Energy Management for Demand Response in a Commercial Building with Chiller System and Energy Storage System

The smart grid which is a modernized electrical grid for producing and distributing the electricity efficiently, reliably, economically and sustainably by information and communication technology between suppliers and consumers are globally emerging for resolving global anthropogenic CO2 emissions, the fossil fuel crisis, generation capacity shortage, and so on while creating some new operation scheme and business opportunities. The smart grid technology would also provide opportunities for end-users such as commercial buildings (COBs), residences and industrial facilities to participate in deregulated power market. Especially, demand response (DR) that is used to shave the peak demand for securing the supply reliability of power system, is one of the attractive options for the end-users. The most popular adjustable demand response resource (DRR) in COB is a chiller system used in heating, ventilation and/or air conditioning loads (HVAC). It can be achieved by load reduction in a specified DR duration by thermal mass control (pre-cooling). On the other hand, installation of an energy storage system (ESS) have been accelerated in the world from the viewpoint of its high economic efficiency. A technique for charging and/or discharging ESS appropriately has been implemented for peak shifting operation to reduce the annual cost of electricity which is the sum of basic cost related annual peak load (KRW/kW) and the electricity usage cost (KRW/kWh) under the Time-Of-Use (TOU) tariff. However, ESS can be also achieved as an attractive DR resource because it can reduce the net load by discharging ESS in a specified DR duration. Based on this background, this paper proposes a new DR energy management algorithm which consists of the following two parts.

First, a day-ahead operation scheduling algorithm of chiller system and ESS is proposed to minimize the daily expected energy cost to ensure the benefit of a COB owner through Time-Of-Use (TOU) tariff and the Korean DR market. In the day-ahead operation, there are difficulties such that the owner does not know in advance when DR event happens. Therefore, this paper presents a scenario driven operation algorithm which makes it possible to vary the operation of chiller system and ESS depending on the DR event signal provided one hour prior to DR. Also, the proposed algorithm considers the uncertainties in the next day’s ambient temperature; therefore, the day-ahead operation schedule which is robust for the assumed size of forecast temperature error can be obtained. From the simulation results, it was cleared that ESS can be charged as preparation for DR and discharged for maximum DR reward during DR duration, and comfort indoor temperature can be guaranteed regardless of DR event.

Second, a method for determining the optimal DR capacity in a COB with chiller system and ESS. In
the proposed scheme, the optimal DR capacity (kW) can be determined so that the total expected cost of a COB becomes minimum by chiller system and ESS while avoiding DR penalty threat adopted in the Korean DR market. Here, since it is to reduce the long computer time needed to run the simulation based on the mathematical formulation, it is necessary to give some representative ambient temperatures. In order to give the desirable representative ambient temperatures, this paper presents a method for determining the representative ambient temperature by the k-means clustering algorithm which is popular for cluster analysis in data mining fields. Simulation results showed that the proposed scheme not only can simply find representative ambient temperatures based on big historical ambient temperature group but also can determine the optimal DR capacity using by chiller system and ESS for minimal energy cost associated with utility cost, DR reward, and DR penalty.

This paper is organized as follows. Chapter 1 describes the background of DR mechanism, type of proposed DR resources, uncertainty, and the objective of this thesis, and Chapter 2 introduces DR participation in the Korean regulation market, behavior for the DR participants, and technical issues for successful DR participation. Chapter 3 proposes the operation scheduling algorithm which divides into day-ahead operation scheduling and rescheduling on D-day in a COB with chiller system and ESS. Chapter 4 proposes a method for determining the optimal DR capacity using chiller system and ESS in a COB. Chapter 5 summarized the achieved results as the above chapter of this thesis.