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Implementation of Multi-Agent Energy Management for Secondary Control of a Microgrid

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Abstract— **The multi-agent energy management system (EMS) is needed to coordinate multiple agents of a microgrid to provide efficient operation of the system. In this study, multi-agent EMS is seen as the middle controller between primary and tertiary control levels. It is responsible for determining the relevant set points based on data gathered from the tertiary control level and sending them to the appropriate primary control level agents. The main objective of this paper is to propose a new optimization model for multi-agent EMS to minimize errors between the forecasted and real-time data at every predetermined time interval. Rather than using a traditional centralized microgrid controller to determine the dispatch of resources, a new framework-based multi-agent coordination is proposed to achieve the following objectives: minimizing load shedding, maximizing load dispatch and reliability, providing frequency, and maintaining voltage stability.**

Keywords- Dynamic energy management; microgrid; optimal control; secondary control.

I. INTRODUCTION

Because of the intermittent and uncertain nature of renewable energy resources, a microgrid (MG) system composed of distributed energy resources (DERs) and storage systems plays an important role in energy management to reduce the negative effects of DERs. It is necessary to find fast and continuous solutions in real time on a small-time scale [1, 2]. Integrating economic dispatch in the secondary control level of a microgrid can provide faster response times, more precise control, increased reliability, reduced communication requirements, and improved scalability compared to integrating it in the tertiary control level [3, 4]. This study focuses on the secondary control level in grid-connected MG to optimize real-time economic dispatch. A multi-agent coordination system at the secondary control level works by solving an optimization problem to find the optimal utilization of each asset and the management of power and load. Hence, it is aimed to provide voltage and frequency stability and self-sustainability and to maximize the system's reliability while satisfying equality and inequality constraints.

II. MICROGRID MODEL

The MG model used in this study is illustrated in Fig. 1. The model consists of solar PV panels (63 kW in total), a DG (375 kVA), a battery energy storage system (BESS; 15 kWh capacity in total), and loads. This paper assumes that the MG operates in grid-connected mode. The primary use of the PV power is to decide whether to get electrical energy from the grid. The electricity prices change at different time intervals, and BESS helps reduce the load by storing excess energy and using it during peak demand times. The MG operation has a finite time horizon defined as $t = \{0, \Delta t, 2\Delta t, 3\Delta t, \ldots, T\}$, where $\Delta t = 1$ min is the time interval and T = 24 hours.

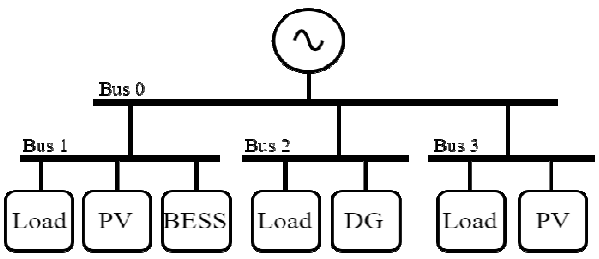

Figure 1. Microgrid system representation.

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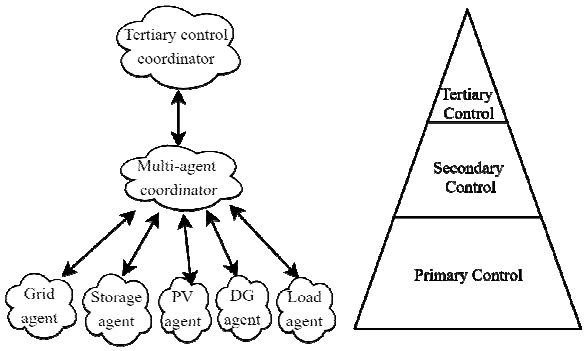

Figure 2. The hierarchical control structure.

III. PROPOSED MULTI-AGENT EMS

The hierarchical control system is typically divided into three layers, each with its own set of control functions and objectives [5, 6]. As shown in Fig. 2, three-level hierarchical control can provide proper MG control. The multi-objective function with constraints is constructed as follows:

$$OF = u1 \cdot P_{g,t}^{dev} + u2 \cdot P_{pv,t}^{dev} + u3 \cdot P_{b,t}^{dev} - u4 \cdot P_{pv,t} + M \cdot P_{l,t}^{sh}$$

$$\text{s.t.} \quad P_{pv,t} + P_{g,t} + \left(P_{b,t}^{d} - P_{b,t}^{c}\right) + P_{l,t}^{sh} = P_{ij,t} + D_t$$

$$0 \le P_{pv,t} \le P_{PV,t}^{act}$$

$$P_g^{min} \le P_{g,t} \le P_g^{max}$$

$$0 \le P_{l,t}^{sh} \le D_{l,t}$$

$$SOC_t = SOC_{t-\Delta t} + \left(P_{b,t}^{c} \cdot \eta_t^c - \frac{P_{b,t}^{d}}{\eta_t^d}\right) \cdot \Delta t \qquad (1)$$

$$SOC_{min} \le SOC_t \le SOC_{max}$$

$$0 \le P_{b,t}^{d} \le P_{b,t}^{d,max} u_{b,t}^{d}$$

$$0 \le P_{b,t}^{c} \le P_{b,t}^{c,max} u_{b,t}^{c}$$

$$u_{b,t}^{c} + u_{b,t}^{d} \le 1$$

$$u_{b,t}^{c}, u_{b,t}^{d} \in \{0,1\}$$

According to the proposed operational strategy proposed, the multi-agent coordinator matches the supply and demand of the MG at a one-minute interval by taking measured real-time and scheduled data. The estimated error is minimized by the proposed economic dispatch optimization model, which produces updated active power set-points for each agent. The main idea of this optimization model is to fulfil the proposed objectives such as minimizing load shedding, maximizing load dispatch and reliability, and providing frequency, voltage stability, and self-sustainability.

IV. PRELIMINARY RESULTS

When the deviation between the actual and forecasted load profile exceeds 5%, the multi-agent coordinator reschedules the setpoints to ensure that the agents receive the correct ones. Similarly, the deviation between actual and forecasted PV powers are considered and related setpoints are recalculated. Fig. 3 presents the setpoints that were optimized because of the comparisons that were carried out by the multi-agent coordinator. Following that, these setpoints are transmitted to the relevant agents. As we look at the figure, we can see that

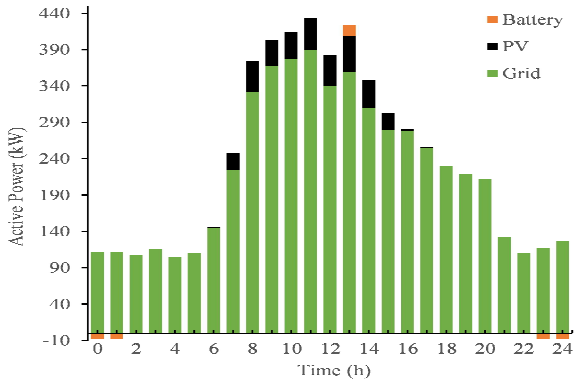

Figure 3. The power of the grid, PV, and battery.

the battery is being charged during these hours since the price of electricity on the power market is cheap between the hours of 11 pm and 1 am. In order to maintain the functionality of the system, the process of discharging the battery takes place from midnight until two in the morning.

V. CONCLUSION

In this study, by using mixed integer nonlinear programming (MINLP) under a GAMS environment, the objective function intends to minimize the deviations of the active power from scheduled ones. With the proposed model, economic dispatch algorithm subjected to the minimum/maximum active power capacities of each generation unit and power balance equations was integrated to the secondary control. It is by this method that it was investigated whether or not the economic dispatch strategy, which is often utilized for the tertiary control, may also be utilized for the secondary control.

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