ENERGY MANAGEMENT AND VOLTAGE REGULATION OF GRID-CONNECTED MICROGRID USING GENETIC ALGORITHM

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1. INTRODUCTION

- At the beginning of the realization of the idea of decentralized electricity generation , due to the simplicity of the microgrids, optimization was not inevitable.
- Today's microgrids consist of many different distributed generators, more interconnected consumers, batteries, and backup generators, and therefore optimization is mandatory for the proper and balanced operation of the microgrid.
- The contribution of this research is from the aspect of reducing power losses and ensuring voltage stability, which results in minimizing the costs of providing electricity in the microgrid and maximizing the financial benefit from the produced electricity.
- The inclusion of penalty costs improves the reliability of electricity supply, but significantly complicates the optimization process.

2. PROBLEM DEFINITION

- The microgrids connected to the local utility grid have a great responsibility to the grid in terms of voltage stability, and their operation, which should not affect the operation of the local network(s) to which it is connected, especially not the consumers.
- The Energy Management System (EMS) should ensure that the storage or sale of excess power to the local grid is in place at the right time while meeting the demand.
- The problem with optimal usage of power generated by distributed generators, optimal battery usage, and trading with the local network is further complicated by taking into account the prices of electricity under different market oriented conditions. This is the main difference between the unit commitment problem in the standard power system and in the microgrids.

3. PROBLEM SOLUTION

- The optimization function takes into account the costs of buying electricity from the grid in case of shortage (C_{grid}) and the financial benefit from the production and sale of electricity to the grid (B_{DER}).
- The optimization function maximizes the profit from the operation of the microgrid, but also takes into account the penalty costs for not supplying power with a defined quality ($C_{pentalty}$) or not supplying power at all.
- The optimization function is shown in Eq. (1).

$$F(C) = \max \left\{ \sum_{i=1}^{T} (B_{DER,i} - C_{grid,i}) \Delta t - C_{penalty} \right\} \qquad (1)$$

Where T represents the analyzed time period.

3. PROBLEM SOLUTION

- The total benefit and the costs of the microgrid are shown in Eqs. (2) and (3), respectively

$$B_{DER,i} = P_{PV,i} p_{pv,i} + P_{wind,i} p_{wind,i} + P_{bat,i} p_{bat} \quad (2)$$

$$C_{grid,i} = P_{buy,i} p_{grid} \quad (3)$$

- Penalty costs for not supplying or supplying substandard electricity with unstable voltage are calculated depending on the Energy Not Supplied (ENS) and duration of not supply:

$$C_{penalty} = f(E_{not\,supplied,i}, \Delta t)$$

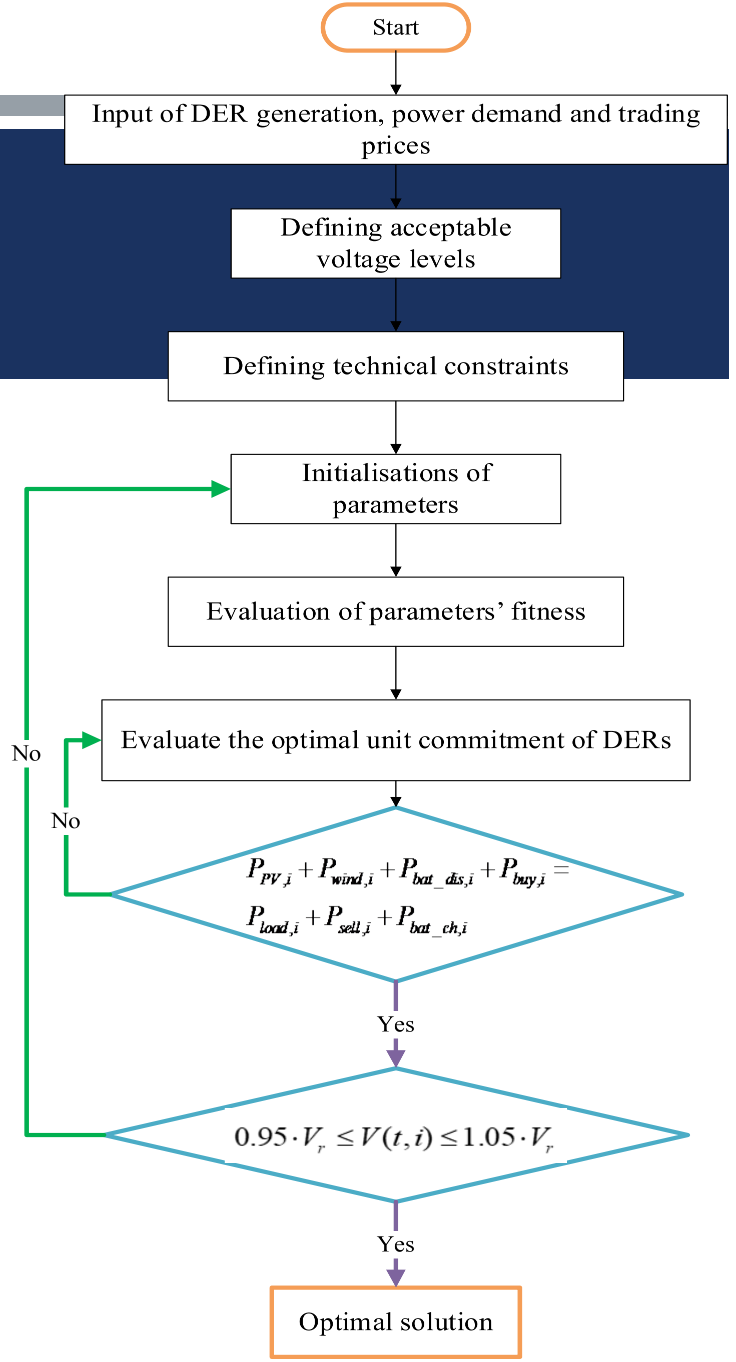

Fig. 1. Flowchart of the proposed algorithm

4. SIMULATION AND RESULTS

- The proposed method is applied to a microgrid composed of PV modules, wind generators, and batteries, simulated in Matlab.
- If the obtained solutions are within the defined limits of the given constraints, the voltage in the nodes is checked. If the voltages are within the limits, of ±5% variation, the solution is accepted. Otherwise, the problem of optimization is reconsidered, until the obtained solution satisfies all the limitations.
- The total profit of the microgrid during one day is 12.56 €. This is a case of high RES production.
- The financial benefit of the analyzed microgrid under the same conditions, using a genetic algorithm, but without taking into account the voltage in the nodes is 12.48 €. In this case, due to the voltage variation, penalty costs are also charged, resulting in a 0.64% lower profit.

4. SIMULATION AND RESULTS

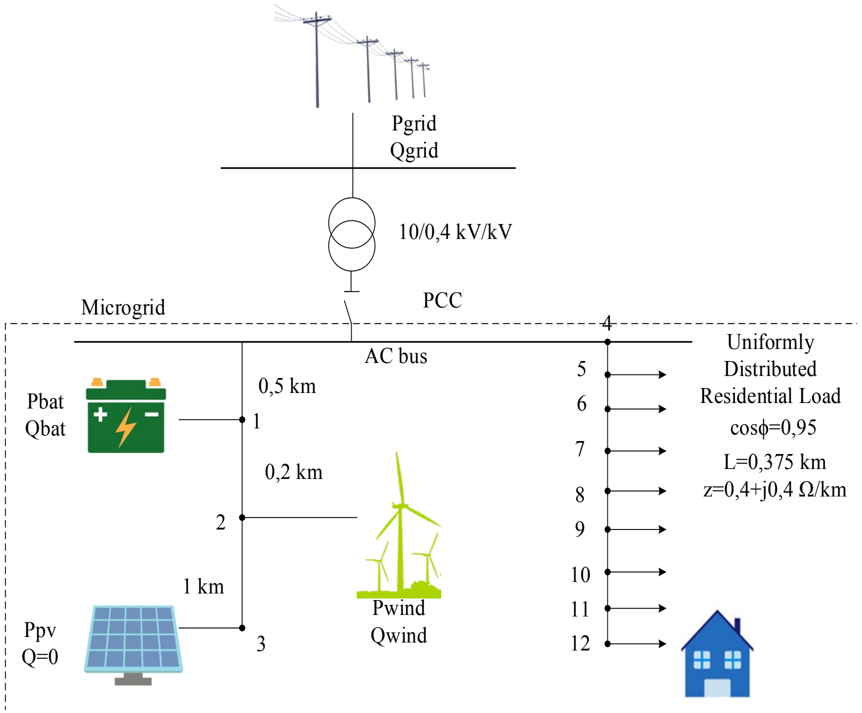

Fig. 2. Microgrid test example

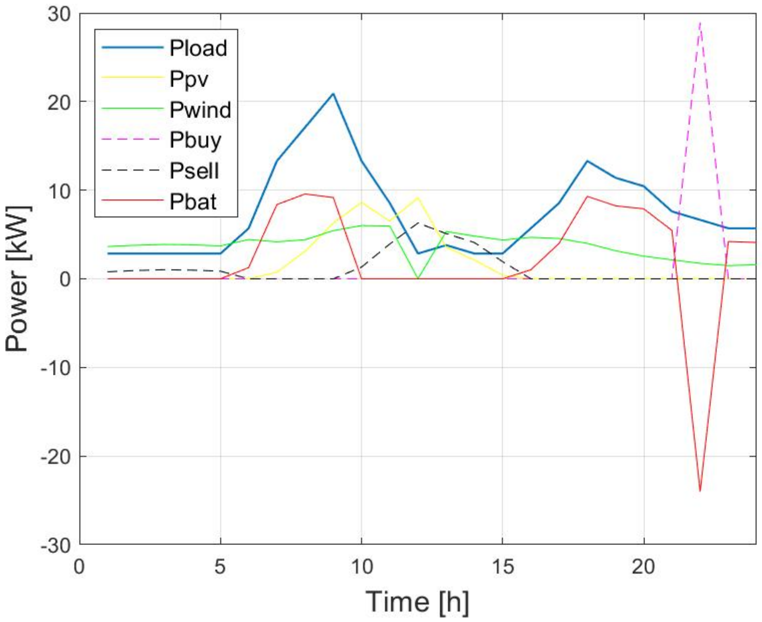

Fig. 3. Optimal power scheduling in the microgrid

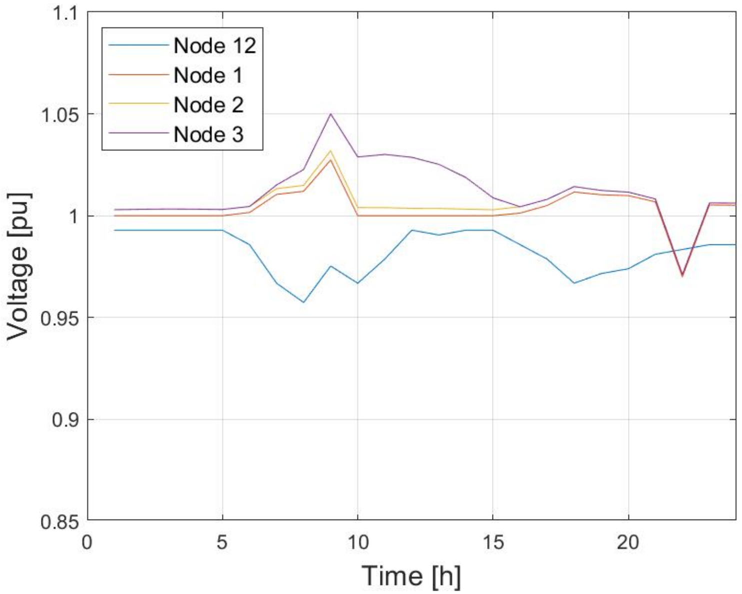

Fig. 4. Voltage variation in the nodes over 24 hours considering voltage regulations as part of the optimization process

5. CONCLUSION

- The method proposed in this paper is based on a well-known optimization technique and is most commonly used to solve this problem: the genetic algorithm. Its application aims at maximizing the financial profit from selling power to the utility grid, under certain technical limitations.
- The obtained results show the importance of voltage regulation in microgrids for providing a quality power supply.
- In future work, the proposed method will be applied and upgraded for analyzing the impact on the distribution network, considering multiple microgrid implementations, and the implementation of prosumers in the microgrids.

Thank you for your attention!