AWS and ARG

Automatic Weather Stations

An automatic weather station (AWS) is defined as a "meteorological station at which observations are made and transmitted automatically" (WMO, 1992*a*).

The surface meteorological observations are being automated by installation of AWS.

The history of Automatic Weather Station (AWS) in India Meteorological Department (IMD) can be classified into three generations in which the first generation was with Data Collection Platform (DCP) in mid eighties, second generation introduced the concept of data loggers with Pseudo Random Burst System (PRBS) transmission, third generation with Time Division Multiplexing Access (TDMA) technology. Communication systems from these AWS systems to the earth stations (at Pune and Delhi IMD) were satellite (INSAT) based and its recent subsequent upgradation with dual mode of transmission, which included satellite as well as GPRS modes (Mobile Network) for communications. The total number of AWS in IMD reached 707 by the year 2020, including the installation at few sites with IMD mast fabricated at IMD Pune workshop and existing data loggers.

1. **Purpose of establishing AWS network**

   The purpose of establishing an AWS network as given in WMO CIMO Guide No.8, 2008 Ed., Part II, Chapter I (Measurements at Automatic Weather Stations) is reproduced below. AWS are used for increasing the number and reliability of surface observations. They achieve this by:
   - Increasing the density of an existing network by providing data from new sites and from sites that are difficult to access and inhospitable;
   - Supplying, for manned stations, data outside the normal working hours;
   - Increasing the reliability of measurements by using sophisticated technology and modern, digital measurement techniques;
   - Ensuring the homogeneity of networks by standardising the measuring techniques;
   - Satisfying new observational needs and requirements;
   - Reducing human errors;
   - Lowering operational costs by reducing the number of observers;
   - Measuring and reporting with high frequency intervals or continuously.

2. **Types of AWS**

The AWS are broadly classified into two types a) Real time and b) Off-line AWS.

- In the case of **real-time AWS**, data is available almost in near real time according to synoptic requirements. These AWS use satellite-based or mobile communication links to ensure that the data reaches the end user, the weather forecaster as early as possible.
- In the case of AWS which use GSM (Global System for Mobile Communication) / GPRS (General Packet Radio System) technology the AWS can be configured over the air (OTA) to sample and transmit the data more frequently in emergency situations.
- The **off-line AWS** record the data as per user-defined time intervals and store them in the data logger. An observer retrieves the data from the system and makes arrangement for mailing the data to the concerned officials.
- There is one more type of AWS known as **Interrogative AWS** which provides the data when the station is contacted through modem / cable link for retrieval of data.

3. **Telemetry**

The backbone of AWS is the usage of the telemetry concept.

- Telemetry is a technology that allows data measurements to be made at a distance by means of a set of instructions. Measurements at various AWS sites (earth segment) are transmitted / uplinked in UHF frequency and received by the satellite which in turn are upconverted and downlinked by the satellite in C-band frequency (space segment) to the earth station (earth segment). So, even when other modes of telecommunication fail during adverse weather situation, satellite communication is reliable and hence this technology is preferred for AWS data transmission.
- Satellite telemetry being used for data transmission has disadvantage that it is a one-way communication hence if scheduled transmission is lost then the valuable data is lost and it cannot be retrieved unless station is visited by maintenance personnel. In view this, it has been decided to have dual telemetry system for data transmission with mobile telemetry system in addition to satellite telemetry.
- The GPRS telemetry being two-way communication system, the lost data can be retrieved remotely. GPRS telemetry also offers higher temporal resolution of data transmission as compared to satellite telemetry.
- Presently satellite telemetry has fixed measurement interval of 1 hour and mobile telemetry systems can be configured remotely by end user using command for desired measurement interval i.e. 15 min etc. or even 1 min during adverse weather conditions.

4. **Sensors**

- **Sensors used in AWS /ARG**
  The meteorological requirements for sensors used at AWSs are not very different from those of sensors at manual observation stations. The sensors must be robust, fairly maintenance-free and should have no intrinsic bias or uncertainty in the way in which they sample the variables to be measured. In general, all sensors with an electrical / electronic output are suitable. Depending on their output characteristics, sensors can be classified as analogue, digital and "intelligent" sensors.

➢ **Analogue sensors**
  Sensor output is commonly represented by a continuously varying signal and small fluctuations are meaningful as well like voltage, current, charge, resistance or capacitance. Signal conditioning is the process in which the transducer (sensor) analog outputs are converted into voltage levels (for example 0 to 100 % humidity corresponds to 0 to 1 V) for further processing in the data logger.

➢ **Digital sensors**
  Sensors with digital signal outputs have information contained in a bit or group of bits(zeros and ones) and sensors with pulse or frequency output. Rain gauge is a digital sensor.

a) **Barometric Pressure Sensor** is a solid state pressure transducer suitable for data collection and monitoring applications.

- The sensor has been designed with low power consumption, high accuracy, full temperature compensation, selectable units, non-volatile setup, and wide operating voltage to serve a wide range of applications.
- The operating range is 600-1100 hPa with an accuracy of 0.2 hPa. The power consumption is 0.25 mA.
- The operating voltage range is 12V and sensor has digital output.

b) **Tipping Bucket Rain Gauge** is a precision instrument with a sensitivity of 0.5 mm per tip used by IMD in their AWS and ARG network. The gauge should be located on the prevailing wind side of any obstruction so as not to disrupt rainfall measurement.

- Rain entering through a funnel assembly with a 7.87-inch (200mm) and 15.7 ml of water orifice passes through a debris filtering screen and is funnelled into one side of the tipping bucket assembly inside the gauge.
- Amount of water (Volume of water)required for one tilt is 3.14*10*10*0.05 = 15.7 cc
- The bucket tips when a given amount of water, determined by gauge calibration, has been collected.
- As the bucket tips it caused a magnet to pass by a ruggedised mercury switch, momentarily closing the switch.
- The tipping of the bucket brings a second bucket into position under the funnel, ready for filling. After the rainwater is measured, it is directed into

drain tubes that allow it to exit out of the holes in the base of the gauge. Mesh screens exist to prevent insect entry. The output of the sensor is a contact output through a magnetic switch. Whenever the rain measured is 0.5 mm it tips and gives a momentary close contact and hence a digital pulse.

- The rainfall accumulated for the 24 hours period ending 03 UTC of today commencing from 03 UTC of the previous day is taken as the cumulative rainfall reported at 03 UTC of today. The rainfall value is reset at 03 UTC and fresh logging and accumulation of the rainfall, if any, takes place as per IMD convention.

c) **Ultrasonic wind sensor** which is a very robust, lightweight unit with no moving parts. The measurement range is 0-116 knots (0 to 60 mps) for wind speed and 0-359° for wind direction. The sensor operates over the power range 9- 30V. The sensor gives two separate outputs for the wind speed and wind direction as a digital output.

- The Windsonic measures the time it takes an ultrasonic pulse of sound to travel from the North transducer to the South transducer, and compares it with the time for a pulse to travel from S to N transducer. The times are also compared between West and East, and E and W transducers. WS/WD is obtained by determining which way the wind is going faster.

- An arrow is engraved in the sensor pointing towards north direction. Using a magnetic compass north direction in the station needs to be located correctly and then sensor is to be mounted.

- The transducers fire ultrasonic pulses to the opposing transducers. In still air (zero wind speeds) time of flight between the two transducers is same for all pulses, both forward and reverse directions.

- When the wind blows, it increases the time of flight for pulses travelling against the wind. So from the changes in the time of flight, the sensor calculates the wind speed and direction. For instance if a North Wind is blowing, then the time it takes for the pulse to travel from N to S will be faster than from S to N whereas the W to E, and E to W times will be the same. The wind speed and direction can then be calculated from the differences in the times of flight on each axis. This calculation is independent of factors such as temperature, altitude and humidity. The microcontroller embedded in the neck of the sensor computes the wind speed and direction and reports them to the data logger.
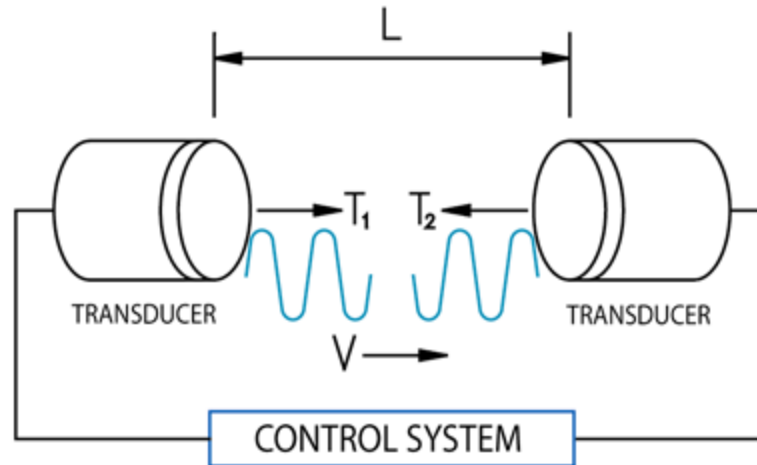
- L = Distance between transducer faces, C=speed of sound (The speed of sound is the distance travelled during a unit of time by a sound wave propagating through an elastic medium. In dry air at 20°C (68°F), the speed of sound is 343.2 metres per second), V= velocity of gas flow (here air) T1 = Transit time of ultrasound in one direction, T2 = Transit time of ultrasound in the opposite direction.

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d) **AT/RH sensor** is a high accuracy sensor with MS connector fitted to a 10 metres long cable. A radiation shield is used for protection of the sensor from direct heat. The sensor gives two separate outputs of 0 to 1 Volt for the air temperature and relative humidity. A. Temperature sensor uses a reference voltage of 12 V.
    - The probe provides a linear 0 to 1V output signal that corresponds to 0 to 100% RH and -40°C to + 60 °C.
    - The maximum and minimum temperatures of the day are retrieved from this sensors.
    - Humidity is the measure of water vapour present in the air. The level of humidity in air affects various physical, chemical and biological processes . Sensor consists of a capacitive humidity sensing element and a thermistor for sensing temperature.
    - The humidity sensing <u>capacitor</u> has two electrodes with a moisture holding substrate as a dielectric between them. Change in the capacitance value occurs with the change in humidity levels.
e) **Soil moisture sensors** estimate the volume of water content based on the dielectric constant of the soil.
    - The dielectric constant indicates the soil's capability to transmit electricity. As the water content of the soil increases, the dielectric constant of the soil

increases, because the dielectric constant of water is much larger than the other soil components, including air.

- Therefore, the measurement of the dielectric constant gives a predictable assessment of water content. Most soil sensors are single-point sensors. They take a measurement at a single location.
- A single point sensor can measure soil moisture and temperature, or soil moisture, temperature and salinity. The sensor can be completely buried in the soil. Some sensors measure volumetric water content for the length of the sensor.

f) **Sunshine duration** is defined by WMO as the time during which the direct solar radiation exceeds the level of 120 W/m².

- Electronic sunshine duration sensors has no moving parts and uses 3 photo-diodes with specially designed diffusers to make an analogue calculation of when it is sunny.
- The output is switched high or low to indicate sunny or not sunny conditions. The calculated direct irradiance value is also available. This sensor operates from 12 VDC power and has built-in heaters to dissipate rain, snow and frost. These are normally switched externally but an optional internal thermostat control is available.

5. **Calibrations of sensor**

Surface Laboratory, the calibration lab of IMD in the O/o Dy. Director General of Meteorology (Surface Instruments), Pune maintains national and working standards. All surface meteorological equipments in the conventional observatories are checked and compared with portable standards once a year for ensuring accurate measurements. Portable standards are traceable to national standards which are regularly compared and calibrated against international / WMO standards.

The Laboratory is recognised by Bureau of Indian Standards as the centre for certification of indigenously made meteorological instruments including thermometers and rain measures.

- **On-site calibrations**

Whenever site visits for preventive maintenance are undertaken, handheld standards are to be taken for checking the following sensors.

(i) Rainfall sensor with rainfall calibrator or syringe / measuring jar.

(ii) Temperature/Relative Humidity sensor with handheld AT/RH standard.

(iii) Station level Pressure with handheld pressure standard.

(iv) Wind Speed with standard handheld anemometer.

If a consistent under/over estimation is observed an offset value can be included in the data logger. Or else, if the sensor performance is erratic it can be replaced with a new one and the defective one can be brought to the lab for more stringent calibration / checks.

- **Soil sensors calibration**

- Most soil moisture sensors are delivered with analogue output and a calibration table, or digital output (SDI-12 for example) with a % VWC output. These are typically derived from a generic soil calibration, which is likely to be different to the soil in your study area.

- It's also worth noting at this point that soil moisture sensors are likely to have different sensitivities, even within sensors of the same model. Individual calibration may be required in some situations.

- Collect soil samples from a representative area and depth. It's important that you collect the type of soil you'll be measuring in your study.

- Sieve out or manually remove any rocks, plant material or non-organic material from the samples.

- Dry the soil samples – The most efficient way to do this is in an oven. The Australian Department of Sustainable Natural Resources recommends a temperature of 105°C to 110°C.

- Soil samples can also be air dried on paper in a warm, dry room; however, this is likely to take days or even weeks.

- Place the dried soil into plastic containers that are large enough for the sensing area of your soil moisture sensor to be completely buried without touching the sides of the container. We recommend at least 2-3 cm of soil between the sensor and the closest edge of the container. You need 1 container for each calibration point you wish to use.

- Create a range of moisture in each sample by adding water, where the first container is kept dry and the final container is fully saturated. You can use the soil moisture sensor to check that each container is increasingly moist. Be sure to measure from the driest to the wettest, or make sure the sensor is fully dried between each container.

- It is important that the soil in each container is well mixed so that the moisture level is consistent.

- Measure and record the sensor output in each container, then take a sample from each container.

- Weigh these samples on an analytic balance and record the wet weight.

- Place each sample into an oven to dry. Once dried fully, record the dry weight of each sample.

- Gravimetric Soil Water content can be calculated as follows:

- ❖ Water Content = (wet weight – dry weight) / (dry weight * 100)

- To convert Gravimetric Soil Water content to Volumetric Water Content, you need the bulk density of the soil. This can be sampled and measured using a SEC 0200 Soil Core Sampler for example. Bulk density is weight by area of soil.
  - ❖ VWC = (Gravimetric Soil Water) x (Bulk Density)

Automatic Raingauge Stations

An automatic raingauge station (ARG) is defined as a "meteorological station at which observations are made and transmitted automatically".

Its main purpose to make rainfall data available in real time.

Norms of AWS site selection criteria and its installation

1. **Each AWS is established in a fenced piece of land admeasuring 12 m X 15 m with good exposure conditions**.
2. **The norms for AWS site selection are**:

   - There shall be no obstruction to the transmitting antenna in south-west direction (170˚-230˚) for azimuth orientation and for 50˚-75˚ for elevation of the antenna if it is satellite communication.

   - The site shall be free from nearby tall buildings, trees, large water bodies, industrial heat source and high tension cables (both overhead and underground).

   - The site shall be selected in such a way that the distance between the fencing and the AWS tower is at least 5 m. This is to minimize the effect of the fence as horizontal obstruction to the sensors.

   - The site with steep slope, high vegetation, low lying place holding water after rain shall not be considered for installation of AWS.

     In order to ensure measurement of unperturbed wind, the guidelines required that distance between wind sensor and any obstruction shall be at least 10 times the height of the obstruction (WMO 1996).

3. **Conditions to be AVOIDED**

- Obstructions like tall buildings, trees etc.

- Location of the site on the edge of a slope, hillocks, cliff or inside a valley

- Large industrial heat sources

- Location near high-tension power lines

- Rooftops, Steep slopes, sheltered hollows, high vegetation, shaded areas or swamps

- Low places holding standing water after rains.

- Underground obstructions like buried cables or conduits.

- Pollution influence from surrounding farms and towns.

4. **Exposure conditions for sensors of meteorological parameters at AWS site.**

5. **Wind speed and direction**

- The wind speed and direction sensors are required to be installed on a mast, at a height of 10m from ground level.

- The sensors are required to be located on the mast, which is installed at a distance of at least ten times the height of nearby buildings, trees or other obstructions.

6. **Air Temp & Relative Humidity**

- The standard measurement height for temperature and relative humidity sensor is 1.25 to 2m.

- The sensor is to be located at a distance of at least four times the height of obstructions like trees, buildings etc.

- The sensors are generally located in an open level area that is at least 9m in diameter.

- The site enclosure should be covered by short grass or natural earth.

- Large paved areas, bitumen surfaces in the vicinity of at least 30m have to be avoided.

7. **Atmospheric pressure**

   - The Atmospheric pressure being an important meteorological parameter, the elevation of the station to which the station pressure relates is very important and hence the chosen site must be located in a flat terrain.
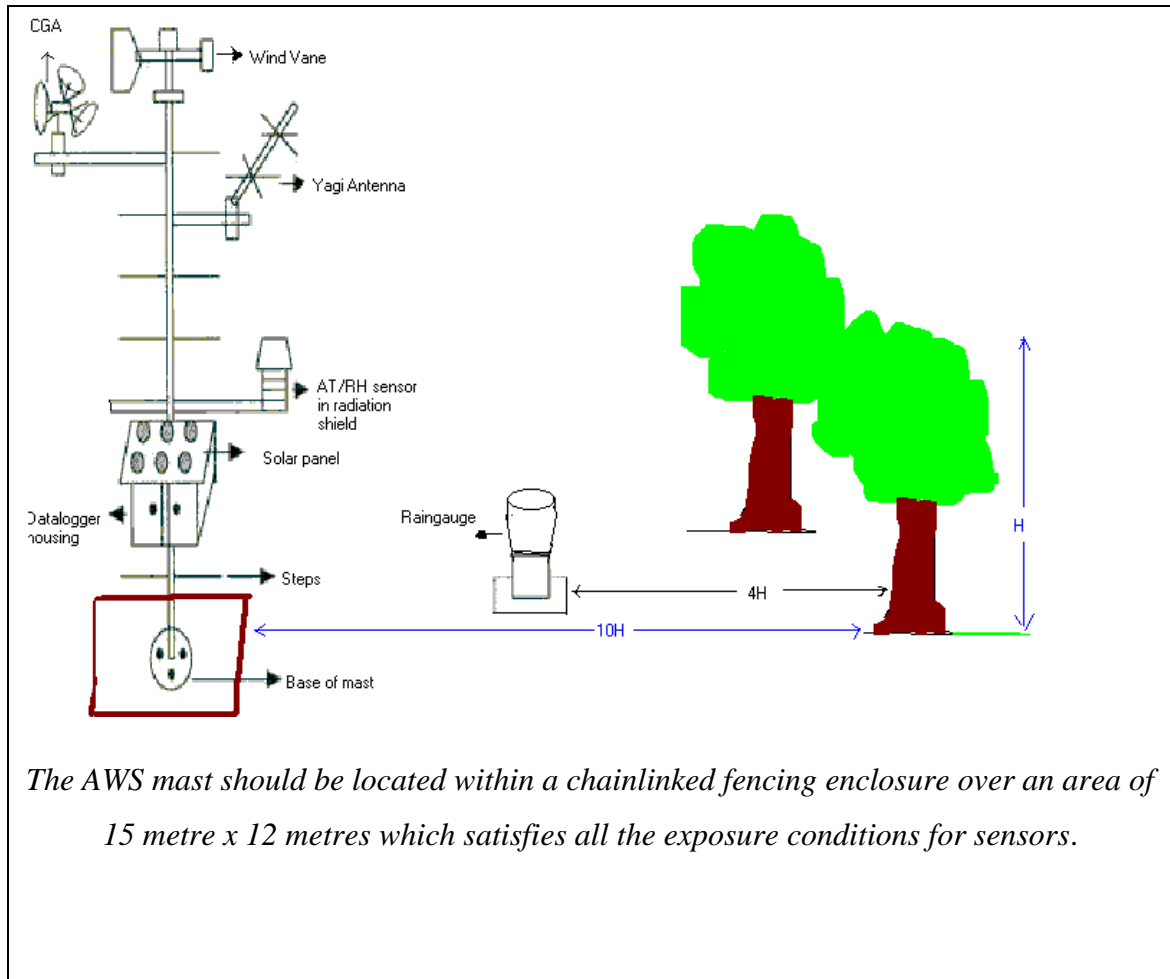
8. **Rainfall**

   - The rainfall sensor (tipping bucket) is placed in an open area as far as possible at a minimum distance of four times the height of any obstruction.

   - The standard measurement height is 30 cm above ground level.

9. **Solar radiation**

   - Solar radiation sensors to be mounted at a minimum height of 3m to ensure easy leveling and cleaning.

10. **A pictorial representation of the AWS site is given below. The figure is broadly suggestive and not exhaustive in nature.**

The AWS mast should be located within a chainlinked fencing enclosure over an area of 15 metre x 12 metres which satisfies all the exposure conditions for sensors.

Norms for ARG Site Selection Criteria and its Installation

1. Each ARG site is established in a fenced piece of land by measuring
   5 m X 7 m with good exposure conditions.
2. The norms for ARG site selection are:
   - There shall be no obstruction to the transmitting antenna in south-west direction (170°-230°) for azimuth orientation and for 50°-75° for elevation of the antenna.
   - The site shall be free from nearby tall buildings, trees, large water bodies, industrial heat source and high tension cables (both overhead and underground).
   - The site shall be selected in such a way that the distance between the fencing and the AWS tower is at least 5 m. This is to minimize the effect of the fence as horizontal obstruction to the sensors.

- The site with steep slope, high vegetation, low lying place holding water after rain shall not be considered for installation of AWS.
- The height of the mast on which the ARG and sensors are mounted shall be minimum 2.5 m from raised platform.

1. Sensor for following met parameter is interfaced to all Automatic Raingauge Stations.

- **Rainfall**

- **In addition to sensor for above mentioned parameters, ARG are also equipped with sensor for Air Temperature and Relative Humidity**.