Solving the Grid-Connected Microgrid Operation by Teaching Learning Based Optimization Algorithm

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Abstract: In this paper, the grid-connected operation of microgrid is investigated where the microgrid can exchange power with the main grid. The proposed problem is modeled as the mixed-integer linear programming (MILP) and is solved by an evolutionary algorithm known as the teaching learning-based optimization (TLBO). Finally, the proposed model is tested on a modified IEEE 33 bus test system to show the performance of the method.

Keywords: Microgrid, TLBO, Optimization, Grid-connected operation

I. Introduction

AGGREATION of loads and distributed energy systems in a small network which is close to the consumers, known as the microgrid [1-5]. Such a network has some significant benefits from two main perspectives: i) technical, ii) economic. This is due to closeness to the consumers, less transmission line, higher reliability, higher resiliency, and higher power quality [6-7].

Although there exist lots of benefits, the challenges in protection and operation are not addressed completely yet. This paper addressed one of them, which is the optimal operation of the grid-connected operation of the microgrid. Islanded and grid-connected operation of microgrid are investigated in [6]. Same authors designed a DC/DC boost converter for the grid-connected operation of the microgrid in [7]. In [8-11] microgrid in the grid-connected mode is solved by several heuristic methods such as CDOA, GA, and PSO. The control of grid-connected and islanded microgrid is widely investigated in [12-15]. Adding the electric vehicles, as well as the security of the microgrid is investigated in [16- 19]. Despite the above works, this research studied the effective operation of the grid-connected microgrid, utilizing a new evolutionary technique known as the teaching learning-based optimization algorithm [20].

II. Mathematical formulations

This optimization problem contains an objective as (1).

A. *Objective function*

The objective is

$$min \sum_{\forall i}[C_i P_{it} I_{it} + SU_{it} + SD_{it}] \quad (1)$$

In which *I* is a binary variable (0 or 1) that control the status of unit *i* at time *t.* Moreover, *SU* and *SD* are the startup and shutdown costs. In the rest of the paper, UT and DT are minimum up and down, $T_{(on)}$ and $T_{(off)}$ are the number of successive on and off hours, and *RU* and *RD* are the ramp up and down of the generators.

B. Constraints

The constraints of the problem are defined as

1. The capacity of the generators

$$P_{it,min} \leq P_{it} \leq P_{it,max} \quad (2)$$

2. Ramp up and down of the generators

$$P_{it} - P_{i(t-1)} \leq RU_i \quad (3)$$

$$P_{i(t-1)} - P_{it} \leq RD_i \quad (4)$$

3. Minimum up and down of the generators

$$T_{(on)it} \geq UT_i(I_{it} - I_{i(t-1)} \quad (5)$$

$$T_{(off)it} \geq DT_i(I_{i(t-1)} - I_{it} \quad (6)$$

III. Teaching Learning Based Optimization Algorithm

As mentioned, microgrid in the grid-connected mode is a MILP problem. This paper suggested teaching learning-based optimization (TLBO) algorithm to solve the problem. This method inspires the students who are in a class and try to learn the course by difference methods. More explanation is in [20]. The flowchart of TLBO is shown in Fig. 1. Overall, heuristic methods are attracted to many considerations because of the fast and precise response [21-24].

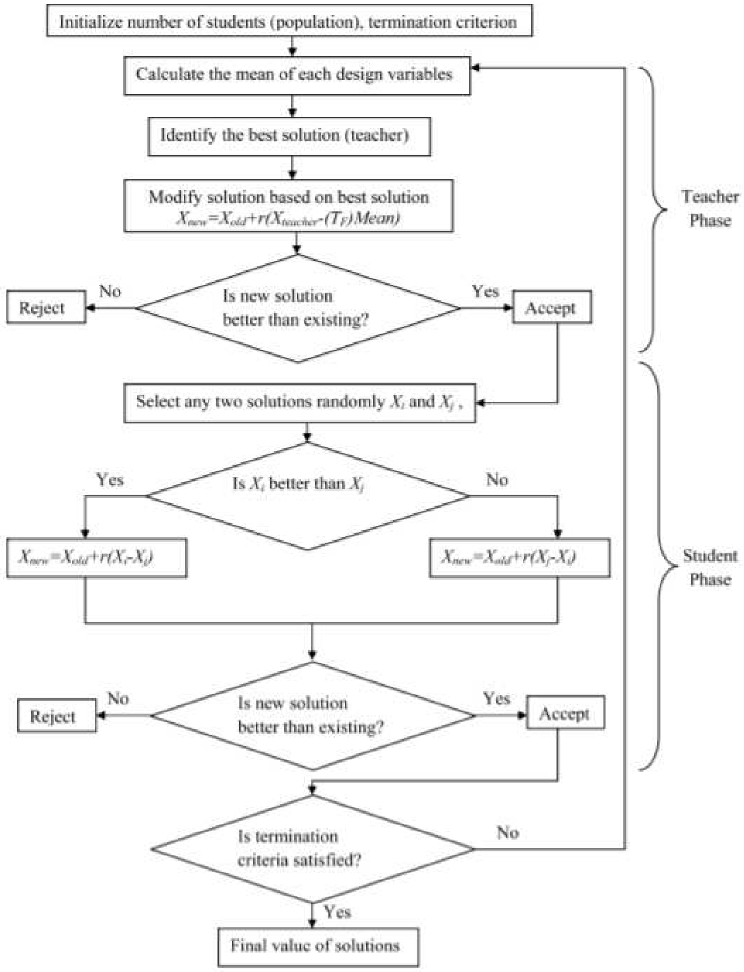

Fig. 1. Flowchart of the proposed method [20].

IV. RESULTS

To shows, the perfect performance of the mode, a modified IEEE 30 bus test network is tested which includes three generation units. Fig. 2 shows the single line diagram of the proposed network. Also, the features of the dispatchable units are shown in Table I. The load demand for the next 24 hours has been shown in Fig. 3.

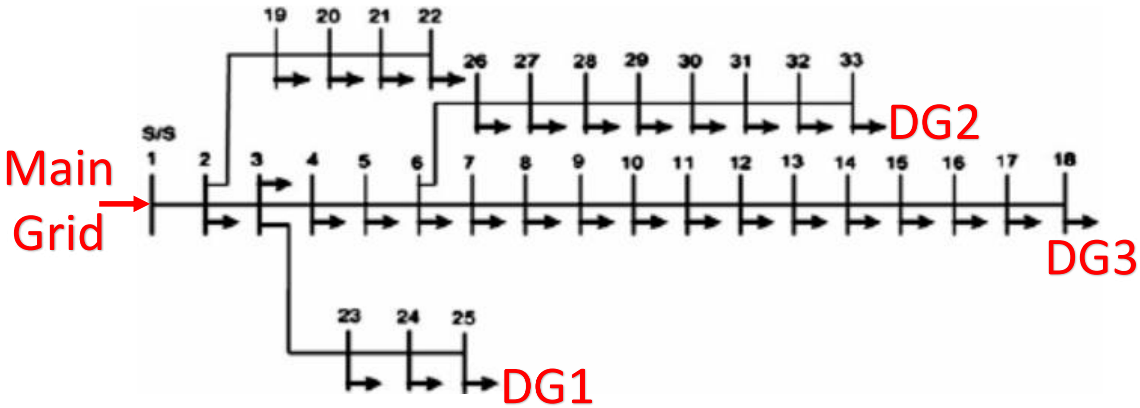

Fig. 2. Single line model

Table I
Dispatchable unit's features

	Minimum output power	Maximum output power
Unit 1 at bus 25	20	100
Unit 2 at bus 33	40	50
Unit 3 at bus 18	1	25

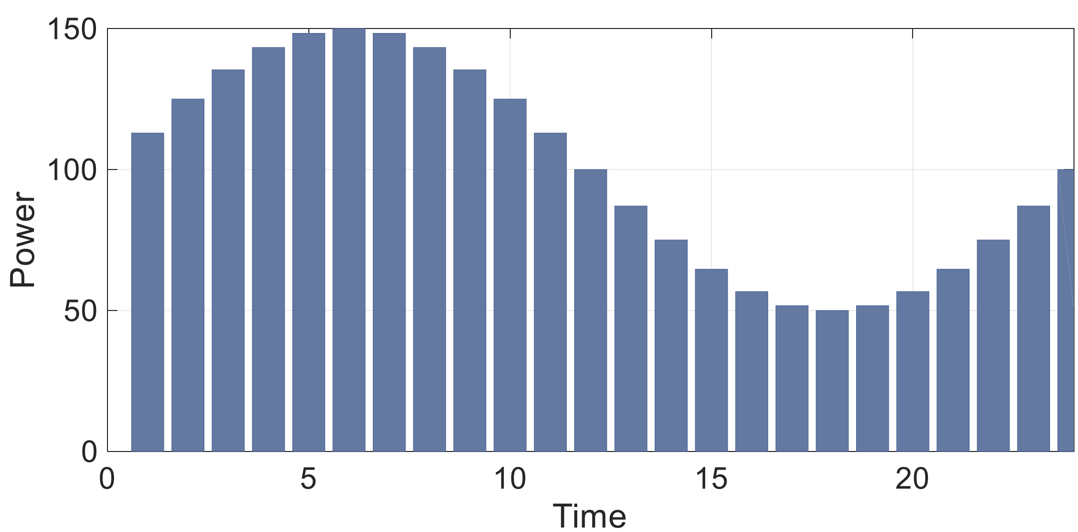

Fig. 3. Load demand for the next 24 hours

The output power of dispatchable units is shown in Fig. 4. According to the figure, the cheapest unit (unit 1) is more participated than other units; that the decision only is based on the economic.

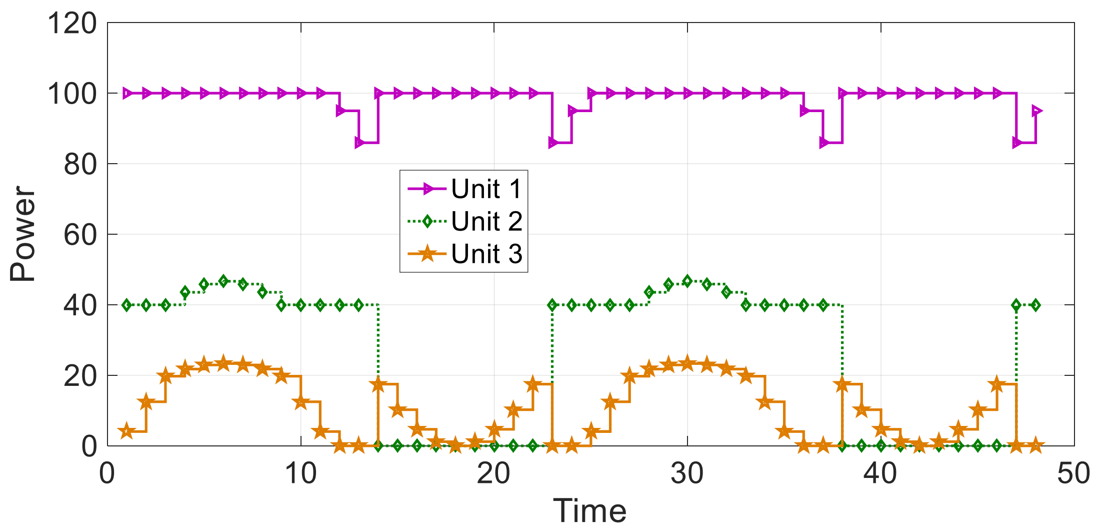

Fig. 4. Generation units output power

The comparison of the cost between the proposed method and other well-known methods such as the particle swarm optimization (PSO) and genetic algorithm (GA) methods is investigated in Table II.

Table II

Cost of operation for several methods

	Operation cost ($)	Computational Time (second)
PSO	4942.1	17.1
GA	4839.5	14.9
Proposed method	4747.7	12.8

V. Conclusion

In this paper, the TLBO is developed for optimal operation of grid-connected microgrid. The microgrid could exchange power in the grid-connected mode. The results show that the proposed method has a very fast response and also lower operation cost, comparing to the well-known methods such as PSO and GA.

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