3.0 OBSERVATIONS AND DATE COLLECTION

This research conducted in high lightning zone in Sri Lanka. Few Telecommunication base stations are selected in Rathnapura, Horana, Galle, Ambalangoda, Kaduwela, Weliweriya, etc for the analysis.

3.1 Tower and the surrounding

The 18 towers inspected in this study are all-metal (made of metal re-bars making a steel lattice that stands on concrete platforms), self-supported structures (no guy wires except in four towers) with height of 60m. All the towers are triangular cross-sectioned having 3 legs, they are tapered over the entire height (i.e. legs are inclines to the vertical). The all members of the towers are typically made of painted galvanized steel. The towers are either used for signal transmission in telecommunication or for broadcasting. A structure of a tower is shown in Figure 3.1.

Figure 3.1: Tower Structure

(*Source*: Author)

The sites have been selected so that they are situated in areas different contours of isokeraunic levels different elevations.

Out of 18 sites,

60-80 isokeraunic level	7 sites
90-100 isokeraunic level	6 sites
Over 100 isokeraunic level	5 sites

If we consider the towers located in Rathnapura region, the iso keraunic level is greater than 100 and also the altitudes of the towers are also higher compared with other sites mentioned in Table 3.5. Also most of the damages and frequency of occur the damages are high in the same region. Most of the tower mounted equipment such as antenna failures are high in same region. One of the remarkable features in the data is that MW antenna failures occur in the site where height greater than 100 m from the sea level at most tower.

3.2 Air Termination

The air terminals are typically arranged on the top of the telecommunication tower to intercept with lightning stepped leader. Generally, Air Terminal covers all antenna structures in the tower within a cone of vortex angle 45 [5]. Here we can see the Air terminal type which we have installed on the towers. And no tower installed with ESE lightning rods. Tin plated solid round conductors which is having 10mm diameter are using for the air termination and that is in accordance with the IEC 62305-3 (2006). See **Annexure III.**

Figure 3.2: Air Terminal system

(Source: Author)

3.3 Down Conductor

The term ''down conductor'' is used to refer any metallic part that is specifically installed to drive lightning current from top of the tower to ground level.

In order to reduce the probability of damage due to lightning current flowing in the LPS, the down-conductors shall be arranged in such a way that from the point of strike to earth:

a) several parallel current paths exist;

b) the length of the current paths is kept to a minimum;

c) equipotential bonding to conducting parts of the structure

Some of our base stations do not have CU down conductor from air terminal to the ground. This is because; it cannot be protecting form steeling. Therefore, Stainless steel tower structure itself use as the down conductor (3 legs behave like 3 down conductors) which having average of 800 mm^2 cross section. The tower structure connected to the ring earth by using CU tape at the bottom of the tower. All three legs are connected to the ring earth as shown in Figure 3.3.

Figure 3.3: Tower structure connected to the ring earth

(Source: Author)

Out of 18 sites, 10 sites having separate 25mmx3mm (75 mm^2) copper down conductor from air terminal to ring earth while same structure grounding also exists. Therefore the down conductor system in accordance with the IEC 62305-3 (2006). See **Annexure III**

Also one tower leg contains around 6 joints and those are arranged in order to make good contact between each other. Therefore we have not observed more than 0.1 Ohm resistance in between them.

Figure 3.4: Tower leg joint

(Source: Author)

3.4 Grounding System

Typical grounding conductor arrangement observed is shown in Figure 3.5. That is a basic crow foot arrangement. There are two earth rings. One is through the tower legs and one is around equipment cabin. The earth electrode using for the grounding system is solid round and having 16mm diameter and it is in accordance with the IEC 62305-3 (2006). See **Annexure IV**

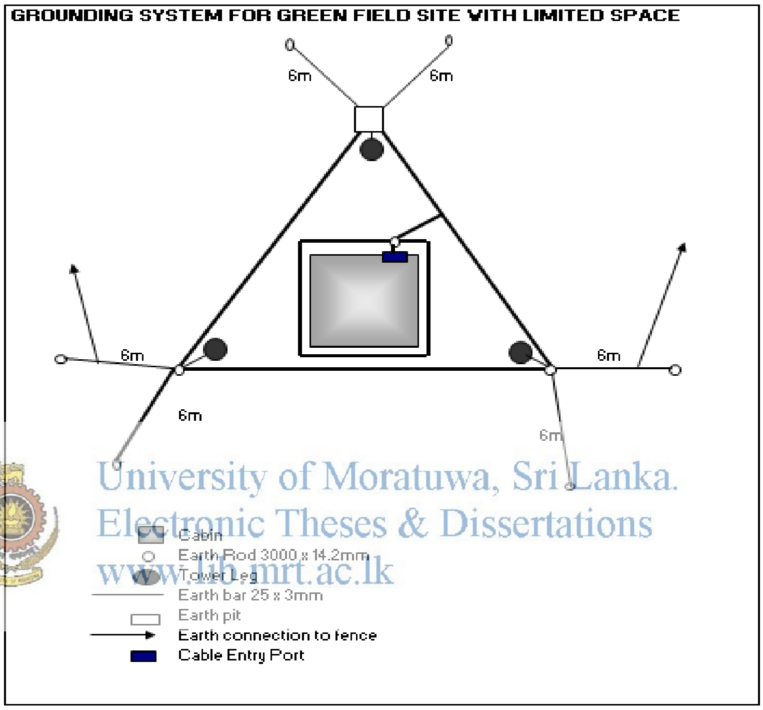


Figure 3.5: Grounding system for green field site with limited space

(Source: Author)

Earth resistance will be measured after this installation. If measured earth resistance is more than 10 ohms, further improvement will be done to reduce earth resistance. But for a particular site we cannot find the exact locations where earth rods are buried, as several improvements may take place since the tower erection date.

3.5 Earth Resistance Measurements

A remarkable feature in this regards is that the measured resistance values of the towers located in rocky area seems very high even after the several earth resistance improvements. Also we can see the measured values for three legs are entirely different to each other.

Earth resistance is measured in some telecommunication tower using fall of potential method and there we can find lot of issues with the measurements. Keselhenawa, Moragahakanda and Erathna sites earth resistance measurements have done to get clear picture about the issues.

In Kehelhenawa measurements, the current electrode can be placed at maximum of 16m away from the system earth. But 61.8% rules tell the earth resistance as 3.02 ohms at one leg and 16.57 Ohms at another leg. Table 3.2 shows the Earth resistance measurements data and Figure 3.6 shows the fall of potential curves for Keselhenawa Radio base station.

Earth measurement (Ohms)							
Distance X(m)	**Leg 1**	**Leg 2**	**Leg 3**	**Distance X(m)**	**Leg 1**	**Leg 2**	**Leg 3**
0.1				9	1.9	10.5	
0.2				9.5	2.2	13.8	
0.4				10	3.02	16.5	
0.7				11	4.57	24	
1	0.71	0.35		12	4.89	29.6	
3	1.05	0.66		12.5	5.34		
5	0.87	1.85		13	7.55		
5.5	0.9	2.7		13.5			
6	1	2.9		14			
6.5	1.2	2.3		14.5			
7	1.03	2.43		15			
7.5	1.2	4.1		15.5			
8	1.5	5.5		16			
8.5	1.7	7					

Table 3.2: Earth measurements Keselhenawa Radio base station

(Source: Author)

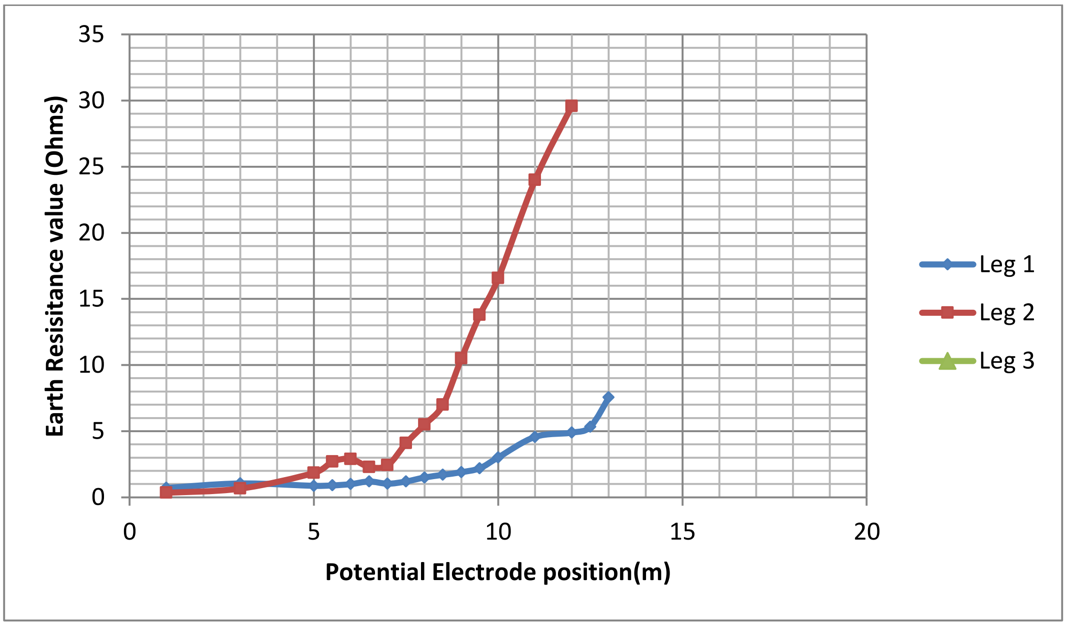


Figure 3.6: Fall of potential curves for Keselhenawa Radio base station

(Source: Author)

Below table and Figure shows the same thing done in Moragahakanda radio base station. In this case also current electrode can be placed at maximum of 16m away from the system earth. In here the earth electrode resistance can be estimated by examining the curves or field data at the 61.8% point as it shows the Non-Overlapping behavior. 14 Ohms is the figure shows as per the 61.8% rule. Table 3.3 shows the Earth resistance measurements data and Figure 3.7 shows the fall of potential curves for Moragahakanda Radio base station.

	Earth measurement (Ohms)		
Distance X(m)	Leg 1	Leg 2	Leg 3
0.1		1.79	
0.2		1.85	
0.4		1.99	
0.7		2.28	
1	0.98	2.27	1.46
3	1.22	2.44	6.64
5	5.5	2.12	8.72
7	10.96	4.3	10.95
8	10.5	6	12.8
9	11	12	13
10	14.78	13.47	13.35
11	15.58	13.7	14.15
12	16.51	15	15.2
13	17.37	17.42	16.17
14	18.12	21.2	17.15
15	19.03	26.5	
15.5			
16			

Table 3.3: Earth measurements Moragahakanda Radio base station

(Source: Author)

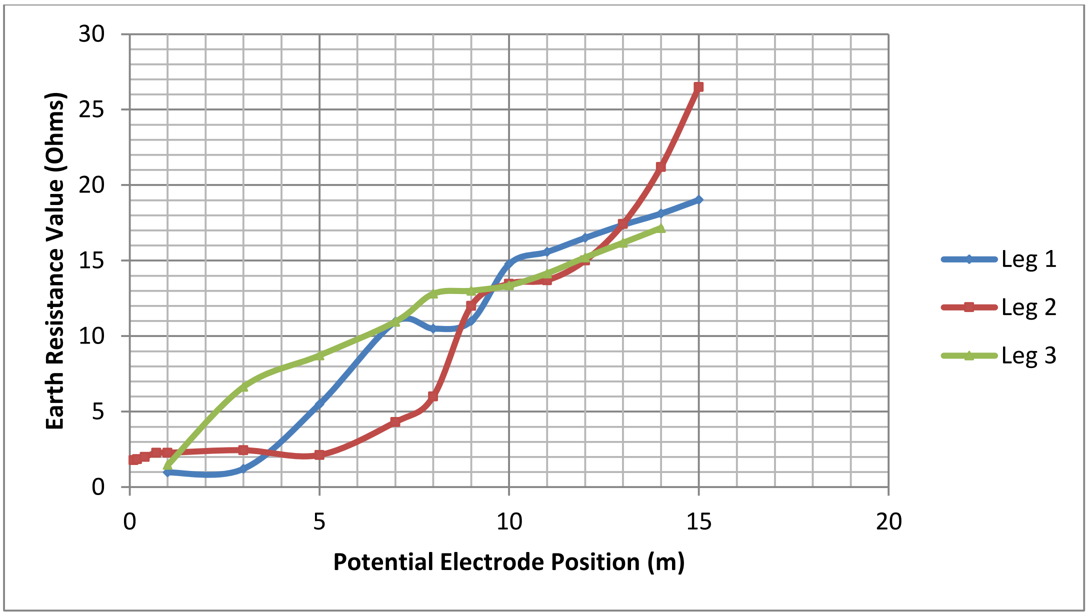


Figure 3.7: Fall of potential curves for Moragahakanda Radio base station

(Source: Author)

The table 3.4 and Figure 3.8 shown the results of earth measurement done in Erathna Radio base station. There we have managed to keep distance between earth system and current electrode. But we can see an irregular behavior in between potential electrode distance 25m to 35m. But totally we can see a non-overlapping behavior and conclude that the earth resistance value is around 30Ω. Table 3.4 shows the Earth resistance measurements data and Figure 3.8 shows the fall of potential curves for Keselhenawa Radio base station.

Distance X(m)	**Leg 1**	**Distance X(m)**	**Leg 1**	**Distance X(m)**	**Leg 1**	**Distance X(m)**	**Leg 1**
15	16.5	28	43.2	40.5	29.2	52	39.3
15.5	19.5	28.5	37.6	41	29.6	52.5	39.1
16	20.2	29	34.5	41.5	29.7	53	42
16.5	17.8	29.5	31.1	42	30.2	53.5	44.2
17	18.5	30	25.5	42.5	30.1	54	45.6
17.5	17.7	31.5	30.9	43	30	54.5	47.4
18	17.4	32	31.8	43.5	31.7	55	50.32
18.5	17.4	32.5	32	44	30.1	55.5	52.33
19	17.7	33	31	44.5	31	56	54.5
19.5	17.4	33.5	32.5	45	30	56.5	55.2
20	17.9	34	26.6	45.5	29.9	57	56.6
20.5	18.8	34.5	26.7	46	30.05	57.5	60.2
21	17.8	35	26.8	46.5	31	58	63.1
21.5	22	35.5	27.2	47	31.5	58.5	63.4
22	20.2	36	27.5	47.5	31.7	59	65.2
22.5	63.6	36.5	28.9	48	32.4	59.5	65.2
23	22.4	37	29.4	48.5	32.2	60	68.4
23.5	60.8	37.5	29.5	49	32.4		
24	31.8	38	28.5	49.5	33.3		
24.5	32	38.5	28.4	50	35.2		
25	41.5	39	28.6	50.5	35		
25.5	38.7	39.5	29	51	37.02		
26	36	40	29	51.5	38.22		

Table 3.4: Earth measurements Erathna Radio base station

(Source: Author)

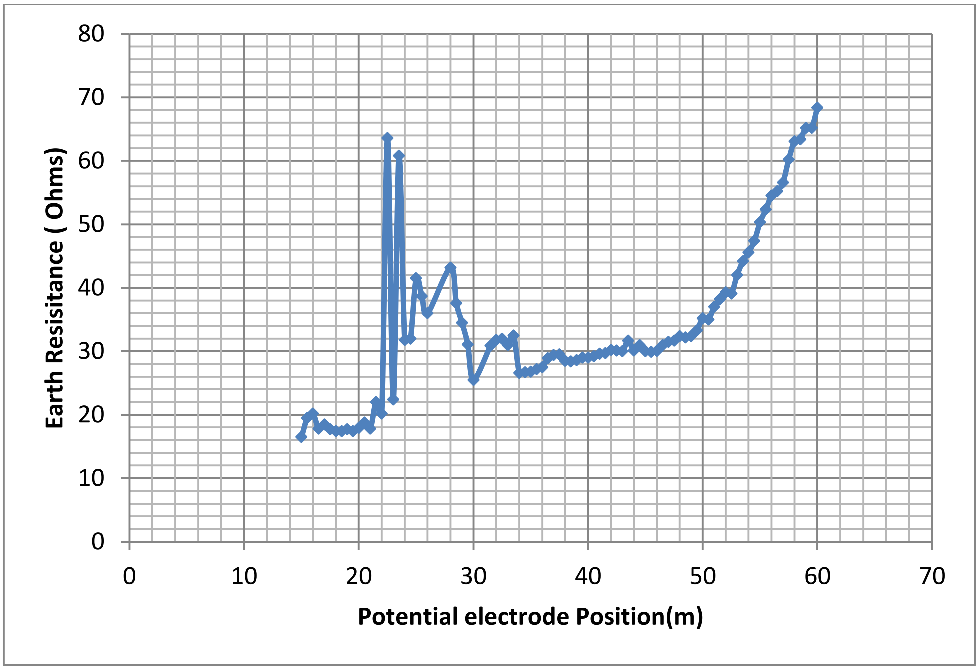


Figure 3.8: Fall of potential curves for Erathna Radio base station

(Source: Author)

3.6 Power line Surge Protection system

In Sri Lanka we follow power distribution system as TT system. The system having one point of the source of energy earthed and the exposed-conductive-parts of the installation connected to independent earthed electrodes.

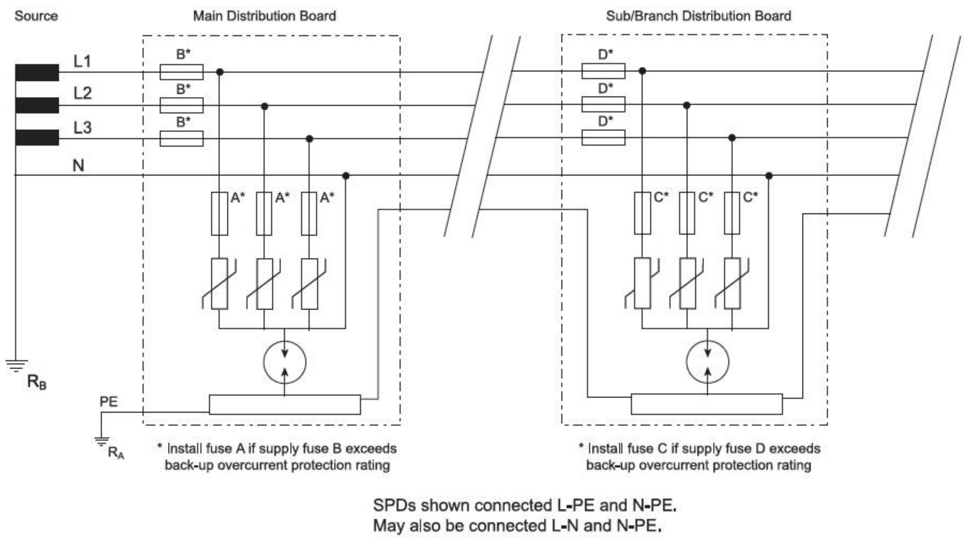


Figure 3.9: Power Distribution Systems and SPD Installation

(Source: ERICO Lightning Technologies)

The Surge Reduction Filter (SRF) installed as the power line protector in radio base station is shown in Figure 3.10. It compromise with two TSG in Line to Neutral and Neutral to earth in power line side. Then there is a low pass LC filter at the load end.

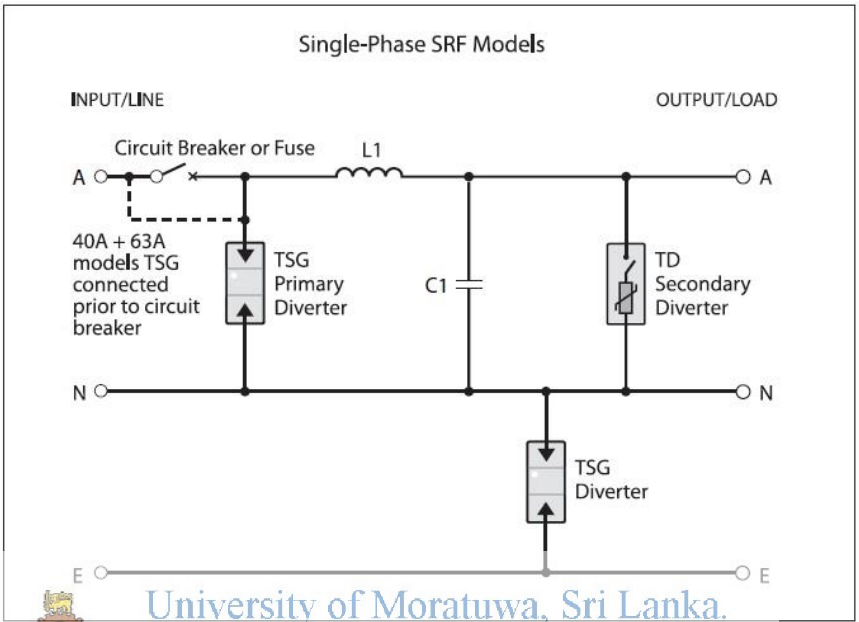


Figure 3.10: SRF 140 Surge reduction filter installed for the power line
(*Source*: ERICO Lightning Technologies)

The cabling and earth wires connected to the filter input is always be run separately, with a minimum clearance of 300 mm between them and all other cables or sensitive equipment as shown in Figure 3.11.

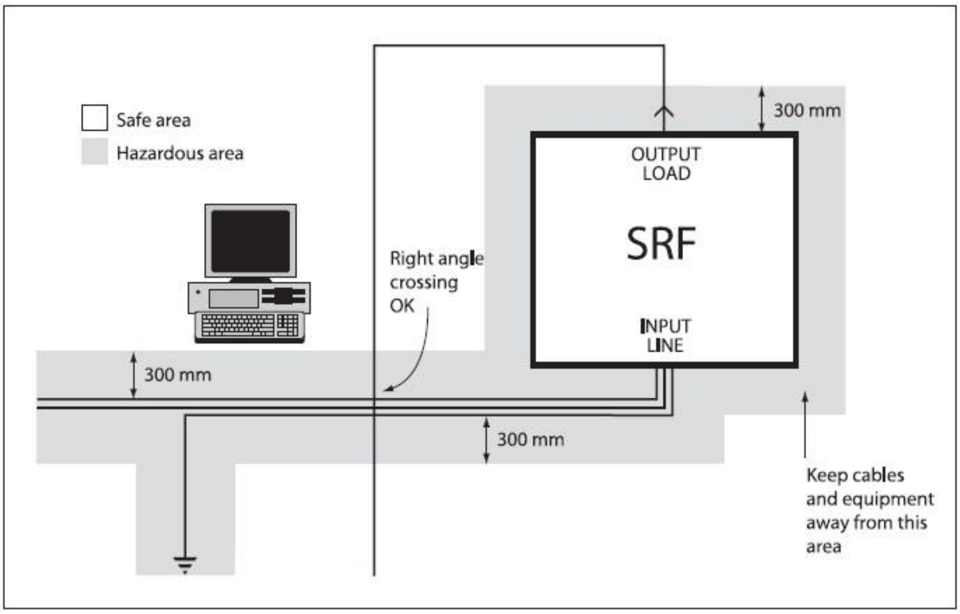


Figure 3.11: Maintaining clearance between input and other cabling

(Source: ERICO Lightning Technologies)

The input cable and earth wire will carry the transient energy, while the "protected" output cable, can be considered to be a "clean filtered" supply. By separating these cables, any incoming transients will not be induced from the input cables onto nearby "clean" cables. This clearance will reduce the possibility of arc-over from input to output cables. Where cables need to run closer together due to space restrictions, input and output cables should cross at right angles and not be installed parallel to each other. Cabling has sized in accordance with all relevant wiring standards to ensure that the full load current can be safely supplied. All cabling or busbars have connected to the protection equipment should be securely anchored to prevent undue stress being applied to the input/output terminals.

The earths for all site equipment have integrated (preferably deploying a single point earthing approach) and an equipotential earth plane has created. The effectiveness of an SRF is intimately related to the impedance presented by the earthing system to which it is connected. A low impedance route to the earth is required (less than 10Ω). This can be achieved by ensuring that the earth electrode system at the site presents low surge impedance with respect to the ground. Additionally, the interconnecting cabling must be of adequate cross sectional area and be routed to provide as short and direct a path as is practical. The earth conductor for the SRF should be sized according to local regulations but with a minimum size of 6 mm2 and we have at least 16mm2 in each and every base station and always maintained limit the cable length to less than 5 meters.

With this configuration, we do not have experienced any side flashes during last three years.

Figure 3.12: Equipotential bonding inside the Equipment cabin

(*Source*: Author)

3.7 Electrical & Electronic Equipment and Other damages

Sites were selected on the basis where most of the lightning damages were reported during April/May 2011. Below shown are the reported damages in last three and half years.

- Equipment cabin rectifier damages
- Outdoor units of the Microwave antenna
- Indoor units of the Microwave antenna
- Meter cubical burst
- Generator control modules, battery chargers, Magnetic contactors etc.
- Electric Energy meter burnt
- Earth terminals for most of socket outlets get burnt
- Wall cracked
- Earth terminals of the Power DBs also got burnt

- Shock felt on their bodies
- Computers and routers
- CRT TV
- Radios
- Refrigerators
- Electrical switch gears
- Bulbs
- Human faint

We observed that there are lots of electrical and electronic equipment damages after the lightning incidents. This is not only for the telecom equipment, but also for the neighbourhoods electrical and electronic equipment. Also we have observed that there are some incidents where the Tower mounted equipment such as Microwave Antenna Outdoor unit and indoor units of them also got failed.

Figure 3.13: MW Outdoor and Indoor units connected through IF cable

(Source: Author)

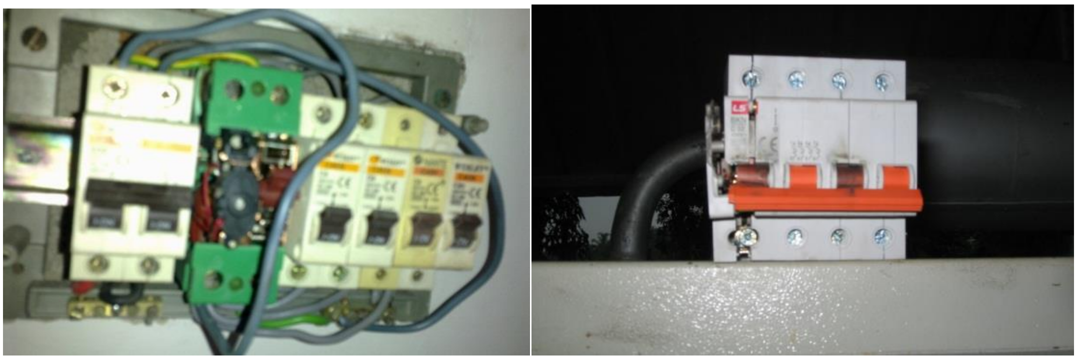


Figure 3.14: MCB damages reported in homes located near the Madampegama Radio Base station

(Source: Author)

Figure3.15: Electrical Bulbs and Holder damages repoted in homes near the Madampegama Site

(Source: Author)

Figure 3.16: ADSL router damaged in home near the Thihariya site

(Source: Author)

Figure 3.17: Computer damaged in home near the Thihariya site

(*Source*: Author)

Figure 3.18: Energy meter and cable damages reported near the Keselhenawa telecommunication tower

(*Source*: Author)

Figure 3.19: Neutral to earth surge arrester damaged in Magalle radio base station

(*Source*: Author)

Figure 3.20: wall damages reported in homes near the Madampegama telecommunication tower

(Source: Author)

Figure 3.21: wall damages reported in homes near the Nakiyadeniya telecommunication tower

(Source: Author)

Figure 3.22: wall cracks reported in homes near the Keselhenawa telecommunication tower

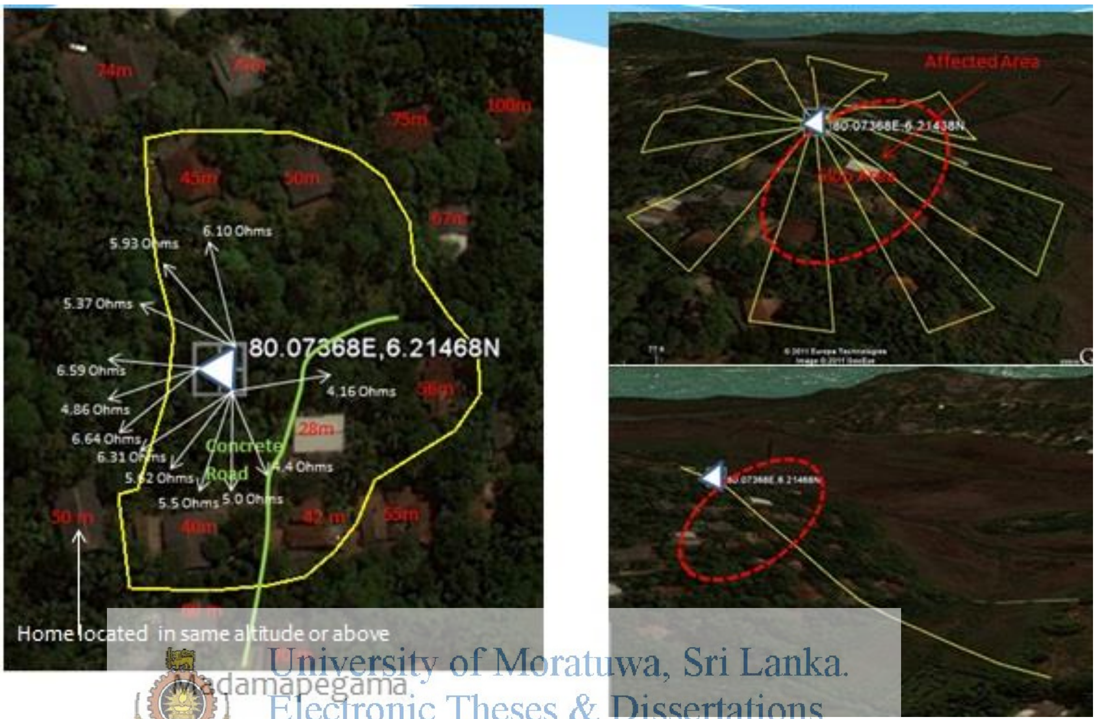
(Source: Author)

Recently few incidents reported with regrads to the Telecom towers and mobile phones. Below incident reported at Madampegama site in Ambalangoda, when a person sleeping on the ground floor with the mobile phone under his arm in his home after the lightning incident to the Telecom Tower.

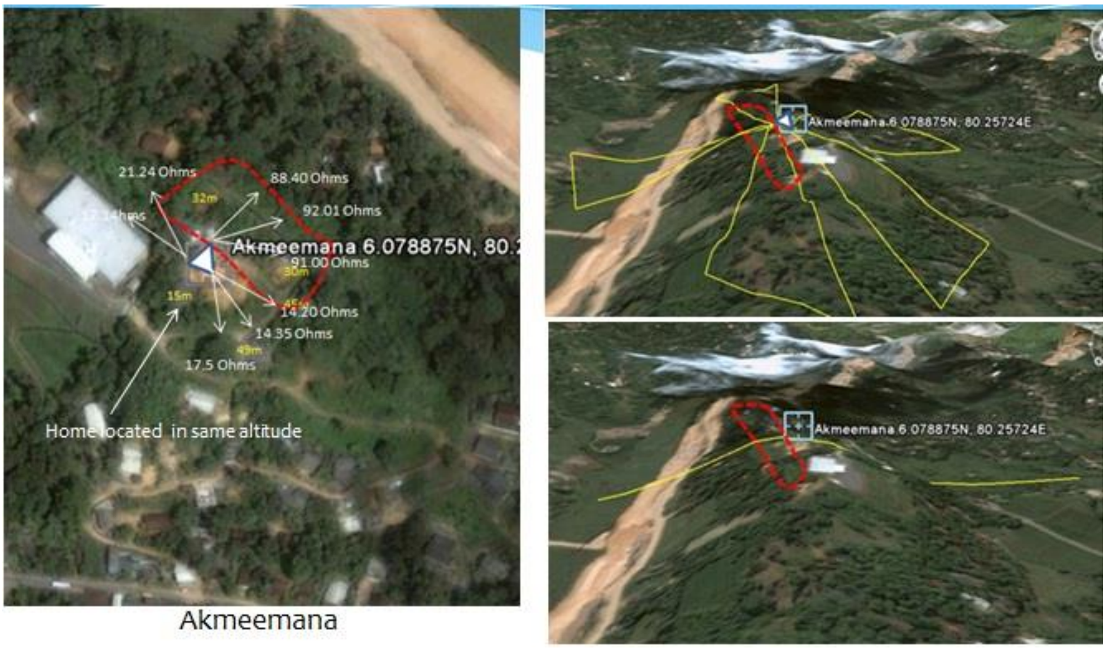
Figure 3.23: Human damages reported in home near the Madampegama Telecommunication Tower

(Source: Author)

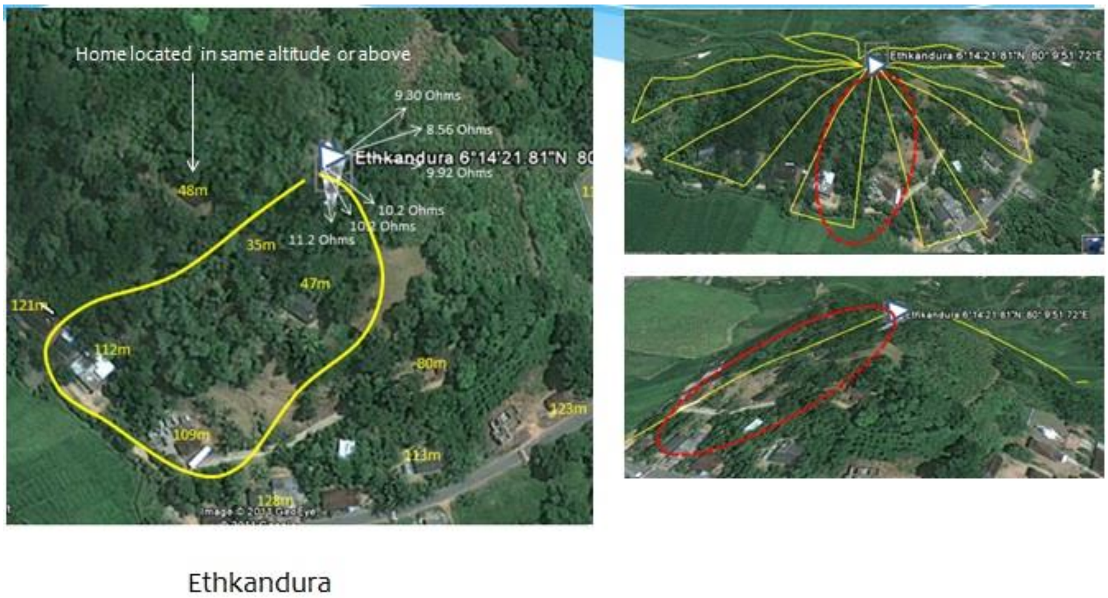
One remarkable future highlighted throughout this research regarding the reported damages and elevation of those homes with respect to the elevation of the tower. It is highlighted that damages reported in homes where elevation is less than the tower elevation. Four sites selected in Ambalangoda region and check the surrounding earth profile and damages reported. All four sites are in same isokeraunic region.



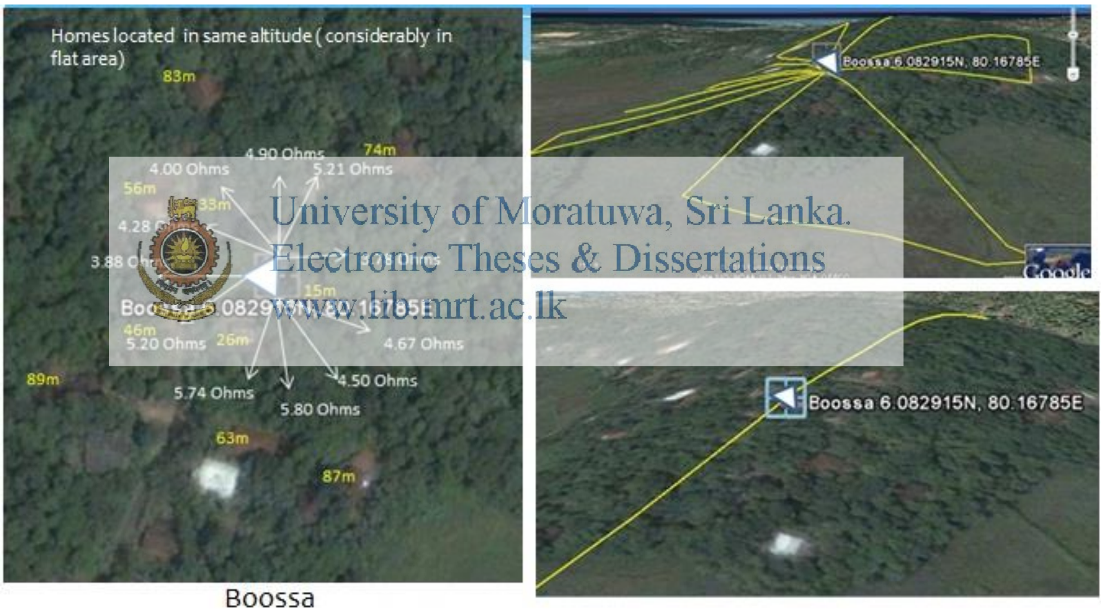
(a)



(b)



(c)



(d)

Figure 3.24: Earth profiles of (a) Madampegama (b) Akmeemana (c) Ethkandura (d) Boossa

(Source: Author)

The tower surrounding earth profile of Madampegama, Akmeemana and Ethkandura are rather steep and damages reported only in homes located in same steep area (Figure 3.24 (a), (b) and (c)). But the surrounding earth profile of Boossa is rather flat and there were no any damages reported either to Tower equipment or neighbourhoods.

Below table shows the data collected throughout this research. As per the observation we can categorize site where

- Both Site equipment and neighborhood damages reported
- No damages to Site equipment but neighborhood damages reported
- Site equipment damages reported. No damages to neighborhood.
- No damages to either site equipment or neighborhood

Site Name	keraunic level	Coordinates	Tower height from sea level	Soil condition	Earth Resistance	Separate Down conductor	Reported Damages	No of neighborhood around the tower 100m	Additional Comments
Thihariya	60-80	Lon - 80.06826 Lat - 7.128039	60-80 m	laterite	8.0 Ohms 14.3 Ohms 27.2 Ohms	Yes	ADSL Router Power supplies	07	Both Site equipment and neighborhood damages reported
Radawana	60-80	Lon - 80.10088 Lat - 7.039889	60-80 m	laterite	30 Ohms 18.4 Ohms 9.4 Ohms	Yes	kWh Meter cubicle	02	Site equipment damages reported. No damages to neighborhood
Pasyala	60-80	Lon -80.12715 Lat - 7.169372	120-140 m	Laterite/Regular	8.4 Ohms 11.50 Ohms 9.2 Ohms	No	kWh Meter cubicle damaged ATS panel	08	Site equipment damages reported. No damages to neighborhood. Site equipment damages reported before and after CU down conductor removal

Site Name	keraunic level	Coordinates	Tower height from sea level	Soil condition	Earth Resistance 3 leg direction	Separate Down conductor	Reported Damages	No of neighborhood around the tower 100m	Additional Comments
Wewldeniya	60-80	Lon - 80.14616 Lat - 7.185607	160-180m	laterite	6.82 Ohms 16.50 Ohms 8.45 Ohms	Yes	MW ODU Bulbs	02	Both Site equipment and neighborhood damages reported
Kirindiwela	60-80	Lon - 80.11826 Lat - 7.047782	90-110 m	Laterite/Regular	4.80 Ohms 8.46 Ohms 7.24 Ohms	Yes	No	15	No damages to either site equipment or neighborhood
Negambo Kattu	60-80	Lon - 79.84641 Lat - 7.241883	60-80m	laterite	9.60 Ohms 13.46 Ohms 7.90 Ohms	Yes	ADSL router Power supply CFL Bulbs TV Fan	24	No damages to Site equipment But neighborhood damages reported
Sandalankawa	60-80	Lon - 79.95138 Lat - 7.30117	60-80m	laterite	6.30 Ohms 7.4 Ohms 8.9 Ohms	No	Generator control module TV Bulbs	24	Both Site equipment and neighborhood damages reported
Agalawatta	90-100	Lon - 80.15908 Lat - 6.534115	120-140m	laterite	32.0 Ohms 34.3 Ohms 8.03 Ohms	Yes	Human shock TV kWh meter	03	No damages reported after Airtel tower erection nearby area

Site Name	keraunic level	Coordinates	Tower height from sea level	Soil condition	Earth Resistance 3 leg direction	Separate Down conductor	Reported Damages	No of neighborhood around the tower 100m	Additional Comments
Ethkandura	90-100	Lon - 80.16442 Lat - 6.239312	100-120m	rocky	8.56 Ohms 10.2 Ohms Cannot measure	No	TV Refrigerator CDMA phone MW IDU MW ODU kWh meter	08	This happen before and after CU down conductor removal
Nakiyadeniya	90-100	Lon -80.33689 Lat - 6.137947	220-240m	rocky	86.0 Ohms 50.10 Ohms 24.0 Ohms	No	Wall Damages TV Radio		No damages to Site equipment But neighborhood damages reported
Akmeema	90-100	Lon -80.25724 Lat - 6.078875	80-100m	rocky	92.20 Ohms 17.14 Ohms 14.20 Ohms	Yes	TV DVD players Human shock Switch gears Bulbs Socket outlets	09	Both Site equipment and neighborhood damages reported

Site Name	keraunic level	Coordinates	Tower height from sea level	Soil condition	Earth Resistance 3 leg direction	Separate Down conductor	Reported Damages	No of neighborhood around the tower 100m	Additional Comments
Boossa	90-100	Lon - 80.16785 Lat - 6.082915	60-80m	laterite	5.05 Ohms 3.78 Ohms 5.13 Ohms	No	No	16	No damages to either site equipment or neighborhood
Galpatha	90-100	Lon- 80.0042 Lat- 6.63512	80-100m	Rocky/iragular	4.2 Ohms 110 Ohms Cannot measure	No		05	
Madampegam	90-100	Lon- 80.07368 Lat- 6.21468	80-100m	Laterite/Regular	6.10 Ohms 6.59 Ohms 4.44 Ohms	No	TV Fan Computer Human shock Switch gears CFL Bulbs Socket outlets Wall damages Human shock Generator ATS kWh Meter	26	Both Site equipment and neighborhood damages reported. Before that the damages reported in the area where another tower located near this area.

Site Name	keraunic level	Coordinates	Tower height from sea level	Soil condition	Earth Resistance 3 leg direction	Separate Down conductor	Reported Damages	No of neighborhood around the tower 100m	Additional Comments
Deraniyagala	Over 100	Lon - 80.32869 Lat - 6.919281	360-380m	Rocky/ laterite	7.86 Ohms 2.63 Ohms Cannot measure	Yes	Refrigerator TV Switch gears MW IDU MW ODU	1	Both Site equipment and neighborhood damages reported
Gataheththa	Over 100	Lon - 80.2277 Lat - 6.901372	120-140m	Rocky/Regular	31.50 Ohms 32.60 Ohms 26.10 Ohms	No	TV Fan MW ODU MW IDU	06	Both Site equipment and neighborhood damages reported
Parakaduwa	Over 100	Lon - 80.29496 Lat - 6.825613	200-220m	Rocky/Regular	27.30 Ohms 36.90 Ohms 32.00 Ohms	Yes	Human shock TV Satalite system Kwh Meter MW IDU MW ODU	06	Both Site equipment and neighborhood damages reported

Site Name	keraunic level	Coordinates	Tower height from sea level	Soil condition	Earth Resistance 3 leg direction	Separate Down conductor	Reported Damages	No of neighborhood around the tower 100m	Additional Comments
Erathna	Over 100	Lon -80.3711 Lat - 6.83	320-340m	Rocky	30.00 Ohms Cannot measure Cannot measure	Yes	MW ODU kWh meter TV Refrigerator	2	Both Site equipment and neighborhood damages reported before and after copper down conductor installtion

Table 3.5: Collected data for lightning incidents

(Source: Author)