Real-time electricity pricing: TOU-MPC based energy management for commercial buildings

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Abstract

An adaptive real-time electricity pricing and optimal control system based on energy management of buildings is presented. This is made in the framework of a smart-grid according to energy demand and time-of-use (TOU) electricity tariff in conjunction with a model predictive control (MPC). The developed model is considered as a multiple single input single output MPC system that acts at a different rate of TOU- electricity tariffs (off-peak, standard and peak). A smart selective timer switching system links one to the other. The performance of the model design is expressed through the simulation results of the adaptive TOU-MPC for commercial buildings.

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1. Introduction

The need for reducing the peak of energy consumption on the demand side is currently a concern of several countries [1]. However, the South African Energy Department states that the energy wastage of today is the shortage of tomorrow. They also argue that saving energy is in the ambit of any end user. In the U.S, The National Energy Technology Laboratory demonstrated that the flexibility of energy consumption in buildings is a function of smart grid infrastructure, operation strategies and building energy control [2]. Smart grid technology therefore offers the opportunity to the utility and the end-users to design a real-time optimum system [3]. On the demand side, this is essential firstly for the stability of power supply and secondly for reducing the cost of energy consumption [4].

A smart grid establishes the power quality requirement, without any disturbance of voltage, as its principal tool of stability analysis. Furthermore, optimization techniques are also considered as of one the
fundamental computational tools for the design of a smart grid [3]. Relatively few works have been developed in context of optimizing the electricity consumption of specified load in commercial buildings [4-8]. This research therefore works on developing an adaptive design of minimizing the cost of electricity consumption according to the inner system design of a commercial building. This is based on shifting the MPCs system design in conjunction with TOU electricity tariff. This is also made by using a timer switching to adapt the MPC-model to the real-time electricity tariff.

The outline of this paper is as follows: the system modeling and design of shifting the MPCs system is proposed in section 2 and section 3 presents the MPC system. The simulation results are depicted in section 4 and section 5 draws the conclusion and recommendations.

2. System modelling and design

2.1. System description

Fig. 1 describes the model of the system. For this, the modeling for a demand management system is considered to be the benchmark for analyzing the inner system behavior. Many frameworks are used as a system model, and any given system can be analyzed according to the purposes envisaged [9]. It is assumed that this system will adapt to any rate of change due to TOU electricity tariffs. Therefore, the developed model given in Fig.1 can be considered as a multiple single input single output MPC system that acts at the different rate of TOU-tariffs (off-peak, standard and peak).

The smart meter of this system operates within the interaction of the optimal control system and the demand side. It also communicates the real-time energy demand of the adaptive MPC system with the demand side. The cost the electricity usage will depend on the energy consumption and the real-time electricity tariffs is defined as:

\[
C(t) = \int_0^t P_{TOU} E(t) dt \quad (1)
\]

where \(C\) is the cost of electricity to pay [Rand], \(E\) the energy consumption [kWh] and \(P_{TOU}\) is TOU-Tariffs [kWh/Rand].
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