect to same temperature range in secondary axis. The need of plotting Dual Y-axis graph is only to show for what range of temperature and speed of sound, dividing factor remain same.

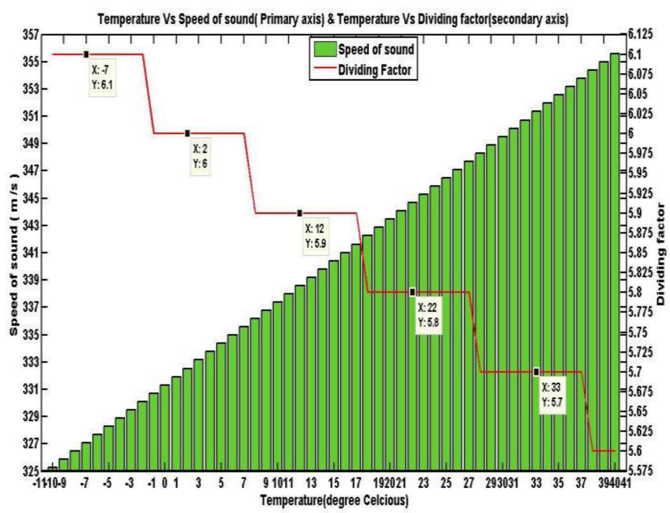


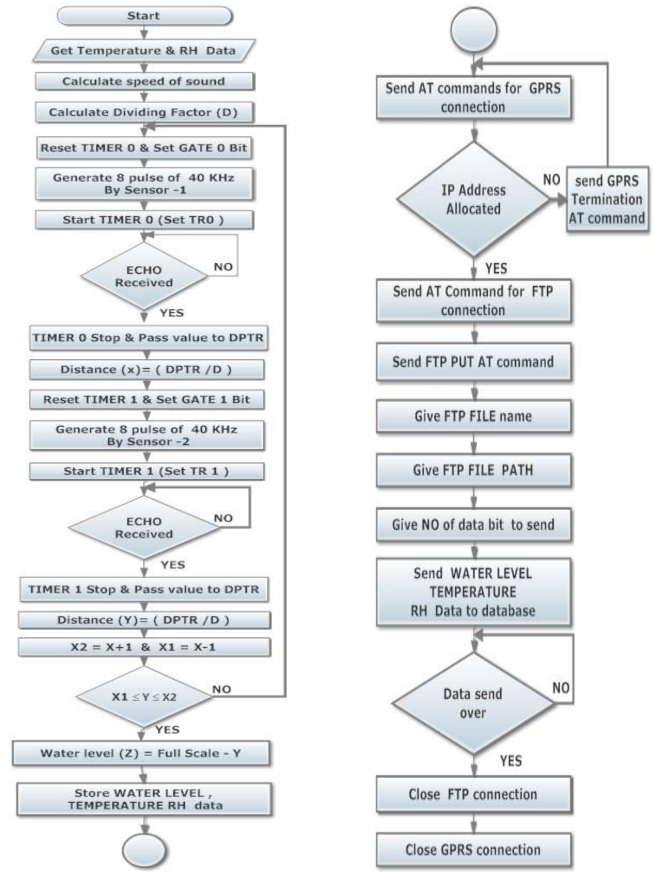
Fig. 3. Speed of sound versus Temperature (primary axis) and dividing factor versus Temperature (secondary axis).

The dividing factor for different range of temperature we have clearly shown in TABLE III.

TABLE III
D FOR DIFFERENT TEMPERATURE AND SPEED OF SOUND

Temperature	Speed of Sound (m/s)	Dividing Factor
From -10˚C to -2˚C	From 325.26 to 330.11	**6.1**
From -1˚C to 7˚C	From 330.71 to 335.56	**6.0**
From 8˚C to 17˚C	From 336.17 to 341.62	**5.9**
From 18˚C to 27˚C	From 342.23 to 347.68	**5.8**
From 28˚C to 37˚C	From 348.29 to 353.74	**5.7**
From 38˚C to 40˚C	From 354.35 to 355.56	**5.6**

After finding dividing factor we must focus on algorithm for designing sensory evaporimeter. It is divided into two parts. In the first part of algorithm [Fig 4.(a)] data acquisition unit gather different sensors data and apply as input to get a user require data. Second part algorithm [Fig 4.(b)] mainly focus on transmit meaningful data to an external FTP server for storage.



(a) (b)

Fig. 4. Algorithm of sensory evaporimeter. (a) Algorithm to get meaningful data from sensor data. (b) Algorithm to send meaningful data to FTP data server using SIM 900 GSM module.

IV. CONCLUSION

The automatic sensory evaporimeter based on IoT will be the best effort on the up gradation of manually operated pan evaporimeter by which a proper irrigation scheduling, crop selection to different geographical area can be done. Due to up gradation, just sitting at a point accessing the online evaporation database government can able to fix the present ongoing food demand with the available water resource by their farmers. There will be no need to upload data in web portal manually and at any instant researchers can access the update evaporation data. If we are able to save our resources with the help of present technology that should be the best return to the mankind.

REFERENCE

[1] W. A. Jury and H. J. Vaux, "The Emerging Global Water Crisis: Managing Scarcity and Conflict Between Water Users," *Adv. Agron.*, vol. 95, pp. 1–76, 2007.

[2] S. L. Davis and M. D. Dukes, "Irrigation scheduling performance by evapotranspiration-based controllers," *Agric. Water Manag.*, vol. 98, no. 1, pp. 19–28, Dec. 2010.

[3] AllenH.Schooley, "An Instrument for measuring evaporation,"

Saclant Asw research center, La Spezia, Technical Ad0471616, September 1965.
[4] G. W. Bloemen, “A high-accuracy recording pan-evaporimeter and some of its possibilities,” *J. Hydrol.*, vol. 39, no. 1–2, pp. 159–173, Oct. 1978.
[5] C. L. Palland, “The ‘evaporation brush’, an evaporimeter for measuring the potential evaporation of meadow grass,” *J. Hydrol.*, vol. 41, no. 3–4, pp. 363–369, May 1979.
[6] M. R. Iruthayaraj and Y. B. Morachan, “Relationship between evaporation from different evaporimeters and meteorological parameters,” *Agric. Meteorol.*, vol. 19, no. 2–3, pp. 93–100, Mar. 1978.
[7] M. G. Reddy, Y. Y. Rao, K. S. Rao, and K. Ramaseshaiah, “A preliminary study on scheduling irrigation with can evaporimeters,” *Agric. Water Manag.*, vol. 6, no. 4, pp. 403–407, Aug. 1983.
[8] A. Ertek, S. Şensoy, İ. Gedik, and C. Küçükyumuk, “Irrigation scheduling based on pan evaporation values for cucumber (Cucumis sativus L.) grown under field conditions,” *Agric. Water Manag.*, vol. 81, no. 1–2, pp. 159–172, Mar. 2006.
[9] H. Liu, A. Duan, F. Li, J. Sun, Y. Wang, and C. Sun, “Drip Irrigation Scheduling for Tomato Grown in Solar Greenhouse Based on Pan Evaporation in North China Plain,” *J. Integr. Agric.*, vol. 12, no. 3, pp. 520–531, Mar. 2013.
[10] Z. Wang, Z. Liu, Z. Zhang, and X. Liu, “Subsurface drip irrigation scheduling for cucumber (Cucumis sativus L.) grown in solar greenhouse based on 20cm standard pan evaporation in Northeast China,” *Sci. Hortic. (Amsterdam).*, vol. 123, no. 1, pp. 51–57, Dec. 2009.
[11] X. Liu, L. Shao, H. Sun, S. Chen, and X. Zhang, “Responses of yield and water use efficiency to irrigation amount decided by pan evaporation for winter wheat,” *Agric. Water Manag.*, vol. 129, pp. 173–180, Nov. 2013.
[12] G. Asrar, R. J. Kunze, and D. E. Linvill, “Automating a class a evaporation pan for semi-continuous recording,” *Agric. Meteorol.*, vol. 25, pp. 275–281, Jan. 1981.
[13] R. Williams, A. Zangvil, and A. Karnieli, “A portable evaporimeter for rapid measurement of the evaporation rate of water,” *Agric. For. Meteorol.*, vol. 32, no. 3–4, pp. 217–224, Sep. 1984.
[14] W. C. Boughton and R. J. McPhee, “An automatic recording Class A pan evapo-pluviometer for long-term unattended operation,” *Agric. For. Meteorol.*, vol. 41, no. 1–2, pp. 21–29, Oct. 1987.
[15] T. L. Chow, “Design and performance of a fully automated evaporation pan,” *Agric. For. Meteorol.*, vol. 68, no. 3–4, pp. 187–200, Apr. 1994.
[16] A. Guven and O. Kisi, “Monthly pan evaporation modeling using linear genetic programming,” *J. Hydrol.*, vol. 503, pp. 178–185, Oct. 2013.
[17] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, “A survey on sensor networks,” *IEEE Commun. Mag.*, vol. 40, no. 8, pp. 102–105, 2002.
[18] J. Gutierrez, J. F. Villa-Medina, A. Nieto-Garibay, and M. A. Porta-Gandara, “Automated irrigation system using a wireless sensor network and GPRS module,” *IEEE Trans. Instrum. Meas.*, vol. 63, no. 1, pp. 166–176, 2014.
[19] R. G. Evans and W. M. Iversen, “Remote Sensing and Control of an Irrigation System Using a Distributed Wireless Sensor Network,” *IEEE Trans. Instrum. Meas.*, vol. 57, no. 7, pp. 1379–1387, 2008.
[20] Y. Zhu, J. Song, and F. Dong, “Applications of wireless sensor network in the agriculture environment monitoring,” *Procedia Eng.*, vol. 16, pp. 608–614, 2011.
[21] LM 21 Meteorological Instruments Sectional Committee, "IS 5973 (1998): Pan evaporimeter [PGD 21: Meteorological," Draft IS 5973 : 1998, 1998.
[22] B.Dundar, "Neural network-based ultrasonic level measurement of fluids," Institute of Natural and Applied Sciences, Adana, MSe Thesis January 2010.