Energy Conversion and Management 76 (2013) 781–793

Contents lists available at ScienceDirect

Energy Conversion and Management

journal homepage: www.elsevier.com/locate/enconman

Enhancement of building operations: A successful approach towards national electrical demand management

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ARTICLE INFO

Article history:
Received 7 May 2013
Accepted 31 July 2013

Keywords:
A/C system
CO_2 emissions
Enhanced operations
Early reduction of cooling supply

ABSTRACT

An approach for managing electrical demand through enhanced building operations in hot climates is evaluated and demonstrated in this paper. The approach focuses on implementing enhanced operations in government buildings, since they are easier to implement and administer. These enhanced operations included early reduction of cooling supply before the end of the occupancy period, improved time-of-day control after occupancy period and reduced lighting. A total of eight government buildings with different construction and system characteristics were selected for implementing these enhanced operations. These buildings have a total air-conditioning area of 4.39×10^5 m^2 and a combined peak electrical demand of 29.3 MW. The enhanced operations resulted in demand savings of 8.90 MW during the national peak hour. Temperatures build up inside the buildings were monitored and found to be within acceptable ranges.

Guidelines for nationwide implementation in similar buildings were developed based on the results of this work. Implementation is estimated to reduce demand by 488 MW by the year 2030, which amounts to capital savings of $585 million. These projected values would be important to adopt energy efficient policies for the country. Additional reductions in energy and fuel consumption are added benefits, which would result in large financial and environmental savings to the country. Moreover, the enhanced building operations would be an important tool to avoid any blackouts by properly reducing the peak electrical demand as well as operating the power plants with a higher thermal efficiency.

1. Introduction

Electrical demand management has received considerable attention worldwide because the availability of electrical supply at all times is very essential for economic and urban progress for any country [1]. Buildings are the major consumer of electricity in hot climates [2]. Management of buildings electrical demand is a prime solution to reduce the peak electrical demand and energy consumption for any utility. Proper design of building envelopes with a high level of thermal insulations, utilization of high efficient electrical systems, thermal energy storage, district heating and cooling systems, building-integrated renewable energy applications, incentive programs for consumers and demand response applications are additional solutions to reduce peak electrical demand [3–11].

The peak electrical demand significantly grew from 6.75×10^3 MW in summer of 2001 to 1.19×10^4 MW in 2011 in Kuwait [12,13]. The peak period starts at 13:00 and ends at 18:00 with a value of 1.14×10^4 MW, and the peak demand occurs at 15:00 with a value of 1.19×10^4 MW, as illustrated in Fig. 1. The Ministry of Electricity and Water (MEW), the only supplier of electricity and water in Kuwait, has faced a challenge in providing sustainable electrical supply due to the huge increase in electrical demand in recent years, especially at peak summer demand periods. This was due to the Air Conditioning (A/C) systems, which consume 70% of the summer's electrical demand and 45% of the annual energy [14]. Reducing the peak electrical demand would also result in operating the power plants with a higher thermal efficiency [15,16]. As such, the MEW's efforts were focused to reduce the electrical demand during the peak summer periods. Accordingly, MEW has recently taken several measures to reduce the national peak electrical demand and produce more electrical supply in recent years. One of these measures is the implementation of enhanced operations in large government buildings. Since the official working hours for the majority of these buildings starts at 7:30 h and ends on 14:00, the application of enhanced operation strategies between 13:00 and 18:00 [17] is the best solution to reduce the national peak electrical demand as shown in Fig. 1.

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http://dx.doi.org/10.1016/j.enconman.2013.07.080

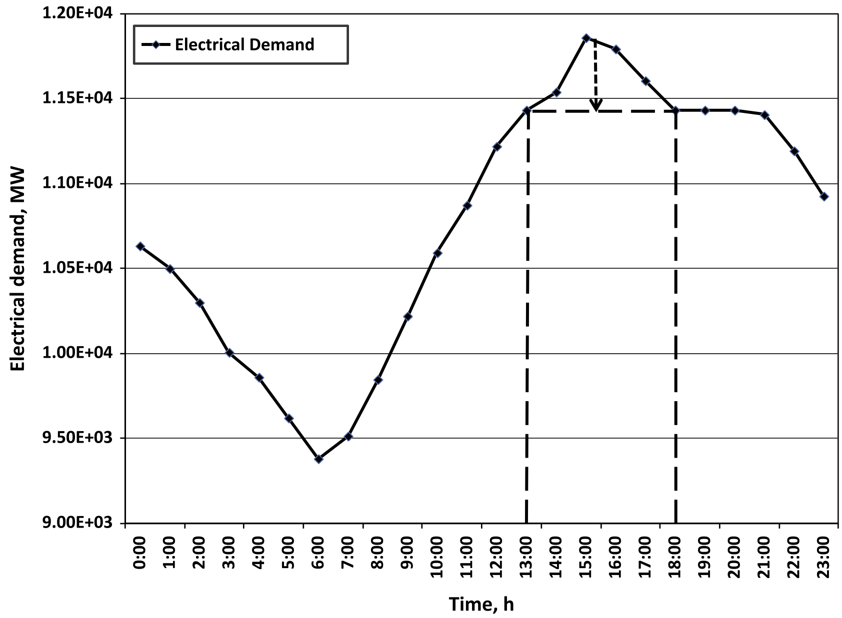

Fig. 1. Hourly electrical demand profile for the peak summer day in Kuwait in 2011.

A reduction of 38.0% in peak demand was achieved by changing the operational strategies of one government building in Kuwait [17]. It was found that identifying losses of A/C loops and subsystems were useful to reduce energy consumption [18]. Using 50% fresh air with half air volume at night significantly reduced energy consumption and it was also economically feasible for different Turkish climate regions [19]. A saving of 23.2% of the annual energy consumption was achieved by optimizing the part load operations of the chillers and pumps, which was executed by an energy management system for a facility in Taiwan [20]. For buildings with intermittent occupancy in hot climates, such as mosques, implementing optimized A/C operational zoning reduced the annual energy consumption up to 30.0% [21]. For an educational facility in a hot and humid area, the simulation results indicated that the main source of excessive energy consumption was the over sizing of installed capacity for the A/C units and that setting up thermostats from 21 °C to 23 °C could save up to 37.0% of the total energy consumption for a typical summer day [22]. In commercial buildings, optimizing the operational schedules of the A/C systems played a significant role in reducing the annual energy consumption and avoiding peak price charges [23]. Additionally, the simulation results showed that a saving of 25.0% in the annual energy consumption for a commercial building in hot and humid climates could be achieved if the A/C system was properly selected and operated [24]. Likewise, optimizing set points of supply air temperatures and supply air static pressure of the A/C system reduced energy consumption by 21.4% without harming the air quality inside the building [25].

The aim of this paper is to develop nationwide guidelines for implementing enhanced operations in existing government buildings and to assess their national impact till the year 2030. Accordingly, eight large government buildings were selected with different construction and system characteristics to investigate the impact of different enhanced building operations on peak demand reduction without affecting thermal comfort. These construction system characteristics included types of glazing and construction materials and lighting systems, size, type and design of the central A/C systems and control capabilities of Building Automation Systems (BASs). Thereafter, nationwide guidelines were developed to implement the same enhanced operations in other government buildings in Kuwait. Finally, an assessment was carried out to show reductions in peak demand and savings in annual energy consumption, as well as financial and environmental benefits to the country. The applicability of the approach utilized in this paper is also addressed for similar and other climatic conditions.

2. Approach and methodology

The concept of enhanced operations included early reduction of cooling supply (ERCS), one hour before the end of the occupancy period at 14:00, and improved time-of-day control (ITDC) after 14:00 in relation to the building occupancy [26]. In addition to the evaluation of peak electrical demand reduction, the increase in temperature build up during the implementation of ERCS and ITDC schemes were monitored to ensure thermal comfort for occupants, and savings in energy consumption were assessed. De-lamping was carried out as an additional measure for demand reduction and energy savings. More importantly, nationwide guidelines were developed for implementing the enhanced operations in similar government buildings and an assessment of nationwide savings till the year 2030 was carried out.

2.1. Selection of buildings

The choice of buildings was carried out with a series of considerations such as the willingness by facility managers and engineers to participate in the project, availability of fully functional Building Automation Systems (BASs) for operation of A/C and lighting systems, a central chilled water system for cooling and the building working hours limited to 14:00. Accordingly, eight large government buildings namely: Ministries Complex (MC), Justice Palace Complex (JPC), Liberation Tower Complex (LTC), Public Institution for Social Security (PIFFS), Ministry of Health (MOH), Kuwait Chamber of Commerce and Industry (KCCI), State Audit Bureau (SAB) and Public Authority of Youth and Sports (PAYS) were selected. The total A/C area and combined peak electrical demand of these buildings were 4.39×10^5 m^2 and 29.3 MW, respectively, with different construction and system characteristics as they were constructed before and after the 1983s Building Energy Code of