

A System for Recording Precipitation Height by the Use of Capacitor Plates

Mohammad Javad Manashti^{1,*} and Hoda Kahrizi²

¹ Research Assistant, Department of Water Resources Engineering, College of Agriculture and Natural Resources
Kermanshah, Iran

² M.Sc. Student, Department of Water Resources Engineering, College of Agriculture and Natural Resources
Kermanshah, Iran

*Corresponding author's email: Mjmanashti [AT] gmail.com

ABSTRACT— *Precipitation is one of the meteorological factors that plays a significant role in water development and other civil projects. The amount of precipitation is considerably crucial in estimating the amount of surface/underground water and runoff. It is also used in predicting the likelihood of flood with the purpose of taking necessary steps. Due to lack of a complete rain gauge station network in the entire world (especially in impassable areas which are out of regular access), it is not possible to accurately measure the amount of precipitation on the global scale. There are different methods for measuring precipitation, involving the volumetric, weight, or ultrasonic methods. Some of these measurement procedures, however, suffer from low measurement accuracy and high implementation costs. In the current study, aluminum capacitor plates were used to design an instrument for measuring precipitation height. In this instrument, capacitor plates were installed on the rain gauge tank. Data were collected in the campus of the Faculty of Agriculture, Razi University of Kermanshah. The capacitance was calibrated to precipitation height and changes in the capacitance in relation to time and precipitation height were recorded. Measurements conducted by the capacitance meter (VICTOR-6013) showed that the precipitation height had been measured with an accuracy of 0.1 mm. Furthermore, the measurement error of precipitation height of the instrument was 4.3.*

Keywords— capacitor plates, measuring the precipitation height, recording data at any moment

1. INTRODUCTION

Precipitation is one of the meteorological factors that plays a significant role in water development projects (e.g. dams, diversion dams, watershed projects, artificial recharge, and drainage) and other types of civil projects (e.g. airports, gravel paths, and sports fields) [1].

Falls in the form of rain, snow, sleet, or a mixture of rain, snow, and dew are known as precipitation [2]. The amount of precipitation is considerably crucial in estimating the amount of surface/underground water and runoff. It is also used in predicting the likelihood of flood with the purpose of taking necessary steps. Due to lack of a complete rain gauge station network in the entire world (especially in impassable areas which are out of regular access), it is not possible to accurately measure the amount of precipitation on the global scale. Rain gauge is a common instrument for measuring precipitation in a certain amount of time [3]. Nowadays, there are different methods for measuring precipitation, involving the volumetric, weight, or ultrasonic methods. The amount of precipitation can also be estimated through radars or satellites. Some of these measurement procedures, however, suffer from low measurement accuracy and high costs of implementation. As a result, we need a new precipitation measurement instrument that is inexpensive to manufacture, accurate in measurement, and user friendly. Furthermore, in order to be able to use this instrument in all areas, including impassable regions, the instrument should have an automatic discharge system which can provide the data at any moment without the need for human intervention [4].

In the current study, capacitor plates were used to design and manufacture an instrument for recording the amount of precipitation during light rains and showers. The instrument was registered as a patent (with the reference number of 78279) in the Patent Office of Iran's Industrial Property Organization.

1.1 Review of literature

Li et al (2010) designed a new siphon rain gauge with a pressure sensor. In this instrument, measurement accuracy is assessed through the pressure sensor and the optimized data algorithm is collected from a remote distance and transferred through a GSM module [5].

Hoofdt and Delobbe (2009) evaluated several radar-gauge merging methods with various degrees of complexity and geostatistical techniques. They concluded that, in the light of the main data, merging methods of geostatistical techniques constitute the best procedure, with 40% reduction of mean absolute error [6].

Simpson and Adler (1988) used TRMM satellite in order to determine precipitation algorithms. They concentrated on radar, microwave and inactive (gheirefa'al) models and emphasized that for determining the dynamic-microphysical model of clouds, radiation model should be taken into account [7].

Kazovsky (1985) proposed a new approach for measuring the real time duration of precipitation. He suggested a simple model for system performance and came up with an algorithm for processing the necessary information. Furthermore, he explained various possible devices for gauging precipitation. He concluded that it is possible to construct a ground-based rain gauge, which may be more accurate than satellite measurement [8].

Calder and Rosier (1976) designed large plastic-sheets and installed them at a one-meter height above trees to gauge net-precipitation under forest canopy. They measured the total runoff above the sheets by the use of tipping bucket rain gauge [9].

Ansari et al (2009) estimated the amount of precipitation in each area on the basis of data obtained from its adjacent weather station. They then investigated the effect of the weather station location (longitude, latitude, and height) on the amount of precipitation through a fuzzy membership function of distance and height difference. This technique was applied to 48 weather stations in Khorasan province of Iran, with the results being compared through inverse distance and averaging methods [1].

Finally, hosseini et al (2005) estimated precipitation through either thermodynamic method or Skew-T1np meteorological chart. Via comparing the obtained indices with the amount of precipitation measured by ground stations of Tehran, the researchers came up with an equation for predicting precipitation shortage [3].

2. MATERIALS AND METHODS

A capacitor is a piece of equipment that stores electric energy in the form of an electrostatic field (electric charge). Every type of capacitor consists of two main parts: two electrical conductors (or plates) that are separated by a dielectric (or an insulator). Thus, every two conductors that are separated by an insulator can constitute a capacitor. The conductors are relatively wide plates usually made of aluminum, zinc, or silver. The two plates are separated by an insulator that is made of air, paper, mica, plastic, ceramic, aluminum oxide, or tantalum oxide. The higher the dielectric coefficient of the insulator, the better its insulation property. The ratio of the electric charge stored in the plates to the potential difference across the battery is known as capacitance. It is a constant that is calculated through equation (1):

$$C = K\epsilon_0 \frac{A}{d} \quad (1)$$

Where C is the capacitance in Farads; ϵ_0 is the vacuum permittivity which is equal to $8.85 \times 10^{-12} \text{ C}^2/\text{Nm}^2$; K is the dielectric constant, A is the area of overlap of the two plates, in square meters; and d is the separation between the plates, in meters.

In this study, the designed instrument consisted of a funnel installed on a cube to direct precipitation into the rain gauge. There was enough space inside the cube to install the camera, the capacitance meter, battery, and the precipitation collector tank. Capacitor plates, which were made of aluminum, faced each other inside the rain gauge tank. Also, the dielectric liquid was rain. As the precipitation height changes in the rain gauge, so does the water level between the two capacitor plates, resulting in the shift of dielectric constant and capacitance. Through measuring capacitance and using the presented calibration diagram, precipitation height can be measured with high speed and precision and a low cost. Figure (1) illustrates the designed instrument.

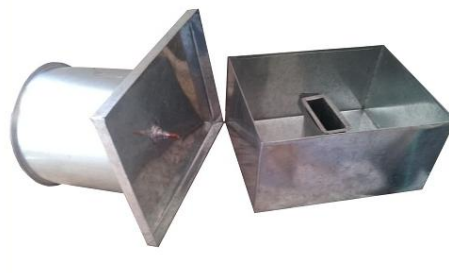


Figure 1: The designed rain gauge

In order to conduct automatic measurement, a circuit was constructed which gauges the capacitance and capacitor's temperature and saves the data Fig. 2.

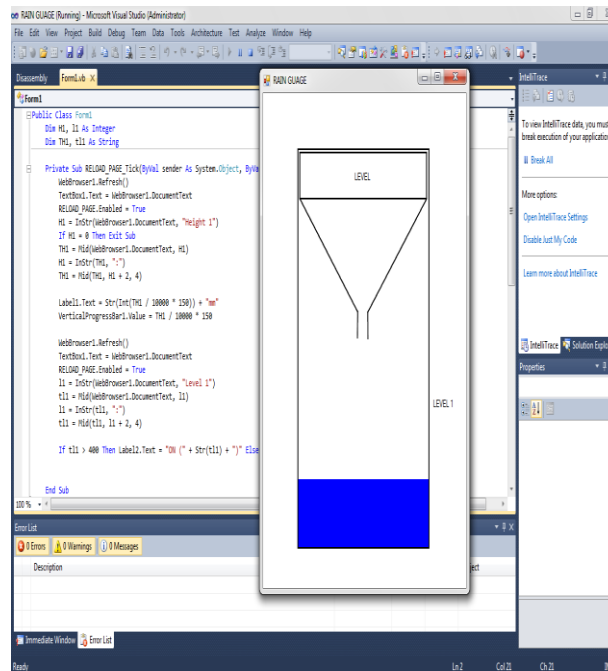


Figure 2: The program for saving rain gauge data

The data are then accessible through:

USB port: It is directly connected to the computer for transferring data. Furthermore, Visual Basic provides an opportunity for the online display of data.

Wireless connection: By the use of this facility, all the data are constantly accessible via World Wide Web. People who have access to wireless internet can retrieve data from www.manashti.com.

GSM/GPRS: Using the internet access provided by cell phone operators, we update all the data in www.manashti.com. These data are then accessible through either the internet or the SMS.

LAN connection: If there is a network in the laboratory, the manufactured instrument can be connected to its port, hence providing the opportunity to have access to the data.

3. DISCUSSION AND CONCLUSION

In order to measure the accuracy of the designed instrument, first, the precipitation height-capacitor curve was drawn. Figure (3) illustrates the calibrated curve.

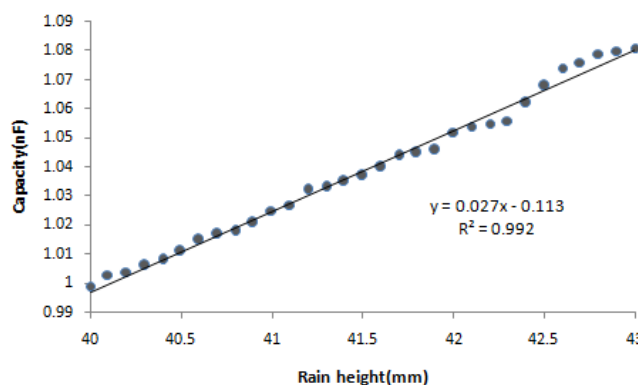


Figure 3: The precipitation height-capacitor curve

In order to further investigate the measurement accuracy of the designed instrument, the diagram related to the observed height-calculated height and the one related to height-time were drawn, Fig. 4.

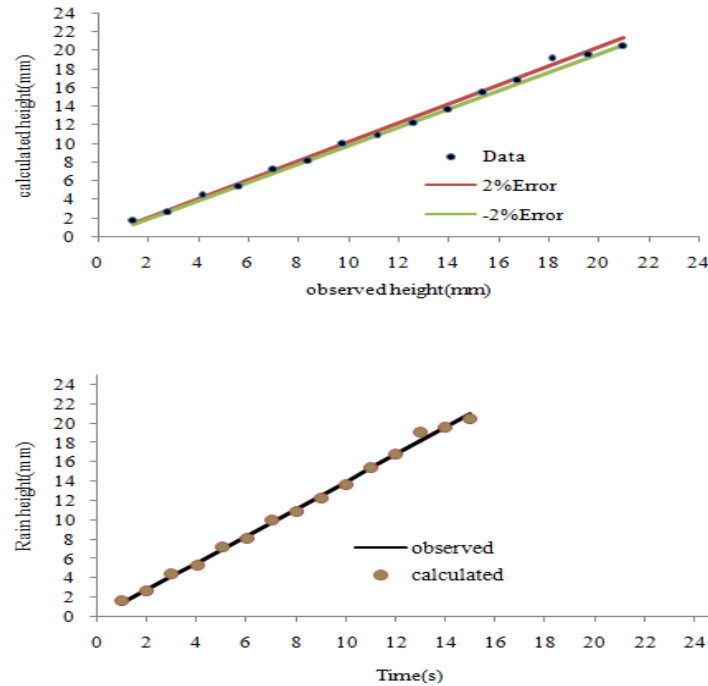


Figure 4: A sample of precipitation height measurement through capacitor plates

In order to evaluate the accuracy of the new instrument in measuring precipitation height, different statistical parameters, including mean absolute error, root mean square error, the efficiency of the model, and the coefficient of residual mass of the model, were applied based on equations (2) - (5):

$$MAE = \frac{100}{n_p} \sum_{i=1}^{i=n_p} \frac{|O_i - S_i|}{O_i} \quad (2)$$

$$RMSE = \left[\frac{1}{n_p} \sum_{i=1}^{i=n_p} (O_i - S_i)^2 \right]^{0.5} \left(\frac{100}{O} \right) \quad (3)$$

$$EF = \frac{\sum_{i=1}^{i=n_p} (O_i - O)^2 - \sum_{i=1}^{i=n_p} (O_i - S_i)^2}{\sum_{i=1}^{i=n_p} (O_i - O)^2} \quad (4)$$

$$CRM = \frac{\sum_{i=1}^{i=n_p} O_i - \sum_{i=1}^{i=n_p} S_i}{\sum_{i=1}^{i=n_p} O_i} \quad (5)$$

In the equations above, MAE is the mean absolute error, RMSE is the root mean square error, EF is the efficiency of capacitor plates, the coefficient of residual mass of the model, O_i is the measured precipitation height, O is the mean of measured precipitation heights, S_i is the precipitation height measured by capacitor plates, and n_p is the numbers of measurement. Table 1 illustrates the value of various statistical parameters used to assess the accuracy of capacitor plates.

Table 1. Statistical parameters used to assess the accuracy of capacitor plates in measuring precipitation height

Evaluation criteria	Ideal value	Obtained value
MAE	0	4.3
RMSE	0	3.15
EF	1	0.99
CRM	0	-0.001

As it can be observed, the mean absolute error of capacitor plates in measuring precipitation height was around 4%, the root mean square error was 3.15, the efficiency of capacitor plates was 0.99, and the coefficient of residual mass of the system was -0.001. The ideal value for the abovementioned parameters are also presented in the table above. Given that manufacturing the instrument and its measurement accessories is inexpensive, it is logical to use this instrument in measuring precipitation height.

4. REFERENCES

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