Lecture Notes

on

AWS and ARG

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INTRODUCTION OF AWS: AUTOMATIC WEATHER STATION

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

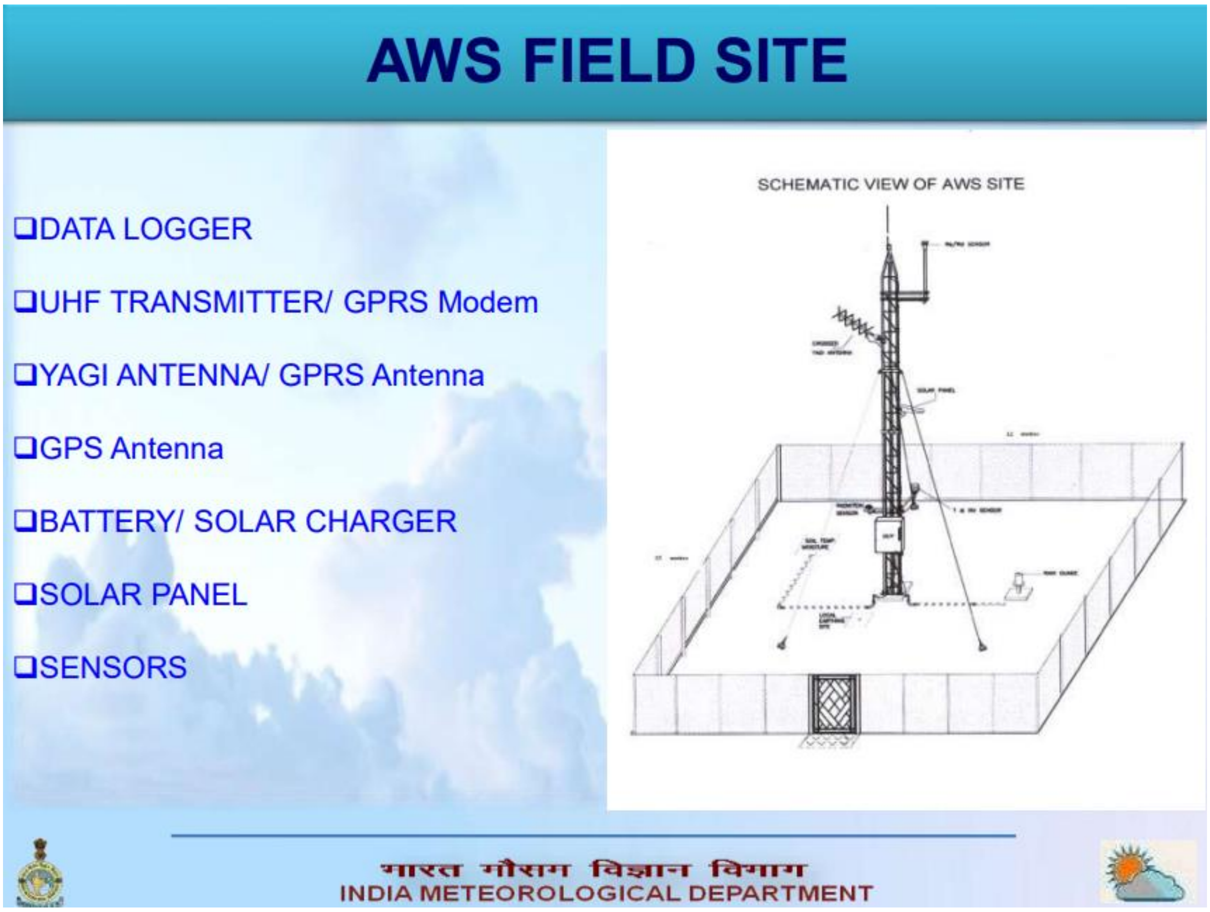
SURFACE OBSERVATION SYSTEMS (AUTOMATIC WEATHER STATION)

❑ An automated weather station is an automatic version of a traditional weather station. They can be single-site or part of a weather network.

❑ Automatic weather stations are the worldwide standard for climate and boundary layer meteorology.

❑ An automatic weather station is an automated version of the traditional weather station, either to save human labour or to enable measurements from remote areas.

❑ A general classification could include stations that provide ➢ Record data in real time ➢ record data for non-real-time or off-line analysis



TYPES OF AWS

1.REAL-TIME AWS:

A station providing data to users of meteorological observations in real time, typically at programmed times, but also in emergency conditions or upon external request. ➢ Typical real-time use of an AWS is the provision of synoptic data and the monitoring of critical warning states such as storms and river or tide levels.

2.OFF-LINE AWS:

A station recording data on site on internal or external data storage devices possibly combined with a display of actual data.

➢ The intervention of an observer is required to send stored data to the remote data user.

➢ Typical stations are climatological and simple aid-to-the-observer stations.

***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.**

ADVANTAGES AND DISADVANTAGES OF AWS

DISADVANTAGES

❑ The main disadvantage of an automatic weather station is that it removes the observer from the real elements being measured, and so the experience of what - 5ºC temperatures or 30 knot winds feel like, is lost.

❑ Loss of data due to communication.

❑ Loss of data due to theft of instruments.

❑ Loss of data due to no maintenance at field site.

❑ Loss of data due to power supply issues at filed site.

ADVANTAGES

❑ Automated weather stations measure all the important surface weather observations. They also offer accurate forecasting options.

❑ These stations are better than traditional ones because they provide accurate and frequent readings, have low power requirements, and can operate practically anywhere.

NETWORK OF SURFACE OBSERVATION SYSTEM

Meteorological and hydrological ground-based observations are collected by the World Meteorological Organization (WMO) through a global network of 8,000+ weather stations.

❑ Rainfall and temperature data provided by the WMO stations are considered most accurate closer to these station locations.

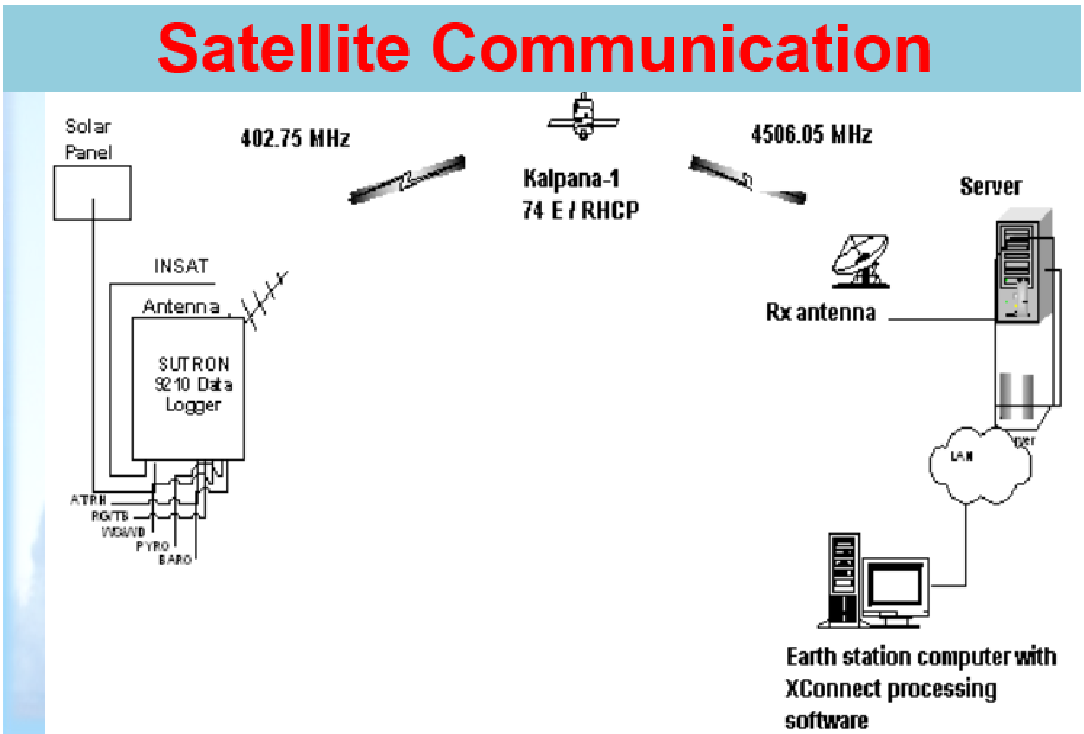
❑ WMO recommends certain densities of rain gauge stations to be followed for different types of catchments.

❑ For small mountainous regions with irregular precipitation, 25 km2 per station is recommended.

❑ According to the same WMO guidelines, the density falls to 10 – 20 km2 per station in urban areas.
❑ AWS for synoptic and climatological networks.

COMMUNICATION CHANNEL OF AWS

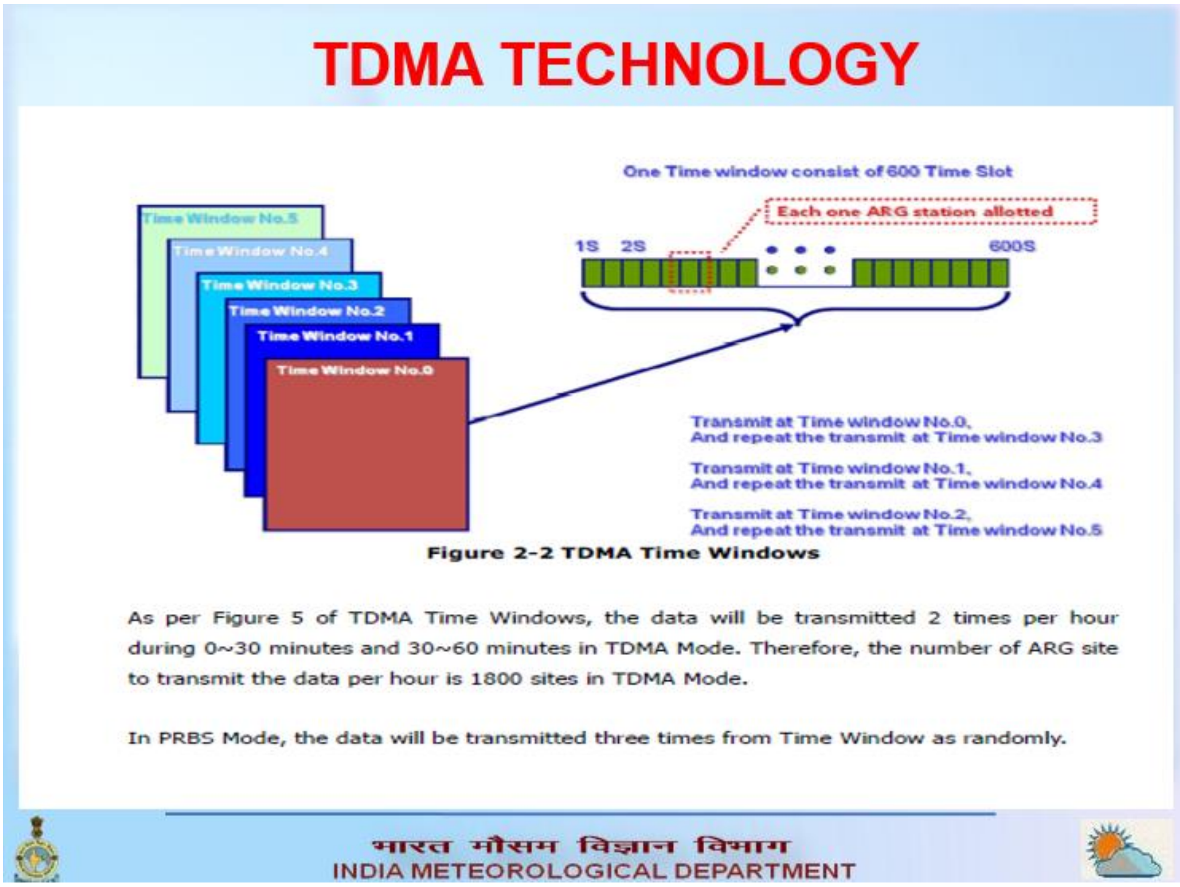
1.SATELLITE COMMUNICATION



- DATA LOGGER
- UHF TRANSMITTER
- YAGI ANTENNA
- GPS
- BATTERY/CHARGER
- SOLAR PANEL
- SENSORS

2. TDMA COMMUNICATION

- Each TDMA type of transmitting AWS / ARG has a unique GPS synchronized time of transmission stamped on the body of the system at the time of installation.
- TDMA technique is an open loop system with timing derived from GPS receiver which is part of AWS/ARG.
- TDMA frame duration is one hour.
- The one-hour frame is divided into 2 time windows, each of 30-minute duration.
- Each AWS is assigned 1-second time slot in any of the 30-minute slot and the repeat transmission is after 30 minutes, which falls in the next time slot.
- So, 1800 AWS/ARG (in a single carrier) will be able to transmit in 30 minutes' slot with repeat transmission and without any collision.
- Sufficient guard time is available and there is no probability of data collision in TDMA type of transmission



DATA TRANSMISSION INTERVALS

DATA TRANSMISSION INTERVALS

Default configurations

Logging interval – 15 mins (4 measurements in an hour - 0000, 0015, 0030, 0045)

FTP Upload interval – 15 mins (4 data in an hour - 0000, 0015, 0030, 0045)

GPS Time sync interval – once in a day (0630 UTC)

Rain measurements: Continuous
Cumulative rain fall values will be reset to zero at 0300 UTC every day

Daily min temperature reported at 0300 UTC every day
(min value in the duration of 1200 ~ 0300 UTC)

Daily max temperature reported at 1200 UTC every day
(max value in the duration of 0300 ~ 1200 UTC)

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 (-) for azimuth orientation and for - 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.

Sensor for following met parameter is interfaced to all Automatic Rain Gauge Stations.

• Rainfall

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

AWS SITE SELECTION CRITERIA

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:

- here shall be no obstruction to the transmitting antenna in south-west direction (-) for azimuth orientation and for -7 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).

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.

EXPOSURE CONDITIONS FOR SENSORS OF METEOROLOGICAL PARAMETERS AT AWS SITE.

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.

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.

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.

RAINFALL

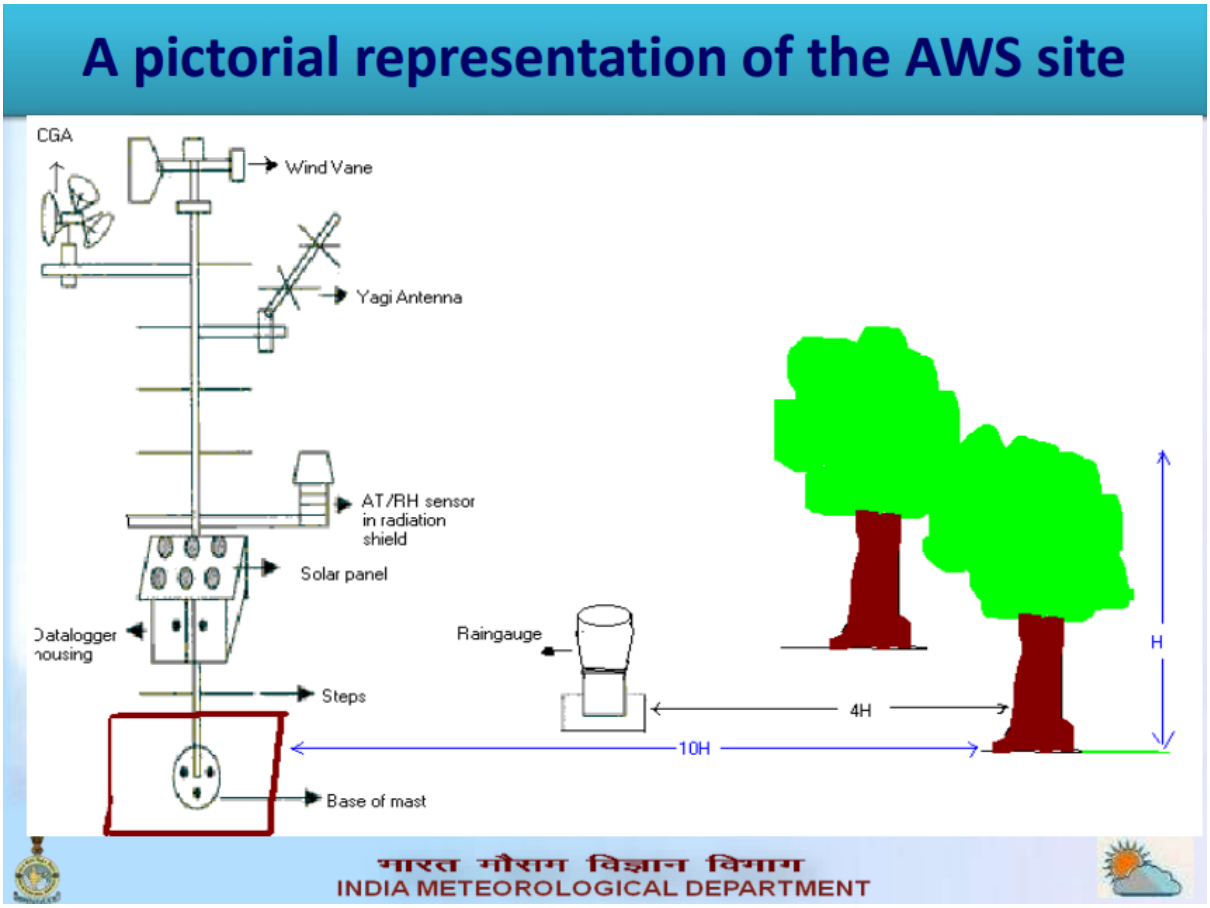
• The rainfall sensor (tipping bucket) is placed in an open area as far as possible at a minimum distance of four times the height of any obstruction.

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

SOLAR RADIATION

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

A PICTORIAL REPRESENTATION OF THE AWS SITE IS GIVEN BELOW.



STATION IDENTIFIERS AND GEOGRAPHICAL DATA

Name: station names usually refer to the city or village where the data are collected.

¬ WMO Code or station number: worldwide, WMO identifies meteorological stations whose data are internationally exchanged with a 5-digit code

¬ Type of station: synoptical, aeronautical, agrometeorological, etc.

¬ Latitude and longitude: preferably with sufficient accuracy that the station is located within a few hundred meters, e.g. in units of 0.001 degree of latitude

HARDWARE / TECHNICAL COMPONENTS OF AWS

1.DATA LOGGER

A DATA LOGGER (ALSO DATALOGGER OR DATA RECORDER) IS AN ELECTRONIC DEVICE THAT RECORDS DATA OVER TIME OR IN RELATION TO LOCATION EITHER WITH A BUILT IN INSTRUMENT OR SENSOR OR VIA EXTERNAL INSTRUMENTS AND SENSORS.

INCREASINGLY, BUT NOT ENTIRELY, THEY ARE BASED ON A DIGITAL PROCESSOR (OR COMPUTER).

2.SD CARD

The image provides instructions regarding the use of an SD card in a data logger:

- **Purpose**: The SD card is used for data storage.
- **Settings**: The data storage interval and other configurations can be done via a menu interface or web browser.
- **Indicator**: During data writing (logging), an LED will light up on the control panel.
- **Preparation**: Before inserting the SD card, create a directory for logging. Ensure that the memory size of the SD card and the logging interval are appropriately selected.
- **Caution**: Do not insert or remove the SD card when the data logger is powered on, as this may damage the card or the data logger.

3.POWER SUPPLY

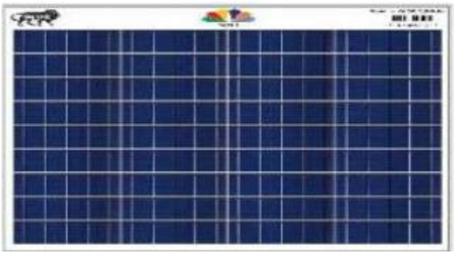
The main power source for an automatic weather station depends on its usage.

- ❑ The purpose of power budget is to ensure that enough power will reach the receiver to maintain reliable performance during the entire system lifetime.
- ❑ Many stations with lower power equipment usually use one or more solar panels connected in parallel with a regulator and one or more rechargeable batteries.

- A solar-powered weather station is a weather station powered by solar power from natural sunlight.

BATTERY

The battery must be maintenance free & it must be of such a capacity that the AWS station will run uninterrupted even in complete cloudy weather for at least 30 days.




SOLAR PANEL

4.SENSORS

SENSORS INSTALLED ON AWS SYSTEM

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.

1. **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.

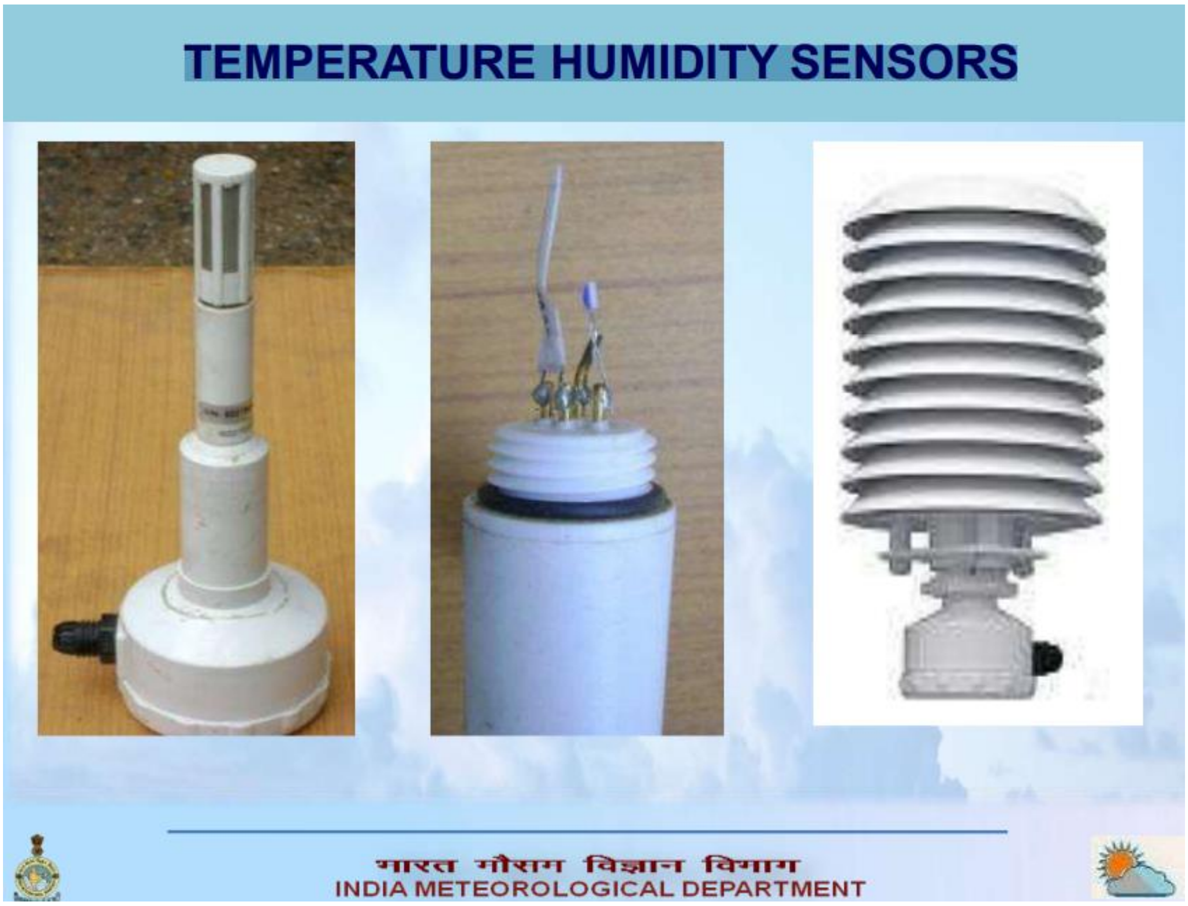
2. **DIGITAL SENSORS**

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.

SENSORS TO BE INSTALLED ON AWS

- ❑ Air temperature and Relative Humidity
- ❑ Wind sensors – Wind speed and Wind direction
- ❑ TBRG sensors - Rainfall Measurement
- ❑ Pressure sensors - Station Level Pressure

1.TEMPERATURE HUMIDITY SENSORS



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 -40ºC to + 60 ºC.

• The maximum and minimum temperatures of the day are retrieved from these 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 capacitor 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.

Air temperature and Relative Humidity is a combined probe with separate sensors for both.

- The sensing element for temperature is a high precision PT 100(platinum resistance) sensor.

- θhe measuring range of temperature –40° to +60°C corresponds to an output of 0 to 1V.
- The sensor for relative humidity is capacitance based. θ 0-100% RH corresponds to 0 to 1V.

2.PRESSURE SENSORS

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.

Pressure sensor is a device for pressure measurement of gases or liquids

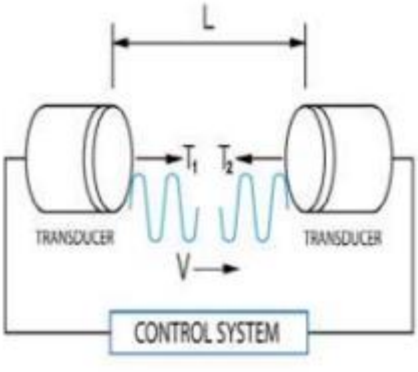
- ❑ A barometric pressure sensor is a sensor that detects atmospheric pressure.
- ❑ A typical example of a barometric pressure sensor is a piezo-resistive type that uses silicon semiconductor. ROHM barometric pressure sensors are silicon based piezo-resistive types.
- ❑ Aneroid barometer consists of an aneroid cell inside. The aneroid cell expands/contracts when there are small changes to atmospheric pressure. Low power design makes it ideally suited for remote monitoring applications. Capable of operating from elevations of 2300 feet below sea level to 18,300 feet above sea level.

Pressure Sensor

3.WIND SENSORS

Gill-make 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.
- ❑ It requires power supply of 12 V and has digital output as RS 232.
- ❑ The Wind sonic 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.



Ultrasonic wind sensor

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 lesser than the time taken for the pulse to travel 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.

$$T_1 = \frac{L}{C+V} \quad \text{and} \quad T_2 = \frac{L}{C-V}$$

Therefore : $$V = \frac{L}{2}\left\{\frac{1}{T_1} - \frac{1}{T_2}\right\} \qquad C = \frac{L}{2}\left\{\frac{1}{T_1} + \frac{1}{T_2}\right\}$$

In AWS, vector averaging of wind speed and direction is done from the 180 samples (@ one per sec) for the three minutes prior to the top of the hour, say, 57:00 to 60:00/00:00 at which hourly observations are sampled for all the sensors.

4.RAINFALL SENSORS

- Diameter of the orifice: 20 cm
- 0.5 mm Rainfall is equivalent to 0.05 cm.
- Amount of water (Volume of water) required for one tilt is
  3.14*10*10*0.05 = 15.7 cc

The sensor is the tipping bucket mechanism and is mounted at a height of 0.6 to 1 m. The collector diameter is 20 cm. So 15.7 cc (product of collector area and resolution) of rain water corresponds to 0.5 mm of rainfall. Each bucket is calibrated to tip when 15.7 cc of rain water is collected in it. At any given time one bucket is always in collection mode. As the bucket tips it causes a magnet to pass by a ruggedized mercury switch, momentarily (0.05 sec) closing the switch. The contact closure initiates event or count accumulation in the data logger. Once the rain is measured, the rain water is directed into drain tubes that allow it to exit through the base of the gauge.

TBRG

AGRO SENSORS

- Sensors used in agriculture for smart farming are known agriculture sensors.
- They provide data that helps farmers to monitor and optimize crops with environmental conditions and challenges.
- These sensors in agriculture installed and fixed in weather stations, drones, and robots used in the agriculture industry.
- Sensors used in smart farming are known as agriculture sensors. These sensors provide data which assist farmers to monitor and optimize crops by adapting to changes in the environmental conditions.

- They are used in agricultural weather stations.
- These equipment’s are equipped with sensors which provide information such as soil temperature at various depths, air temperature, rainfall, leaf wetness, chlorophyll, wind direction, solar radiation, relative humidity, atmospheric pressure etc.

1.SOIL SENSORS

The Soil Moisture Sensor is a Stevans hydra probe using a SDI-12 output and the unit of measurement of soil moisture is water fraction by volume(wfv).

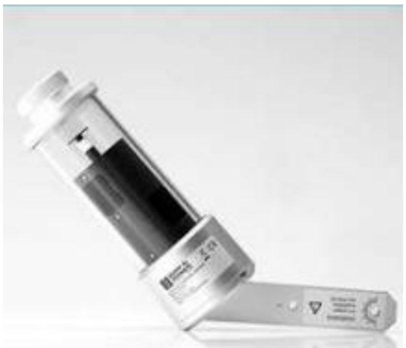
- The Hydra soil moisture probe determines soil moisture and salinity by making a high frequency (50 MHz) complex dielectric constant measurement which resolves simultaneously the capacitive and conductive parts of a soil's electrical response.
- It’s “dielectric impedance” measurement principle differs from TDR, capacitance, and frequency soil sensors by taking into account the energy storage and energy loss across the soil area using a 50 MHz radio frequency wave.

- The Delta-T (ML2x) theta probe is used for soil moisture at 20 cm measurement in Agro AWS.
- The sensor determines soil moisture by making a high frequency (50 MHz) complex dielectric constant measurement which resolves simultaneously the capacitive and conductive parts of the soil’s electrical and conductive response.

- The capacitive part of response is indicative of soil moisture. θ Soil Moisture is measured as volumetric soil moisture content
- Measuring range is from 0 to 1 m3/m3.
- It does not require routine maintenance but requires calibration every year with gravimetric method.

2.SUNSHINE DURATIONS

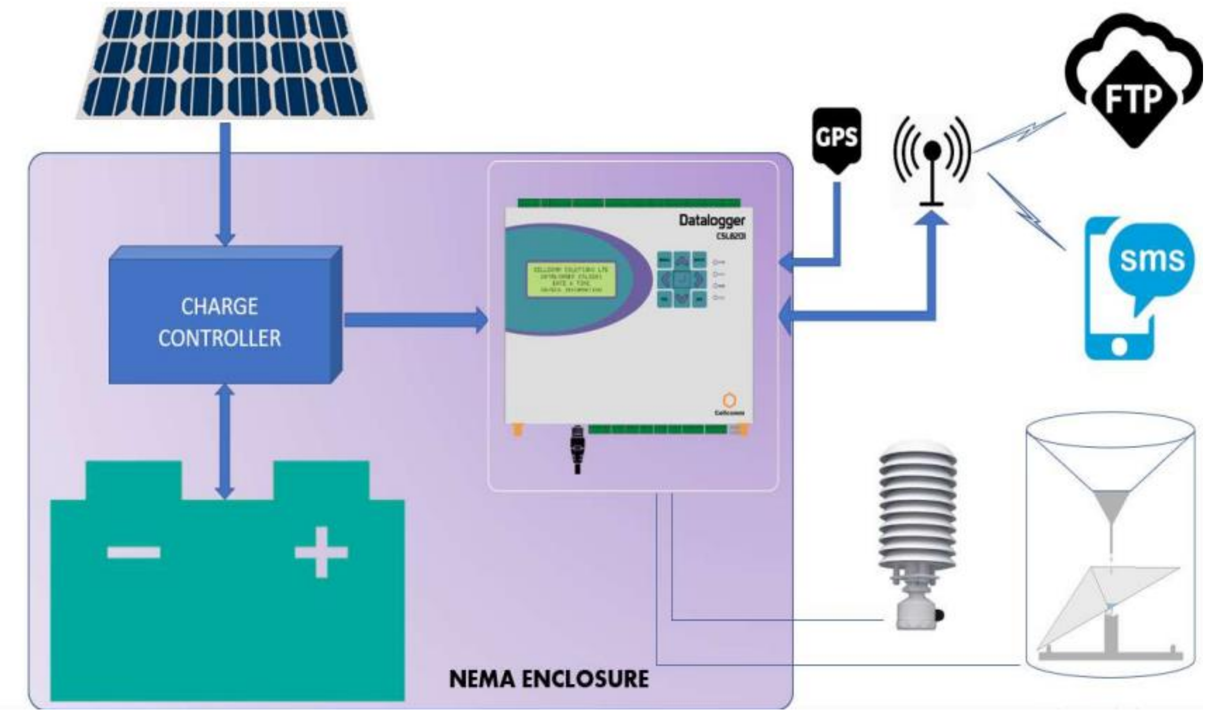
CSD3 measures sunshine duration. Sunshine duration is defined by WMO as the time during which the direct solar radiation exceeds the level of 120 W/m². It has no moving parts and uses 3 photo-diodes with specially designed diffusers to make an analogue calculation of when it is sunny. The output is switched high or low to indicate sunny or not sunny conditions. The calculated direct irradiance value is also available.



ARG STATION

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



ARG SENSORS

SENSORS INSTALLED ON ARG SYSTEM

- ❑ Air temperature and Relative Humidity
- ❑ TBRG sensors - Rainfall Measurement

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 equipment's 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.

(v) 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: ϖ 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. ϖ VWC = (Gravimetric Soil Water) x (Bulk Density)