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PC Controlled Rain Simulation

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Abstract— Rainfall simulators have a long history of successful use in both laboratory and field investigations. A challenge faced today is to have practical method of assessing the impact of various natural phenomena on day to day life. With the climatic change taking place globally, there is necessity to simulate rain to assess and estimate its impact on our lives. It is developed with an objective to simulate rainfall which is computer controlled hardware implemented simulation for scaled model food godown. In this paper, we describe simulation of rain practically on a scaled model. The simulator is controlled by PC which can be programmed as per the requirement of user and can be modified and adopted easily. The process of PWM is achieved using a PC which has custom developed program interfaced to drive a water delivery system through PLC and MOSFET drive.

Keywords—*PC; PLC;MOSFET;*

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I. INTRODUCTION

The primary purpose of rainfall simulator is to simulate natural rainfall accurately and precisely. Young and Burwell(1972) pointed out the advantage of using simulated rain as opposed to natural rainfall is desirable as it represented natural conditions at a given place, data acquisition is very slow and the spatial and temporal distribution of rainfall intensity, duration and kinetic energy can be controlled.[1, 4]

A rainfall simulator is relatively easy to operate and transport while maintaining critical intensity, distribution, energy characteristics and time response of natural rainfall. It is developed with objective to simulate rainfall which is PC controlled hardware implemented simulation for scaled model food godown.

Rainfall simulators used in the past can be divided into two basic types, drip simulators and nozzle simulators. Drip simulators include those that use hanging yarn, glass tubing, hyper-dermic needles, etc. to form small tips from which drops fall by gravity. The main advantage of drip simulators is in their ability to produce a combination of relatively large drops at a low rate of application [1]. However, impact velocities approaching those of natural rain cannot be achieved unless the dripper is placed more than 10 meters above the soil. Because of this height the drip simulators are not practical for field investigations.

Nozzle simulators include a large number drop sizes which produce distribution. Impact velocity can terminated similar to the terminal velocity if nozzle is directed downwards increased pressure, however, reduces the size of drops.

In this paper, scaling has been carried out to achieve the variable rainfall intensities and distribution excluding the factor of wind effect by conducting nozzle test and distribution test by a technique of pulse width modulation using a PC which has custom developed program interfaced to drive a pump through PLC and MOSFET driver

II. RELATED WORK

J.B Humphry, T.C Daniel, D.R Edwards and A.N Sharpley in 2002 developed the portable rainfall simulator to produce a simulated rain on 1.5-X 2.0-m plot in remote locations for runoff. It is single nozzle operating simulator capable of producing 28kpa nozzle pressure. [1]

Jacqueline Blanquies, Misty Scharff and Brent Hallock in 2003 designed a simulator which is easily setup and maintained as well as able to create a variety of rainfall regimes. The nozzle test and lateral spacing tests were performed. [2]

T.G. Wilson, C. Cortis, N. Montaldo condition and J.D Albertson in 2014 developed a variable intensity rainfall intensity simulator. The system was tested with three configurations of common pressure washing nozzles producing rain intensities 62, 43 and 32 mm/h over a plot 15.12sqm. [3]

G.B Paige, J.J Stone, J.R Smith and J.R Kennedy in 2003 developed a computer controlled variable intensity rainfall simulator with the objective to quantify the relationship between rainfall intensity and steady state infiltration rate. [4]

Drop- forming simulators require huge distance of approximately 10 meters to reach terminal velocity. It uses small pieces of yarn, glass capillary tubes, hypodermic needles, polyethylene tubing or metal tubing to form drops. The disadvantage of drop forming simulators is, they do not

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produce a distribution of drops unless a variety of drop forming sized tubes are used. [5]

Nozzle simulator produces large drop size and distribution. If the nozzle is directed downwards increased pressure, impact velocity is terminated similar to terminal velocity. [6]

The rotating disk rainfall simulator developed. It utilizes best nozzle co.full jet 1-1/2H30. This nozzle produces an intensity of 1540mm/hr, when elevated 2 meters and operated at pressure of 0.6 atmospheres. It uses slotted metal disk which was rotated on vertical axis beneath the nozzle, to reduce intensity. Intensities can be changed from 0 to full nozzle capacity by rotation of disks with size openings. [7]

McAfee and Darrel Norton in 1979 developed a Norton simulator which produces variable intensity storms. A clutch brake starts and stops the boom as regulated by a signal from the control box. The four nozzles are supplied with water in sets of two; each set of nozzles has its own hose and pressure gauge to adjust for differences in elevation. [8]

III. SYSTEM DESIGN OF RAINFALL SIMULATOR

The rain simulator design takes into consideration of various system design aspects. As the simulator is to be installed in the lab, it needs to be appropriately scaled so that its performance closely matches to the real situation.

A. CHARACTERISTICS OF NATURAL RAINFALL

Some of the important parameters considered for characterizing natural rainfall are rainfall intensity, fall velocity, drop size and rainfall distribution. The typical value of the parameters generally considered and their related details are given below.

- Rainfall intensity: 5 to 100mm/h.
- Fall velocity: 5m/s.
- Drop size: 3 to 7mm for medium rainfall.
- Distribution of rain can be uniform or Gaussian distribution.

B. SCALING OF RAIN SIMULATION

Scaling techniques are frequently used in engineering to see the feasibility of new approach and evaluate practically the various design aspects. The data and results are used for implementing at the actual size and configuration. This helps in achieving the required results in short time and economical solution. The aim of such simulation is to bring out all technical issues of implementing a new technique.

Rainfall is of generally Gaussian distributed of 1km by 1km. In this research work, our aim is to simulate rain in an area which is of interest. Over an area of 100m by 100m, it is generally considered as Gaussian distribution and varies gradually as we move out of this area up to 3km. In our simulator, the area to be simulated is taken as 100m by 100m and simulation area is taken as 3m by 3m from the lab requirement and for practical implementation. Therefore the scaling of area works out to be: 100m by100m/ 3m by 3m i.e., approximately 1000 times.

Standard rain parameters are considered for scaling. Velocity depends on the area; rainfall intensity is related to distribution of rainfall. As velocity decreases, the area where distribution takes place also decreases which is one of the limitation of scaling.

- Rainfall intensity: 5 to 90mm/h
- Drop size: 3mm to 4mm
- Area: 2.7m by 2.7m
- Distribution: Gaussian and Uniform
- Velocity: 2-5m/s.

Rainfall intensity is measured using a measuring glass jar readily available in chemistry lab, which is a close approximation to cylindrical rain gauge.

- **Simulating an area:**
  0.3m i.e., 300mm
  0.3m×9 (Pumps) = 2.7m

  Therefore scaled area = 2.7m by 2.7m.

IV. SIMULATOR IMPLEMENTATION

Simulator implementation has been carried out in the lab and its performance has been evaluated. During the implementation of the simulator, there was a necessity to use multidisciplinary knowledge and hardware. The implementation was carried out in an organized systematic way by analysis of the requirement, evaluation of available hardware, cost effective solution, and availability of proven product.

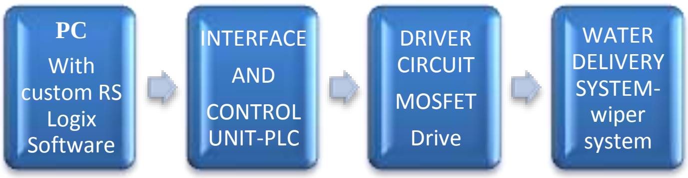

Fig 4.1: Block diagram of PC controlled rain simulation

The above fig 4.1 shows the block diagram of rain simulation. The delivery system consists of 12V automobile wiper pump connected to wiper tank and the nozzle. The MOSFET drive switches the motor between on and off state. PLC acts as a control strategy, it interfaces between computer and driver circuit. PWM signals is used to control the speed of the motor, which is produced by programming using RS logix software. The language used for programming is ladder logic, which logic function like AND, OR etc., are used to generate the program.

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V. EXPERIMENTAL RESULTS

Several experiments have been carried out to simulate rainfall in the laboratory depending on the requirements.

Experiments are conducted in two ways: manual control using voltage supply and Automatic control using PLC and MOSFET drive.

A. Manual control (using voltage supply)

The manual control of motor is done to obtain the data which is not provided by the manufacturers. The main objective of doing manual control is to check the performance of the motor, rating of the motor, temperature of the motor and performance degradation of the motor as a function of voltage.

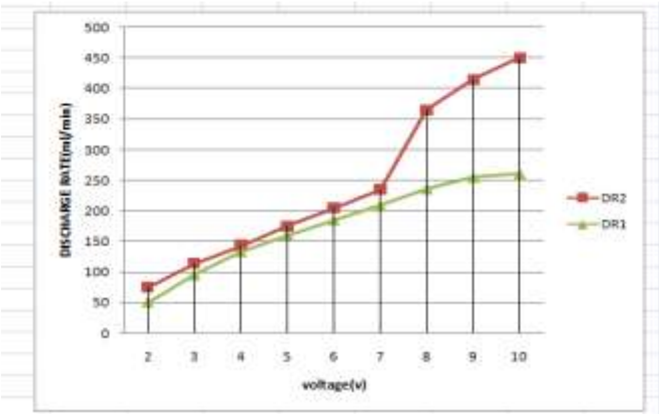

Fig 2: Graph showing discharge rate versus voltage

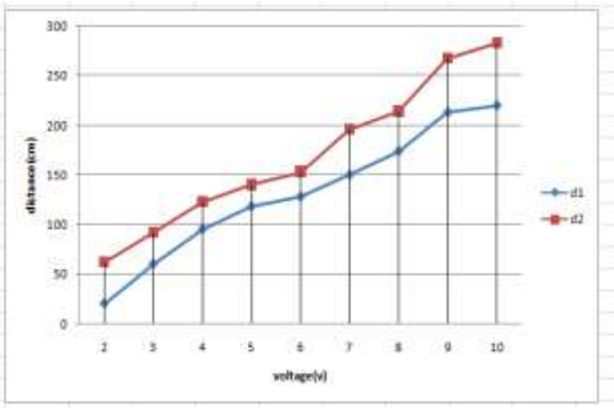

Fig 3: Graph showing distance versus voltage

By varying the voltage discharge rate of the pump and distance travelled for various voltages are obtained. The 12V DC pump is made to run for particular usage hours approximately 56 hours and same experiment was conducted to check the performance variation of the motor.

B. Automatic control (using PLC and MOSFET drive)

Automatic control of the motor is performed using PLC and MOSFET drive. As explained in the chapter 4 MOSFET drive is interfaced between PLC and water delivery system. A programming is done using custom RS logix software and loaded into PLC which helps to drive the pump. The main objective of automatic control is to control the speed of the motor as per the requirement.

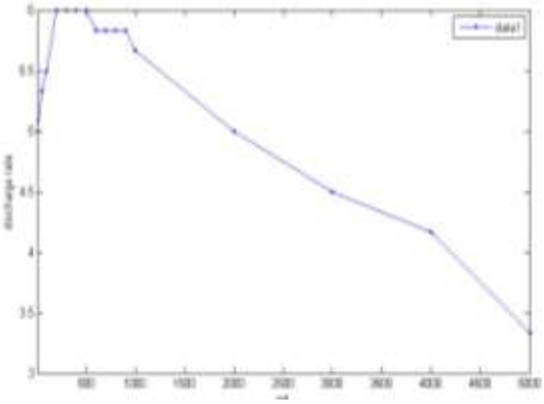

Fig 4: Graph showing discharge rate versus PRF

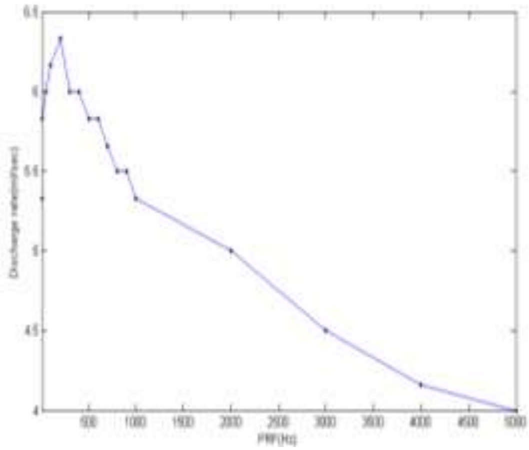

Fig 5: Graph showing discharge rate versus PRF with two motors connected in series.

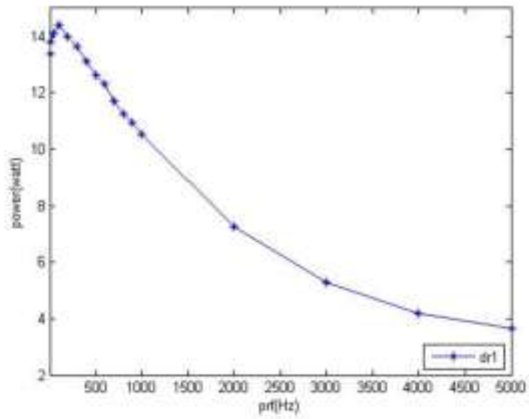

Fig 6: Graph showing power (VI) versus PRF (Hz)

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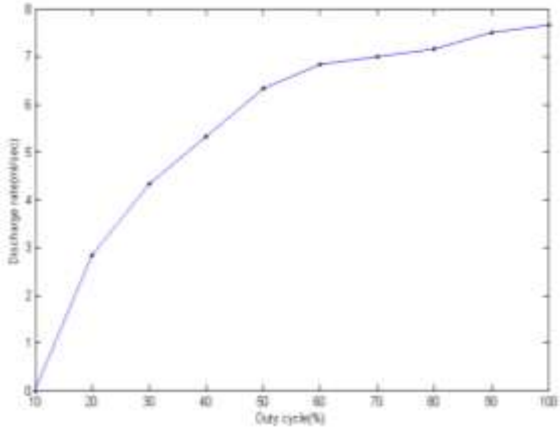

Fig 7: Graph showing discharge rate vs. duty cycle.

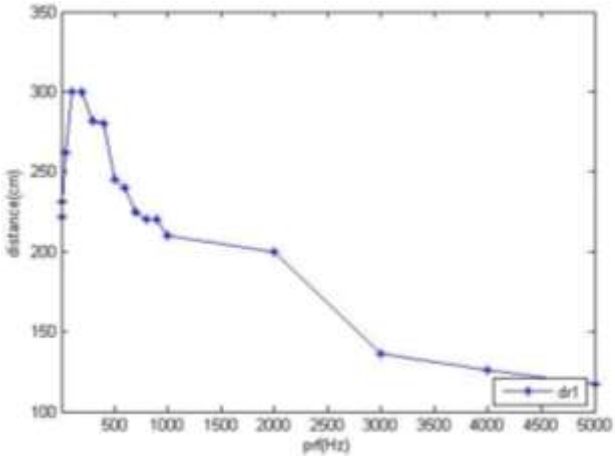

Fig 8: Graph showing distance vs. PRF

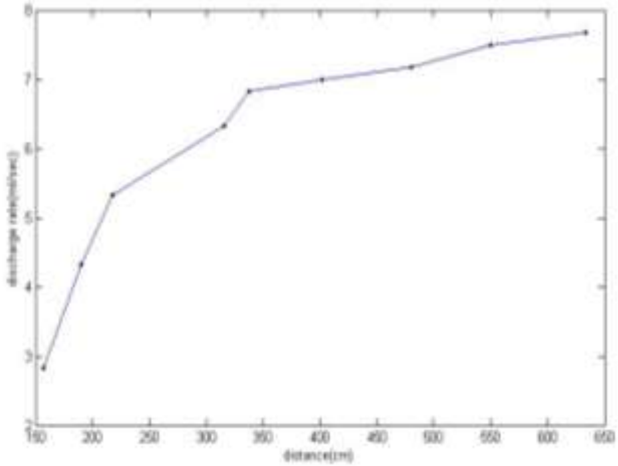

Fig 9: Graph showing discharge rate vs. distance graph

Observation:

In fig 4, it is observed that from 300 to 600 Hz the discharge rate obtained is maximum i.e., 6ml/sec at a constant duty cycle 50%.

Fig 5 shows the graph of discharge rate versus PRF (Hz) with two motors connected in series; it is observed that at 200 Hz, a maximum discharge rate of 6.33ml/sec is obtained at 50% duty cycle. Hence frequency of 200 Hz is fixed for further simulation.

Comparing fig 4 and 5, the discharge rate obtained in fig 7 is more; hence frequency of 200 Hz is fixed for further simulation. Since the output of PLC is 24V two motors is connected in series to carry out experiments.

Fig 6 shows the power versus Frequency graph, it is observed that there is drastic decrease in power even though duty cycle is kept constant which is due to limitations of transient response of the pump.

At a PRF 200Hz, it is observed from the experiment that the performance of the pump is optimum and the same PRF is used for further experiments. From fig 7 it is shown that that as duty cycle increases discharge rate also increases, these results is used to fix the discharge rate as per the requirements.

Fig 8 and 9 are the graphs needed for scaling and lab simulation and also to conduct distribution test. It helps to fix the velocity or distance as a function of frequency and also to fix distance for various discharge rates depending on the requirement.

C. DISTRIBUTION TEST

Using automatic control method, a distribution test is carried out to determine the changing rainfall intensity with an area and also to determine the uniformity over that particular area.

Rainfall uniformity is an important criterion to evaluate the similarity of a rainfall simulation compared to a nature rainfall process.

During a nature rainfall process or an actual rainfall simulation, the intensity always changes continuously within a certain range. As an artificial machine, rainfall simulator may achieve different uniformities when outputs have different r A rectangle area of 56cm×50cm with the nozzle over its centre was appropriate for working pressures of 38kpa.

As the area receiving artificial rain is larger than the plot sizes, rainfall was estimated by installing gauges. 10 x 10 cups were placed on 56cm x 50cm grid.

Rain was collected in the cups for 5 min of continuous flow from simulator. Both the nozzles were tried out and the integral nozzle tilted at an elevation of 30° was giving better distribution compared to the first prototype of needle designed syringe nozzle. There is a scope for further improvement for this nozzle.

Rainfall intensity is calculated using formula:

$$\text{Rainfall Intensity} = \frac{\text{Total Amount of Rain water}}{\text{Duration of Rainfall}}$$

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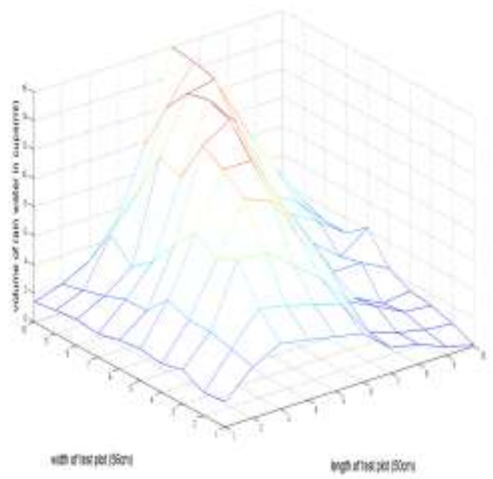
Fig 10: Distribution of simulated rainfall

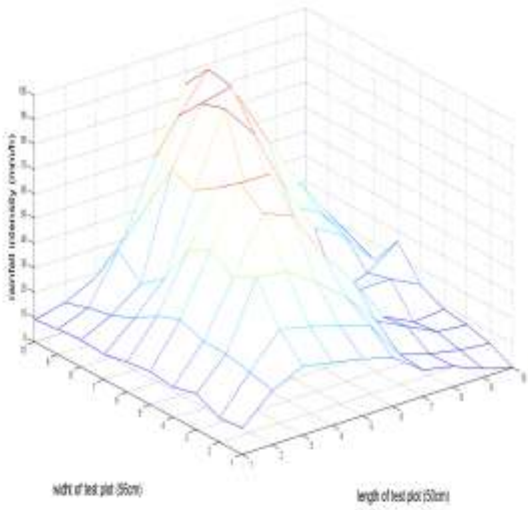
Fig 11: Distribution of rainfall intensity (mm/h)

Observation:

Fig 10 shows the plot of volume of rain water filled inside the cups across the test plot of 56cm X 50cm. the rainfall intensity is calculated using above equation and distribution of rainfall intensity is plotted as shown in the fig 5.13.

From the fig 11 it is observed that the highest rainfall intensity achieved is 92mm/h, which can be scaled to lower or higher intensities as per the requirements. It approximately appears like Gaussian distribution.

VI. CONCLUSION

Based on the study, analysis and outcome of the experimental results, practical scaled rain simulation has been realized with parameters matching closely to the theoretical expected values. Realization has been achieved in the lab using PLC control and the MOSFET driver for the DC pump. Necessary experiments have been carried out interfacing pump with PLC and PC. Rain intensity and distribution are the two major parameters which can be designed to the actual rainfall generally expected. It is shown that the requirements can be scaled appropriately for realizing it in the lab. From the rainfall distribution and nozzle test, rainfall intensity has been varied to get the required simulated conditions. Standard nozzles as well as custom designed nozzle using syringe needles also have been evaluated. Distribution over the required simulated area is achieved by using a combination of nozzles appropriately positioned over the area of rain simulation. Hence the simulation of rain has been implemented and the variation of the results from the expected is within the limit of expectation.

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