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Research Article

Investigating The Impact of Renewable Energy Sources on Networked Microgrids Using Probabilistic Load Flow

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Abstract – Efforts to reduce the environmental impact of fossil fuels have led to the proliferation of renewable energy sources in the power grid. As a result of the increase in renewable energy sources such as solar and wind, uncertainties in the grid have increased. It is not possible to observe these increasing uncertainties with deterministic methods. Therefore, it is necessary to observe the output values for different input conditions using stochastic methods. Probabilistic power flow (PPF) was used as a stochastic method in our study. We performed the study on a micro-grid (MG) test system with Monte Carlo Simulation (MCS), which gives more accurate results than other methods. This method records the results by performing the deterministic power flow repeatedly with high repetition numbers. With the increasing processing power of computers, Monte Carlo simulations can be performed much faster. The test system used utilizes multiple microgrids (MGs). There are no studies in the literature using MGs of this complexity. In the test system used, four microgrids are connected to each other. In the results obtained, we can see the total losses region by region. Only the lines between the microgrids are approaching their limits. The aim of this study was to produce a program that can perform probabilistic power flow analysis in MGs. By making improvements in the developed program, probabilistic load flow was performed in a very high busbar system in a short time.

Keywords – Microgrids (MG), Networked Microgrids (Mgs), Monte Carlo Simulation (MCS), Probabilistic Power Flow (PPF), Photovoltaic (PV), Wind Turbine (WT)

I. INTRODUCTION

In this study, MCS method is used because it obtains more accurate results than other methods and is more straightforward to implement than other methods. MCS simulation is used to test the accuracy of other PLF methods [1]. It is observed in the study that the computational cost of this method is no longer a problem thanks to the increasing processing power of computers.

In the literature, probabilistic load flow analysis on networked microgrid test systems has not been performed before.

According to the report published by EIA, it is predicted that 50%-60% of global energy production in 2050 will consist of PV and nuclear energy [2]. Nuclear energy. This situation shows that renewable energy systems will increase gradually. This increase brings with it uncertainties.

II. Materials and Method

If the way the program works is explained in order, it can be explained as follows. First, the program reads the line values. Then, the value is assigned in each cycle according to the distribution of generators. Similarly, the consumption value of the busbars is determined for each cycle. Then the power flow is made, and the results are recorded. The results obtained because of this cycle are recorded. This process is repeated for the number of cycles entered.

Load flow analysis was performed using Matpower [3] on Matlab. The program automatically names and saves the results obtained from the probabilistic power flow.

The program checks whether there is a limit exceedance on the lines. Similarly, it also checks whether there is a limit exceedance in bus voltages.

A. *Modelling the loads.*

To simplify the consumption model, a normal distribution was used. The normal distribution was obtained with the random function on Matlab. Mean and standard deviation values were based on existing studies. The mean value was taken as the demand's own value, and the standard deviation value was taken as 5% of the load [4]. The probabilistic density function of the consumption model is given in the equation below.

$$p(x|\mu,\sigma^2) = \frac{1}{\sigma\sqrt{2\pi}}\exp\left(\frac{-(x-\mu)^2}{2\sigma^2}\right) \qquad (1)$$

III. Case Study

The test system consists of four interconnected microgrids (MGs). The line data of the test system, the single line diagram, and the information required for the probabilistic power flow can be found in [5]. The line values were taken as in the test system used. The generation and consumption were modelled using probabilistic distributions. In this case study, generation and consumption values are based on the base values of the system.

The power generation distributions of the PV panels were added to follow the beta distribution. The shape parameters of the beta distribution were used as 2.06 and 2.5, respectively [4]. The power outputs of the 10MW panels used in a similar study [6] were scaled and made suitable for the test system used. In the test system, PV busbars were connected in this way. Wind generation was modelled using the Weibull distribution as in [7]. The Weibull parameters of the WTs with appropriate power from the baseline study were used.

Synchronous generators were modelled using a binomial distribution. The relevant probability values are based on the test system's own data.

Apart from these, no modifications were made to the test system. Simulations were performed in this way, and results were obtained.

IV. Results and Discussion

The variation of the magnitudes of the voltages at the busbars is given in Figure 1. Due to the good power balance in the system, the busbar voltages did not exceed the limits.

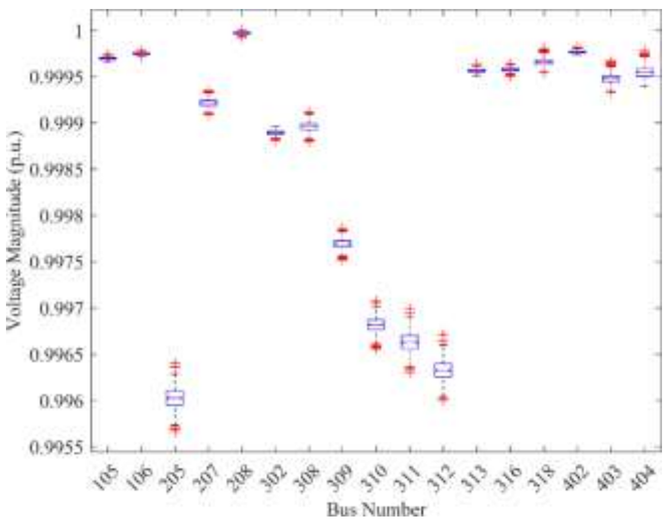

Fig. 1 Bus voltages

As seen in Figure 2, most of the lines are operating well below their current capacities. However, as in lines 201-202, 301-302, the lines through which the entire power of MG passes are operating at the limit of their capacities. However, despite this, there is no overrun on the lines.

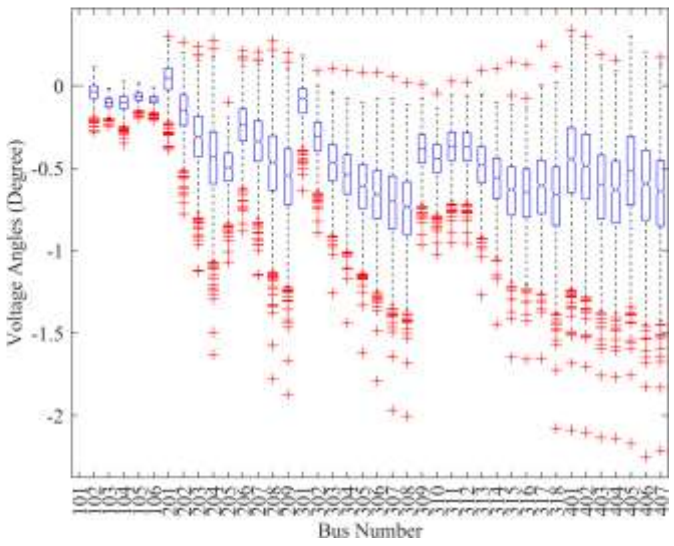

Fig. 2 Bus angles

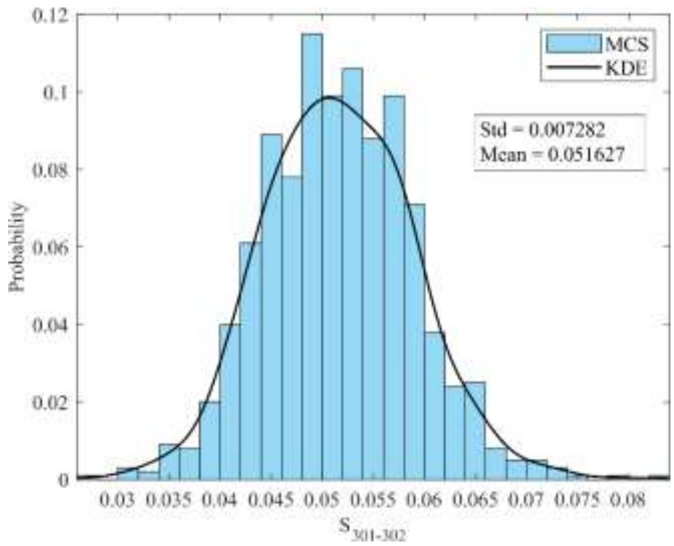

Fig. 4 Apperent power flow in line 301-302

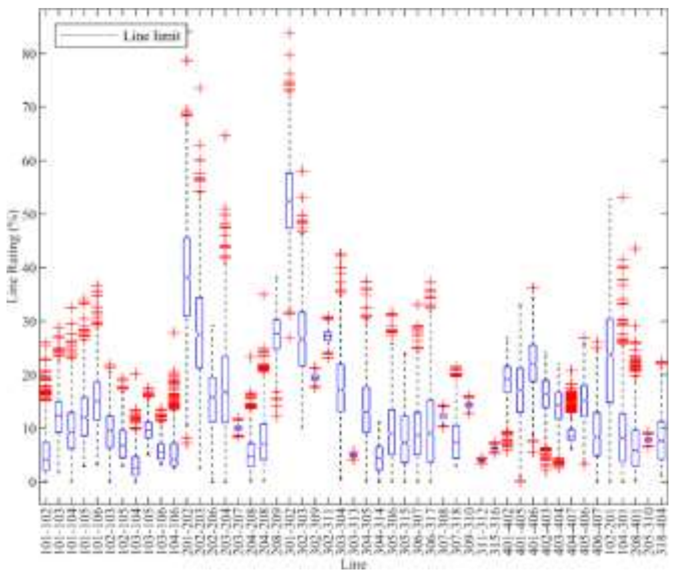

Fig. 3 Power flow results in base case

The apperent power flow distribution of lines 301-302, one of the lines with the highest utilization of capacity, is given in Figure 4. Standard deviation and expected values are given above the results. The part indicated by the line is calculated using Kernel Density Estimation (KDE) [8]. The columns give the results of the Monte Carlo simulation as histograms.

Real power flow in between busses 104-301 given in figure 5. As can be seen, there are certain differences in the distribution of power flow due to the merger of two different regions. Since the two regions are dominated by different generation sources, we observe this in the figure as they merge.

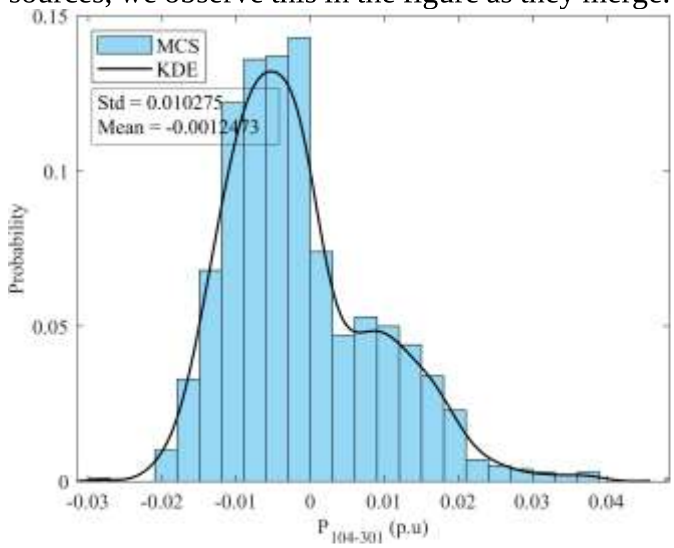

Fig. 5 Real power flow in line 104-301

The program also gives the total loss of all zones. The actual losses in the system are given in Figure 6.

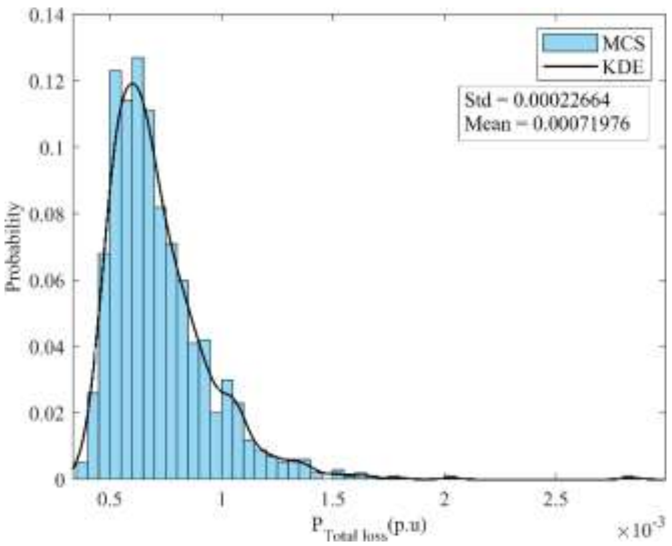

Fig. 6 Total real loss of system

Comparing the values in Table 1 with my previous work [9], the simulation time did not increase much despite the increase in the number of busbars. This is due to the development of the code. Some changes were made to the code to speed up the code. The part that should be considered here is that the simulation time only gives the time for the probabilistic power flow. It does not include the time it takes to generate the result graphs.

Table 1. Simulation time

	Simulation time(s)
Case study	114.4716907

V. CONCLUSION

The analysis in this study was done to observe the situation at a certain time of the day. In the system to be established in the future, instead of observing at a certain time of the day, there will be a study to observe 24 hours a day. After observing that the installed system works well, it was decided that the conclusion that this study was trying to reach was reached, and the publication was published in this way. In future studies, the response of the lines can be observed in cases where some MGs are turned off. New PV or WT generation can be added to different busbars. In this case, the response of the system can be observed.

In future studies, the correlation between wind and PV can be added, and its effect on the results can be observed. Wind speed can be modelled in more detail instead of simply modelling it with a Weibull distribution. Similarly, the power generation of PV panels can be observed to change during the day. Consumption can also be modelled to change during the day. However, it would make sense to integrate all these add-ons into the system only if a 24-hour simulation is performed.

As a result, a program that can perform probabilistic power flow analysis in multiple networked microgrids (MGs) has been written. The program gives results as expected. It will be used as a base program in future studies. In future studies, studies will continue to be carried out by closing different regions and adding productions. The desired results were obtained.

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