AUTOMATIC WEATHER STATION (AWS) AND ITS UTILITY

Project submitted by

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CERTIFICATE

This is to certified that project report title "Automatic weather station (AWS), Kolkata" is work done by Sri Supriya Bhattacharyya, MET A, IMD Advance Training in Meteorological. Instrumentation &Information System Batch No. –VIII, ICITC. Under my supervision.

I recommend the project report for submission.

PLACE: RMC, Kolkata.

DATE: 25/08/2021

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3. Introduction:

An automatic weather station (AWS) is defined as a “meteorological station at which observations are made and transmitted automatically”. The surface meteorological observations are being automated by installation of AWS. IMD established a network of 100 Data Collection Platforms (DCPs) across India. Due to system design limitations, network performance achieved was not satisfactory both in terms of data reception and data quality. In 1997, the AWS network was upgraded by induction of 15 new state of art microprocessor/microcontroller-based systems across India under Test and Evaluation mode. The performance of the network during 1998-2005 was observed to be satisfactory in terms of data reception and data quality. It was therefore decided to expand and upgrade the network of AWS under the project “Replacement of old obsolete DCP network with AWS and establishment of data receiving Earth Station at Pune”. During the year 2006-07, a network of 125 AWS has been established across India. The objectives of AWS network are to 1) establish a network of 125 sophisticated state of art AWS for measurement of about 8 to 12 meteorological /agro- meteorological parameters and transmission of these data via a UHF transmitter, in near real time. 2) Reception of the data at the receiving Earth Station via a dedicated meteorological satellite for data processing, archival, data message generation and dissemination of data. 3) Sharing of data with the IMD forecasting centers, and research community through Global Telecommunication System. (The data is also shared with private agencies through email) 4) Augment the manned weather observatory network by providing high temporal resolution data in a cost-effective manner.

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4. History of Automated Weather Station (AWS):

The concept of automation of meteorological observations and their dissemination is not new to the meteorological fraternity. The automation began way back in 1877 when Dutch meteorological instruments designer Olland developed Telemeteograph on suggestion of Buys Ballot. Similar attempt was made in Belgium but the concept could not flourish at that time due to high production and maintenance cost involved. U.S. Navy sponsored development of AWS with radio communication in 1940ies. This AWS was developed by the U.S. National Bureau of Standards. This perhaps was the first AWS in operation. Since that time development of AWS has undergone phenomenal changes. With the advancement in technology especially with the advent of microprocessor technology in 1960s the concept of automatic weather station in its modern form brought revolution in meteorological observations.

The history of Automatic Weather Stations (AWS) in India can be traced back to 1980 when India Meteorological Department (IMD) conducted a pilot experiment with Indian Space Research Organization (ISRO) to operate a small network of Data Collection Platforms (DCP) via SEO satellite to the receiving station at Shriharikota Rocket Range. 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.

5. Types of AWS:

The AWS are broadly classified into two types a) Real time and b) non-Real time (OFF LINE) AWS.

a) Real time: 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

b) Non-Real time: In the case of **Non –real time (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 during adverse weather conditions.

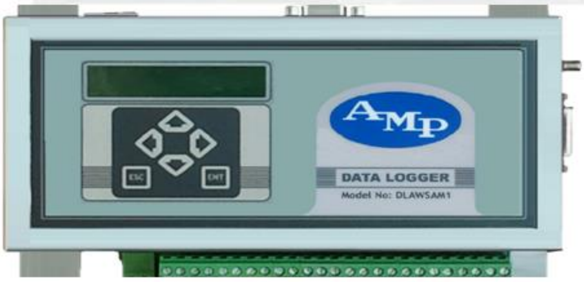
6. Parts of an Automatic Weather Station:

The component parts of an Automatic Weather Station are-

a) DATA LOGGER
b) YAGI Antenna
c) GPS
d) Battery/Charger
e) SOLAR Panel
f) SENSORS

a) Datalogger:

- **A** Datalogger (also 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)



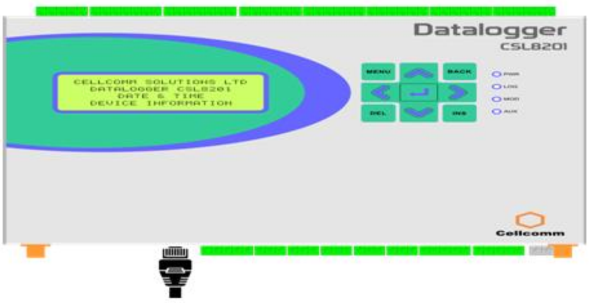


Figure 6. 1-Different types of Data Loggers

- **Data loggers** can monitor temperature, humidity, carbon dioxide, pH, pressure, voltage, current, and pulse – making them useful for a number of **applications**.
- Most **data loggers** operate on batteries, but some models can also be powered externally.
- Usually **data loggers** consume very low power.
- Many **data loggers** have non-volatile memory which ensures that recorded **data** is still safe if the battery fails or power is lost.

b) YAGI Antenna:

Figure 6.2 - YAGI ANTENNA

In AWS/ARG, crossed Yagi antenna is used for uplinking the data to the satellite from the remote field sites. An antenna is a transducer that converts radio frequency electric current to electromagnetic waves that are then radiated into space.
The electric field or "E" plane determines the polarisation or orientation of the radio wave.

c) GPS:

GPS antenna are used for Datalogger clock time synchronization.

Figure 6.3- GPS Antenna

The Global Positioning System (GPS) is a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites.

GPS is used in AWS/ARG for time synchronisation with RTC clock of data logger/transmitter.
GPS time is theoretically accurate to about 14 nanoseconds
Place the GPS antenna in a clear open space as much as possible or high up on the AWS mast on a horizontal position, facing the sky. This arrangement helps to achieve a "full sky" view with the antenna

d) Battery/Charger:

- The AWS are operated with a DC power supply from a 12V / 65 AH Sealed Maintenance Free (SMF) battery which is float-charged by the solar panel of 40W capacity.
- Solar charge regulators are used to regulate the charging voltage from the solar panel which can be even 18V during day time.
- The charge regulators ensure that the battery gets only a voltage of up to 14.5V while charging.

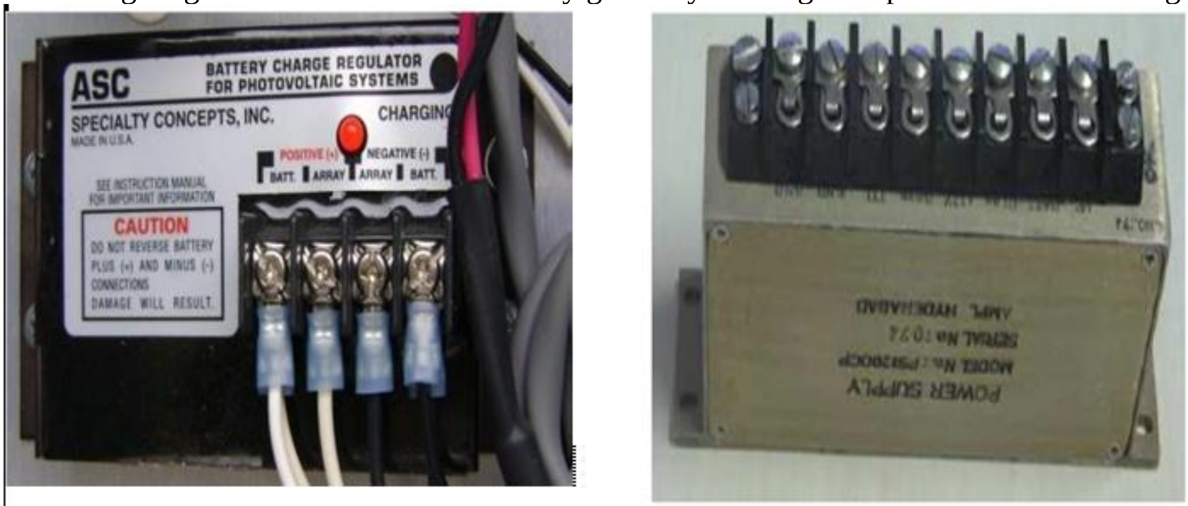


Figure 6.4 - Battery/ Charger

e) SOLAR Panel:

- The main element of a solar panel is the photo-voltaic cell, a semi-conductor device.
- The cell absorbs photons when exposed to sunlight (solar radiation) and produces a voltage potential across the junction of the semi-conductor.
- The most commonly used solar cell is the silicon cell with a PN junction.
- The open circuit voltage for the 30W solar panel is 21V and short circuit current is 2.4 A.
- The solar panel is mounted in the southern direction at a height of about 3-4 m from ground level with an inclination angle which is the total value arrived at by adding the numerical value of the latitude of the place to 10 to 15 degrees.

Figure 6.5 - Solar Panel

7. Sensors used in AWS /Agro 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.
- **Intelligent sensors/transducers:** Sensors including a microprocessor performing basic data-acquisition and processing functions and providing an output in serial digital or parallel form are called intelligent sensors. The Gill ultrasonic sensor is an intelligent sensor with a microprocessor arrangement mounted in the neck of the sensor which performs the basic data acquisition and processing.

a) Temperature Humidity Sensors:

Figure 7.1 - Temperature Humidity Sensors

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

b) Pressure Sensors:

Figure 7.2 - Pressure Sensor

- **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
- Low power consumption } Solid state construction

c) Wind Sensors:

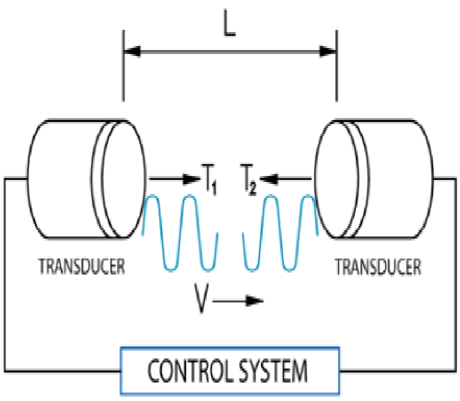


Figure 7.3 – Wind Sensor

- 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 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.

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

L = Distance between transducer faces,
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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
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.

d) Rainfall Sensors:

Figure 7.4- Rainfall Sensor

- 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.

- The collector diameter for Astra TBRG is 159.6 mm and collector area is 200 cm2.
- Since the resolution of the gauge is 0.5 mm, 10 cm3 / 10 ml (product of collector area and resolution) of rain water corresponds to 0.5 mm of rainfall.
- Each tipping bucket is calibrated to tip when 10 cm3/10 ml 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 ruggedised 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.

- 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.

e) Soil Sensors:

Figure 7.5- Soil Sensor

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.
- Soil Moisture is measured as volumetric soil moisture content θV (m3/m3 or % volume).
- Measuring range is from 0 to 1 m3/m3.
- It does not require routine maintenance but requires calibration every year with gravimetric method

f) Sunshine Durations:

Figure 7.6- Sunshine Duration model

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

8. Communication System of AWS:

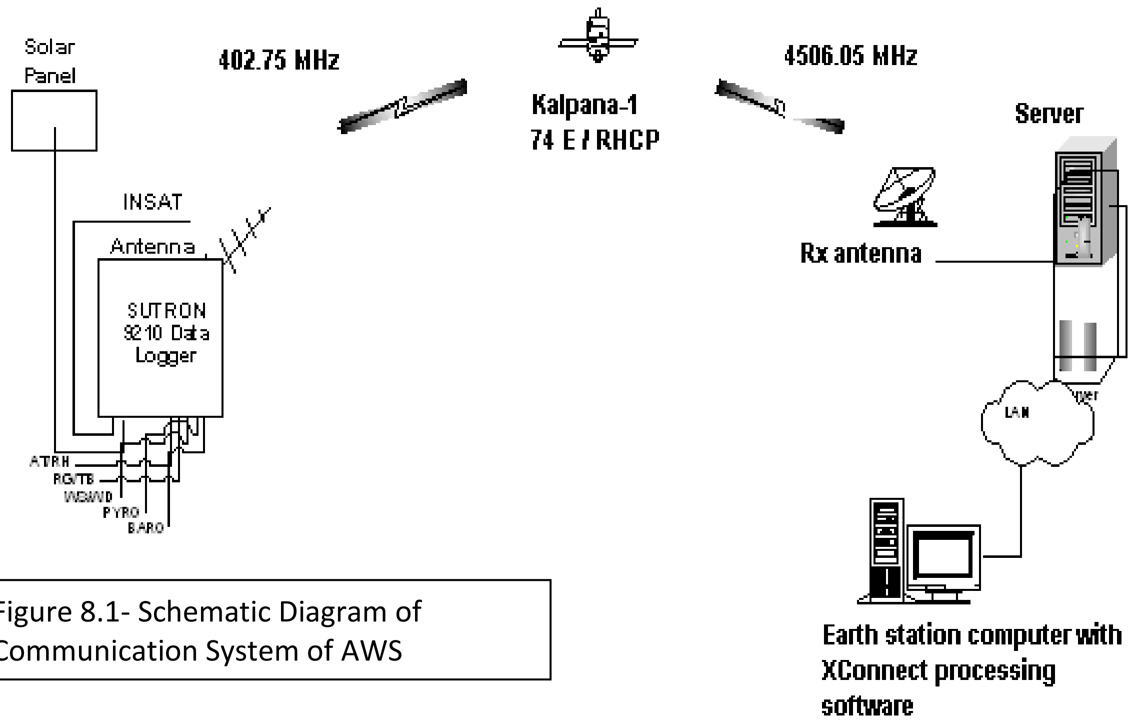


Figure 8.1- Schematic Diagram of Communication System of AWS

i) TDMA Technology:

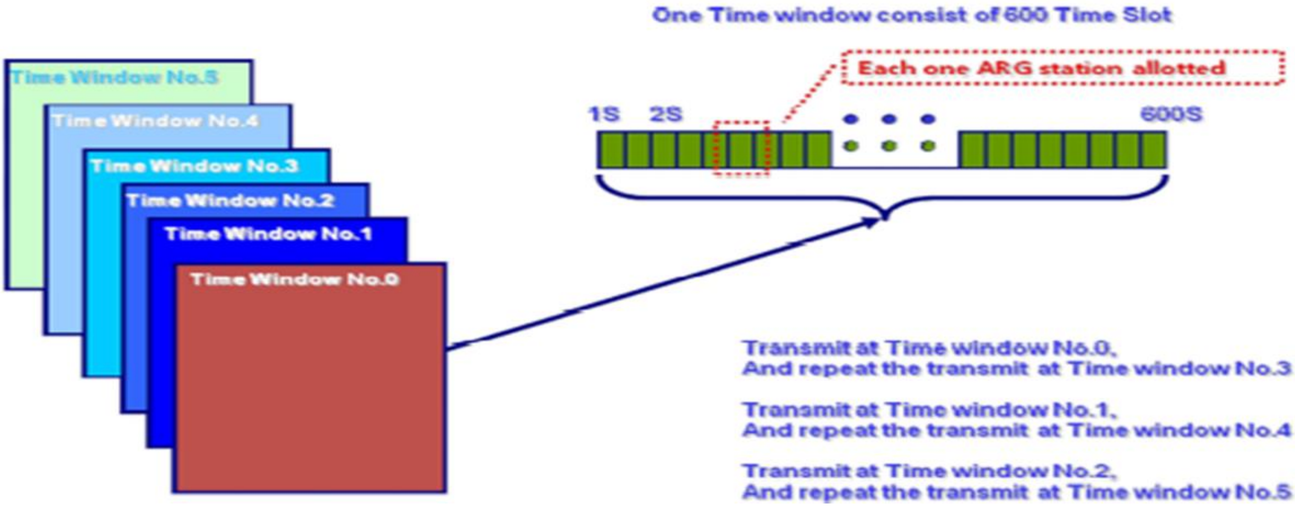


Figure 8.2- TDMA Technology

- 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

ii) Parabolic Antenna for Down Link:

Figure 8.3- Parabolic Antenna for Down Link

In the AWS / ARG data receiving earth station, 3.8m parabolic dish antenna is used which has a gain of 45 dB and receives extended C-band signals from satellite INSAT-3D.

The parabolic antenna is essentially an electromagnetic wave lens which focuses the RF energy (signal) into a narrow beam and converges on a single point known as focus.

The signal is fed to the low noise amplifier via the feed horn assembly on the antenna which is referred to as feed.

iii) GPRS based AWS:

- **GPRS based Data logger used for AWS.**
- **Feature of GPRS Based Data Logger:**
- **Station ID and Static IP address with Port No is required.**
- **GPRS based communication with 2G/3G/4G MODEM.**
- **Dual way communication.**
- **Quality Control at field Level.**
- **Reception of AWS data through Email from AWS site.**

Figure 8.4- GPRS Based AWS Model

v) GPRS Communication:

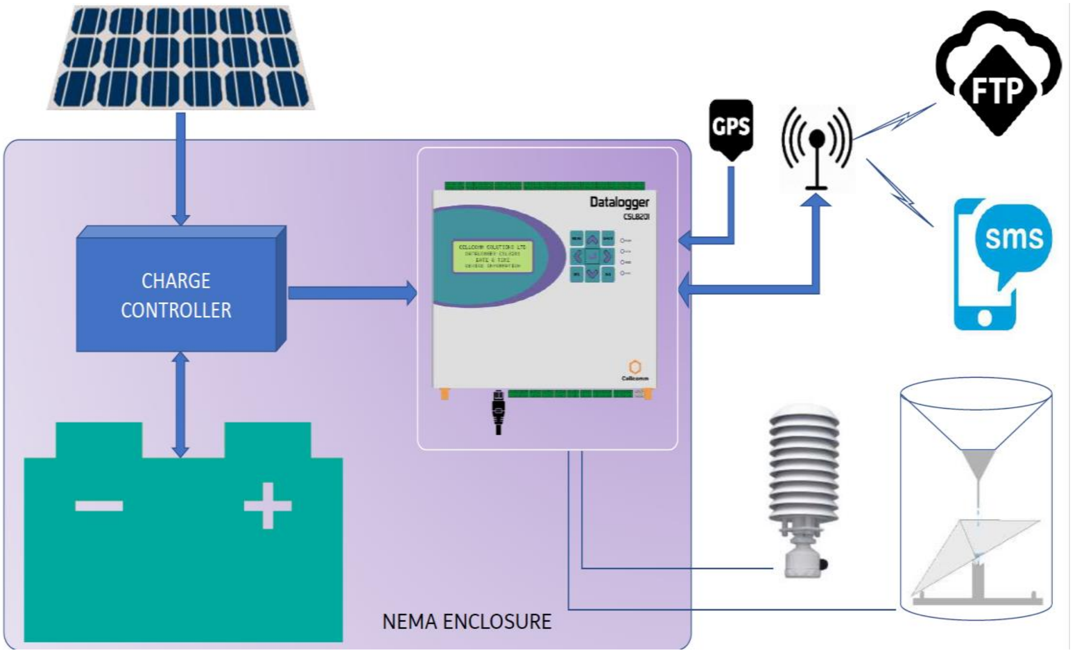
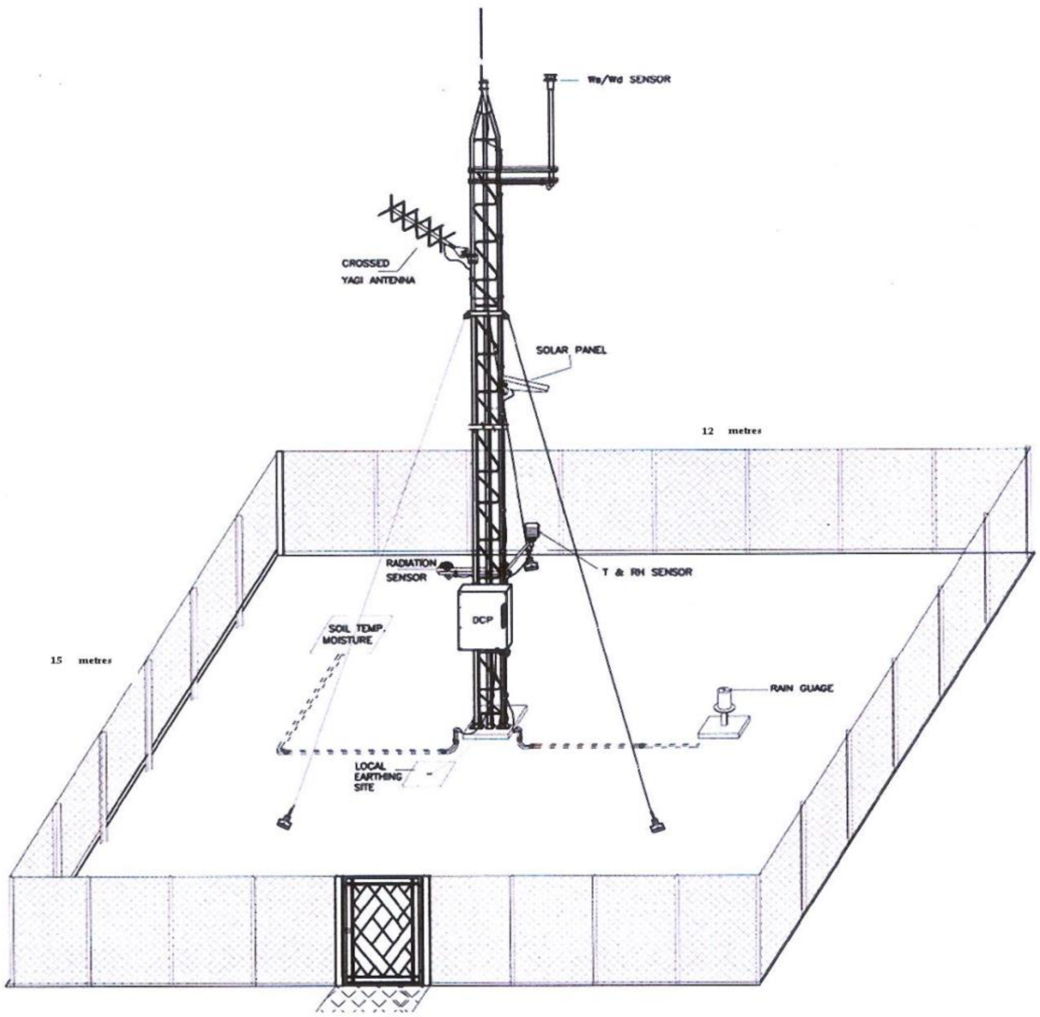


Figure 8.5- Schematic Diagram of GPRS Communication

9.AWS setting up guidelines:

The station layout is shown in Figure 2. A 10 m galvanized iron tower with red oxide coating is used to mount the system enclosure and sensors. The tower is erected on a concrete foundation of 3-5 feet depth depending on site requirement. In addition the tower is supported by three guy ropes. The NEMA 4 enclosure is fixed on the tower at a height of about 1.8 m. Temperature sensor is mounted at 1.2 to 2.0 m above ground. Wind measurement is taken at a height of 10 m above ground. Wind sensor is mounted on a shaft at least 3 feet from the tower. The pyranometer is mounted on a shaft at a height of approximately 1.8 m above ground. The shaft for pyranometer is kept to the south to minimize the effect of tower shadow. The crossed Yagi antenna is installed on a tower at an approximate height of 6-7 m. The antenna elevation and azimuth angle depends on latitude and longitude of the field site and the satellite longitude (74 E). For the AWS network the azimuth angle is greater than170 . The antenna is therefore mounted on the tower facing to south. The tipping bucket rain gauge is installed at a minimum distance of 3 m from the tower. The height of the collector is approximately 0.6 to 1.0 m above ground depending upon the site requirement.

SCHEMATIC VIEW OF AWS SITE



Budget will obviously be one important factor, but three other key considerations to help get your deliberations started are:

i) Selection of sensors:

The first step is to decide which sensors we would like to see in a station, remembering that typically the fascination with weather monitoring grows and the value of the readings is increasingly appreciated after a new station is installed. So whatever sensor specification we choose initially, it may be sensible to choose a station model that offers the option of adding more sensors later.

ii) Selection of make:

Once you've decided on an outline specification for the system, the next step is to choose the best make and model for your needs. Visitors to this site are typically looking for a station providing good accuracy and reliability, but at a price that won't break the bank.

iii) Siting the outside sensors:

The last general point to consider is how and where the outside sensors will be installed. To obtain accurate weather readings it is vital that the outside sensors are mounted with good exposure to the weather parameters being measured.

10. Application of AWS:

Since automatic weather station is applied more and more widely, it mainly can be classified into following four types according to the construction purpose:

i) ***Standard automatic weather station:***

This kind of weather station can measure air temperature, humidity, rainfall, wind direction, wind speed, air pressure, ground temperature, radiation, sunlight, evaporation and other parameters.

ii) ***Automatic weather station for anemometer tower of wind farm:***

The automatic weather station for anemometer tower of wind farm acquires wind speed, wind direction, temperature, humidity, air pressure and other data, providing real-time data source for wind power forecasting system.

iii) ***Automatic Weather Station for Status Monitoring of Power Transmission Line:***

This kind of weather station carries out real-time monitoring of wind speed, wind direction, temperature, humidity, air pressure, rainfall, optical radiation and other meteorological elements for Weather Online Monitoring System of Overhead Transmission line and also can realize real-time video image monitoring of power line as required, providing reliable data base for status monitoring and maintenance of transmission line.

iv) ***Automatic Weather Station for PV Power Station:***

The automatic weather station for PV power station is applied to monitor the meteorological conditions in solar power plant, which samples total radiation, perpendicular incidence, scattering, wind speed, wind direction, temperature, humidity, air pressure, solar panel temperature and other parameters, providing real-time weather data for solar power forecasting system.

11. Conclusion and Advancement:

Records of daily weather conditions have been kept for 200 years and more, of course, but traditionally have always required a diligent and dedicated human observer to record readings from manual instruments at a fixed time, without fail, every single day.

The benefits of AWS are as follows:

- Routine daily maintenance chores (eg emptying the rain gauge) are done automatically;
- AWS stations can automatically record maximum and minimum values for a range of weather parameters through each day and keep track, for example, of total monthly and yearly rainfall;
- Readings can be easily taken direct from the console display;
- A data logger and PC can be readily linked to the station so that all weather data is automatically logged. This means that;
    - Automated systems can run for weeks and months without attention whilst continuously recording all details of the weather;
    - Much greater within-day detail is available eg the complete pattern of wind speed & direction through the day can be logged;
    - Comprehensive statistics can be automatically calculated and analyzed;
    - Impressive visual graphics can be displayed;
    - Detailed weather conditions may be viewed at any distance from the station itself, for example over the Internet;

- 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 standardizing 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.
- Comparison of Remote Sensing / Satellite data with actual ground data.