Lome microgrid energy storage

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Despite two-way communication facilities and the advanced metering infrastructure (AMI), the optimal management capability of electrical energy among appliances and resources remains behind the rapid growth in power demand. Because of the modern lifestyle of consumers, the application of electrical appliances has increased dramatically. Therefore, it is estimated that global electricity demand will increase by 2.1 per year by 2040 (twice the rate of primary energy demand)1. Furthermore, the invention of several renewable energy sources (RES) aims to achieve sustainable electrical energy generation. Photovoltaic (PV) devices are the fastest-growing RES category with a growth rate of 60% whereas the growth rates of wind power and biofuels are 27% and 18%, respectively2.

Furthermore, the massive penetration of renewable resources and energy storage systems (ESS) is essential to mitigating electrical energy demand without a higher carbon emission volume. ESS technology can immediately transform and store electrical energy from the electrical power network and inject the electrical energy back according to the applied scheme or when the base units are unavailable for generation3. However, integration of ESS with proper management and resource scheduling is arduous. The home energy management system (HEMS)4 provides a possible solution by managing the energy consumption and PV generation with the integration of a battery ESS (BESS) that balances supply and demand cost-effectively.

However, accurate active demand (AD) and PV power generation forecasting are essential for precise scheduling of the BESS in leading continuous and secure power supply by avoiding blackouts. Because of the advancement in deep learning (DL) technology, numerous studies have been conducted on time-series forecasting (i.e., demand, generation, and price) using these techniques. In16, the authors used bidirectional long short-term memory (Bi-LSTM) for short-term PV power generation prediction. For ultra-short-term PV power prediction, an improved Bi-LSTM algorithm was proposed to increase performance when the prediction model inputs come from multiple PV output series17.

Toubeau et al.18 focused on multivariate predictive scenarios for multistep-ahead prediction. The authors in19 proposed a Bi-LSTM algorithm for different interval-ahead predictions in large-scale PV power plants. In20, a day-ahead peak demand forecasting was accomplished by applying a Bi-LSTM-based sequence to the sequence regression technique. Some recent studies also focused on this algorithm for predicting short-term wind speed21,22. However, previous studies16,17,18,19,20 only considered the operational constraints of the predictive model for improving performance parameters.

Stochastic optimization for HEMS was developed in the context of electrical energy allocation among the BESS, energy demand, and utility grid, which explicitly integrates probability distributions of trip duration and trip length. The optimization problem was formulated using time-varying electricity pricing and time-varying energy usage27. Moreover, a genetic harmony search algorithm was integrated with the home energy management controller to reduce electricity expense and enhance user comfort by considering real-time electricity pricing and critical peak pricing tariffs28.

From the aforementioned discussion, we may deduce that the existing studies utilized the PV-BESS energy completely on a daily basis owing to not considering the day-ahead constraints. However, if there is no PV generation and no energy stored in the BESS, existing studies fail to determine the optimal strategy for utilizing PV-BESS energy since the system requires power from the grid again, resulting in higher electricity bills due to exceeding the daily grid power allowance. Therefore, the proposed system presents an innovative approach for scheduling and optimization that incorporates day-ahead generation and consumption. The scheduling and optimization procedure was carried out in such a way that the BESS was able to keep energy for mitigating day-ahead energy demand.

This study proposes a novel scheme for a HEMS that optimally schedules and manages the PV-BESS for the customer in a dynamic environment. This study is the first (to the best of our knowledge) to simulate the integration of a predictive model with a control algorithm for optimal scheduling and maximizing the discharge amount by including dynamic tariffs. Significant contributions of this study are as follows:

In this study, we designed and developed a Bi-LSTM model for day-ahead energy consumption and generation forecasts (described in "Controlling mechanism" section). Training with the predictive model ensures consistent day-ahead forecasting performance by diminishing prediction errors.