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Application of Monte Carlo simulation to calculate the reliability index LOLE.

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ABSTRACT

Loss of load expectation (LOLE) is a commonly used index in electric power systems reliability evaluation. This paper aims at calculating LOLE index by using Monte Carlo simulation (MCS). A generation system with five units is considered and also load duration curve is defined to calculate the LOLE. Simulation results demonstrate the effectiveness of the proposed method.

Keywords: Loss of Load Expectation, Monte Carlo Simulation, Reliability, Electric Power System

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INTRODUCTION

Reliability evolution of electric power system has been widely investigated and reviewed by researchers [1-5]. Paper [1] discusses that power market analysis should be incorporated in reliability assessments of deregulated power systems. For the Nordic power system, this is done by using The Multi-area Power-market Simulator (EMPS) for long-term power market analysis, where EMPS finds the optimal socio-economic dispatch on a weekly basis, with respect to, e.g., hydro reservoir levels. The EMPS analysis results in a set of load and generation scenarios, and these scenarios are interpreted as a sample of future power market behaviour, and is used as basis for a reliability assessment. These load and generation scenarios are referred to as power market scenarios. The power market analysis produces a large number of power market scenarios, and to include all these scenarios in a reliability assessment results in excessive computation time. The scenario selection method is presented and discussed. Scenario selection is used to pick out a subset of the generated power market scenarios, to only use this subset of scenarios as a basis for the reliability assessment. The paper provides some general guidelines for application of the scenario selection method. It is shown that the scenario selection method can reduce the scenario set by about 90%, with little loss of accuracy in the reliability assessment. Paper [2] presents a method to optimize the reliability of an electric power system by the introduction of distributed generation using biomass as fuel. The reliability index of the system is determined as the failure probability of the system. Probabilistic load flow is used to calculate the reliability index. This probabilistic load flow is solved by the method combined of cumulants and Gram–Charlier expansion. To determine the reliability index a number of contingencies should be simulated, the more the number of contingencies, the more accurate the index is. This probabilistic method uses the random variables as starting data, so both generators and loads are modelled as random variables. Generators considered for distributed generation are biomass fuelled gas engines, that are very abundant in Spain. This paper applies a new method utilizing Shuffled Frog-Leaping Algorithm and probabilistic load flow to solve this problem. Acceptable solutions are reached in a small number of iterations. Numerical applications are presented and considered regarding the power system IEEE 14-bus and including biomass fuelled gas engines at several nodes. The results obtained show the improvement of the reliability index due to the presence of distributed generation. Paper [3] discusses that recent investigations have revealed the significant role of reactive power in blackout events. The associated disturbances frequently emerge in the form of voltage instability and collapse. Due to the computational complexity of modeling and analysis of enormous contingencies, DC approximation of the power flow, without accounting the role of reactive power, is usually used to evaluate the contingencies and to mitigate the associated probable violations. Paper [3], at first, presents a linear power flow model based on an approximated version of AC power flow formulation. The proposed model is then used to develop an efficient reliability assessment approach which is capable of taking both active and reactive powers into account. The analysis technique is based on the linear programming format which leads to an optimal solution within a short computation time. Voltage and reactive power violations as well as transmission system overloads are alleviated by generation rescheduling or load shedding as the last resort. Numerical tests on the IEEE-RTS and the Iranian power grid show the acceptable accuracy of the results along with a significant reduction in the computational effort. Various sensitivity analyses are also investigated to reveal the robustness and performance of the proposed model.

This paper applies MCS to calculate the LOLE index. A generation system with five units is considered and also load duration curve is defined to calculate the LOLE. Simulation results demonstrate the effectiveness of the proposed method.

Monte Carlo simulation

Monte Carlo simulation is a computerized mathematical technique that allows people to account for risk in quantitative analysis and decision making. The technique is used by professionals in such widely disparate fields as finance, project management, energy, manufacturing, engineering, research and development, insurance, oil & gas, transportation, and the environment. Monte Carlo simulation furnishes the decision-maker with a range of possible outcomes and the probabilities they will occur for any choice of action.. It shows the extreme possibilities—the outcomes of going for broke and for the most conservative decision—along with all possible consequences for middle-of-the-road decisions.The technique was first used by scientists working on the atom bomb; it was named for Monte Carlo, the Monaco resort town renowned for its casinos. Since its introduction in World War II, Monte Carlo simulation has been used to model a variety of physical and conceptual systems.

Monte Carlo simulation performs risk analysis by building models of possible results by substituting a range of values—a probability distribution—for any factor that has inherent uncertainty. It then calculates results over and over, each time using a different set of random values from the probability functions. Depending upon the number of uncertainties and the ranges specified for them, a Monte Carlo simulation could involve thousands or tens of thousands of recalculations before it is complete. Monte Carlo simulation produces distributions of possible outcome values. By using probability distributions, variables can have different probabilities of different outcomes occurring. Probability distributions are a much more realistic way of describing uncertainty in variables of a risk analysis. Monte Carlo simulation provides a number of advantages over deterministic analysis:

- Probabilistic Results. Results show not only what could happen, but how likely each outcome is.
- Graphical Results. Because of the data a Monte Carlo simulation generates, it’s easy to create graphs of different outcomes and their chances of occurrence. This is important for communicating findings to other stakeholders.
- Sensitivity Analysis. With just a few cases, deterministic analysis makes it difficult to see which variables impact the outcome the most. In Monte Carlo simulation, it’s easy to see which inputs had the biggest effect on bottom-line results.
- Scenario Analysis: In deterministic models, it’s very difficult to model different combinations of values for different inputs to see the effects of truly different scenarios. Using Monte Carlo simulation, analysts can see exactly which inputs had which values together when certain outcomes occurred. This is invaluable for pursuing further analysis.

- Correlation of Inputs. In Monte Carlo simulation, it's possible to model interdependent relationships between input variables. It's important for accuracy to represent how, in reality, when some factors goes up, others go up or down accordingly.

Test system

A generation system with 5-generation units is considered as case study. The system data are listed in Table 1. Load duration curve is also depicted in Figure 1. It is clear that maximum load is 160 MW and minimum load is 64 MW.

Table 1: The system data for generation system

Generation unit	Size (MW)	FOR
G1	40	0.01
G2	30	0.01
G3	50	0.02
G4	20	0.02
G5	60	0.03

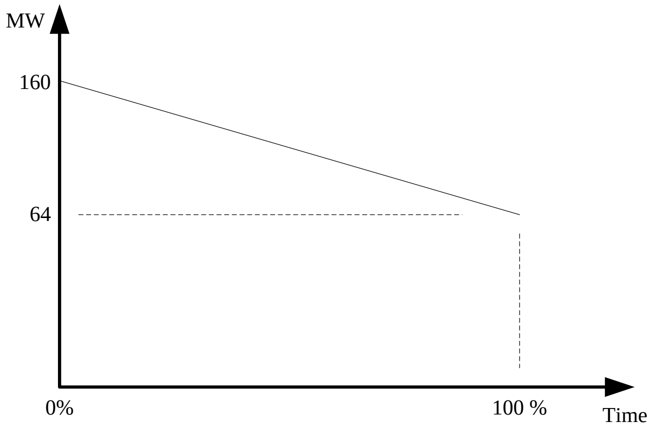

Figure 1: Load duration curve

Simulation results

In order to assess the effects of scenarios on the results, the simulations are carried out with consideration of following cases:

Case 1: 5×10^3 scenarious
Case 2: 5×10^4 scenarious
Case 3: 5×10^5 scenarious

The simulation results following the proposed cases are depicted in Figures 2 to 4. Figure 2 shows the LOLE index following 5×10^3 scenarios and it is clear that the convergence is not suitable. Figure 3 shows the LOLE index following 5×10^4 scenarios and the convergence is better than the previous case. Figure 4 shows the LOLE index following 5×10^5 scenarios, the convergence in this case is reached, and the output is completely converged for such number of scenarios.

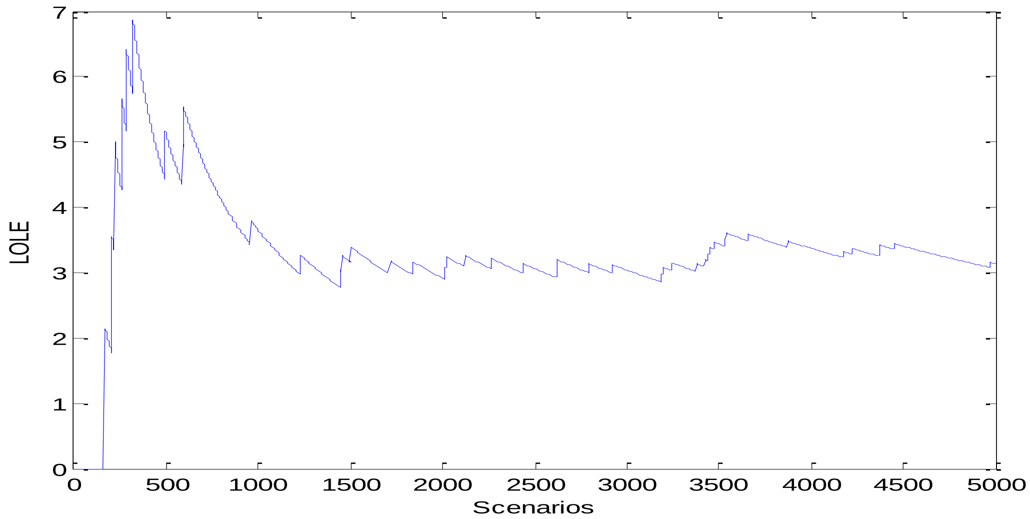

Figure 2: LOLE index following 5×10^3 scenarious

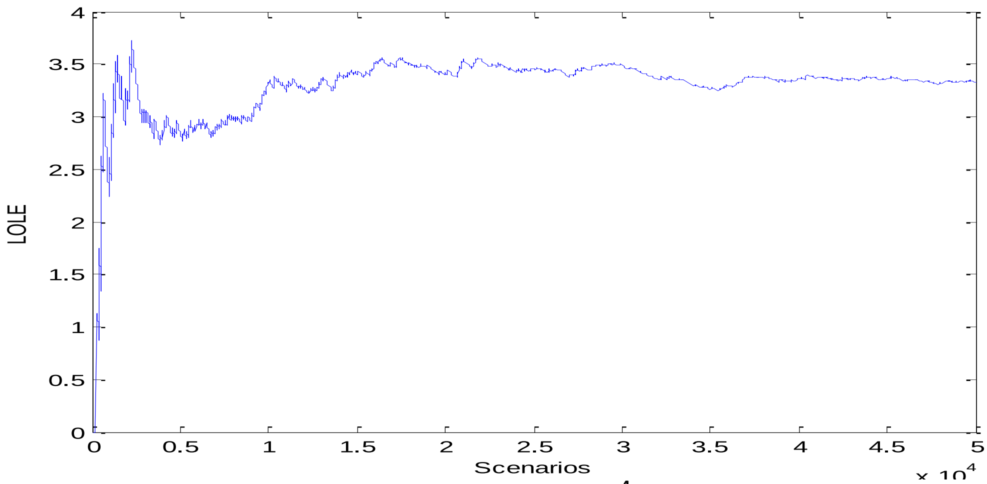

Figure 3: LOLE index following 5×10^4 scenarious

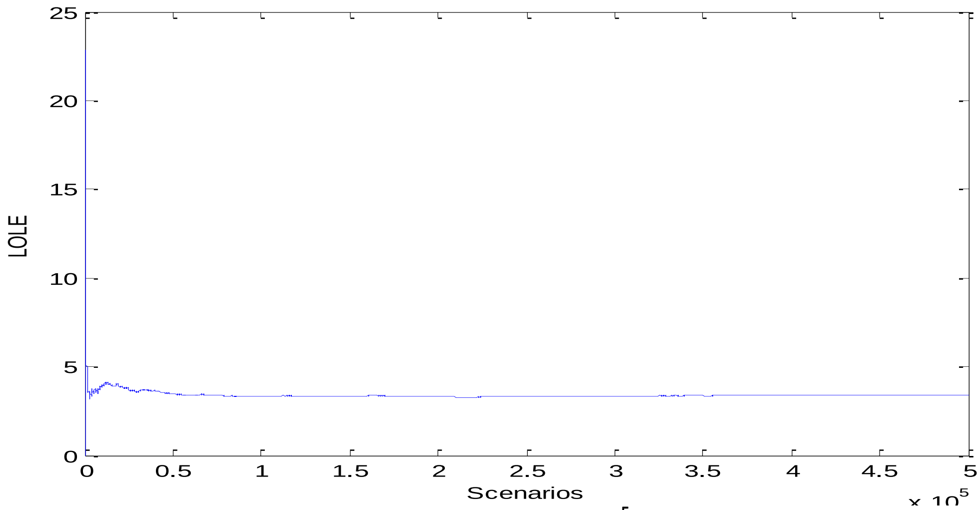

Figure 4: LOLE index following 5×10^5 scenarious

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CONCLUSIONS

This paper addressed Monte Carlo simulation (MCS) to assess the power system reliability indexes, where, loss of load expectation (LOLE) was calculated and assessed following different scenarios. Simulation results demonstrated that MCS could be successfully applied to calculate power system reliability indexes.

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