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A RELIABILITY IMPROVEMENT PROPOSAL (RIP) MODEL FOR RELIABILITY ASSESSMENT OF ELECTRICAL DISTRIBUTION SYSTEMS

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ABSTRACT

In Nigeria, the average interruptions that customers experience are very high and the degree varies from place to place, thus making it impossible to achieve a satisfactory degree of reliability in the power system. The need for an effective planning tool to evaluate alternative reliability improvement proposal in order to establish and prioritize reliability improvement recommendations for optimization of reliability performance of a power delivery system has necessitated the development of a Reliability Improvement Proposal (RIP) model. The model uses quantitative processes to optimize reliability performance expectations of both customers and regulatory authorities. This research paper focuses on a Reliability Improvement Proposal (RIP) model for reliability assessment of electrical power distribution systems. Seven major distribution systems-Ibadan, Ikeja, Ilorin, Port Harcourt, Kano, Kaduna and Benin were used as case studies. The development of the model started with identification and computation of major system reliability indices before and after the proposal. The changes in the system reliability indices and the weighting coefficients were then estimated using appropriate mathematical relations. The weighting coefficients show the extent to which the system reliability indices change when a RIP is suggested. The results of the RIP model showed that the system reliability indices has changed from 0.3433, 0.1198, 0.2291, 0.2629, 0.2352, 0.1964 and 0.0.4032 before the proposal to 0.9772, 0.9855, 0.9863, 0.9858, 0.9905, 0.9860 and 0.9793 after the proposal for Ibadan, Ilorin, Ikeja, Port Harcourt, Kaduna, Kano and Benin distribution systems respectively. The highest CAIDI weighting coefficient of 5.158 was recorded on Kano distribution system while the least SAIFI weighting coefficient of 0.0009214 was recorded on Ibadan distribution system as a result of the level of industrial activities of the city. Kano distribution system has the least RIP value of -5.589 while Kano distribution system has the highest RIP value of 8.87 because of the level of power requirement of the city compared to any city in the case study.The results of this research paper will assist electrical power system engineers in making effective planning policies and prioritize reliability improvement recommendations so as to optimize reliability performance of electrical power system.

Keywords: *Reliability, improvement proposal, quantitative, projected changes, constant weighting, functional weighting.*

INTRODUCTION

Accurate Reliability analysis of power system helps to predict future failure, behavior and make appropriate maintenance plans (Kovalev and Lebedeva 2000, Berfoldi et al,2003). Reliability performance of distribution utilities has received considerable attention in recent years (Elena and Vitaly, 2010). The reliability of power distribution systems is greatly affected

by outages caused by different environmental factors on overhead lines. Since animals cause significant outages on overhead distribution systems, it is important to investigate these outages (Eduardo et al, 2009). The RIP model focuses on the development of a mathematical model to establish the correlation between the net benefit of an alternative RIP with respect to the projected changes in the system reliability Indices. MATLAB software programme can be used for simulation of the reliability performance of an electrical power system under a number of different conditions. It can also be used to obtain the projected changes in reliability indices which are associated with a specific proposal (Bishmu and Vijay, 2010). The model is made up of a number of terms, each term corresponding to the projected change in a specific reliability index. Each projected change in a specific reliability index must be weighted independently of the others based on its relative importance. There are two possible weighting methods namely constant weighting method and the functional weighting method (El-Kady et al, 2007). In the constant weighting methods the projected changes in reliability indices are weighted with constant coefficients while in the functional weighting method, the projected changes in the reliability indices are weighted using functions of themselves. In this research paper, the constant weighting method is used.

Functional Weighting method

In the functional weighting method, the projected changes in the reliability indices are weighted using functions of themselves.

$\mathrm{RIP} = -\sum_{x=1}^{X}\left(\int \mathrm{W(RIx)}\ \mathrm{dRIX}\right).$ ---------- (1)

Integral range from RIX_f to RIX_i where

x= specific reliability index

X= total number of reliability indices included in the equation

RIX_i= initial value of reliability index x before the proposal is implemented.

RIX_f= final value of reliability index x after the proposal has been implemented.

$\mathrm{W(RIx)}$= specific Weight for reliability index x and is a function of reliability index x.

dRIx = incremental change in reliability index x

REVIEW OF RELATED WORK

Roberts et al (1999) carried out a comparative analysis of distribution reliability improvements that can be achieved by using various outdoor distribution devices. Every device offers some improvement in reliability. Switches will improve SAIDI; midpoint switches also possess significant value for the point applications where feeder ties are possible. Sectionalizers and re-closers perform very close functions with various configurations except that re-closers offer more improvement for MAIFI. They also investigated the effect of proposing a reliability improvement scheme on various outdoor distribution devices.

MATERIALS AND METHOD

In this research paper, the constant weighting method is used with the following procedural steps to formulate the Reliability Improvement Proposal (RIP) model:

Step I: Computation of the major system reliability indices – SAIDI, SAIFI, CAIDI, etc.

Step II: Computation of the system reliability indices before and after the proposal.

Step III: Computation of the change in the system reliability indices (ΔRI_x)
Step IV: Development of an empirical equation for each of the system reliability indices (SAIDI, SAIFI, and CAIDI)
Step V: Computation of $W_{x,}$ (Weighting Coefficients of reliability indices)

Constant Weighting Method

The projected changes in reliability indices are weighted with constant coefficients in constant weighting method.
The RIP equation is:

$$\mathrm{RIP} = -\sum_{x=1}^{3}(\mathrm{Wx} * \Delta\mathrm{RIX}) \quad \text{---------- (2)}$$

Where x= corresponds to a specific reliability index
X= total number of reliability indices
Wx = Weighting coefficients of reliability index x
ΔRIX = Projected change in reliability index x.

$$\mathrm{RIP} = -\sum_{x=1}^{n}(\mathrm{Wx} * \Delta\mathrm{RIX}) \quad \text{---------- (3)}$$

Where n= number of reliability indices used.

RESULTS AND DISCUSSIONS

The system reliability indices before the proposal for Ibadan, Ilorin, Ikeja, Port Harcourt, Kaduna, Kano and Benin are 0.3433, 0.1198, 0.2291, 0.2629, 0.2352, 0.1964 and 0.4032 respectively. This shows that a high level of improvement needs to be proposed for the system reliability indices. In this context, Benin distribution system is relatively more reliable than any of the distribution systems while Ilorin is the least reliable of the distribution system before proposing the reliability improvement scheme as shown in Figure 1. The system reliability indices after the proposal for Ibadan, Ilorin, Ikeja ,Port Harcourt , Kaduna, Kano and Benin distribution systems are 0.9772, 0.9855, 0.9863, 0.9858, 0.9905, 0.9860 and 0.9793 respectively suggesting the necessity for introduction of the proposal to aid reliability improvement as shown in Figure 2. The change in system reliability indices are 0.6339, 0.8327, 0.7767 ,0.7229 ,0.5786 ,0.7896 and 0.5761 for Ibadan, Ilorin, Ikeja, Port Harcourt, Kaduna, Kano and Benin distribution system respectively as shown in Figure 3.This shows that high level of improvements were recorded on the distribution system with the introduction of the RIP scheme. Figure 4 shows the relationship between the distribution system and the weighting coefficients. The weighting coefficients show the extent to which the system reliability indices of the distribution system changes when a Reliability Improvement Proposal scheme is introduced. Kano distribution system has the highest CAIDI weighting coefficient of 5.158 compared to all other distribution systems used as case study in this research paper. This is due to the level of power requirement of Kano distribution system. Ibadan distribution system has the least SAIFI weighting coefficient of -0.0009214 compared to all other distribution systems which could be traced to the level industrial activities in the city. Figure 5 shows the approximate values of RIP that each of the distribution systems would require while Figures 6 to 8 show the changes in the system reliability indices with respect to the distribution systems. Kano distribution system would require the highest RIP value of 8.87 owing to the level of power requirement of the city.

Kaduna distribution system has the least RIP value of -5.589 compared to any other cities used as case study in the research paper.

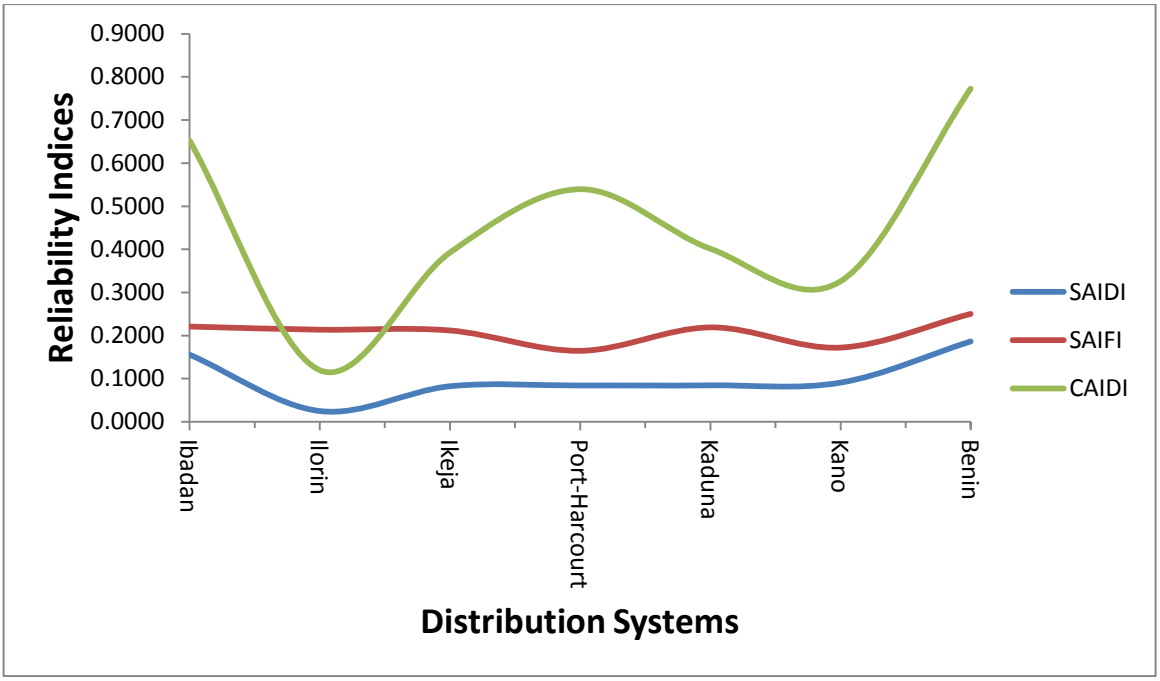

Figure 1: System reliability indices before the proposal.

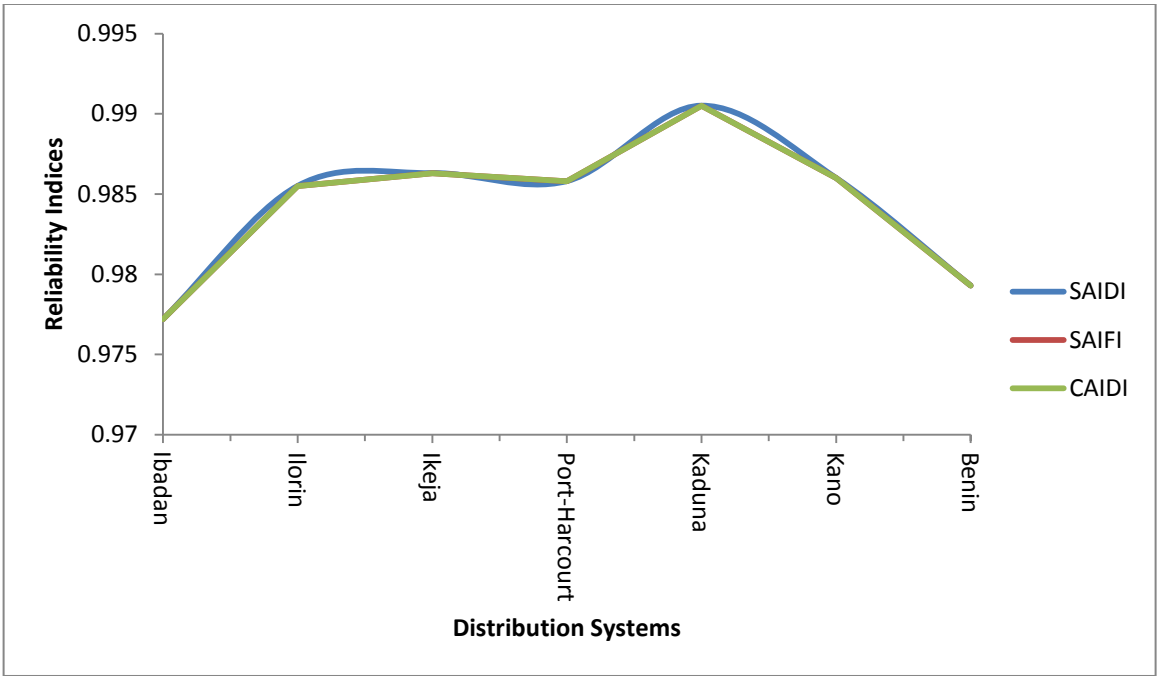

Figure 2: System reliability indices after the proposal.

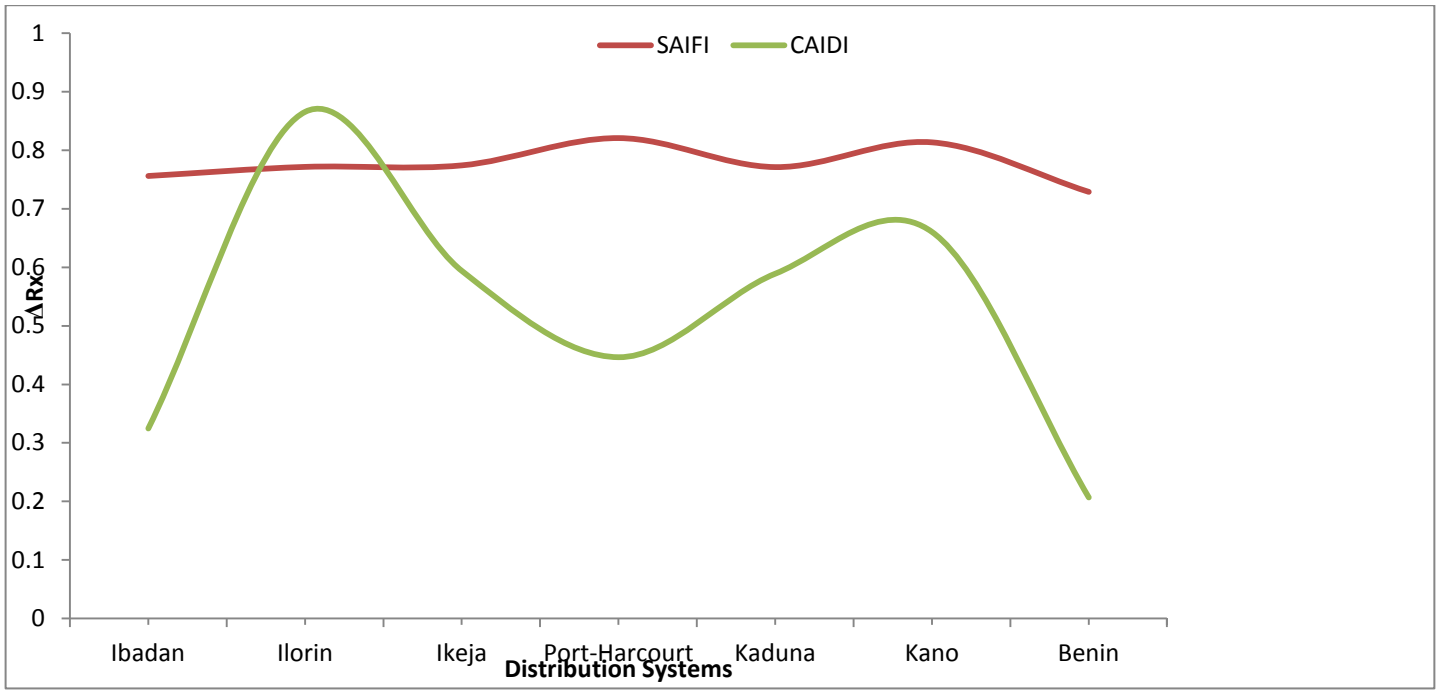

Figure 3: Change in system reliability indices versus Distribution Systems.

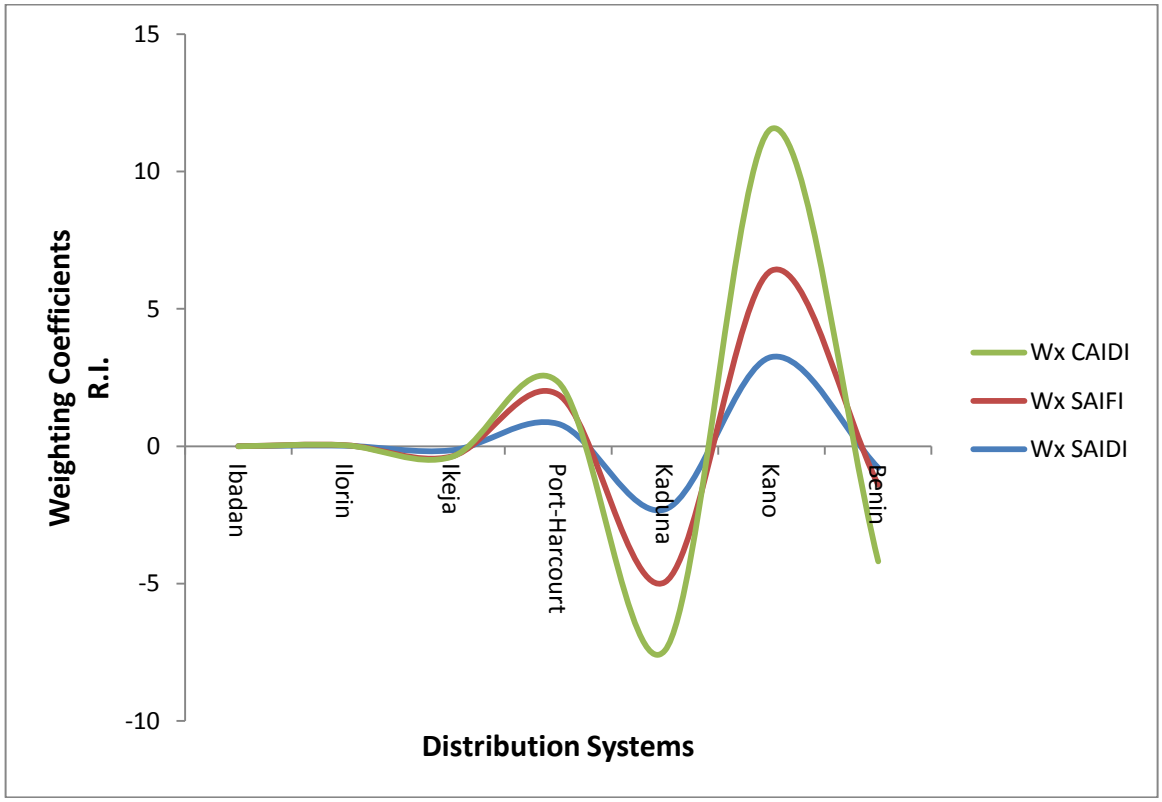

Figure 4: Relationship between Distribution Systems and Weighting Coefficients.

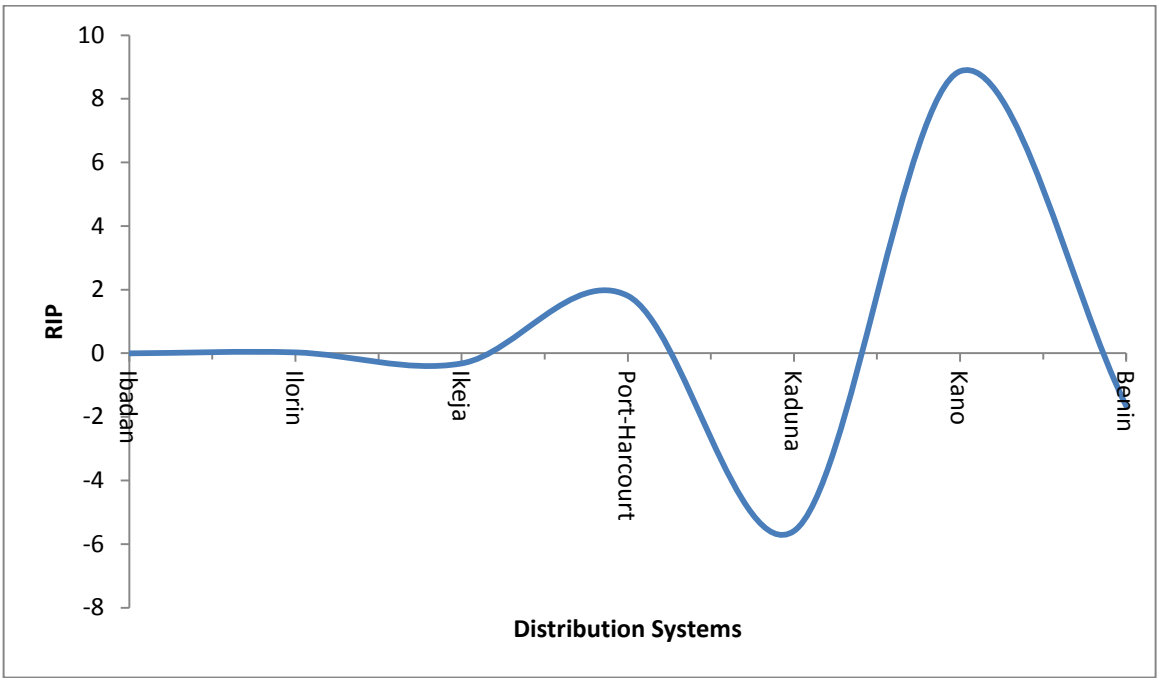

Figure 5: Reliability Improvement Proposal versus Distribution Systems.

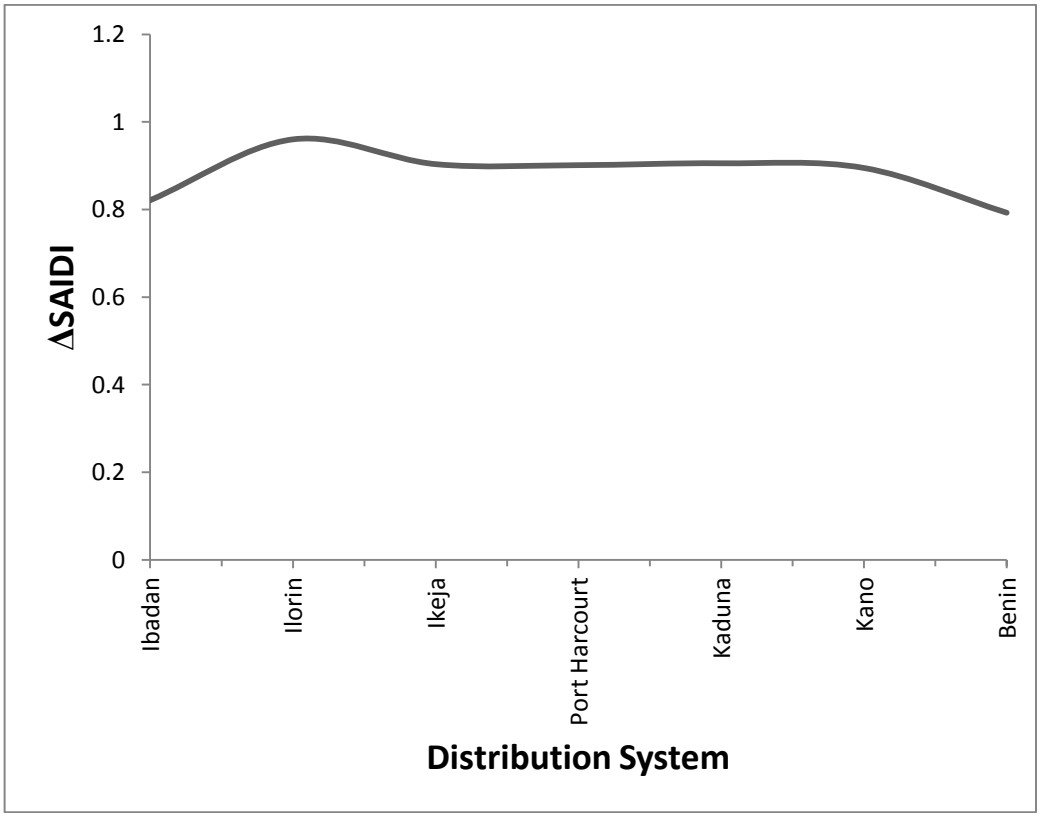

Figure 6: Change in SAIDI versus Distribution Systems

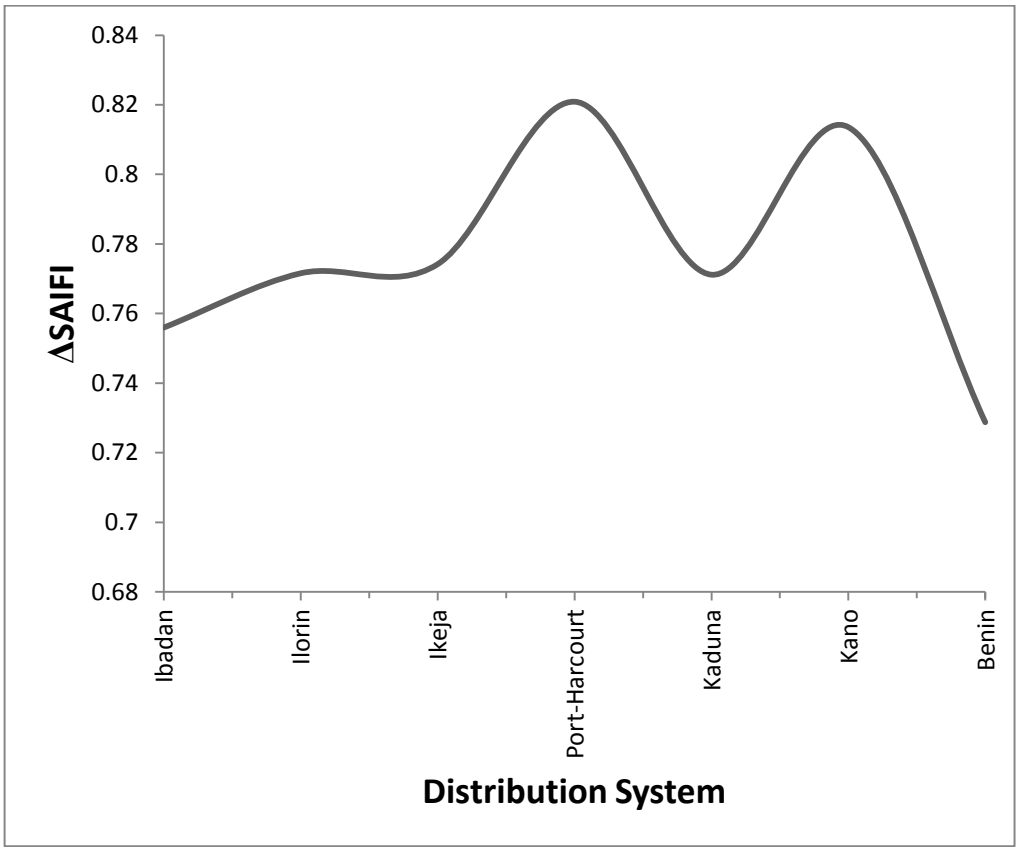

Figure 7: Change in SAIFI versus Distribution Systems.

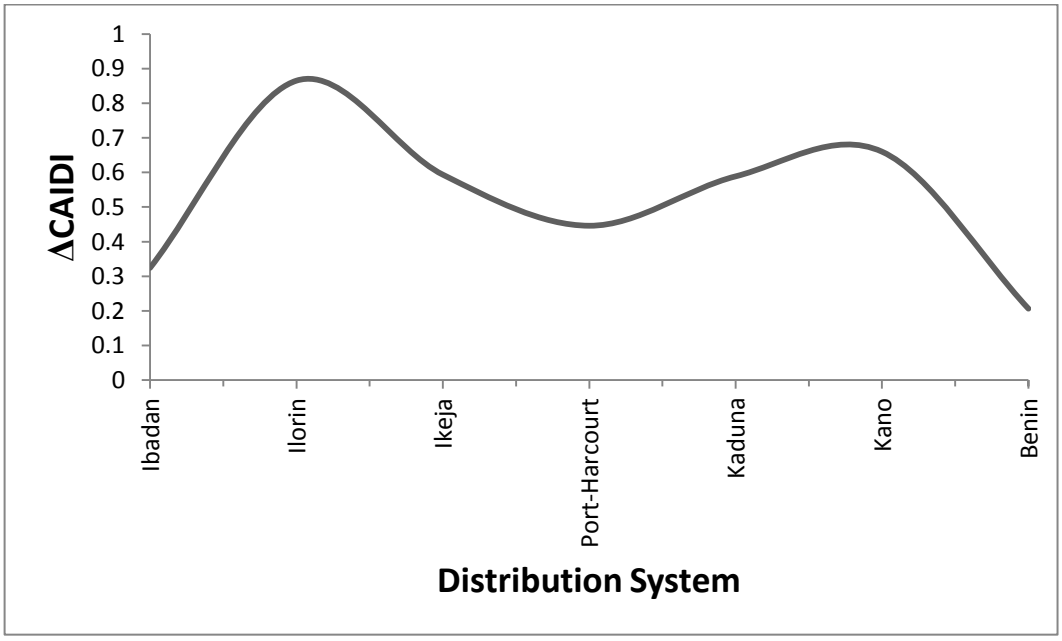

Figure 8: Change in CAIDI versus Distribution Systems.

CONCLUSION

The Reliability Improvement Proposal (RIP) model for evaluating the reliability indices of electrical distribution system has been presented in this paper. The change in the system reliability after the RIP model for Ibadan, Ilorin, Ikeja, Port Harcourt, Kaduna, Kano and Benin were 0.6339, 0.8327, 0.7767, 0.7229, 0.5786, 0.7896 and 0.5761 respectively indicating a high level of reliability improvement. Ibadan distribution system recorded the least SAIFI weighting coefficient of -0.0009214 while Kano distribution system had the highest CAIDI weighting coefficient of 5.158 due to the power requirement of the city. The RIP model is a valuable planning tool capable of evaluating alternative reliability improvement proposals with the goal of establishing and prioritizing reliability improvement recommendations that will optimize the reliability performance of a power delivery system. The RIP method is unique in that it uses quantitative processes to optimize reliability performance expectations of both customers and regulatory authorities.

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