Cloudburst Predetermination System

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Cloudburst Predetermination System

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Abstract: *Cloudburst is a devastating disaster that usually occurs during rainy seasons at Himalayan regions. The recent floods in the 'Kedarnath' area, Uttarakhand are a classic example of flash floods in the Mandakini River due to cloudburst that devastated the country by killing thousands of people besides livestock. The traditional methods used for cloudburst prediction are weather forecasting, data mining techniques for weather prediction by modelling meteorological data, laser beam atmospheric extinction measurements from manned and unmanned aerospace vehicles. These techniques are more expensive and time consuming along with uncertainty of accurate prediction. The proposed method in this paper is Arduino based cloudburst predetermination system with real time calculation of rainfall intensity.*
Keywords: *aerospace; disaster; forecasting; intensity; prediction;*

I. Introduction

Cloudburst is an extreme amount of precipitation, sometimes with hail and thunder,which normally lasts no longer than a few minutes but is capable of creating flood.A cloud burst can suddenly dump 72300 tons of water over one square area. A cloudburst usually occurs when rainfall intensity is greater than or equal to 100mm per hour.Cloudburst events over remote and unpopulated hilly areas often go unreported. The states of Himachal Pradesh and Uttaranchal are the most affected due to the steep topography. Most of the damage to property, communication systems and human causalities result from the flash floods that accompany cloudbursts. In Kedarnath disaster [3]the main reason for flood was cloud burst causing a glacial lake burst and flash flood downstream. Though the duration of the event was small compared to other flood disasters in the country, it resulted in severe damage to property and life. Post-disaster satellite images depict that the river banks were eroded completely along the Kedarnath valley due to the flash floods and few new channels were visible. Extreme erosion took place in the upstream portion of Kedarnath. The satellite images show in figure 1 and 2 that massive landslides occurred in the upstream northeast region of the Kedarnath valley due to high intensity rainfall. The disaster was due to an integrated effect of heavy rainfall intensity, sudden outburst of a lake 'Chorabari', and very steep topographic conditions. During the peak pilgrimage season from 13th-17th June 2013, peaking on 16th, the region received unexpectedly heavy rain, about 375% more than normal, causing unprecedented magnitude of death and destruction[15]. Rainfall measurements for June 16 and 17 at the Dehradun station, of 220 mm and 370 mm respectively, indicate the severity of the rain during these days in the region. Haridwar received 107 mm and 218 mm of rainfall on the two days. Uttarkashi received 122 mm and 207 mm. Mukteshwar (altitude over 2000 meters) received 237 mm and 183 mm respectively on June 17 and 18. Nainital on the same days received 176 mm and 170 mm of rainfall in these two days. Tough rainfall over a 24-hour period in different parts of Uttarakhand has greatly exceeded these figures in past (on many occasions above 450-500 mm and once even 900 mm at Rajpur near Dehradun), prolonged heavy rainfall for nearly three days over a large area. More pertinently, these numbers do not give the actual quantitative picture of the very heavy rainfall in the higher reaches of the Himalayas (above 3000 meter) in Uttarakhand. Kedarnath, Gangotri and Badrinath are located in this region and the impact has been most severe. This is because the rain gauge stations of the India Meteorological Department are located largely in the lower Himalayan reaches (below 2000 meter) and there is no stations in the higher reaches (above 3000 meter). The satellite images of pre disaster and post disaster clearly state that the town has almost disappeared from both east and west valley [8]. There is no actual rain gauge present at the affected region. The satellite images were provided by NASA and IMD after the devastating disaster took place. The image below shows the flow of water after cloud burst in both 'Mandakini' and 'Alaknanda' rivers[7].

Fig 1: Satellite Image of the valley after cloudburst.

Fig 2: pre disaster and post disaster images of the valley.

On 13th September 2012 night in Chwanni, Mangoli and Kimana villages of Okhimath block in Rudraprayag district of Uttarakhand (India), heavy rains completely inundated over 4 villages and eroded 2 more villages. There are no clues about 20-25 families in these villages. Given that the rainy days were almost over, in western parts of Indian Himalayanmountains, there was continuous rainfall for over 2 months, that is usually erratic, leading to flash floods and huge land-slides. The nature's fury is on, and people are paying the toll to natural calamities, an alarming situation all over the region in terms of increasing disaster frequencies in last few years. The Uttarkashi flood was one of the recent in this in Uttarakhand state. The area flooded has huge chunk of dense forest that forms is part of famous protected corridor Kedarnath Musk deer sanctuary and beautiful natural lake 'Devaria tal' in mid-Himalayan range.A cloud burst was reported near Leh in Jammu and Kashmir around 0130–0200 hours IST on 6th August, 2010 leading to flash flood and mud slides over the region. It caused huge loss of lives and properties. The orography of the region plays a dominant role by increasing the convection and hence the intensity of cloud burst. It also occurs over other orographically dominant regions like the north-eastern states and Western Ghats region. It can occur also over the plain areas, but the frequency of such occurrence is very rare. However Laddakh region of J&K is not known to be frequently affected by this type of phenomena. It is a cold desert and average rainfall for the month of August is 15.4 mm only. The satellite images of Leh cloudburst are shown in figure.

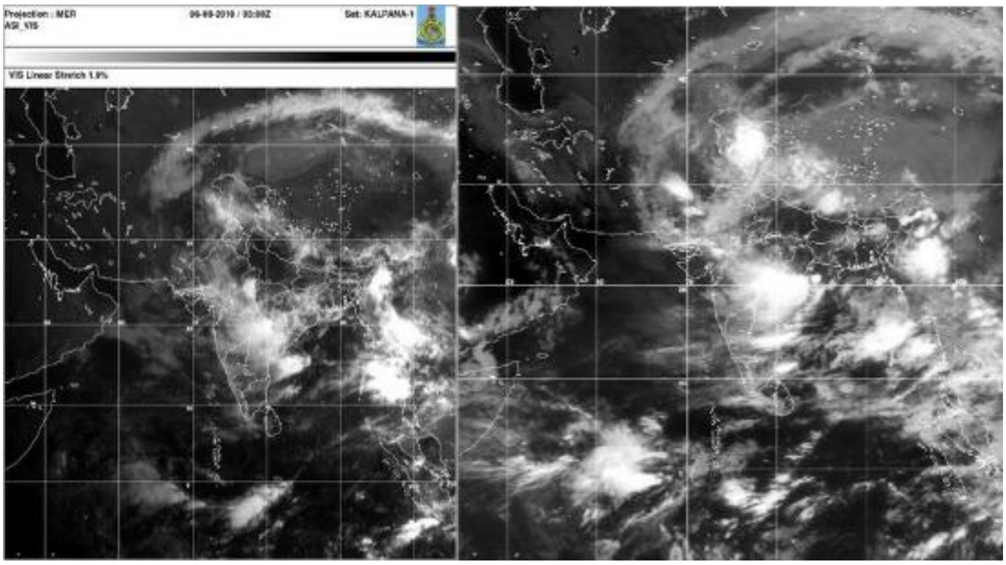

Fig 3: Satellite Images of Leh Cloudburst.

The above satellite image displays the formation of clouds over the affected region. If we see the cloud formations before the cloudburst at Leh, we conclude that monsoon from Indian ocean and Bay of Bengal hit the Himalayan region to form denser clouds and produce rain in western and southern parts of Himalayan mountains. These denser clouds with continuous rain result Cloudburst. The satellite image of monsoon clouds is shown below.

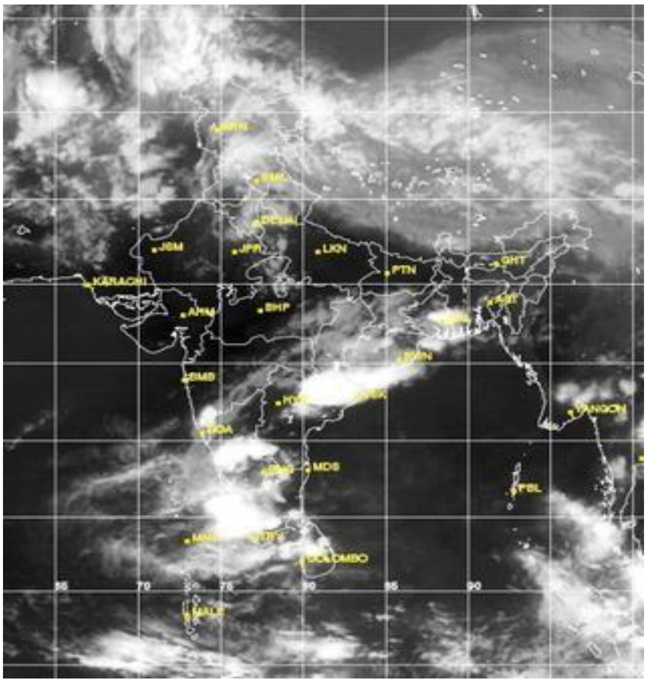

Fig 4: Satellite images before cloudburst at Leh

II. Related Work

The basic research method of cloud burst prediction is Synoptic weather prediction [6]. It is the traditional approach in weather prediction. Synoptic concerns with the observation of different weather elements within the specific time of observation. In order to keep track of the changing weather, a meteorological centre prepares a series of synoptic charts every day, which forms the very basic of weather forecasts [10]. It involves huge collection and analysis of observational data obtained from thousands of weather stations. The method consists of predicting meteorological data with the help of satellite images. The images provide data regarding various types of atmospheric changes and expected change in climate due to current atmospheric conditions of particular area. The modern weather forecasting began by the invention of Electric Telegraph in 1835. Weather forecasting provides data about change in oceans, wind, clouds, temperature etc. Numerical weather prediction [12] is the technique for weather forecasting. The technique uses the current state of the fluid and applying equations of fluid dynamics or thermodynamics to predict the state after some time. Numerical weather prediction (NWP) models are reasonably successful for large-scale medium-range weather forecasting, prediction of precipitation remains a challenge. Mesoscale models, forced by the initial and boundary conditions from the global model forecasts, are widely used to obtain regional forecasts at high spatial and temporal resolution. They account for the influence of detailed topography, land cover, vegetation which are either missing or smoothed in global models. Several operational forecasting centres apply mesoscale models for detailed weather forecasts over small geographical regions. Mesoscale processes are influenced by surface inhomogeneities in elevation, moisture, temperature, snow cover, vegetation, and surface roughness. Mesoscale weather systems can be divided into two general categories: those forced primarily by instabilities in travelling systems (e.g., squall lines or mesoscale convective complexes) and those forced by surface inhomogeneities (e.g.mountain/valley circulations). Pielke (1984) noted that terrain-induced mesoscale systems are easier to predict because they are forced by geographically fixed features. Paegle et al (1990) suggested that terrain forced circulation is inherently more predictable than the synoptically induced flows, which are sensitive to the data used to initialize the NWP models. Cloud Burst forecasting is predicted by the prediction of rainfall and formation of clouds. The satellite based systems are expensive and require complete support system. Another technique for cloud burst prediction is Data Mining techniques for weather prediction. Data mining is a process which finds useful patterns from large amount of data. Data mining can also be defined as the process of extracting implicit, previously unknown and useful information and knowledge from large quantities of noisy, ambiguous, random, incomplete data for practical application. Weather prediction in Data mining concern with finding hidden and useful patterns from a large amount of meteorological data. E. G. Petre presented a small application of CART decision tree algorithm for weather prediction [16]. The data collected is registered over Hong Kong. The data is recorded between 2002 and 2005. The data used for creating the dataset includes parameters year, month, average pressure, relative humidity, clouds quantity, precipitation and average temperature. Laser beam atmospheric extinction measurements from manned and unmanned aerospace vehicles are also a method to predict cloud burst. The technique is based on measurements of the laser energy incident on target surfaces of known geometric and reflective properties, by means of infrared detectors or infrared cameras calibrated for radiance. The technique is too costly and needs full government support in order to be used.

III. Proposed Work

The work proposed in this paper is based on Arduino connected to a rain gauge in order to calculate real time rainfall intensity. A Float Switch is connected to the rain gauge that monitors the water level in the rain gauge. Additionally a submersible pump is also attached to the rain gauge. The main advantage of this type of pump is that it prevents pumpcavitation, a problem associated with a high elevation difference between pump and the fluidsurface. Submersible pumps push fluid to the surface as opposed to jet pumps having to pullfluids. Submersibles are more efficient than jet pumps. A float is a device used to measure the level of water in the water gauge. It consists of a fixed contact and moving contact. The fixed contact is fixed to the gauge and the moving contact moves up and down based on the level of water. Float switches range from small to large and may be as simple as a mercury switch inside a hinged float or as complex as a series of optical or conductance sensors producing discrete outputs as the liquid reaches many different levels within the tank. The most common type of float switch is simply a float raising a rod that actuates a micro-switch. A very common application is in sump pumps and condensate pumps where the switch detects the rising level of liquid in the sump or gauge and energizes an electrical pump which then pumps liquid out until the level of the liquid has been substantially reduced, at which point the pump is switched off again. Float switches are often adjustable and can include substantial hysteresis. That is, the switch's "turn on" point may be much higher than the "shut off" point. This minimizes the on-off cycling of the associated pump.The pump shaft is connected to the gas separator or the protector by a mechanical coupling at the bottom of the pump. Well fluids enter the pump through an intake screen and are lifted by the pump stages. Other parts include the radial bearings (bushings) distributed along the length of the shaft providing radial support to the pump shaft turning at high rotational speeds. An optional thrust bearing takes up part of the axial forces arising in the pump but most of those forces are absorbed by the protector’s thrust bearing. Arduino is a single-board microcontroller, intended to make the application of interactive objects or environments more accessible. The hardware consists of an open-source hardware board designed around an 8-bit Atmel AVR microcontroller, or a 32-bit Atmel ARM. Current models feature a USB interface, 6 analog input pins, as well as 14 digital I/O pins which allow the user to attach various extension boards [1]-[2]. Multiple Arduino boards are connected to form a shield called Arduino Shield. Arduino Shield is used for various types of applications. The Arduino Uno board is shown in figure below.

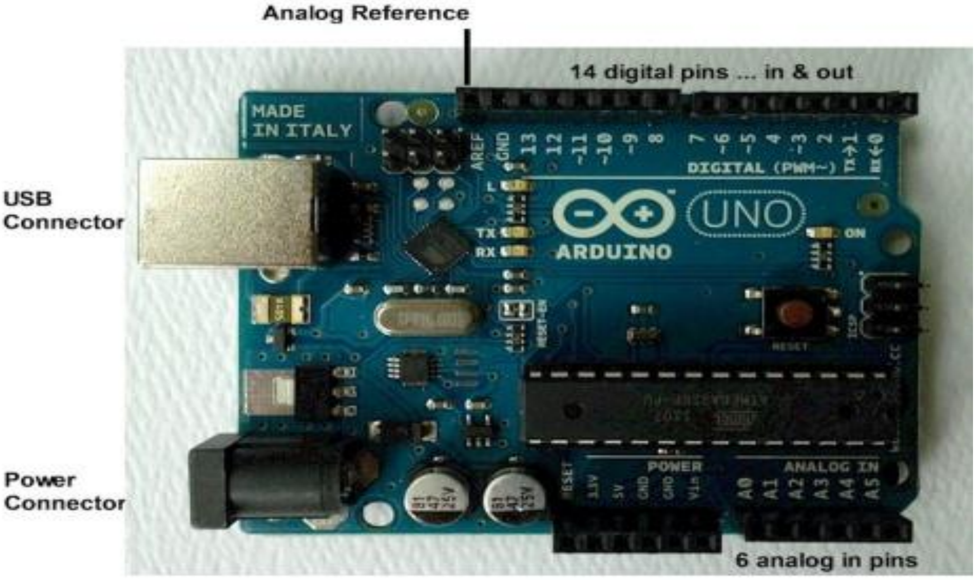

Fig 6: Arduino Uno board.

Arduino works on plug and program principle. The board is attached to the pc via USB and is programmed with Arduino IDE, Integrated DevelopmentEnvironment, a tool kit to program the attached board. The programs written in IDE are uploaded to the board and the board works as an automatic microcontroller. External power come either from an AC-to-DC adapter which is plugged directly in wall-wart or battery. Leads can be inserted in Gnd and Vin pin headers of the power connector. The board can operate on an external supply of 6 to 20 volts. The recommended range is 7 to 12 volts. Each of the 14 digital pins of the board are used as an input or output, using pinMode(), digitalWrite(), digitalRead() functions. They operate at 5 volts. Each pin is able to provide or receive of maximum of 40 mA and has an internal pull-up resistor of 20-50 kOhms. Some of the pins have specialized functions. Pin0(RX) and Pin1(TX) are reserved for receiving(RX) and transmitting(TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.Pin2 and Pin3 are configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value.The Arduino has a number of facilities for communication with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL serial communication, available on digital pins 0 (RX) and 1 (TX). An ATmega16U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The '16U2 firmware uses the standard USB COM drivers, and no external driver is needed. The Arduino software includes a serial monitor that allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-Serial chip and USB connection to the computer (but not for serial communication on pins 0 and 1). A Software Serial library allows for serial communication on any of the Arduino's digital pins. After the desired use, the uploaded program is removed and any new program is uploaded to the board for a different functionality. The rain gauge calculates real time rainfall intensity with the help of arduino and arduino records the data. The Servo mounted on arduino board provides the capability of controlling the board from anywhere in the world. The board is programmed with 3 stages of alarms which are raised according to the real time intensity. Cloud burst generally occurs at rainfall intensity greater than or equal to 100 mm per hour. Alarm stages are associated with 3 threshold values. The data recorded by Arduino board is monitored at base station or is sent to the configured device directly. Whenever alarm rises, alert messages are broadcasted to the cellular phones of the people of nearby areas.The extreme condition of alarm is Alarm 3 at which people are transported to a safe place. Message broadcasting to the cellular phones of the nearby people is done with the help of an extra module mounted on the board. This extra module is plugged in the Arduino board and is called 'Arduino GSM Shield'. GSM shield is an effective element of Arduino for communications. GSM shield is shown in following figure.

Fig 7: Arduino GSM Shield.

GSM shield is a small module with Sim Card slot provided to communicate with other devices, terminals, Arduino boards. GSM shield uses GSM or CDMAsim cards. These cards are registered to the corresponding network services provider by a sketch. A set of instructions in Arduino SDK is called a sketch. Configuration of the sim card is done by connecting it to the computer. The Arduino GSM shield allows an arduino to make/receive voice calls, send/receive sms messages. To make/receive voice calls, Arduino requires an external speaker and a microphone. The shield uses a radio modem M10 by Quectel. The GSM library consists of a large number of methods to communicate with the Arduino board. The shield uses digital pins Pin 2 and Pin 3 for software serial communication with M10. Pin 2 is connected to M10’s transmitter pin TX and Pin 3 is connected to M10’s receiver pin RX. M10 is a Quad-band GSM/GPRS modem that works at GSM850 MHz, GSM900 MHz, DCS1800MHz and PCS1900 MHz. The GSM shield supports TCP/UDP and HTTP protocols due to internet services. It provides a maximum speed of 85.6 kbps for both uplink and downlink. The shield supports audio interfaces AIN1 and AOUT1, analog input channel and analog output channel respectively. The functionality of GSM shield is similar to a cellular phone with internet facility. The real time data is uploaded to the server with the help of GPRS services or is sent to the base station by text messages. Arduino broadcasts UDP messages to multiple terminals. UDP broadcasting allow us to communicate with other terminals without using GSM shield. The proposed method is represented diagrammatically as follows.

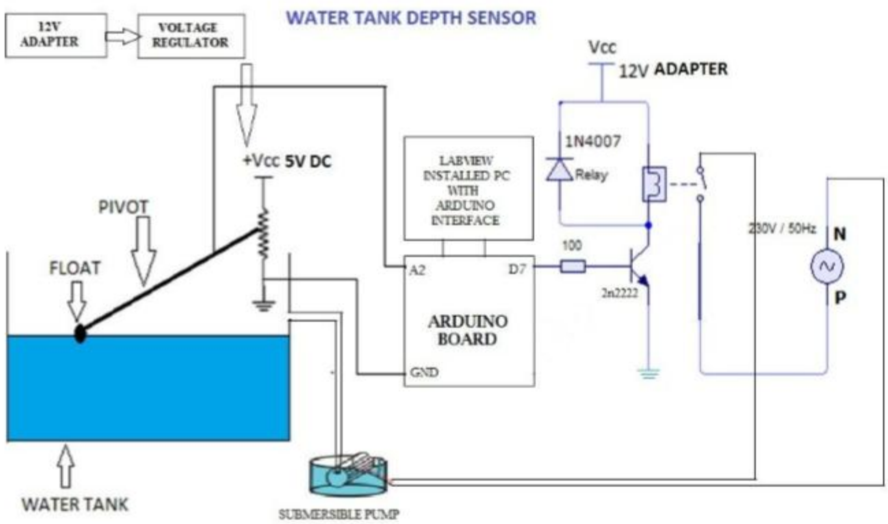

Fig 8: Design of proposed system

The proposed system uses rain gauge in order to save cost for rainfall intensity calculation. Rain gauge is easy to build accurately and monitoring is easy by using float switch. The float switch monitors the precipitation depth of the rainfall and sends results to the Arduino and Arduino calculates real time rainfall intensity.

IV. Simulation And Results

The design of the rain gauge plays a crucial role for accurate calculation of precipitation depth. The pump is used to withdraw water from the gauge when the gauge is full. Pump-Gauge mechanism is simulated in Proteus software. Proteus allows virtual arrangement of electronic components and their real time simulation. It provides a powerful set of tools to build real time systems. Simulation screenshot of automatic pump-gauge mechanism is shown in the figure below.

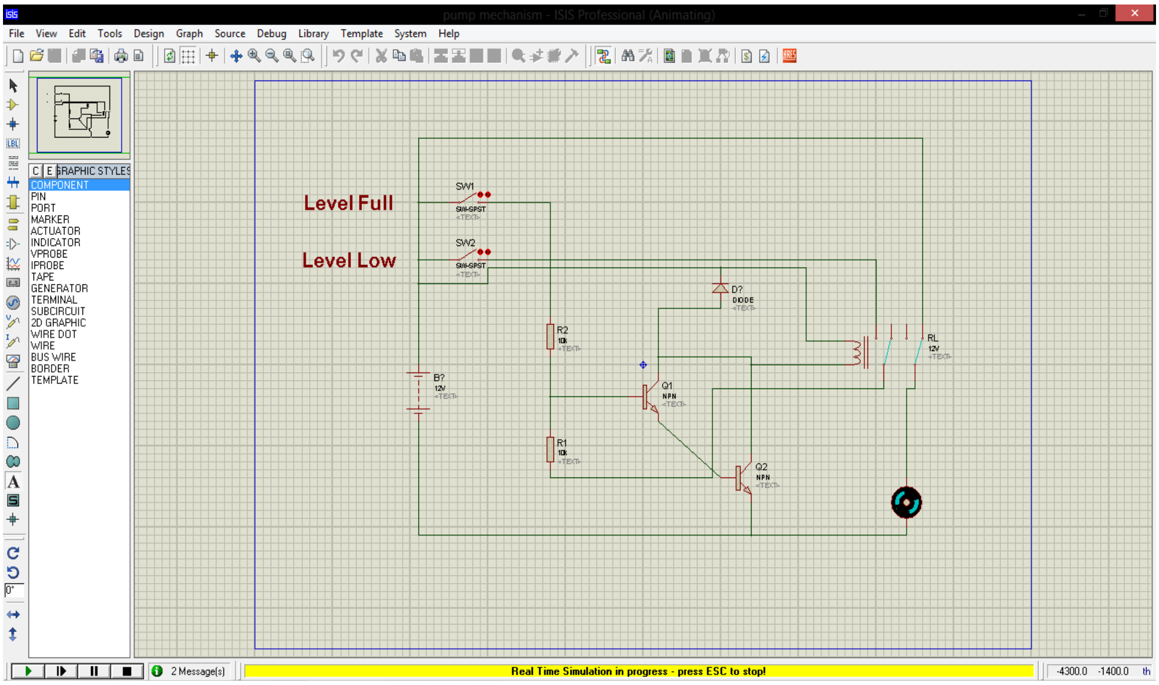

Fig 9: Proteus simulation of pump-gauge mechanism.

Water level indication in Gauge is simulated in labVIEW software and block diagram of circuit and simulation screenshots are shown in figure below.

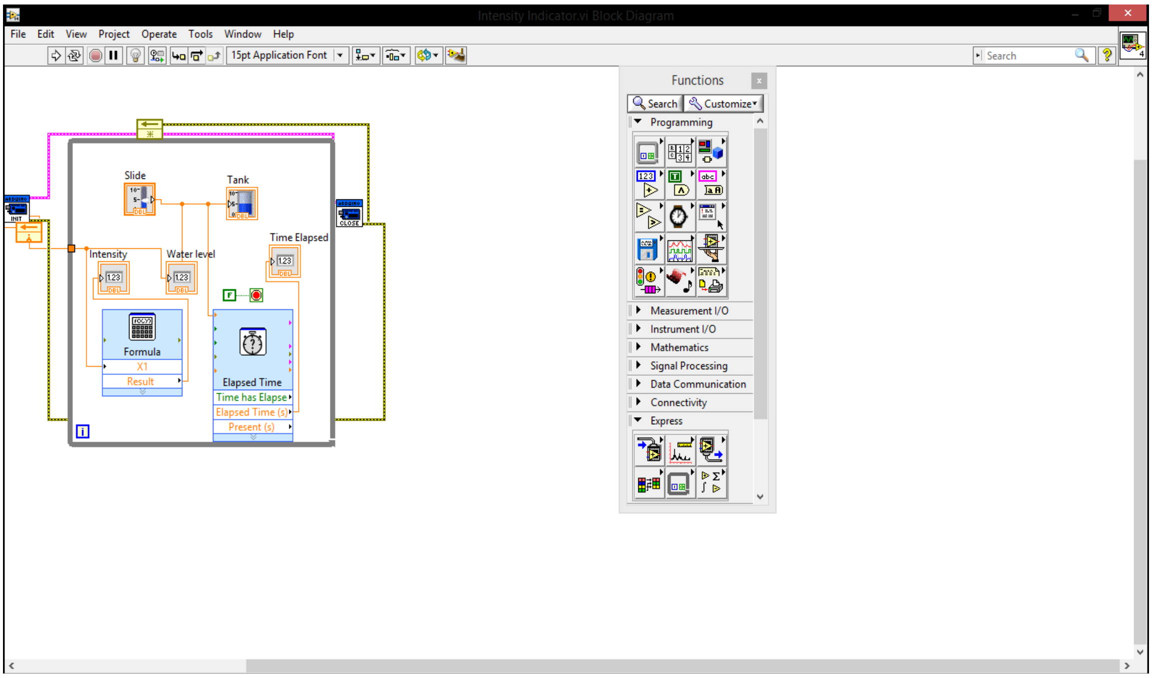

Fig 10: Circuit diagram of water level indication

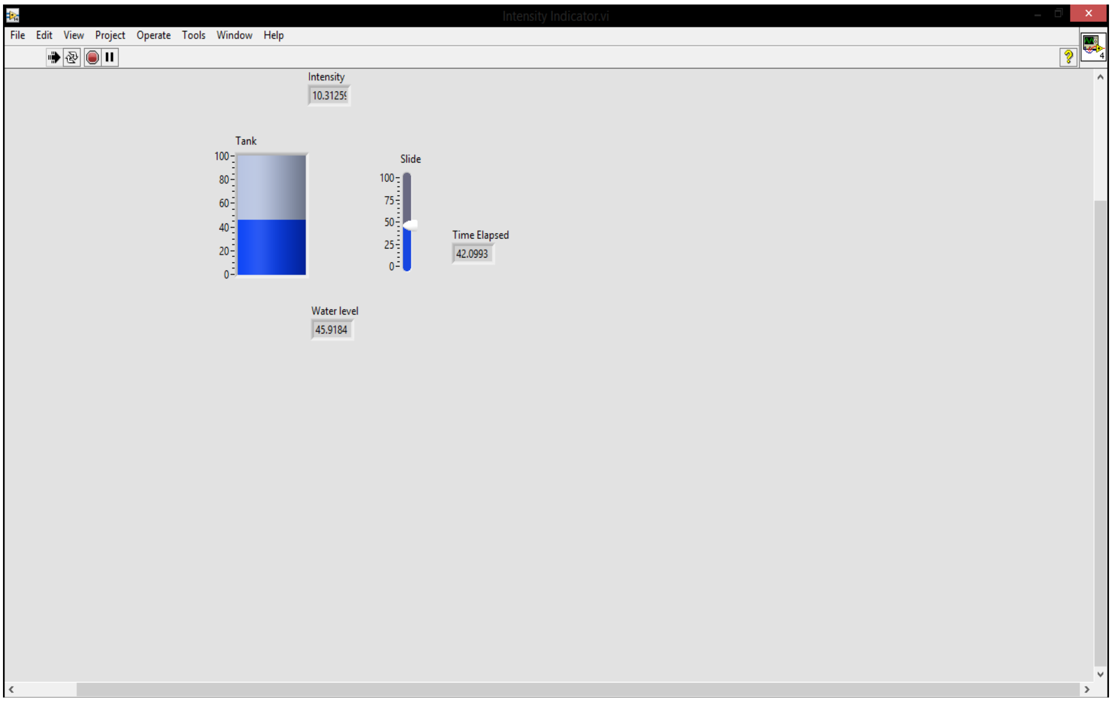

Fig 11: Increasing water level in the gauge

First of all the circular area of the top of the gauge is calculated. Let the diameter of the rain gauge is d mm. Let precipitation depth is P mm.
Radius=d/2 mm

(1)Circular Area of top of the gauge = $\pi*(d/2)^2$ mm² (2)Current rainfall intensity = Precipitation Depth/Area of top of the rain gauge(3)
Current rainfall intensity =P/ [3.142*$(d/2)^2$] mm (4)

The rainfall intensity is calculated by Arduino on the basis of precipitation depth provided by the float switch.Three types of threshold values are provided according to the real time rainfall intensity. These threshold values are responsible for alarm generation. Variation in threshold values is provided according to the season. Rainfall intensity is maximum in rainy season as compared to that of winter and summer seasons. Therefore threshold values for monsoon season are greater than that of winter and summer 0seasons. Whenever rainfall intensity crosses the first threshold i.e. 45 mm, Alarm 1 is generated and first alert message is broadcasted to the people of nearby area concerning the cloud burst may occur. As the current rainfall intensity crosses the second threshold i.e. 60 mm, Alarm 2 is generated and second alert message is broadcasted to the people of nearby area to pack their essential things up and be ready to move towards safe place. When the current rainfall intensity crosses the third threshold i.e. 80 mm, Alarm 3 is generated and third alert message is broadcasted to the people of nearby area insuring them to leave as when the rainfall intensity crosses the value of 80 mm, there are 90% chances of cloud burst to occur. The simulation is done in LabVIEW. LabVIEW is a breadboard simulator.LabVIEW is the software that was used to interface the computer with the control device. It allows for easy interfacing and control because of the fundamental concept behind which it has been developed, that is, graphical programming. In order to interface the parallel port of the computer with the drive control hardware, and ultimately, the synchronous pair, National Instruments LabVIEW was used. LabVIEW is an acronym for: Laboratory Virtual Instrumentation Engineering Workbench. The programs written inLabVIEW are called "Virtual Instruments" or VI's due to the instrumentation-related origin. The programs created are independent of the type of machine that they are created for so programs can be transferred between different operating systems. Additionally LabVIEW has a large set of built-in mathematical functions and graphical data visualization and data input objects typically found in data acquisition and analysis applications.

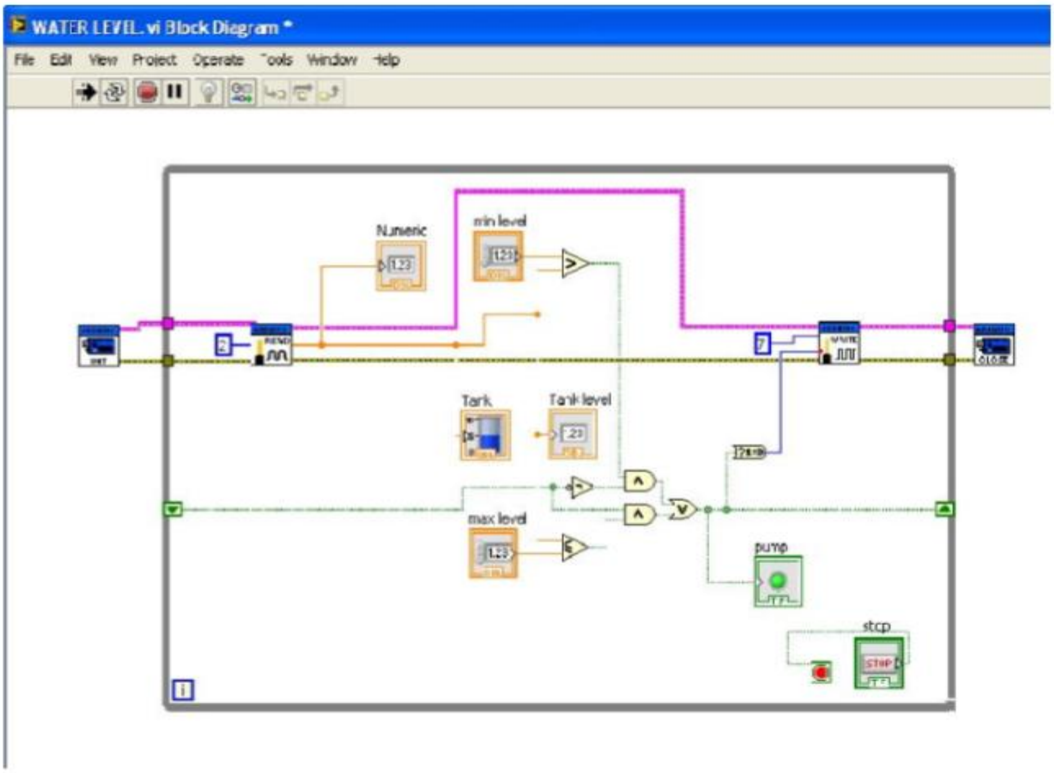

Fig13: Circuit layout of proposed system in LabVIEW.

The another cloud burst sensitive zone Pauri Garhwal, Uttarakhand, average temperature-rainfall intensity on yearly basis is shown in following figure.

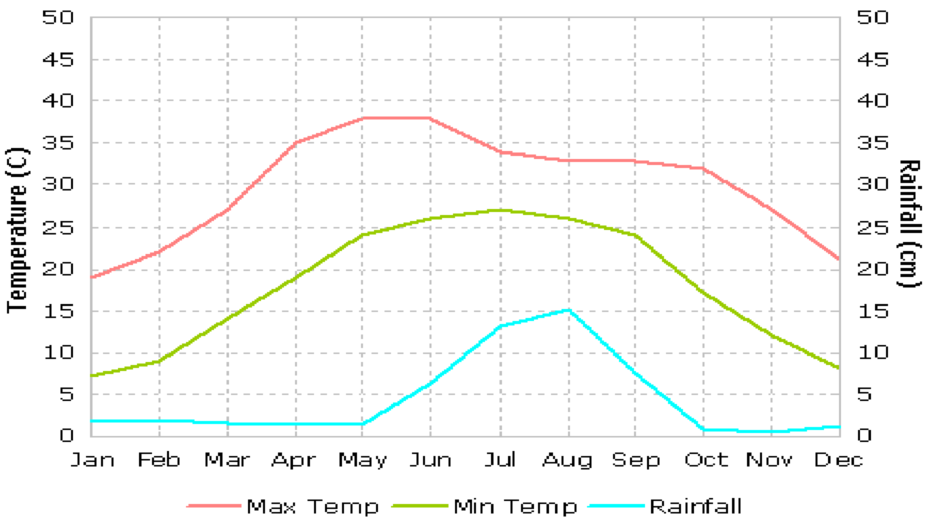

Fig 14: Average temperature rainfall analysis of Pauri

V. Conclusion

The proposed method for cloud burst predetermination is very effective as it calculates real time rainfall intensity. No special permission or complex assembly is needed. No database is needed to predict as compared to traditional methods. It consumes very less amount of time to be implemented unlike other techniques that consume a lot of time to process very huge database and further finding patterns of hidden knowledge in order to produce predictions. The method costs very less as the rain gauge can be built by human efforts and board is programmed easily. We can use same board for different purposes.

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