Variation of Reliability Indices with Generation Techniques Applied.

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Abstract: —Reliability indices are considered to be reasonable and logic way to judge the performance of an electrical power system. This paper implements this algorithm to compare between four suggested generation techniques, one of them will be renewable namely, wind energy. A MATLAB software based program was developed to obtain the predicted values of the required indices. This program applies Monte Carlo simulation method and the failure and restoration times are considered to be exponentially distributed. A case study where a radial system is fed by different generation techniques is presented through this paper.
Key-Words: - Generation Techniques, Monte Carlo simulation, Reliability indices, Wind energy.

1 NOMENCLATURE

List of Abbreviations

λ	average failure rate (failure/yr)
DG	Distributed Generation
RTS	Reliability Test System
MTTF	Mean Time To Fail, hours
MTTR	Mean Time To Repair, hours
GTs.	Generation Techniques
SAIFI	System average interruption frequency index
SAIDI	System average interruption duration index
CAIFI	Customer average interruption frequency index.
CAIDI	Customer average interruption duration index

2 Introduction

Power generation techniques are highly concerned by the power engineers nowadays. Running out of conventional fuels like oil, coal, and the raw materials used in nuclear stations forced power engineers to find other to generate electricity from unconventional energy sources such as; sun, wind, and tidal energy. We can not totally depend on these renewable energy sources as primary supplies in our power networks and systems, so it is better to use them in distributed generation which have many applications; peaking power, back-up, and other ones [1]. Reliability indices which are proposed by the IEEE [2] will be used to evaluate the performance of each case study. Two ways are available to obtain these indices; analytical and simulation methods. Monte Carlo simulation method [3] is used to predict the value of each index after a certain number of samples. Previous studies focused on obtaining mathematical models to represent the reliability aspects of non-conventional energy sources [4] [5].

Others went to find an acceptable modeling for the different states of a certain component [1] [3] [6]. Some studies included the determination of suitable probability distributions to obtain the random variables TTF and TTR which are evaluated in the two-state model of a component. These distributions may be Exponential, Gamma, Lognormal and Poisson [6] [7]. This paper applies the exponential distribution to obtain the TTF and TTR for the system elements within each sample.

This paper drives a comparison between three GTs. which are widely spread all over the world; hydro stations, fossil steam stations, and nuclear stations. On the other hand wind energy is considered to be the renewable energy source that will be studied. A simple radial system is the tool used to apply the case studies showed by this paper. The components of this system are selected with high reliability, such that outcome of the applied strategies reflect only the effect of the generation techniques.

The first section of this paper explains the steps of the algorithm followed to obtain the reliability indices related for each sample. Third section enumerates and discusses the case studies that are analyzed through this paper. Reliability of the used system and its components and the methodology of electrical generation are briefly explained in the fourth section. Finally, results are analyzed; comments and conclusions are obtained thru the fifth section.

3 The Proposed Approach

The main objective is to get the parameters of the reliability of each GT; these parameters are the load point and the system indices. A certain procedure will be executed to obtain the load point indices at any point in an electrical power system. The methodology applied in this analysis states that power delivered to certain load point flows through a defined path formed of several types of components including transmission lines, transformers, fuses and circuit breakers. Each one of these components has its own MTTF and MTTR [3] [6] [7]. If any of these components is interrupted then the load connected at this load point will be interrupted too. Monte Carlo simulation [7] is used to predict the values of CAIDI and CAIFI at any load point. Through each sample (1 year) in the Monte Carlo simulation it was assumed that the chronological state curve is variant based on the random generated values and the number of customers at each load point will be fixed. Detailed steps are stated below:

1-Determine the TTF and TTR of each component [7] using an exponential probability distribution.

2-Generate the chronological state curve (up state=1, down state=0) for each component.

3-Add all the chronological curves that the load point depends on to obtain a chronological curve for the point itself. Note that any failure for one component or more will cause the interruption of power transmitted to the load point under investigation (the curve should be at the down sate). Switching time of protective devices that respond for faults that do not affect the load point studied will be considered in the load point chronological curve.

4-The periods at which curve of the load point is in the down state will refer to the interruption of the load feeding. As a conclusion the duration of each interruption could easily be determined and also the number of interruptions per the time span of simulation.

5-Finally, generate a Monte Carlo prediction curve for the CAIDI and CAIFI [11];

$$CAIDI = \frac{No.\text{ of interruption hours during the simulation sample}}{No.\text{ of customers at the load point}} \quad (1)$$

$$\text{CAIFI} = \frac{\text{No. of interruptions at a certain load point}}{\text{no. of customers at this load point}} \quad (2)$$

The system indices were also determined by the chronological curve data of the system components; based on these curves the load point's chronological curves were obtained. In turn the number of interruptions and duration of each interruption for each point can be calculated. Equations (3) and (4) were used [2].

$$SAIDI = \frac{No.\text{ of interruption hrs. over the system during simulation sample}}{No.\text{ of customers in the whole system}} \quad (3)$$

$$SAIFI = \frac{No.\text{ of interruption times over the system during simulation sample}}{No.\text{ of customers in the whole system}} \quad (4)$$

4 Case Studies

An electrical system can operate with or without an alternative supply, also it can be fed by many aspects of generation; conventional or renewable GTs can be used as it was discussed earlier. To test the effect of each GT on the performance of the system, different assumptions for the method of feeding loads in a simple electrical distribution system will be considered.

The system under study is a typical distribution feeder that is formed of 3 load points A, B and C. laterals contains fuses to isolate the failed sector from the rest of the system, but a switching time will be needed to restore the supply after any fault occurs in the system. The main feeders are equipped with isolation switches to improve the reliability of the system.

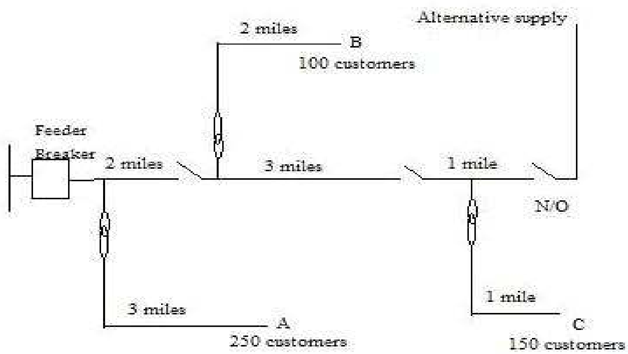

Fig. 1 Radial simple test system

In order to asses the reliability of the system under study the following cases will be implemented:
Case A: the main supply is considered to be fully reliable in other words never interrupted of course this is not practical but the results of this assumption will be taken as a reference to compare the results of the other cases. No alternative supply
Case B: Single supply is used to provide all loads with electric power. The following technologies will be studied;_Hydro, Fossil steam (oil fueled) and Nuclear. These three technologies were selected as they can be considered the most dominant generation techniques used allover the world. Each technology will be examined alone to compare the obtained results.
Case C: the main supply is hydro station while the alternative one is a combustion station.
Case D: the main supply is a hydro station, but a wind energy farm will deployed as an alternative supply. The modeling of the power generated by this wind farm was based on the model presented in [8].
Cases C and D represent the alternative supply as an online running reserve. When a failure happens it will be able to feed the loads immediately without any starting time. Only the switching periods will be considered. For each simulation sample a new chronological state curve for the alternative supply will be generated. Through each case CAIFI, CAIDI, SAIFI and SAIDI will be evaluated and a comparison will be held between the six cases. The alternative supply support each load point with another path for power delivery, so if any of these two paths are available the load will not be interrupted, but there will be an interruption during the switching process from the main supply to the alternative supply path, as a conclusion the number of interruptions may be more if compared to the cases that do not have alternative supply. But the interruption duration will be reduced much. The chronological state curve of the load point in this case will be resultant of the two paths. System details will be discussed in the next section. Results and conclusion are displayed at the end of paper.

5 System Reliability Analysis

The methodology stated in section 2 will be implemented through a system that has two types of feeders; main feeders and lateral ones. The failure rate of both is a function in their lengths, it equals 0.1 failures/circuit mile/yr. (main feeders) while the laterals failure rate is 0.25 failures/circuit mile/yr. the average repair times for the main feeders and laterals are 3 hours and 1 hour respectively. To calculate MTTF of both types of feeders; (5) and (6) were used [4] [7].

$$\lambda\text{=(failure rate/length)*length of feeder} \quad (5)$$

$$MTTF = \frac{8760}{\lambda} \quad (6)$$

The reliability data of each component in the system are presented in table (1). Based on the suggested procedure load must be fed if and only if sections x and w are healthy. If there is an alternative supply sections y, z and the supply should be healthy.

Table 1 Reliability Data of the used system

Section name	Section length	MTTF	MTTR
X	2 miles	43800	3
Y	3 miles	29200	3
Z	1 mile	87600	3
W	Valid for all	17520	1

Figures 2 and 3 will show the chronological state curves of the section w, the main supply respectively through one sample (1 sample =8760hours=1 year) on which load point A depend whose corresponding chronological state curve is shown in figure 3. Figures 2, 3 and 4 insure that any failure in any one will cause failure at point A. Main feeder breaker should also be healthy otherwise the path between the load point and the supply will be interrupted. Interruptions are also caused by switching actions due to failures far from the target load point. These switching interruptions were also considered in the software used; where one switching operation requires one hour.
Three types of supply were used as a main supply; Hydro, Fossil steam (oil fueled) and nuclear generation station. These GTs were selected as they represent three different levels of reliability based on their MTTF and MTTR stated in the RTS [7] [9]. First of all, each type of the previously stated GTs will be applied as a main supply without an alternative one.
After this Hydro will be the main supply utility while combustion turbine generation station will act as a backup supply which is always running but loaded only in case if supply failure. Finally the wind farm is used as an alternative supply instead of the combustion station. The four indices will be obtained for each case. Note that the load point that will be studied to obtain the customer indices is point A. when the wind energy is used it will be assumed that the minimum output power required is

1.3Mwatts. The average power generated by the connected wind farm is 0.85 Mw, table (2) gives more information about the generation rates of this wind farm. Results are analyzed and conclusions are obtained next.

Table 2 Wind farm generation data

Generated Power	Duration (hours/year)
None	94
1 Mw up to 1.3 Mw	1934
0.6 Mw and less	3638
0.4 Mw and less	4798
0.2 Mw and less	6336

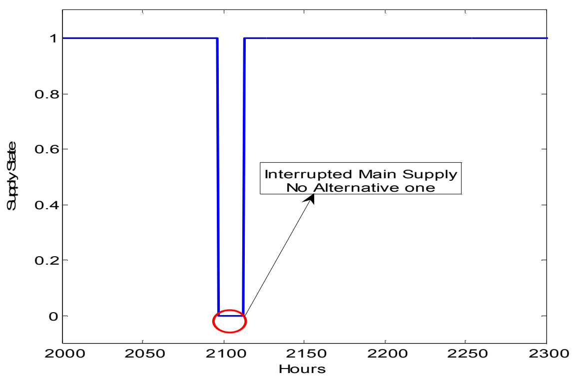

Fig. 2 supply chronological state curve

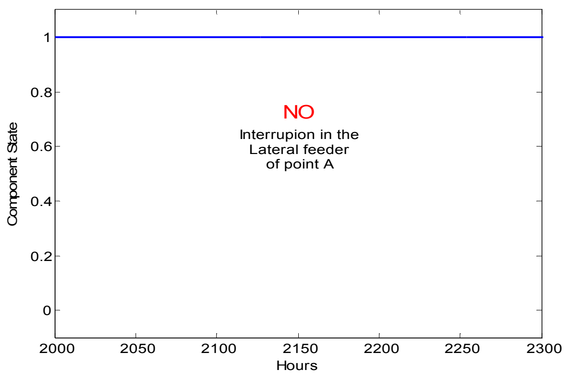

Fig. 3 (w) component chronological state curve

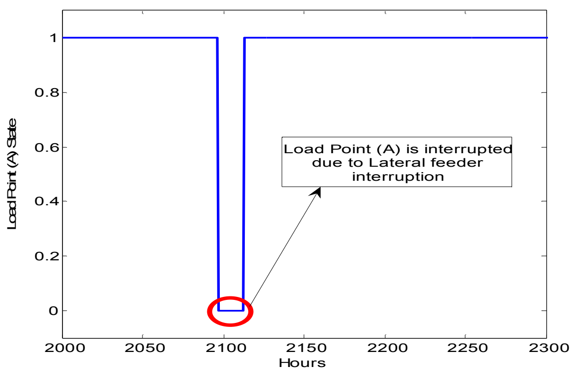

Fig. 4 Load point (A) chronological state curve

6 Results

Table (3) shows reliability indices for the feeder under study which are calculated for the cases of study stated in section 3 Hydro GT led the system to a performance very near to its performance if a wind energy farm is connected as a backup supply, for example; the CAIDI in case D is 0.2175 hours, while when a hydro generation station is connected the CAIDI is 0.2722 hours, the difference is about 0.016 hours. On the other hand the Fossil steam (oil fueled) GT recorded least interruption frequency (0.0285) after that of hydro but with a poor interruption duration. This supports the point view that nuclear stations need longer time for maintenance or repair.

Table 3 Reliability indices of study cases.

Case/ Indices	A	B(hydro)	B(oil)	B(nuclear)	C	D
CAIDI	0.00054	0.2722	1.2146	3.6746	0.0216	0.2175
CAIFI	0.00055	0.0176	0.0285	0.0292	0.0026	0.0213
SAIDI	0.00083	0.4067	1.8156	5.5207	0.0425	0.3523
SAIFI	0.00085	0.0262	0.0428	0.0434	0.1615	0.0300

Oil GT recorded moderate values for both; load point indices and system indices, as a conclusion nuclear GT causes less number of interruptions while hydro GT decrease the duration of interruption but with a higher density of occurrence.
Alternative supply improved the performance of system from the point of view of duration based indices for example SAIDI was reduced by about five hours when a combustion turbine station was applied as a backup supply to the main hydro supply (case B and F). Switching from the main supply to the alternative one increased the frequency of occurrence of interruptions if compared to the cases that do not a backup supply. Wind farms have recorded the highest interruption times per the simulation sample in the CAIFI and SAIFI; this may be due to the instability of the fuel of thus GT which is wind. Many other factors affect the wind generation stations; the temperature, the air density, and of course the wind speed. Consequently the wind generation stations are not always capable of supplying the system or a certain load point with the required level of power; this will lead to many interruptions. But in overall the interruption duration is less if compared to a system that does not have any backup supply. Therefore the combustion turbine station when used as an alternative generator; it caused less number of interruptions than that of wind GT, as the level of generation of combustion turbines is nearly fixed. The decision of implementing a specific technology to support

system reliability requires the analysis of many aspects; Land scarce, the environmental impacts, the fuel and cost represent examples for these aspects. The cost of adding new component, to the system to improve the system to improve system reliability is known as reliability cost, while the benefits gained from adding these components to the system is known as reliability worth. In the future work, reliability cost/worth analysis in implemented to provide the decision makers with same information that might help in planning the system. Monte Carlo simulation curves of the four reliability indices evaluated in this paper for some cases of study are shown in figures 5 to 8.

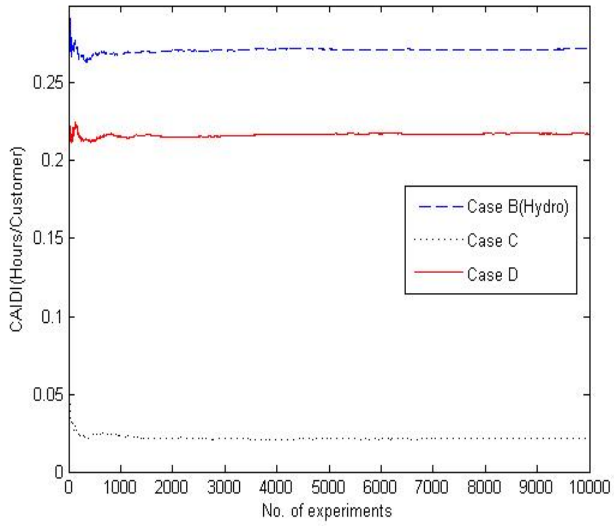

Fig. 5 Monte carlo simulation for CAIDI of cases B (Hydro),C and D

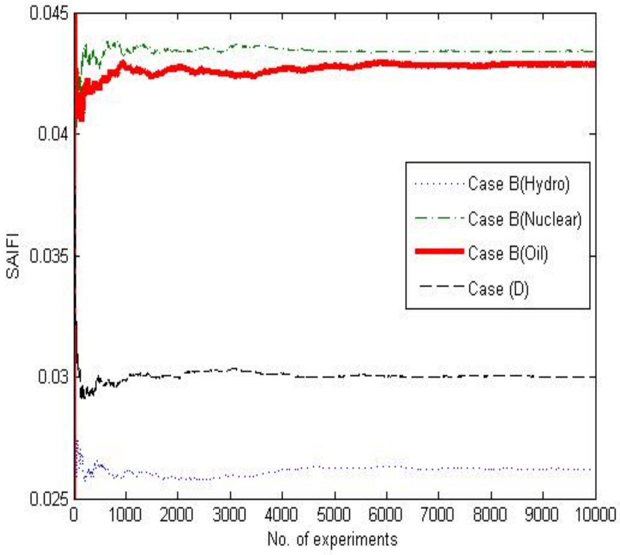

Fig. 6 SAIFI indices for B and D cases.

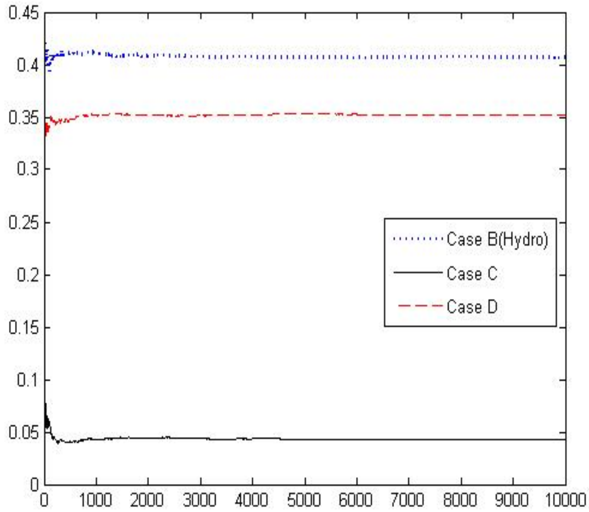

Fig. 7 SAIDI indices for A, B (Hydro), C and D.

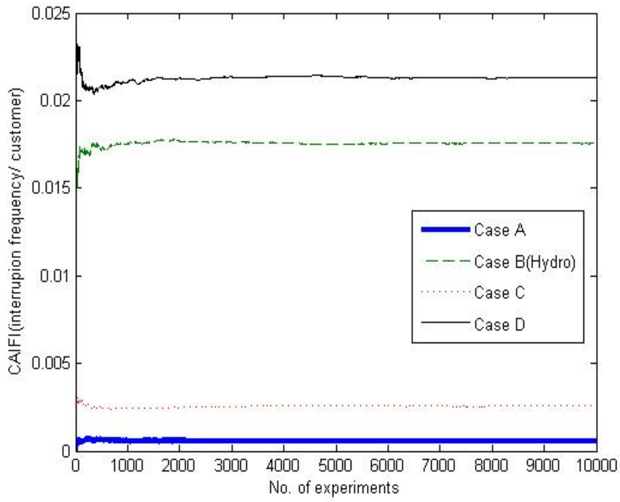

Fig. 8 Monte Carlo simulation for CAIFI of A, B (Hydro), C and D

7 Conclusions

The impact of the generation techniques on the reliability of the distributed generation system is presented in this paper. A comparison between the four suggested GTs is implemented on a typical radial feeder. The results showed that Hydro GT has recorded the lowest interruptions times and durations with respect to the other two GTs. While the combustion turbine generation GT is preferred as an alternative or a back-up supply if its reliability indices are compared to that of wind energy GT. This is due to the stability in the level of generation of the combustion turbine GT. Although the cost/worth analysis is important for power system studies but it was not presented in the paper. Therefore, this topic will be the target of my future work.

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