Chapter 53
Using Fuzzy Control Methods for Increasing the Energy Efficiency of Buildings

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ABSTRACT

The energy sector worldwide faces significant challenges that everyday become even more acute. Innovative technologies and energy efficiency measures are nowadays well known and widely spread, and the main issue is to identify the more effective and reliable in the long term. In order to do so the decision maker has to compensate many factors. This article investigates the feasibility of the application of new intelligent control methods in modeling and controlling the performance of a building. For the first time a performance comparison of Fuzzy Logic vs Fuzzy Cognitive Maps (FCMs) theories is performed and interesting results are presented. Multi-level intelligent controllers to manage the various parts of a building's automation and increase its energy efficiency are presented. For the first time the Building Energy Management System has been modeled using FCMs. Simulation studies with real environmental data have been performed and useful results have been obtained and discussed. Challenging future research topics are provided.

INTRODUCTION

The energy sector worldwide faces evidently significant challenges that everyday become even more acute. Innovative technologies and energy efficiency measures are nowadays well known and widely spread, and the main issue is to identify those that will be proven to be the more effective and reliable in the long term. With such a variety of proposed measures, the decision maker has to compensate environmental, energy, financial and social factors in order to reach the best possible solution that will ensure the maximization of the energy efficiency of a building satisfying at the same time the building's final user/occupant/owner needs.

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The 21st Century is characterized by a large increase in the global demand for energy. The picture depicting the future of the energy resources worldwide is rather dark. A great amount of responsibility belongs to the building sector which requires the 35-40% of the total energy consumption. The field of intelligent buildings and the use of renewable energy sources has gathered a lot of attention nowadays as it can provide realistic solutions to many energy problems, while at the same time it can achieve the reduction of the CO_2 emissions. Many approaches and definitions have been used to describe what an intelligent building really is. Our research focuses on increasing the energy efficiency of buildings without compromising the occupants' comfort. Our goal is to propose low cost solutions through the most effective use of the buildings automation. To this end we are using the methods of fuzzy logic and fuzzy cognitive maps as a means to create simple and easy to use control systems that can be applied to a large variety of buildings.

At first the article discusses the world energy outlook and provides an overview of an Intelligent Building (IB) concept along with its definitions as well as how to develop an IB. Then it analyses the Fuzzy Logic Control (FLC) and Fuzzy Cognitive Maps (FCMs) methods that will be used in modelling the energy efficiency of buildings. Based on these methods, energy saving models are created through the effective use of buildings automation techniques. For the first time a performance comparison of Fuzzy Logic vs Fuzzy Cognitive Maps (FCMs) theories is performed and interesting results are obtained and presented. Simulation studies with real environmental data from the south part of Greece have been performed and useful results are obtained and discussed. Multi-level intelligent controllers managing the various parts of a building's automation and increasing its energy efficiency are presented. For the first time the Building Energy Management System (BEMS) has been modeled using Fuzzy Cognitive Maps theories. Finally, overall conclusions are summarized and future research topics are proposed.

WORLD ENERGY OUTLOOK

The precipitous fall in oil prices, continued geopolitical instability and the ongoing climate changes are witness to the dynamic nature of today's energy situation. In a time of so much uncertainty and confusion, understanding the implications of the shifting energy landscape for economic and environmental goals and for energy security is vital to future world's stability and sustainable economic growth for all nations.

As stressed in the introduction the world undergoes a severe energy crisis. As shown in Figure 1, while the conventional energy resources reach their end the renewable energy sources still fail to replace them, a fact that has many consequences not only to the future of the energy production but also to the environment, as the gas emissions still increase rapidly.

So now more than ever it is of outmost importance to concentrate our efforts to develop solutions that will lead to an environment friendly and energy independent future. Throughout the world the data are not encouraging. For 2001 to 2004 the primary energy consumption showed a large increase; 1.3% for Europe, 1.1% for USA, 2.2% for South and Central America, 5.3% for the Middle East, 3.7% for Africa and 8.6% for Asia Pacific, which implies an overall increase of the world's energy consumption by 3.7%. Even with the lowest possible estimations a 2% average annual growth is going to lead to double by 2037 and triple by 2050, energy demands. (Filippín & Larsen, 2007)

The building sector is responsible for a large proportion of this increase. 41% of the USA's and 37% of Europe's total energy consumption is due to the buildings; at the levels of transport and industry sectors. These large amounts of energy consumed are not only affected by the construction which until