Review of Medium Voltage Power Interruptions in the Tema Metropolois, Ghana

Rodnell Ebi. Bilson, Samuel Odai. Afotey

Abstract— The Tema Metropolis is an industrial hub of the country, Ghana. It is the home to steel smelting plants, many major manufacturing plants in the country, petroleum refinery and a harbor. All these activities rely heavily on reliable and quality electricity supply.The requirement for reliable and quality electricity in this Metropolis need not be over emphasized. However, this level of reliability has not been achieved satisfactorily. This work examines the major causes of power interruptions in the medium voltage distribution network of the metropolis. It was found that majority of the interruptions occur in the 11kV network and are lightning related.

Index Terms— Distribution networks, Electricity, Faults, Lightning, Medium Voltage, Power interruption

1. INTRODUCTION

The power distribution network of southern Ghana spans the entire southern part of the country of which the Tema Metropolis is a part. This part of the country has the majority of the country's population, high population densities and varied land use such as domestic, commercial and industrial. The Tema Metropolis is also an industrial hub of the country. It is the home to steel smelting plants, many major manufacturing plants in the country, petroleum refinery and a harbor. All these activities rely heavily on reliable and quality electricity supply.

Subtransmission and distribution of electricity in the Tema Metropolis is done by the Electricity Company of Ghana (ECG) and it is done at three voltage levels namely 33kV, 11kV and 0.415kV. The 33kV and 11kV networks which have basic insulation level of 170kV and 75kV respectively are used for subtransmission and high voltage distribution and consist of underground cables and overhead lines.

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Demand for electricity in this Metropolis is high 164MW according to [1]. The requirement for reliable and quality electricity in this Metropolis need not be over emphasized. However, this level of reliability has not been achieved satisfactorily. The network is located in an area of ground flash density of about 10 flashes/sqkm/yr according to [2]. Since the network has a height of only about 10m above ground and is shielded other taller objects such as trees, buildings and transmission lines, it will not usually experience direct lightning strikes [3], [4] however, lightning strikes to taller objects close to the line or lightning strikes to the ground nearby is common a occurrence [4], [5], [6]. [7] and [8] have indicated that distribution networks with basic insulation level below 300kV are likely to experience insulation flashovers due to induced voltage resulting from lightning striking objects or the ground close to overhead lines. This will result in protection relays tripping circuit breakers of affected feeders (overhead lines or cables) and cutting off power supply until circuit breakers are closed manually or automatically. This affects reliability of electricity supply [9], [10], [11] and [12] and also creates voltage dips on other feeders connected to the same bus as the faulted feeder.

Although there are many opinions on the subject, there is no literature found on the distribution of power interruptions and major causes of power interruptions in the Tema Metropolis.

The objectives of this work are to:

- Determine the distribution of MV power interruption in Tema
- Determine main causes of MV power interruption in Tema
- Determine seasonal variation in the power interruptions

2. DESCRIPTION OF THE TEMA NETWORK

The MV network of the Metropolis is made up of 33kV and 11kV networks consisting of both overhead lines and underground cables. The 33kV network is made up of ring circuits and radial circuits. The 11kV network is mainly radial feeders with normally open points.
Opening of a circuit breaker in 33kV radial circuits will lead to interruption of power supply to customers. Opening of a circuit breaker in 33kV ring circuits may lead to interruption of power supply to customers depending on whether the one side of the ring circuit can carry the entire circuit load.

An opening of any 11kV circuit breaker will interrupt the power supply to customers on that circuit because of the radial nature of the 11kV circuits.

3. ANALYSIS OF DISTURBANCE RECORDS

All circuit breaker switching activity in the MV network and the reason for the switching are recorded as System disturbance records (SDRs) in ECG. In the Tema Metropolis, substations are controlled via SCADA. SCADA also captures all disturbance records from substations which is then sent to various offices of ECG (protection, operation and maintenance offices) for analysis. The system disturbance records (SDRs) contain information such as date, time of fault, circuit involved, circuit breaker operation and protection relay indications

3.1 Distribution of MV power interruptions

SDRs from 2009 to 2011 were analyzed and the following observations were made:

Faults in the 11kV network accounted for 86% of all faults during the period and faults in the 33kV network accounted for 14%.

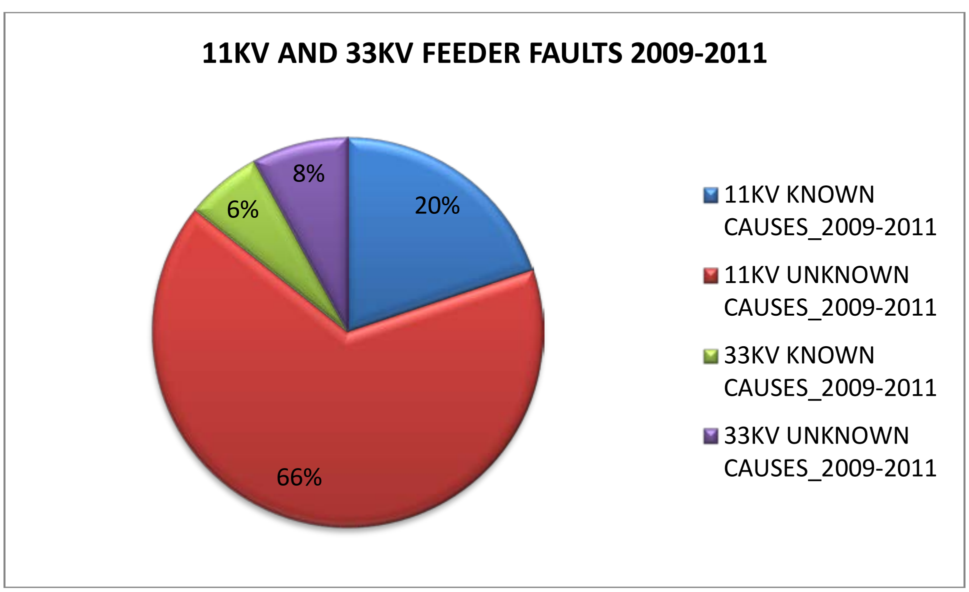

Figure 1: 11kV and 33kV feeder faults in Tema for 2009-2011 (Source: Field data)

3.2 Summary of faults in the 11kV network

- A total of 1689 interruptions were recorded involving 72 feeders each a maximum of 12km.This is an average of 7.8 interruptions per feeder per year.
- The most tripping feeder tripped averagely almost 6 times (46.3 per year) the feeder average interruption.
- The feeder which was interrupted most by unknown cause was interrupted 5.2 times the feeder average (average of 40.7 interruptions per year).
- The number of interruptions increased each year within the period for the above feeders.
- 76% of all interruptions during the period are transient with unknown cause and location.
- The most occurring number of interruptions for all feeders is 1 interruption in 3years.

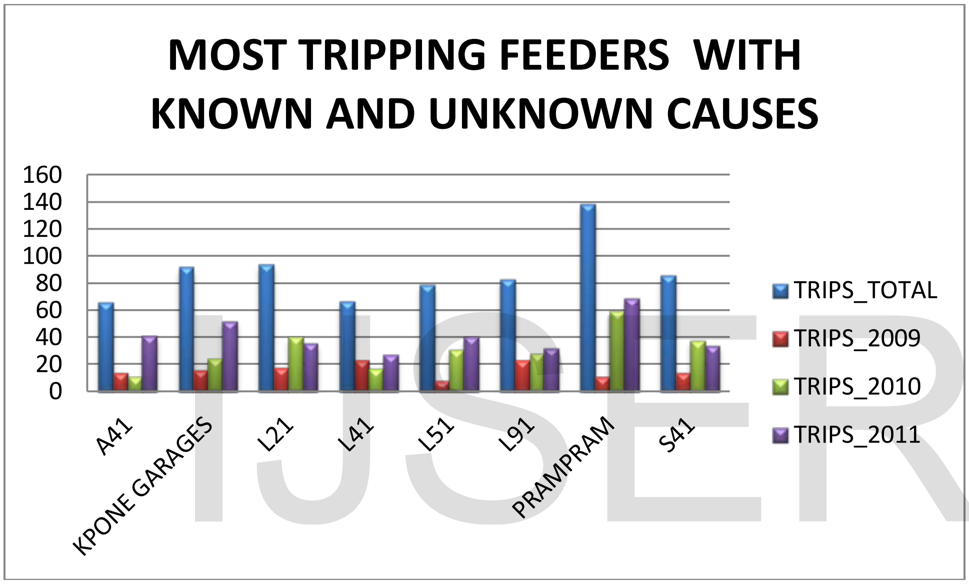

Figure 2: Most interrupted 11kV feeders in Tema for 2009-2011 (Source: Field data)

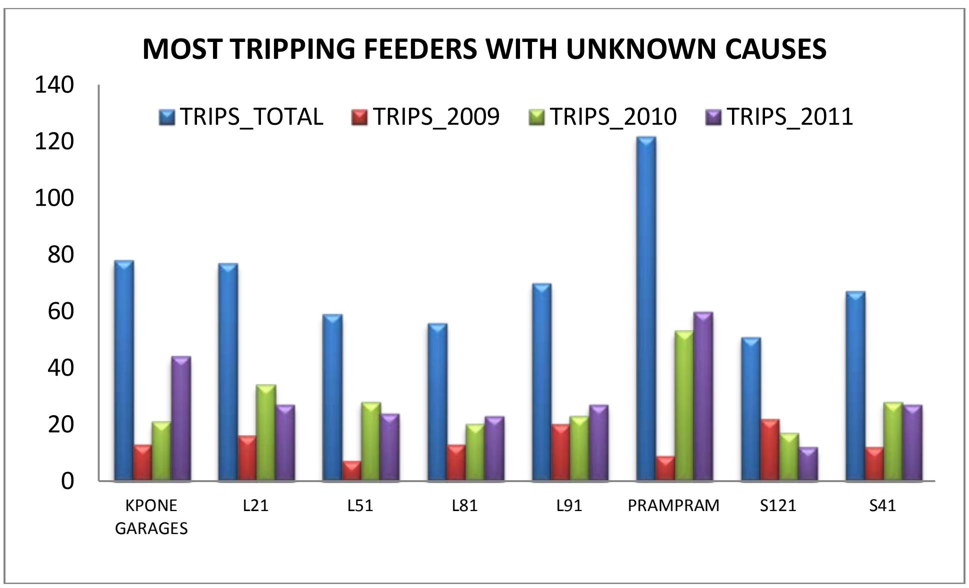

Figure 3: Most interrupted 11kV feeders with unknown causes in Tema for 2009-2011 (Source: Field data)

3.3 Causes of power interruptions

The major causes of power interruption are shown in the figure below. The most prominent among them are:

- overhead line faults (jumper cuts and broken conductors)-10%
- underground cable faults (cable insulation failure, joint failure and termination failure)-13%
- Unknown (transient faults whose cause and location are not identified because they clear upon trial switching)-73%

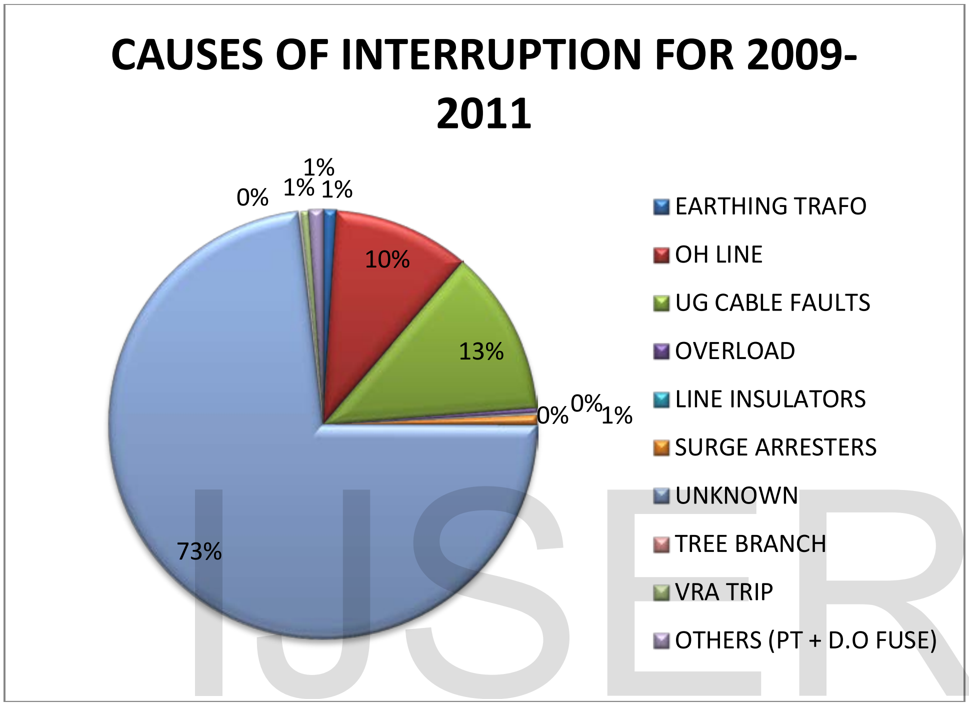

Figure 4: Causes of power interruption in Tema for 2009-2011 (Source: Field data)

3.4 Type of fault

Fault in the 11kV network account for 85% of all faults recorded during the period and 60% of all faults are 11kV faults involving earth.

It can also be noted in figure 6 that the number of 11kV faults grew over the period.

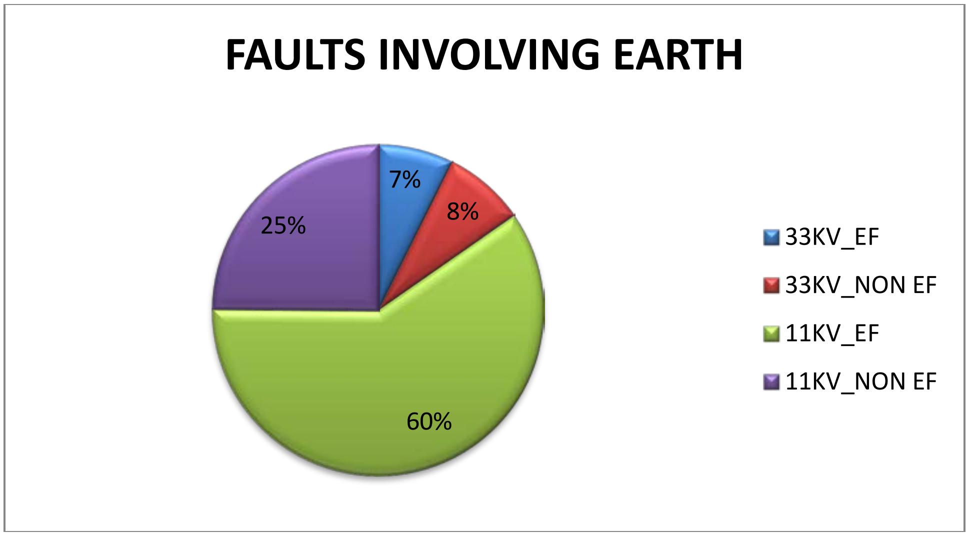

Figure 5: 33kV and 11kV faults involving earth in Tema for 2009-2011 (Source: Field data)

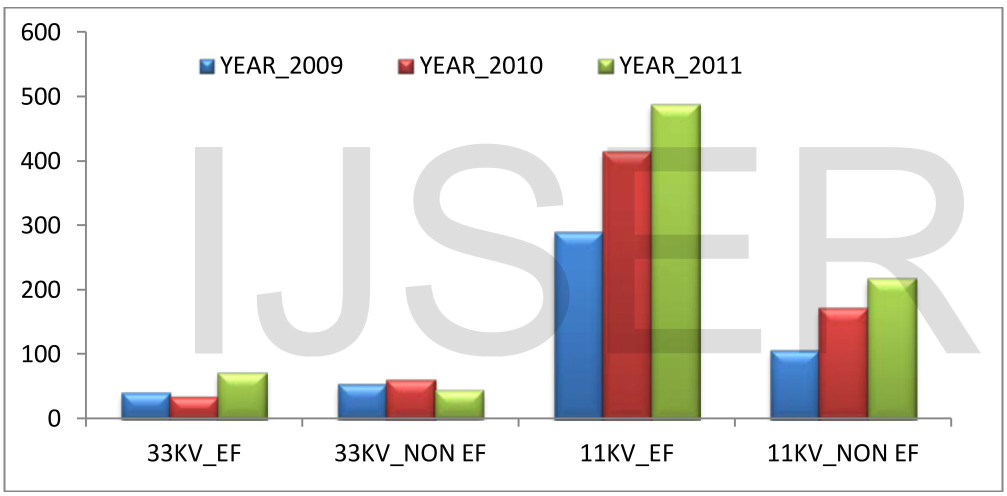

Figure 6: 33kV and 11kV faults involving earth in Tema for 2009-2011 (Source: Field data)

4. CORRELATING RAINFALL, THUNDERSTORM AND POWER INTERRUPTIONS

For the three (3) year period, 2009-2011, MV SDRs were analyzed with respect to rainfall and thunder occurrence data were collected from Meteorological Department of Ghana. The following observations were made:

a) The occurrence of thunder has a linear dependence on the occurrence of rainfall. Thunder may occur in Tema even when there is no rainfall. However the occurrence of thunder increases linearly with increase in rainfall.

b) The total number of 11kV faults has a weak quadratic dependence on the number of thunder occurrence but a weaker quadratic dependence on the amount of rainfall.

c) The number of 11kV faults with unknown cause has a quadratic dependence on the amount of rainfall and a relatively stronger quadratic dependence on the level of thunder occurrence.

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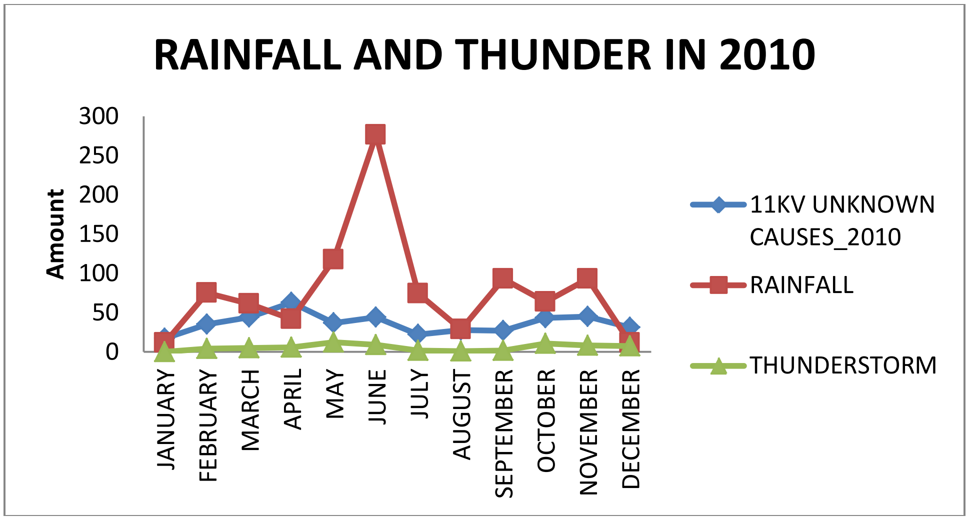

Figure 7: Monthly rainfall and thunder in Tema for 2010 (Source: Meteorology Department, Ghana)

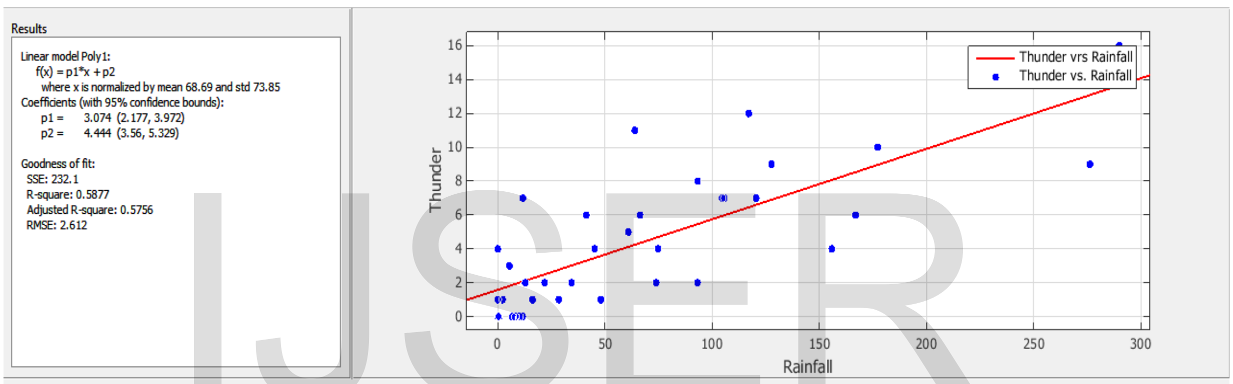

Figure 8: Graph of thunder vrs rainfall in Tema for 2009-2011 (Source: field data)

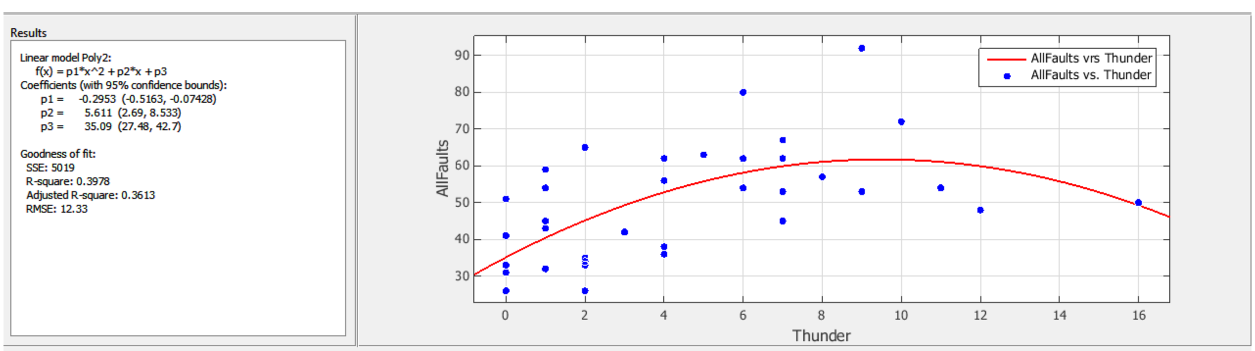

Figure 9: Graph of all 11kV fault vrs thunder (Source: Field data)

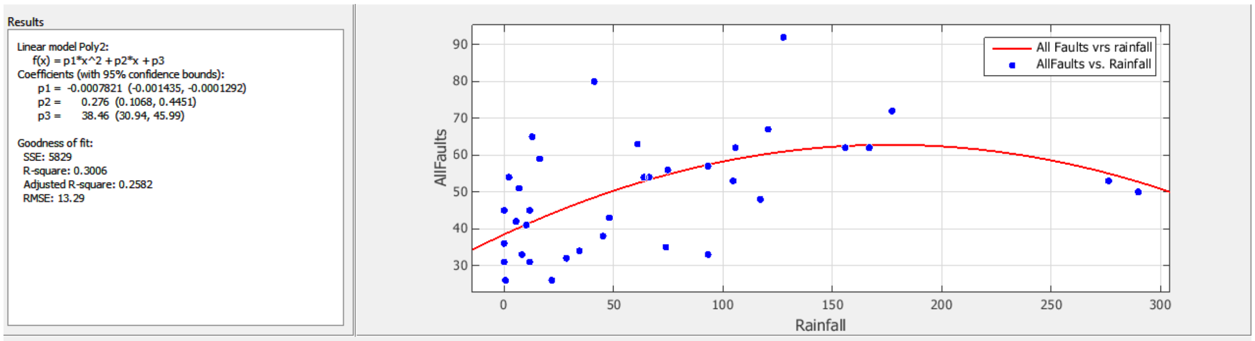

Figure 10:Graph of all 11kV fault vrs rainfall (Source: Field data)

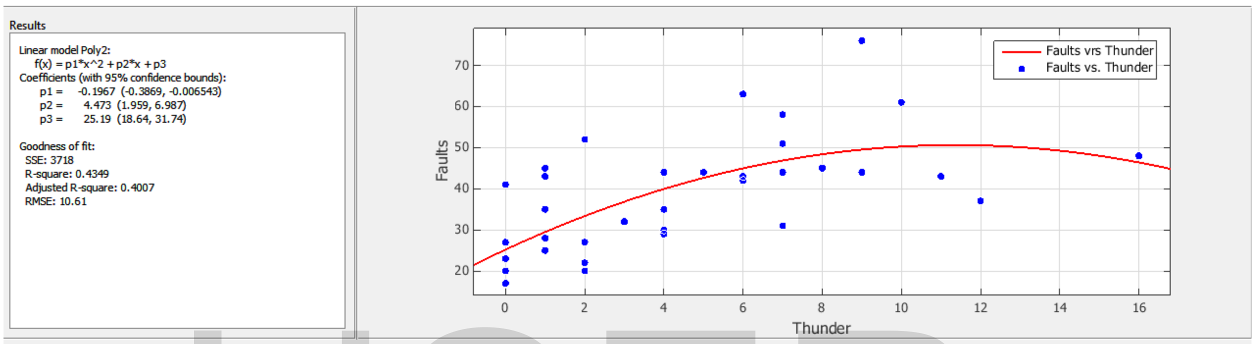

Figure 11:Graph of 11kV unknown-cause fault vrs thunder (Source: Field data)

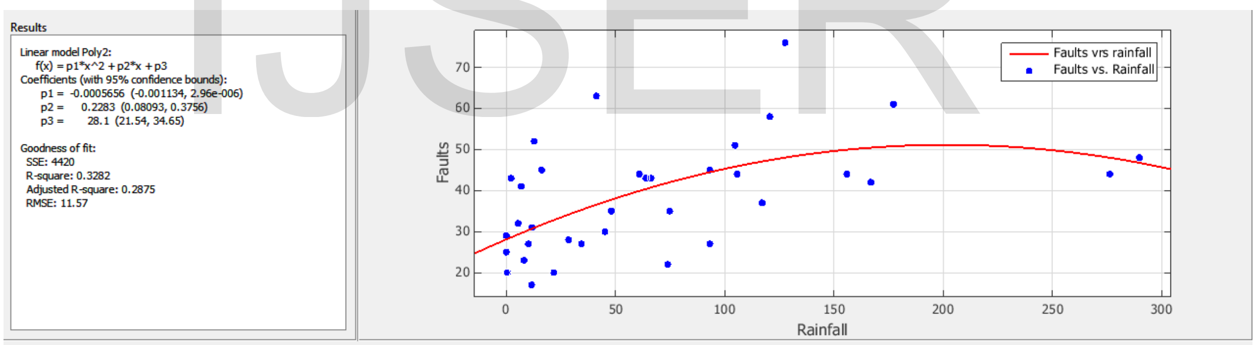

Figure 12: Graph of 11kV unknown-cause fault vrs rainfall (Source: Field data)

5. CONCLUSION

The following conclusions are made:

Majority (86%) of all interruptions in the Tema metropolis during the period occurred in the 11kV network.

A significant amount of interruptions in the 11kV network are lightning related.

The data above agrees with [13], [11] and [14] that faults with unknown causes and locations are mostly lightning caused faults as is the case with faults in the 11kV network.

It was also found that few 11kV feeders contributed to the large number of lightning related interruptions. This suggests that the surge protection systems of the feeders are not functioning satisfactorily and need to be investigated.

Curtailing lightning caused faults by installation of surge protection devices will help reduce power interruptions by about 50%.

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