Coexistence of Automatic Weather Station (AWS) System in harsh environmental conditions at National Meteorological Centre (NMC) Colombo, Sri Lanka.

Nuwan Kumarasinghe
Department of Meteorology, Bauddhaloka Mawatha, Colombo 07, Sri Lanka.
Telephone: 94-11-2681039, Fax: 94-11-2698311, e-mail: nuwan1960@yahoo.com

ABSTRACT

The main objective of the AWS system is to monitor near real time weather in frequent time periods. AWS system has to be suited for any harsh environmental conditions. Though the 2004 December Tsunami severely affected the country, loosing more than 40,000 lives in the southern and eastern parts, the impact of other disasters such as flood, land slide and lightning is more, considering the annual human deaths and property damage including sophisticated electronic equipment. Several modernization projects were initiated to improve the quality of service of National Meteorological Centre(NMC) Colombo, Sri Lanka. Among the many projects, establishing of 38 AWS in Sri Lanka was implemented under the Japan International Cooperation Agency (JICA) grant aid project. This project was initiated in May 2007 and completed in mid July 2009. Most of the sensors used in the project are of the high quality. It is noticed that some sensors which are already installed are in faulty condition, specially *Vaisala's WS 425* Ultrasonic wind sensor. The said sensor is recognized as a reputed wind sensor and used in all parts of the world. Faulty conditions occur mainly due to natural disaster like lightning. Precautionary measures against lightning are a must for meteorological sensors. This paper discusses a case study of equipment damage to *Vaisala's WS 425* wind sensor due to lightning and improper earthing arrangement. Precautionary methods are also being discussed.

1. Introduction

A project of installing thirty eight (38) AWS was taken place in Colombo NMC in Sri Lanka under the Japan International Cooperation Agency (JICA) grant aid. This was a part of the modernization process of Colombo NMC after Tsunami disaster, which severely affected many parts of the island in December 2004. The main objective of the project is to improve the quality of meteorological data in the country in regular intervals. The design of the project was done by the Japanese experts after performing a preliminary site survey in many parts of the country. It was planned to install 31 AWS by the Japanese contractors and the balance seven (7) AWS are supposed to be installed by the Department of Meteorology in Sri Lanka. These seven AWS were planned to install in the northern and eastern parts of the country where country's civil war was taken place nearly three decades. Presently 33 automatic weather stations have been installed throughout the country.

The system collects meteorological data in every one minute and stores in a data logger and then transmits to Colombo NMC in every 10 minutes via Very Small Aperture Terminal (VSAT) link. The system comprises of quality meteorological sensor block, data logger and satellite communication block. Some regular faults are noticed in the system during the past 11 months period. Malfunction of the wind sensor is badly highlighted. Seventeen (17) wind sensors of 14 locations have been found faulty during the past eleven month period. These ultrasound wind sensors are of in good quality *Vaisala WS 425* have a reputed name in meteorological community across the world. In some locations, even after the replacement with the new components, some were damaged.

2. Main objective

The main objective of this paper is to find the possible root cause of these faults. This paper further describes how a *Fishbone Diagram* (Fig. 1) can be used to identify problems with *Vaisala WS425* ultrasound wind sensor. It is a valid fact that the design of the ultrasound wind sensor is of the high quality and many automatic weather systems use this type of sensor for reliable data acquisition. There are so many possible factors (in no particular order) which may influence the faulty of the sensor;

- Sitting issues
- Interface problems
- Damages due to lightning
- Power issues

Each of these factors contains several sub-factors, any one of which could cause poor performance of the wind sensor.

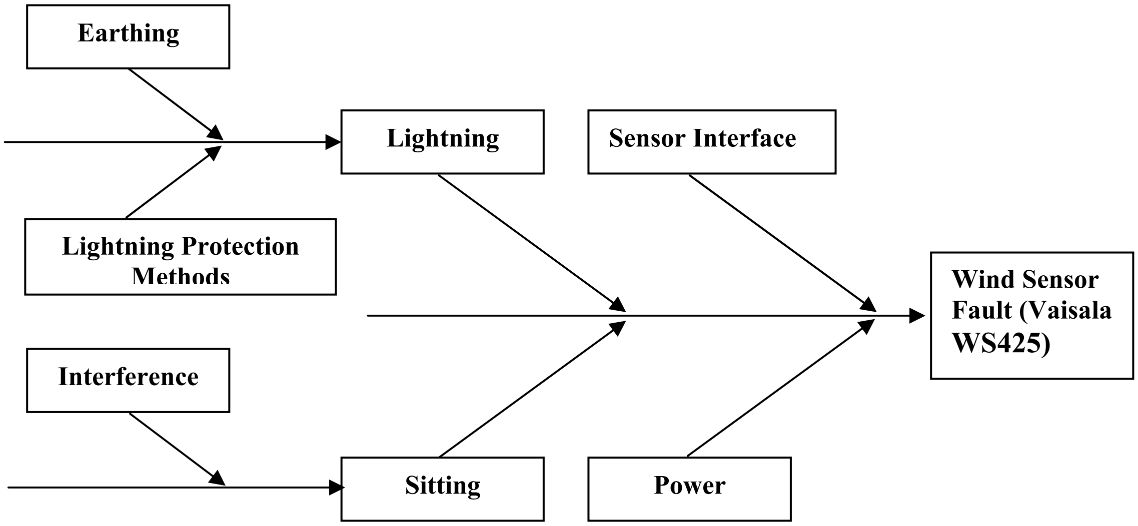
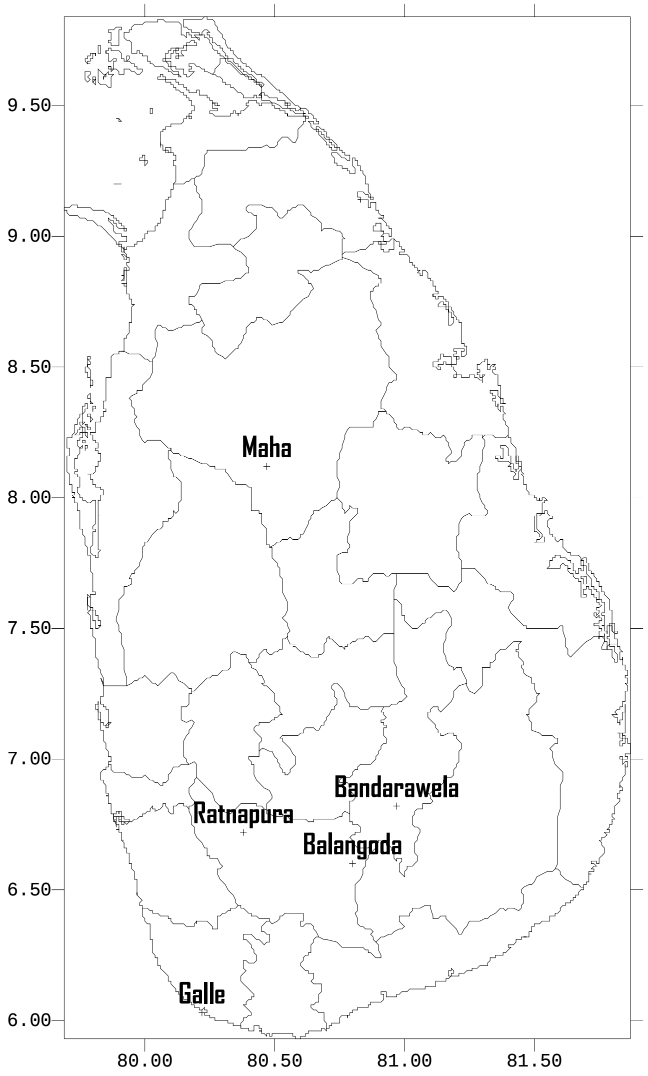


Fig. 1 Fishbone Diagram for Fault Analysis

This paper concentrates only the effect of lightning and influence of its sub factors for the continuous damages of these sensors. Lightning data, earth resistance and soil resistivity data of five stations namely *Galle,Ratnapura, Mahailluppallama, Balangoda and Bandarawela* (Map 1) are considered for this study.

STATION MAP



Map 1 AWS station Map

3. Why a Fishbone Diagram uses for troubleshooting?

Fishbone diagrams were invented in 1943 by *Kaoru Ishikawa*, who pioneered quality management in the *Kawasaki* shipyards, and they are sometimes called “ *Ishikawa Diagrams”* (they are also called “ Cause and Effect Diagrams”). The value of the fishbone diagram is to assist in categorizing many potential causes of a problem in an orderly way in identifying root causes. It provides a comprehensive picture of all the causes of a particular outcome, in this case particular damaged wind sensor.

The advantages of using a fishbone diagram are several. First, it permits a rigorous analysis which overlooks to identify the root cause for the particular effect. Without using this organized methodology, the approach might be “trial and error” depending on individual expertise. Another aspect is, it fosters “ brainstorming” among several troubleshooting team members such as operators, engineering and technical staff, installers and designers, and gives “ clear picture” as to possible causes or influencing factors.

4. *Vaisala WS425* Ultrasound wind sensor

The WS425 sensor (Fig. 2) uses ultrasound to determine horizontal wind speed and direction. The measurement is based on transit time, the time taken for ultrasound to travel from one transducer to another, depending on the wind speed.

Fig. 2 *Vaisala* WS 425 Sensor

The transit time is measured in both directions for a pair of transducer heads. Using two measurements for each of the three ultrasonic paths at angle 60^0 to each other, WS 425 computes the wind speed and direction. This sensor uses very sophisticated electronic components which are susceptible for lightning surge currents.

5. Influence of lightning in component failures

Lightning is very common phenomena which brings lot of human and property damages in Sri Lanka. The Keraunic number, i.e. number of thunderstorm days per year (Td/Yr) or Isokeraunic level, is a measure of exposure rate. The higher the Keraunic number, the greater the stroke activity encountered in that area. In Sri Lanka this number varies from 40 days (*Pottuvi*l) to over 160 days. Proper counter measures against lightning effects have to be taken during the installation of any electronic based system such as AWS.

Depending on the type of lightning flash, each lightning discharge consists of one or more partial strikes of lightning. One can distinguish between short strikes with less than 2 ms duration and long strikes with a duration of more than 2 ms.

Lightning consisting of both impulse and continuing currents are load-independent. If a load-independent active electrical current flows through conductive components, the amplitude of the current, and the impedance of the conductive component the current flows through, which help to regulate the potential drop across the component flown through by the current.

If a current is formed at a single point on a homogeneous conducting surface (Fig. 3), potential gradient area arises. This effect also occurs when lightning strikes homogeneous ground. Higher the conductivity of the ground, decreases the shape of the potential gradient area. The risk of dangerous step potential also been reduced.

The undesired consequences of lightning surges include both equipment damage and equipment malfunction or lockup. Equipment damage occurs when excessive surge voltage flashes over or punctures semiconductor junctions. Semiconductors are also sensitive to accumulated over voltage stress. Successive surges chip away at the insulating layers in a process referred to as "electronic rust". When the equipment finally fails it is often not attributed to surges because there was no known major event such as a lightning storm coincident with the damage.

Surges can cause equipment malfunction or lockup without causing damage. A small surge in a digital circuit can cause a false data pulse and lock up the operating system.

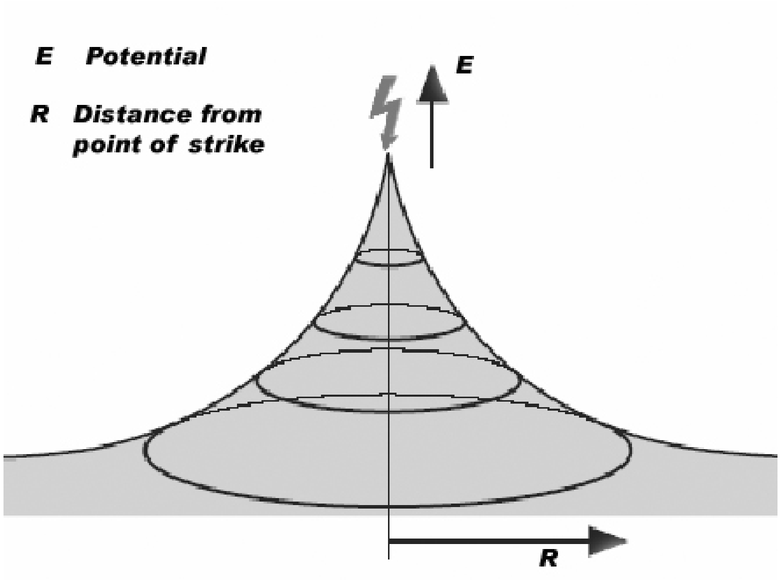


Fig. 3

If lightning strikes a structure such as AWS mast which is already equipped with Franklin rod type direct lightning protection system, the lightning current flowing away via the earth termination system of the AWS mast. It gives rise to a potential drop across the earthing resistance of the AWS system. Therefore it is necessary to bond all conductive parts of the system together to avoid any possible lightning current passes. If this is disregarded, possible component failures of the equipment can be expected. Equipment can be damaged mainly in two ways;

i. lightning strikes the AWS mast either as a direct hit or secondary effect then induced lightning current passes through the equipment or the circuit.
ii. once lightning strikes the AWS mast, lightning current discharges through the mast. At the point of strike on the surface earth potential rises. If different voltages induced in different parts of the AWS system lightning surge current travels from higher potential point to the lower potential point damaging the sophisticated equipment or circuits (Fig 4).

As the wind sensor is fixed on the mast which is the highest point, the probability of lightning strikes is higher than the other locations in the system. Therefore, the direct lightning current or the induced lightning current due to the secondary effect of lightning passes through the equipment damaging sophisticated electronic circuitry.

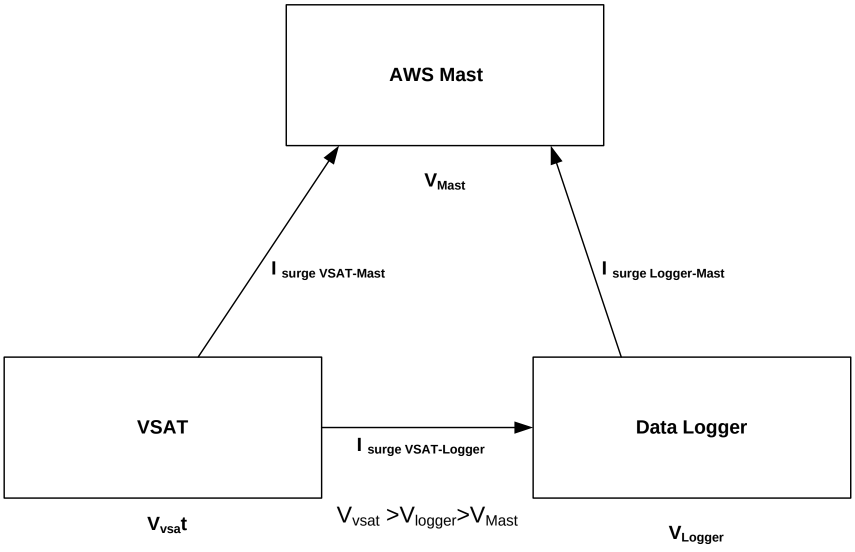


Fig. 4

6. Case study

Wind sensors of fourteen (14) AWS locations have been damaged during the past eleven month period. A total of 17 wind sensors have been damaged during this period. In our case study, five (5) AWS locations have been selected in *Balangoda, Bandarawela,Galle,Maha Illuppalama and Ratnapura*. Soil resistivity and earth resistance of AWS Mast, VSAT and Data Logger were measured. Thunder reported date/s are also been considered for this study. Earthing arrangement is also been considered. Satellite pictures of METEOSAT were used for the verification purposes.

Soil resistivity, earth resistance values, faulty date/s and whether thunder reported or not are listed in Table 1.

No	AWS Location	Faulty Date/s And Time (SLT)	Soil Resistivity (Ohm-m)	AWS Mast Earth Resistance (Ω)	VSAT Earth Resistance (Ω)	Data Logger Earth Resistance (Ω)	Whether thunder reported or not
1	Balangoda	20-7-2009 (@15:20) 16-12-2009 (@15:20)	145	8.0	12.0	12.8	Severe thunder
2	Bandarawela	27-8-2009 (@6:20)	475	29.0	47.0	69.0	Possible thunder
3	Galle	17-7-2009 (@0:10) 30-8-2009 (@18:30)	44.5	9.3	12.2	10.3	Severe thunder
4	Maha Iluppallama	17-4-2010 (@15:50)	23	6.55	4.19	6.28	Severe thunder
5	Ratnapura	18-12-2009 (@21:20)	300	17	82	14.0	Severe thunder

Table 1

It is noted that earth resistance values of AWS Mast, VSAT and Data Logger are different in above five cases. This is due to disregard of common earthing during the installation.

6.1 Damaged wind sensors

Wind speed and direction are both important meteorological parameters in routine meteorological work. *Vaisala* WS425 ultrasound wind sensor is a known quality sensor used among the meteorological and environmental community. The measuring range of the sensor is 0- 65 m/s for the wind speed and 0-360^0 for the wind direction. Current consumption is around 12 mA and power supply used is DC 10- 15 V. This sophisticated sensor can withstand for only few hundred volts in a transient situation such as lightning strike. *Franklin* rod type direct lightning protection system has been installed in order to minimize the damage, but earth terminal of the *Franklin* rod is not bonded to the sensor equipment, therefore sensor is in floating mode.
A photo of a damaged PCB circuit of a wind sensor (Ratnapura AWS site) is shown in Fig. 5.

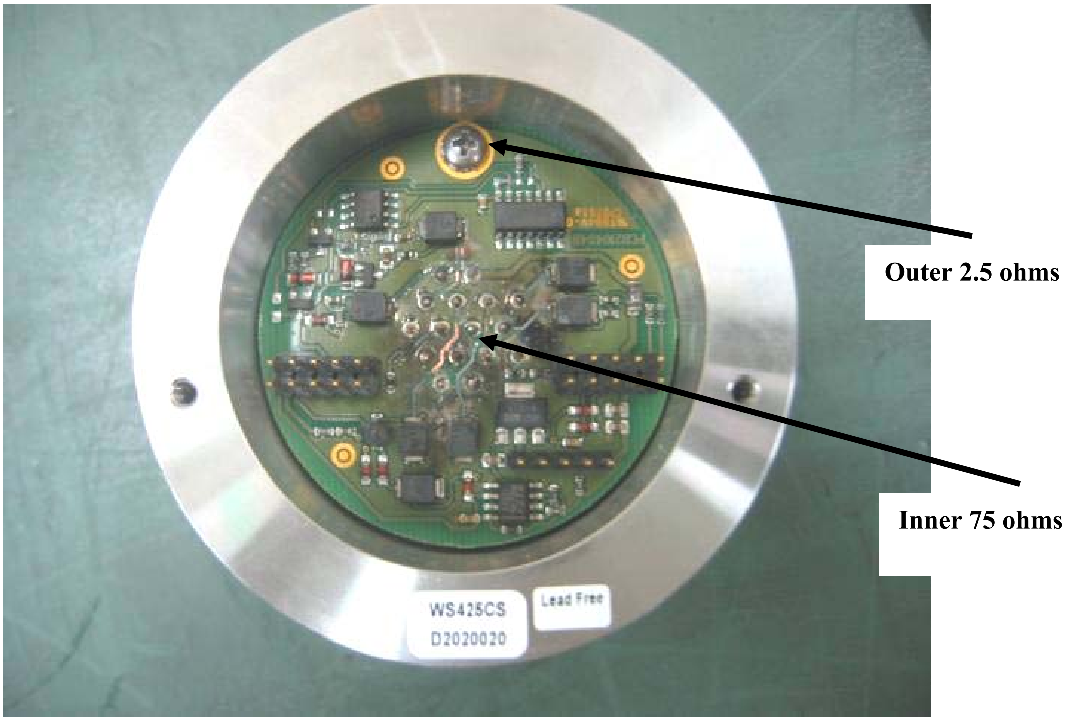


Fig. 5 damaged wind sensor circuit in *Ratnapura* AWS Site

Earth resistance of the outer of the sensor is measured as 2.5 ohm where as the inner earth resistance value is measured as 75 ohms. Low resistance value of 2.5 ohm is given due to the consequence of lightning strike, otherwise this point should be in floating mode with a higher resistance value. Outer cover is normally not bonded to the lightning rod earth. This faulty is mainly due to the improper installation practice avoiding the equi-potential bonding. Photos of the damaged wind sensor adapter and circuit are given in Fig. 6 to Fig. 8.

Fig. 6 Wind Sensor

Fig. 7 Adapter Wind Sensor side

Fig. 8 Adapter AWS Mast side

6.2 Probable cause for wind sensor damage in *Ratnapura* AWs Site

Measured soil resistivity, earth resistance of AWS mast, VSAT and the Data Logger in Ratnapura AWS site are 300, 17, 82 and 14 (Fig.9- 12) respectively. Three earth resistance values are high and different, therefore different earth potentials can be induced when lightning strikes. Hence lightning surge current passes through the mast to the earth by damaging the sensitive electronic circuitry. Soil resistivity value is also relatively high (300 Ω -m). Higher the resistivity of the ground, increases the shape of the potential gradient area.

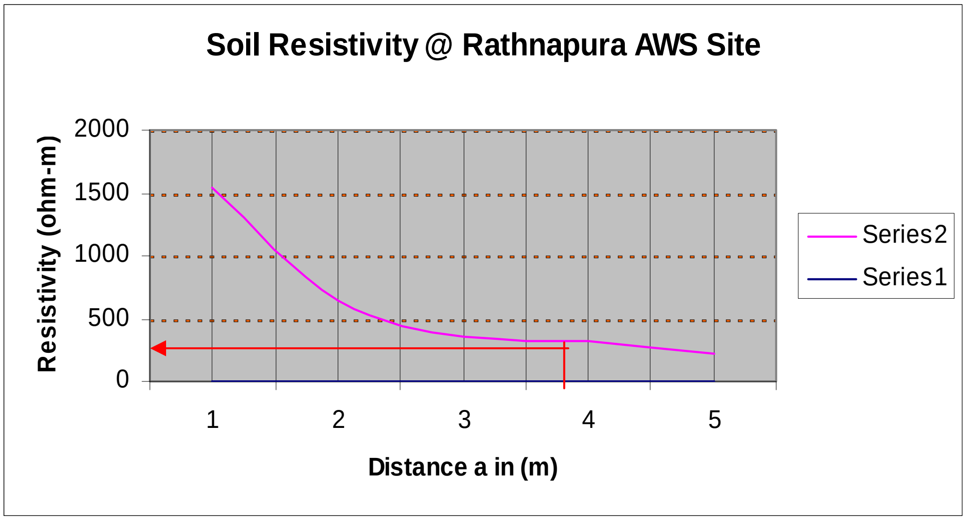


Fig. 9 Soil Resistivity at *Ratnapura* AWS Site

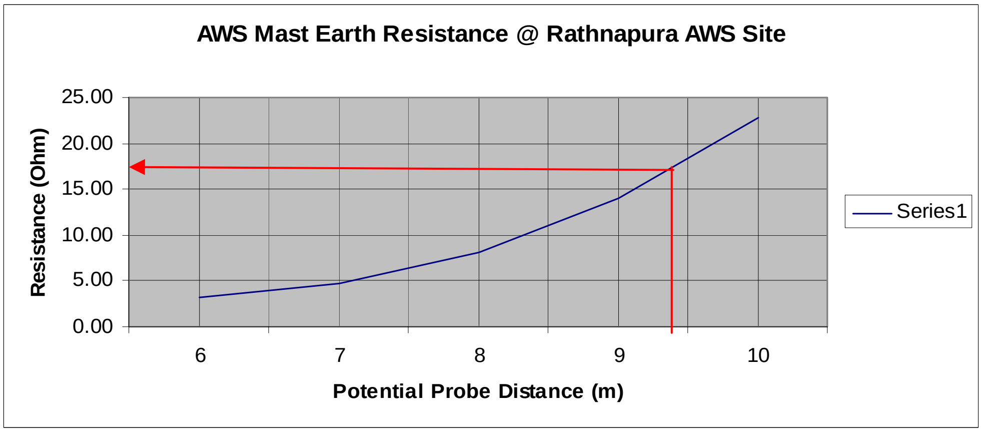


Fig. 10 Earth Resistance of AWS Mast at Ratnapura AWS site

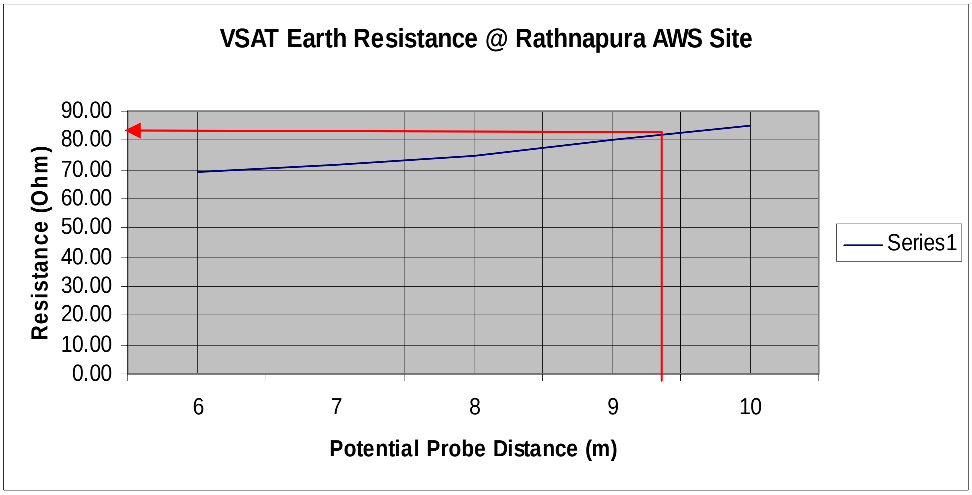


Fig. 11 Earth Resistance of VSAT at Ratnapura AWS site

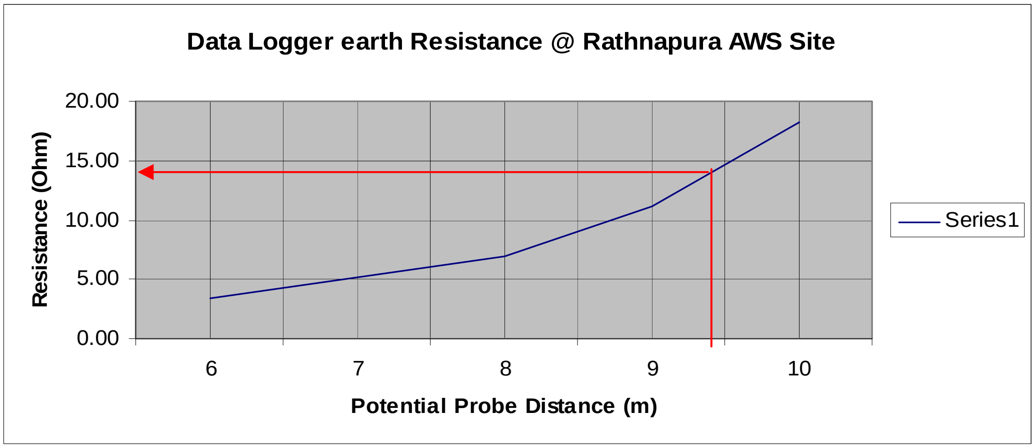


Fig. 12 Earth Resistance of Data Logger at Ratnapura AWS site

6.3 Verification of lightning and thunder activity in AWS sites

Visual thunder observation at each site and METEOSAT cloud imaginaries (Fig. 13-17) are used to verify whether lightning occurs in each site at particular time. It is clearly indicated that lightning has taken place in all five sites in fault reported dates and times.

Visual inspection of the damaged wind sensors and respective earth resistance values also confirm these damages are due to lightning and improper earthing mechanism used during the installation.

7. Conclusions

It was a tough target to find out the root cause for continuous damage of *Vaisala* WS425 ultrasound wind sensor. More than 50% of wind sensors used for AWS project in Colombo NMC have been found faulty. Systematic approach by using a *Fishbone Diagram* used to identify problems with *Vaisala WS425* ultrasound wind sensor. It was identified that lightning and improper earthing were the main causes for continuous damages of the wind sensor.

As a remedial action, the following corrective measures have to be taken in AWS installations, otherwise by using only a high quality sensor like *Vaisala* WS 425, one cannot expect accurate and continuous data in AWS network.

- Conduct a proper site survey with soil resistivity test and also analyze lightning data in the area concerned at least for last 10 years prior to the installation.
- Avoid high tension power lines (it was noticed that some AWS locations were in close proximity of high tension lines) in the vicinity of the proposed AWS site to avoid any inductive and resistive coupling during lightning.
- Equipotential bonding of all individual earth terminals in order to avoid possible flash over during lightning.
- Introduce lightning surge protection devices for power and data lines to avoid induced surges.
- Measure earth resistance values of the AWS system in every 6 month period prior to intense lightning activity periods (two inter Monsoon periods March-April and October-November) and maintain the resultant earth resistance values below 10 ohms.
- Do all earthing work according to accepted lightning protection and earthing Standards.
- Clean all sensors periodically.

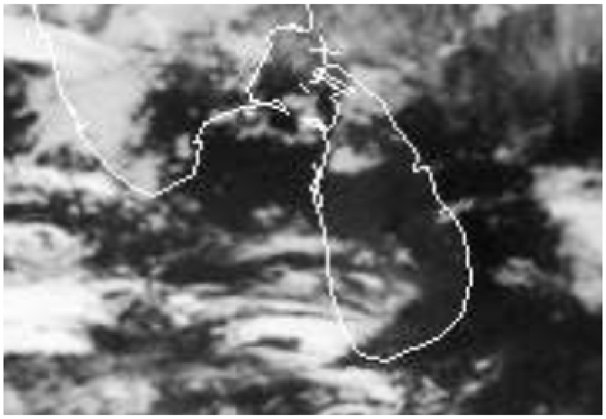


Fig. 13 METEOSAT Image at 1800 UTC on 17th July 2009

Fig. 14 METEOSAT Image at 0000UTC on 27th August 2009

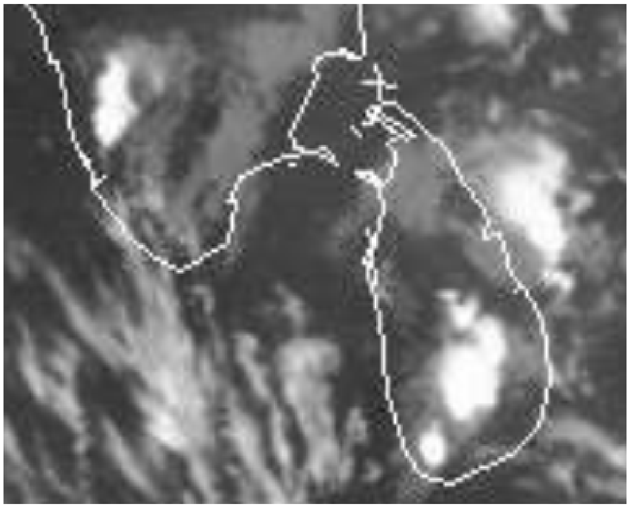


Fig. 15 METEOSAT Image at 1200 UTC on 16th December 2009

Fig. 16 METEOSAT Image at 1200 UTC on 18th December 2009

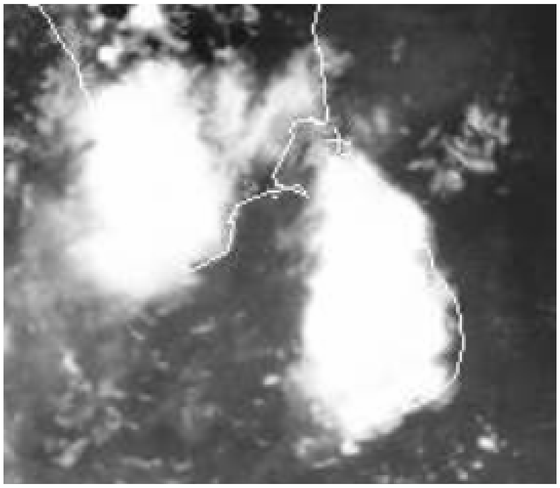


Fig. 17 METEOSAT Image at 1200 UTC on 17th April 2010

The life time of the sensors and the overall system can be increased by maintaining the AWS system in regular basis,

8. References

(1). Brassard, M. & Ritter, D. (1994). The Memory Jogger II. Methuen, MA:GOAL/QPC. A good basic guide on the various ways to evaluate quality for CQI (continuous quality improvement) programs. Covers all the methods, i.e., Activity Network Diagram, Affinity Diagram, Brainstorming, Cause & Effect/Fishbone Diagram, to Nominal group Technique, Pareto Charts, etc.

(2). Reliability Analysis By Failure Mode - A useful tool for product reliability evaluation and improvement, *Necip Doganaksoy, Gerald J. Hahn and William Q. Meeke*r, Quality Progress June 2002.

(3). User’s Guide , vaisala WINDCAP Ultrasonic Wind Sensor WSR425.

(4). AWS Operation manual , Meisei, Meteorological Disaster Information Network System for Sri Lanka.