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Determination of Optimal Energy Storage System for Peak Shaving to Reduce Electricity Cost in a University

Unchittha Prasatsap[a,b], Suwit Kiravittaya[a,b,]* and Jirawadee Polprasert[a,b]

[a] *Department of Electrical and Computer Engineering, Faculty of Engineering, Naresuan University, Phitsanulok 65000, Thailand*
[b] *Center of Excellence on Energy Technology and Environment, Naresuan University, Phitsanulok, 65000, Thailand*

Abstract

This paper presents an approach to determine the optimal capacity of battery energy storage system (BESS) for peak shaving of the electric power load in Naresuan University (NU), Phitsanulok, Thailand. The topology of the system consists of main grid, loads and the proposed BESS. Experimental data are daily load profiles, which were recorded for every 15 minutes over the last year. The consumed electricity energy can well correlate with the temperature as well as the schedules of NU activities for both annual and daily scales. Peak shaving is proposed to reduce the electricity cost contributed from the high load peak during the daytime. Realistic parameters for both AC/DC converter and battery are taken into account. An optimal BESS capacity for saving the electricity cost by peak shaving is calculated by first considering the date when the highest energy demand is recorded. Our results show that the optimal BESS can shave the peak load efficiently. Oversized BESS can further decrease the load peak but the reduced cost per battery capacity is not optimal. In addition, we present and discuss two different management strategies, i.e., time-based and differentiated power criteria, for operating the BESS in this system. BESS with different storage capacity is included into the system and the equivalent electricity cost is estimated. Both time-based and differentiated power criteria can reduce the cost.

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Keywords: *Battery Energy Storage System; Peak Shaving; Electric Load Profile; Management Strategy*

* Corresponding author. Tel.: +66 5596 4356; fax: +66 5596 4005.
E-mail address: suwitki@gmail.com

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1. Introduction

National electrical power systems are constantly improved globally. Nowadays, many concepts are being applied to the electrical power system in Thailand [1]. Recently, changeover from conventional grids to smart grids and microgrids is an interesting developing direction for improving the power system [1,2]. Within this technology, renewable energy resources such as photovoltaics, wind energy, and biomass, are proposed to integrate into the system since the variety of energy resources can increase the stability and flexibility of the system. For these resources, energy storage system is sometimes utilized to separate the power in/out-flow and to control the power flow level [3]. Energy storage systems with conventional battery bank so-called battery energy storage system (BESS) is commercially available [4]. Engineering the usage of BESS is desired on the demand side since it is possible to be used for further reducing the total electricity cost [5-8]. In this work, we investigate on the utilization of an energy storage system in order to apply a peak shaving scheme to reduce the electricity cost. A usage of BESS is considered and the method to determine the optimal BESS size is presented. Various observed/realistic data (electricity cost, energy, peak power as well as weather data) of the year 2016 are considered in this work. Two possible management schemes for peak shaving criteria are numerically simulated and the result in term of equivalent electricity energy cost is discussed.

2. System and Load Characteristics

2.1 System description

Naresuan University (NU) campus is located at Tambon Tha Pho, Amphoe Muang Phitsanulok, in Phitsanulok province in the Lower North region of Thailand (latitude of 16.7386 and longitude of 100.1947). Figure 1 shows the topology of the electrical distribution system of NU. The main grid of Provincial Electricity Authority (PEA) of Thailand is connected the power lines of the NU system at the NU substation located in the campus. The received voltage rates are 115 and 22 kV. The 115 kV is reduced to 22 kV. The electric power is transferred to 47 NU loads (the main buildings in the university) distributed over the whole campus area. The rated voltage is further reduced to 220 V by transformers nearby the load. The proposed BESS is assumed to be installed at the low voltage side near the main load (i.e. NU load no. 1 in Fig. 1) in order to decrease the overall electricity cost. Typically, the load power P_L of a few megawatts (MW) constantly flow from PEA to the NU loads. Normally, electricity cost of the whole university is ~10 million Baht/month. The highest cost typically occurs in Mar.-Apr. (~16 million Baht/month) since they are the month where academic semester is still opened while the ambient temperature is the high (see Sec. 2.2).

The mentioned electricity cost is calculated from three parts, i.e., (i) consumed energy (in kWh), (ii) peak power (in kW), and (iii) other marginal management/service costs. For the cost from the consumed energy, it is further divided into on-peak (9:00-22:00) and off-peak (22:00-9:00) periods in normal weekdays. By having a BESS (as shown in the dashed rectangle in Fig. 1), one can charge BESS with the battery power inflow P_B (> 0) and discharge it (P_B < 0) when the peak shaving is operated. For simplicity, we assume a constant conversion efficiency of 90% for the AC/DC converter and a deep of discharge *DoD* of 0.8 for the considered battery. These parameters determine the range and limit of the BESS for the considered system.

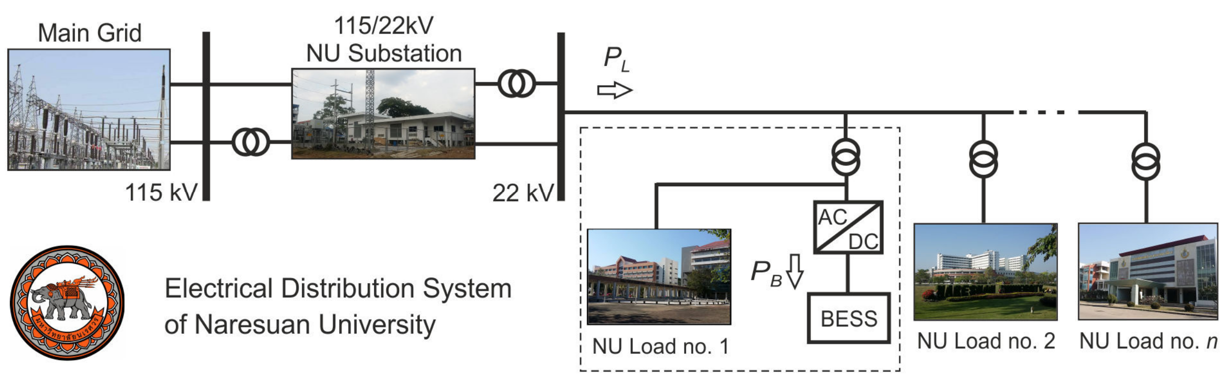

Fig. 1 The topology of the electrical distribution system of Naresuan University (NU).