Application of Monte Carlo Simulation for Evaluation of LOEE in Power Systems Including Hydraulic and Thermal Units

Somayeh Farhadkhani
Master Student - Shahed University
Tehran, Iran
s.farhadkhani@yahoo.com

Mehrdad Rostami
Faculty member - Shahed University
Tehran, Iran
rostami@shahed.ac.ir

Amir Naghizade Gogdare
Master Student - Shahed University
Tehran, Iran
a.nagizade@ymail.com

Abstract — **It is of great importance to understand system reliability pertaining to each equipment unit under study when analyzing system performance capability. This is especially true since reliability measures act as very good indictors of system's ability in providing consumer electrical energy. The Monte Carlo simulation method is, without doubt, one of the most powerful existing probability methods for reliability analysis.**

In this article, the sequential and non-sequential Monte Carlo methods have been used in order to analyze power-generating systems by taking into account hydro and thermal units. The IEEE-RTS sample network has been used in order to assess the operation of the presented program.

Keywords- reliability; sequential Monte Carlo; analytical method; IEEE-RTS

I. INTRODUCTION

One of the most important goals of power-generating organizations is system reliability maintenance. This task is a natural part of any adequate and intelligent design and its implementation.

A power system's reliability is a good indicator of its correct and adequate operation, suitable service response and of its ability in performing pre-determined tasks. That indicator is especially suitable for systems experiencing instable conditions leading to partial miss-operation or system break-down.

Power system designers and implementers are logically bound by economic constraints while aiming to provide adequate and secure electrical energy for consumers.

Reliability studies include the two concepts of adequacy and security. Adequacy is the system capability in handling the demand load at any given time during system operation, all confined to designated system areas and within allowed and safe system voltage limits.

Adequacy depends on system's level of reaction to discrepancies and is evaluated by its proper response in case of malfunction, effectively assessing system reliability in dynamic conditions.

In the last decade, knowledge in the field of probability methods has finally reached a level that it could now directly be used in designing real-life problems and practical decision-making situations. Various methods exist in this field today among which the following two main methods are worth the mention:

- Analytical method (Enumeration method)
- Simulation method

The majority of research and submitted articles have so far been based on the analytical method. Simulations methods have had little role in specialized applications in this field. The main reason behind this has been the need for long-running computer calculations as well as the fact that the analytical methods have simply been sufficient for obtaining necessary results aiding designers and implementers in their decision-makings. Nowadays, however, interest has been building up in more complete system behavior modeling and more accurate analysis of reliability parameters. This trend is the main reason for the need for the Monte Carlo simulation method.

In this article, it has been aimed to analyze the reliability of the IEEE-RTS sample network in level of HLI, using the sequential and non-sequential Monte Carlo simulation method. The outcome is then proven by comparing the results obtained from the suggested model against the ones presented in other relevant articles.

II. MONTE CARLO SIMULATION

The Monte Carlo simulation method works on sampling from the entire state space, which can easily cover most situations and configurations. Transmission and composite reliability evaluation were then carried out using this state selection method. [7]

There are two types of Monte Carlo simulation approaches: non-sequential and sequential. A non-sequential simulation process considers each hour to be independent of every other hour. Therefore, non-sequential simulation cannot accurately model issues that involve time correlations, i.e. hydro plants modeling with limited water. Sequential simulation has been used only when the to-be-analyzed system is past-dependent; which is, the state of the system at any given time is partially determined by the historical evolution of the system. This is true for many real systems, but acceptable simplifications can often make the system past-independent. The analysis of hydroelectric power systems is one case where sequential simulation is totally justified, since the available power at any moment, is dependent on, among other factors, the past water inflows, past operation policies and historical evolution of the load. Simplifications given a time-independent representation lead to very unrealistic results. [8]

For the system under study, all system components are modeled by means of the classical two-state probability model which considers that a component has only 2 states: available and unavailable (up and down). The transitions between these operative states are defined by means of the probability distributions of time to outage (TTF) and time to restoration (TTR). The two-state Markov chain is shown in Fig.1, and the random values of TTR and TTF are calculated by using the equation (1) as below:

$$TTF = -\frac{1}{\lambda}\ln u_1$$
$$TTR = -\frac{1}{\mu}\ln u_2 \qquad (1)$$

Where λ is the failure rate, μ is the repair rate and u_1 and u_2 are uniform random numbers in range of [0 1].

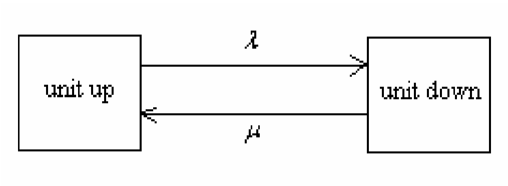


Figure1. Representation of two-state Markov chain model

III. MONTE CARLO SIMULATION USAGE IN GENERATION-LEVEL RELIABILITY ANALYSIS

A. *Generation units' states*

A generation unit could be situated in one of various states. In a two-state simulation, the probability of being in the on or off state (healthy or ill state) in sequence, or having access and non-access capability is defined. Modeling a generation unit in MCS for a two-state unit is relatively simple. This model is resulted by generation of a random number U in range (0,1). This U value is comparable with the FOR amount. (FOR, in fact, is the rate of failure which is part of the RTS article information). If U<FOR, then it is concluded that the unit is in failure state and otherwise it is accessible.

B. *Load model*

There are two main models showing load variance: Time model and non-time model. Both models are used within the Monte Carlo method. In the first model, load levels are counted using time sequence (main count). This method could be based on an annual or any other sequential time frame. This model can only be used to demonstrate daily values (365 values per year), hourly (or semi-hourly) values or 8760 distinct values per year. Distinct daily load values could be placed in descending order in order to obtain a condensed model which is known as the Daily Peak Load Variation Curve (DPLVC). The resulting model is known as the Load Distribution Curve (LDC).

C. *Generation system modeling*

In this section, three main points have been illustrated. The first point is the main principle in implementing MCS over the issue of generation capacity. The second point illustrates that MCS can be implemented for a particular issue and results comparable to the analytical method can be obtained. Finally, the third point is proof that the MCS method can obtain a larger set of results compared to the analytical method. In order to achieve the above three points, two relevant studies are analyzed as described below:

- Reliability analysis (LOEE) of the generation system (HLI) using Load model without time sequence
- Reliability analysis (LOEE) using the sequential time model which has demonstrated additional advantages of usage of MCS

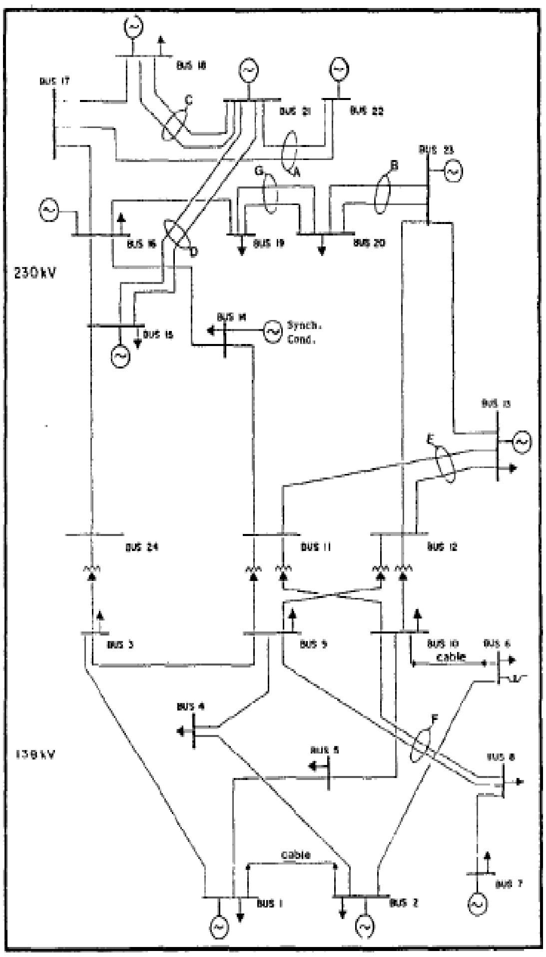
IV. CASE STUDY

The reliability evaluation has been implemented through using the MATLAB utility and tested on the IEEE-RTS96.

The RTS 96 reliability test system is shown in Fig.2. It consists of 24 buses, 33 transmission lines, 5transformers and 32 generating units. The system peak load is 2850MW. The total installed generation capacity is 3405 MW. There are 6 hydro units in IEEE_RTS with 50 MW capacities for each unit. These hydro units have 100% capacity for the first half of the year and 90% capacity for the remainder. Their quarterly energy distribution is as follows: 35%, 35%, 10%, 20% where 100% is 200GWh. Annual system indices including loss of expectation energy (LOEE) for the above-described system are shown in table I, for 5000 sample years. Fig.3 shows the variation of LOEE against the sample of years in applied sequential MCS.

TABEL I. Result of simulation

Reliability indication	LOEE(MWh/Year)		
	Analytical method	***Sequentional MCS***	***Non-sequentional MCS***
LOEE	1176	1167	1157



(Figure2. IEEE RTS-96)

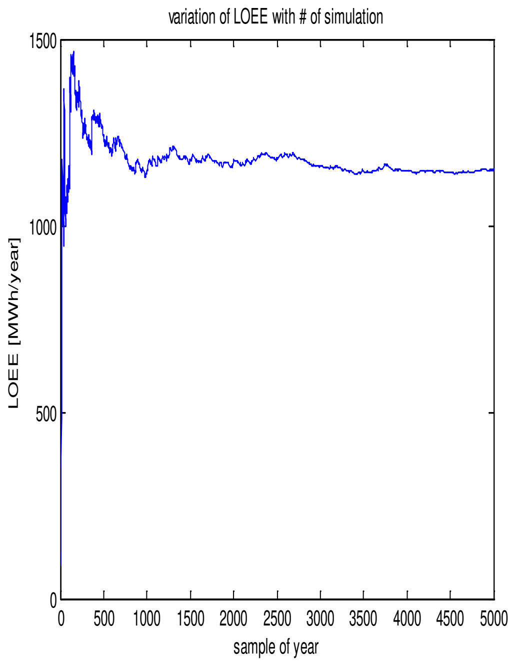


Figure3.Variation of LOEE against sample of years

V. Simulation Result

Comparison of results in table 1 against the results from the analytical method indicates correctness and accuracy of the subject Monte Carlo program.

VI. Conclusion

Reliability indicators have an undisputable importance in design and implementation of power systems. The Monte Carlo simulation method has many advantages of which the main ones are as the following:

- Simulation capability of all system states
- Simplicity of formulation, concepts and usage methods

This simulation method, thus, was used in this article to calculate LOEE in IEEE-RTS system. The subject program was developed using the MATLAB utility and its correctness was confirmed. In conclusion, it became apparent that the Monte Carlo simulation is a suitable method in evaluation of power system reliability indicators, including hydraulic and thermal systems.

REFERENCES

[1] Wang shao, zhou jiaqi, "A reliability evaluation model for two transmission lines in parallel, "proceeding of the CSEF, 2003,23(9):53-56.

[2] zhao yuan,zhou jiaqi,"Research of the optimal load-shedding model in the composite generation and transmission system reliability evaluation,"powersystem technology,2004,28(10):34-37

[3] y. zhao,N.C. zhou, J.Q. zhou,X.zhao,"research on sensitivity analysis for composite generation and transmission system reliability evaluation," IEEE2006

[4]Armando M. leitedasilva, Leonidas C. resende, Luiz A. F. manso, "Application da of monte carlo simulation to well-being analysis of large composite power systems,"Stockholm,Sweden_ june11_15 , 2006

[5] Andrea M.rei,Marcus th.Schilling, fellow,IEEE, andAlbert C.G Melo,"Monte carlo simulation and contingency enumeration in bulk power systems reliability assessment," june_11_15,2006

[6] J.R. Ubeda, and R.N.Allean, "Sequential simulation applied to system reliability composite evaluation,",IEEEpro,vol.139,no.2,p.p.81_86,March 1992

[7] R.Billinton,and W.Li, "reliability assessment of electric power system using monte carlo methods,"1 sted.New york:press,1994

[8] J.W.Labadie,"optimal operation of multi reservoir systems: state-of-the-art review,"journal of water resources planning and management ASCE,march_april_2004