Weather and Reliability

A. Islam and A. Domijan

***Abstract-- Network-centric infrastructure* demands robust systems that can respond automatically and dynamically to natural, accidental and deliberate faults, be they on a local scale, regional or national. The effects of weather, from heat waves and cold fronts to hurricanes and ice storms, on the electrical infrastructure are expected to escalate. The consequent power interruptions are an economic hardship of +100 billion dollars annually on the states affected and pose a significant threat to public safety nationally. The electrical infrastructure is fragile, and as each adverse weather system passes over our critical electrical infrastructure it becomes increasingly difficult to supply energy and restore service in case of disruption. A transformative research initiative will be discussed that will begin to protect and harden our nation's critical electrical infrastructure. This vision would lead to next generation power systems to come into being that are flexible, reliable, and intelligent electrical energy delivery systems. A revolutionary new way of sensing, intelligence gathering, and corrective actions is envisioned. The goal is to provide near uninterruptible service during severe weather events and make feasible monitoring of the critical electrical infrastructure in real time.**

***Index terms*—power distribution, meteorology, reliability, statistics.**

I. Introduction

Electric distribution system infrastructures were developed, modified, refined, improvised and finally unleashed into the market for countries and subcontinents to acknowledge, implement and install. It has been a while that any major changes have been brought to modify the already established distribution structures. It is easy to modify and refine a newly developed system rather than one which has successfully performed for decades, delivered results for years at the least possible costs and has complete trust and understanding of its fraternity. But something has changed; there are more questions than ever over the reliability of the distribution setup. Why are all the trusted distribution systems showing signs of weaknesses. Is it because of ever high expectations of the consumers or is there something more than that.

This paper assimilates efforts of the Power Center For Utility Explorations (PCUE) and its laboratory Power & Energy Applied Research Laboratory (PEARL) to find answers to the questions posed by the modern world over the reliability of distribution network. At PEARL research work has been done to identify different causes affecting the reliability. Ongoing work is focusing on improving sensing, intelligence gathering and envisioning corrective actions to make the system more robust. Further discussion on the work at PEARL will show that many parameters have changed in the equation, which had formed the basis of the existing system characteristics and limits (maximum withstand capacity). It is worthwhile to start looking at all the parameters that affect the reliability of the system and finally the ones which define stringent design values for the robustness of electric infrastructure.

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II. Procedure

Electric power reliability is measured in many quantitative ways and one of the common indices is SAIFI.

A published study [1] states "that a common method for measuring the reliability of an electric distribution system is based on the number of customers interrupted, which is proportional to the number of interruptions. IEEE Standard 1366 defines the System Average Interruption Frequency Index (SAIFI) with the following formula:

$$SAIFI = \frac{\sum_{1}^{N_i} C_i}{C_b} \tag{1}$$

Where;

Ni = Number of interruptions (sustained interruptions lasting over 1 minute)

Ci = Customer interrupted for each interruption

Cb = Customer base or customers served

SAIFI indicates how often the average customer experiences a sustained interruption (>1min.) over a predetermined period of time, and it has a special importance in decision making for engineers working in distribution reliability.

Power reliability is an important concern for most electric utilities due to the costly effects of power disturbances. According to Contingency Planning Research Company's annual study, downtime caused by power disturbances result in major financial losses as shown in Fig. (1)."

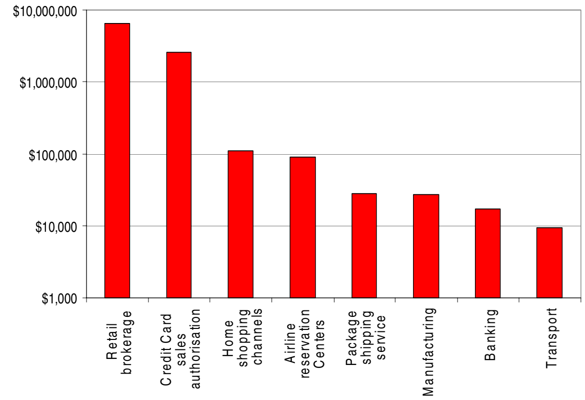


Fig. 1. Average hourly impact of downtime and data loss by business sector [1]

Weather has been found to be the major parameter affecting the reliability of the system many times indirectly [2][3]. The paper [2] states, "that the distribution of identified causes of interruptions, (Fig.2) for the area under study during the period of study, shows that, directly, weather contributes approximately 10% to the total number of breakdowns/faults (N). However, this paper will show that as much as 50% of the variation from the mean N can be accounted for by weather. It is the premise of this paper that the effects of weather on power reliability can be linearly modeled, and the model can be used as a predictor of N.

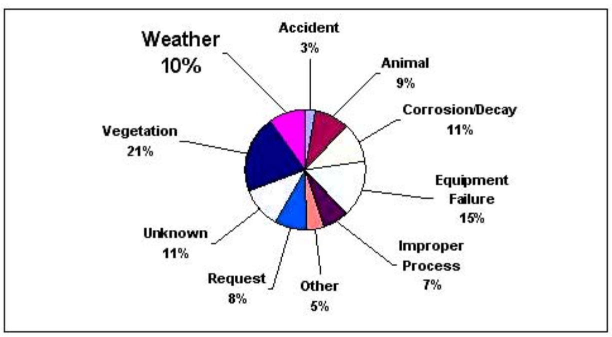


Fig. 2. Distribution of Interruptions by Identifiable Causes

The primary weather parameters contributing to N in the area under study are wind, temperature, rain and lightning. It has been shown previously that there is significant correlation between wind, temperature and rain and N [1]. Other parameters, such as humidity, which is a function of wet-bulb and dry-bulb temperatures, have not shown significant effects, and will not be included at this time." Analysis was done to model these relationships and equations were found which best fits the plots of these weather parameters [2], [3]. If we plot four years of rain (RAIN) and lightning strikes (LS) data with respect to time in months, many general conclusions can be drawn. The plots are shown below. The Rain data is shown in inch (in):

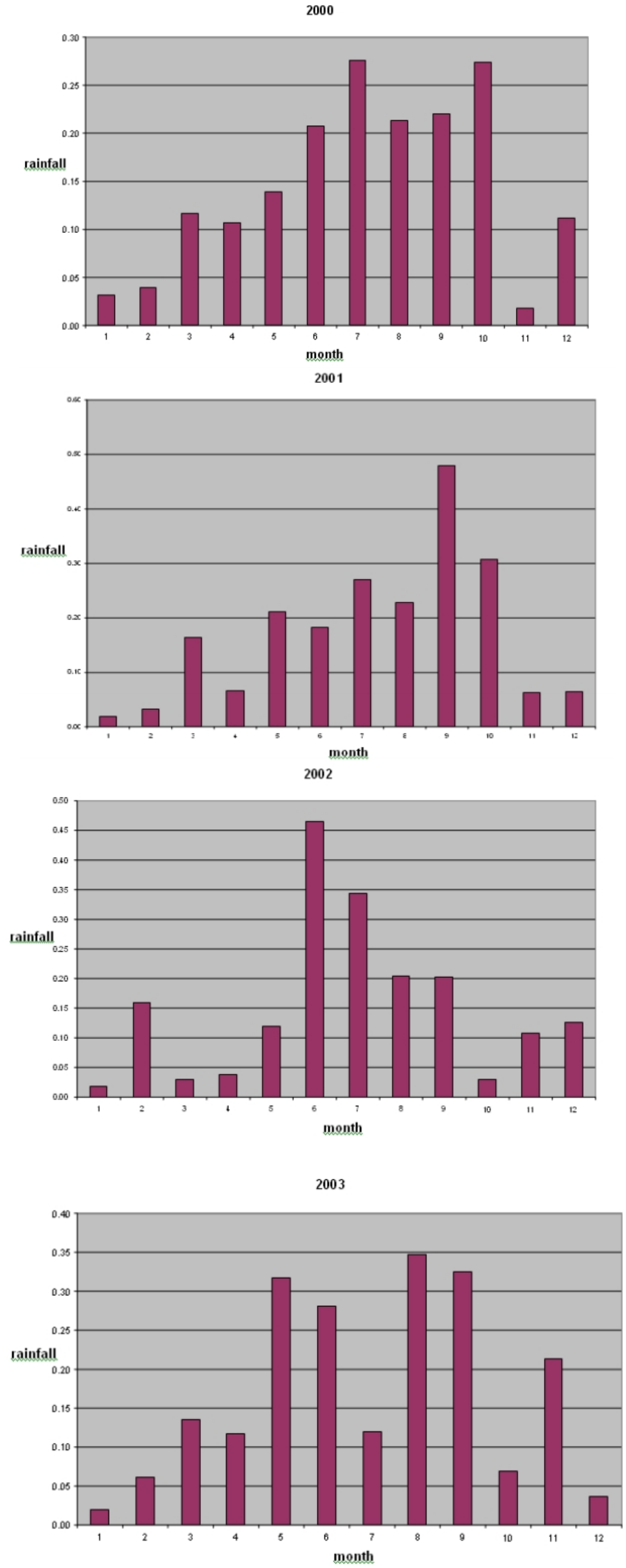


Fig. 3. Monthly mean distribution of Rain for year 2000 -2003

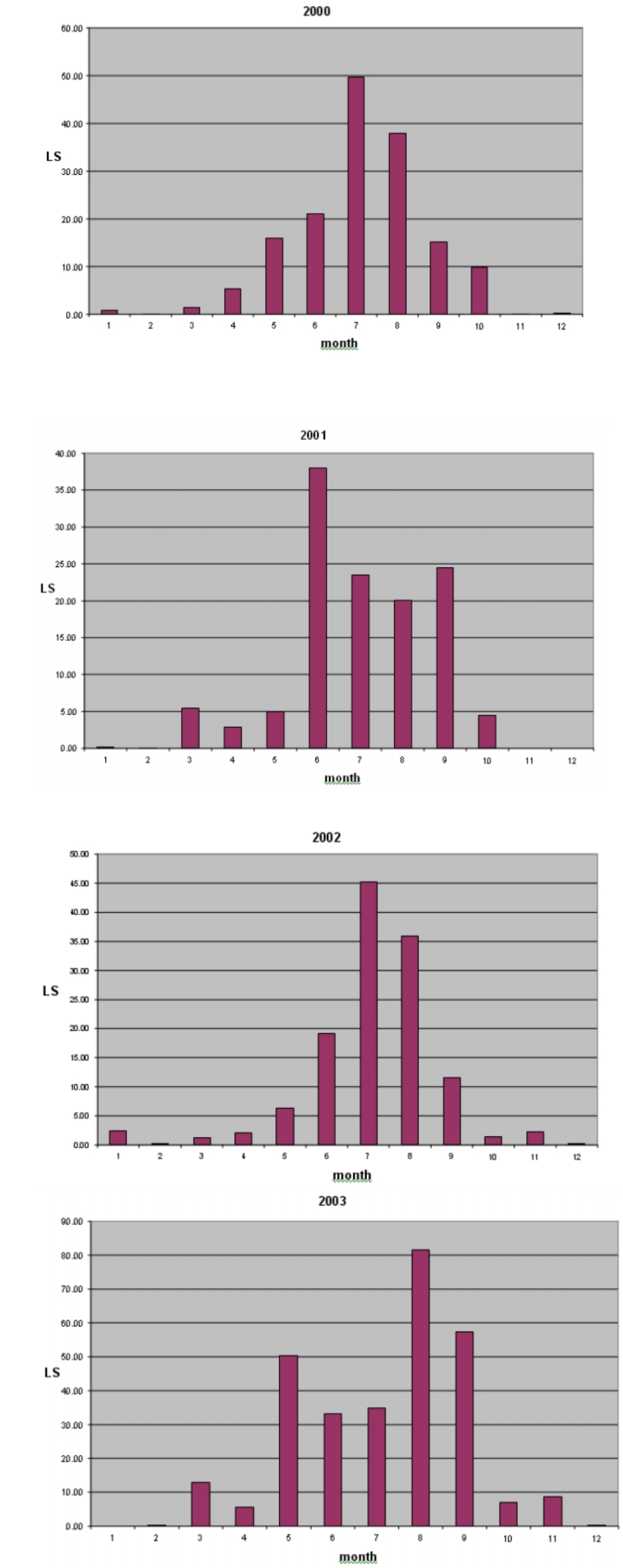


Fig. 4. Monthly distribution of LS for year 2000-2003

There is year to year variation in monthly averages as seen in Fig. (3) & Fig. (4), for which the reliability reports needs to adjust for seasonal weather patterns, otherwise the information would be misleading. It is equally likely that the earlier year might have milder weather as compared to the present year and consequently less number of interruptions. Thus we would like to develop a model which takes care of adjustment of indices in both directions making it a bilateral analysis. The main idea is to provide reliability engineers with an even field and that the reliability indices should not show variations due to effects of weather shifts. The engineers can then focus on changes of reliability indices due to parameters which are quite visible with no conjecture. An earlier study shows the impact of daily temperature variations on the Power interruptions due to transformer failures [3].

"The monthly averages (means) of the maximum temperatures and the monthly means of the total number of interruptions due to transformer failures, for 4 years (1998-2001) for all the Management Areas (MA) were plotted as shown in Fig. (5). With these conditions, the total number of monthly data points came to be around 567.

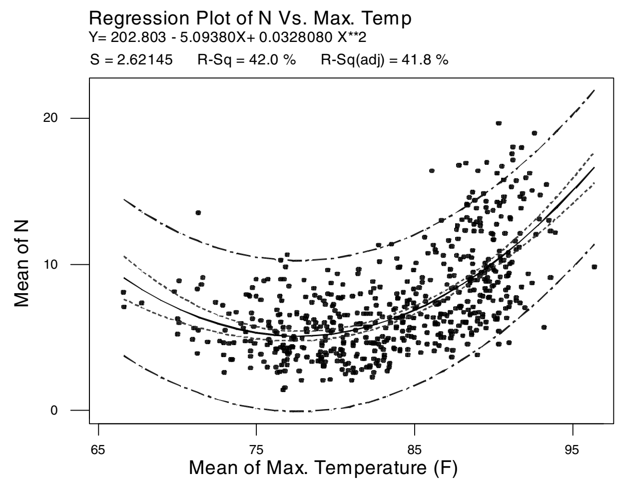
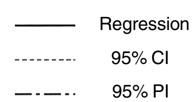


Fig. 5. Variation of Avg. N due to Transformer Failures Vs. Maximum Temperature

The legend of Fig. (5) is as shown below:



PI – Prediction Interval limits
CI – Confidence Interval limits

The terminology is true for all the plots represented in this paper.

From Fig. (5), it can be observed that the plot has peaks over the two edges of the X-axis. The reason can be attributed due to the heavy load on the transformers because of the maximum usage of power during these temperatures. It looks at around 750F to 800F, there won't be much increase in the transformer failure interruptions and hence is an optimal temperature. Approximately after 800F, the curve increases in an exponential way. The right skewness of the graph indicates that the higher temperature effects are more predominant than lower temperatures; this is true for Florida where most of the year it is sunny.

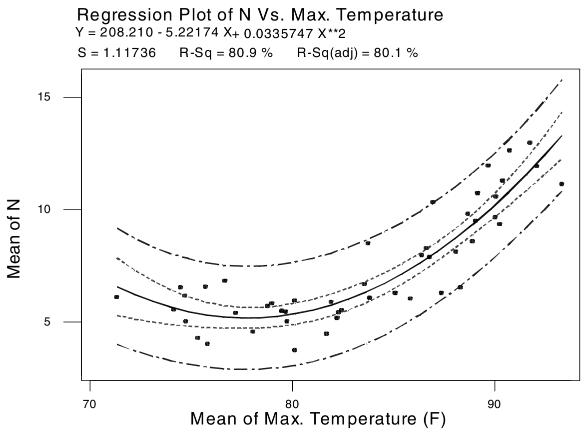


Fig 6. Variation of Avg. N due to Transformer Failures Vs. Maximum Temperature (Avg. per month per year)

Fig (6) was plotted with the same exact information used to plot Fig. (5), but the data of the corresponding months of the 4 years for all the MAs was averaged giving a total of 48 points. Similarly in

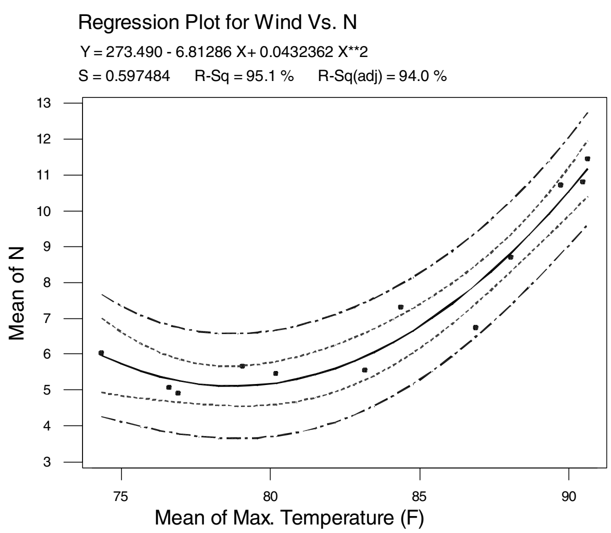


Fig 7. Variation of Avg. N due to Transformer Failures Vs. Maximum Temperature (Avg. per month)

Fig. (7) the data of the corresponding months of all the 4 years was averaged to give 12 data points. The important thing we should observe is that as the number of data points is getting lesser and lesser, the plot is getting smoother with the increase in the R2 value but at the cost of losing the finest details of the data points because we are averaging out all the variations for each month. This method of averaging out the data points gives the clear pattern between the variables by suppressing the disturbances/noise in the data set."

Improving accuracy of equipment is another task which can improve the reliability of distribution systems. The use of microprocessor based technology in the circuit protection and other devices have definitely reduced many long term failures into short interruptions. If we can improve the procedure of identifying failures and are able to calculate accurately the parameters, then the system can react to reliability issues in a better way.

To achieve an overall benefit in designing a robust system, better than the present one, we need to have higher accuracy equipments, sensors and measuring devices. At PEARL, Lin and Domijan [4] were able to develop novel methods which may result in developing better accuracy equipments.

III. RESULTS

Research and analysis done so far at PEARL shows that weather does play an important role in defining the robustness or reliability of the distribution system. The modeling of various weather parameters and designing more accurate instruments are the future paths to improving the reliability indices such as SAIFI. There is a possibility of significantly improving the distribution system performance by combining the various research conducted by the PCUE group.

IV. CONCLUSION

Escalated effects of weather, on the electrical infrastructure can be buffered by utilizing the modeling work at PEARL to design more robust systems.

Network-centric infrastructure demands for robust systems can be addressed by utilizing the tools developed by PCUE. The vision is to form next generation power systems that are flexible, reliable, and intelligent electrical energy delivery systems. The goal to provide near uninterruptible service during severe weather events and to make monitoring of the critical electrical infrastructure in real time, feasible; all this can be achieved if we combine the research work discussed in this paper with another branch of research going at PCUE which relates to alternative energy resources and its developments. Further aspects of the study and research work are beyond the allotted limits for this conference but can be discussed if desired.

V. REFERENCES

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VI. Biographies

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