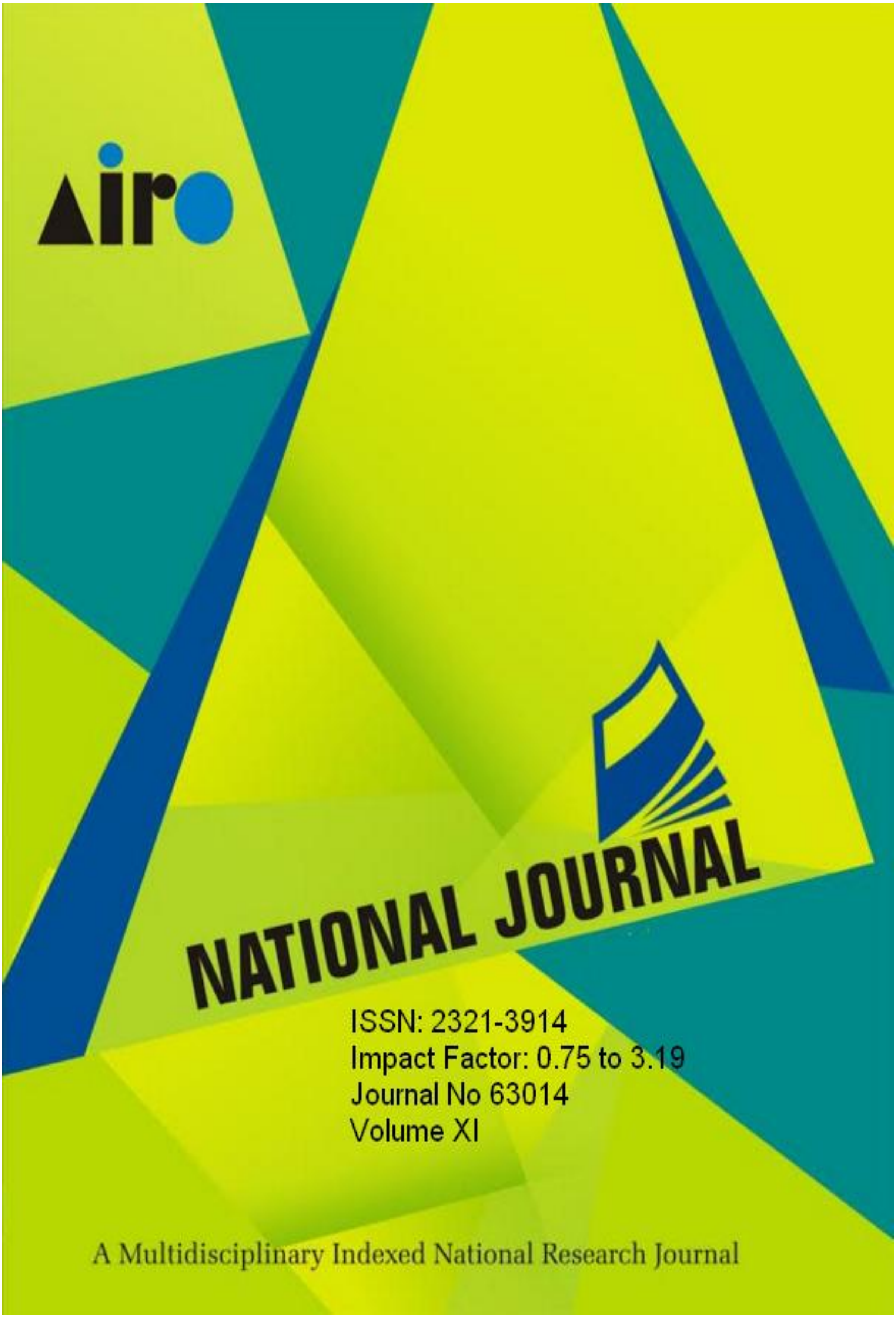
Airo National Research Journal
Volume XI, ISSN: 2321-3914
August, 2017
Impact Factor 0.75 to 3.19

ज्ञान-विज्ञान विमुक्तये
UGC Approval Number 63014



Airo

NATIONAL JOURNAL

ISSN: 2321-3914
Impact Factor: 0.75 to 3.19
Journal No 63014
Volume XI

A Multidisciplinary Indexed National Research Journal

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MODELLING AND SIMULATION: AN EFFECTIVE ANALYSIS WITH REFERENCE TO ENERGY MANAGEMENT IN CONTROL

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ABSTRACT

This report is concerned with improving the integrity and applicability of building energy management systems in control systems. The present work attempts to overcome certain inadequacies of contemporary simulation applications with respect to environmental control systems, by developing novel building control systems modelling schemes. These schemes are then integrated within a state-of-the-art simulation environment so that they can be employed in practice. After reviewing the existing techniques and various approaches to control systems design and appraisal, taxonomy of building control system entities grouped in terms of logical, temporal and spatial elements, is presented.

This work is focused on modelling and simulation of this system using the formalism (DEVS). Our motivation is explained by the fact that DEVS is a tool for modelling of discrete event systems and it decomposes the overall system into subsystems in order to facilitate the achievement which is consistent with the characteristics of multilayer architecture of the chosen system. This paper presents modelling, control strategy and simulation results of an energy management strategy (EMS) for a specific plug-in hybrid electric vehicle (PHEV). A good control strategy is required among components, such as the energy storage system, an electric motor, a power control unit, and an internal combustion engine in order to ensure that the vehicle achieve an improvement in energy efficiency, reduction in emissions, fuel use, weight and cost. In this work, firstly, through a power flow analysis, the vehicle components are sized to meet the expected power and energy requirements of a typical 5- passenger car.

Keyword: control system, energy management, modelling

INTRODUCTION

For the past 30 years most building energy simulation programs have shared a similar architecture: an input file describes the building form, fabric, and heating, ventilation, and air-conditioning (HVAC) systems; weather data and user schedules apply external and internal environmental forces that drive the simulation forward in time; control algorithms respond to changing conditions to meet operational requirements; and ultimately, the simulation program predicts the building performance.

Historically, control algorithms in building energy simulation programs have been designed to model typical operational strategies. Examples are thermostatic control, flow control, daily and seasonal schedules, outdoor temperature reset, economizer control, equipment load staging, and day lighting control. Most simulation input for components has predefined control sequences with only schedules and set points accessible to the user. Interactions between components are limited and are usually hard-coded in the simulation program. With the advent of the energy management system (EMS), today’s control algorithms quickly transcend the typical operational strategies that are found in most simulation programs.

This is subsequently used to identify the models, algorithms, and features comprising a comprehensive modelling environment. Schemes for improving system integrity and applicability are presented based upon a simulation approach which treats the building fabric and associated plant systems as an integrated dynamic system. These schemes facilitate the modelling of advanced EMS control structure and strategies, A simulation of a dynamic ecosystem such as the smart city can test new concepts for reducing energy consumption. Research related to energy management can be divided into two categories: predictive control (anticipative) and adaptive control (reactive). A new energy management system of a building (EMS) which is the chosen system to validate treats a long-term anticipative control and introduces a reactive control that adds another level of intelligence to the EMS.

An EMS is a dedicated computer that can be programmed to control all of a building’s energy-related systems, including heating, cooling, ventilation, hot water, interior lighting, exterior lighting, on-site power generation, and mechanized systems for shading devices, window actuators, and double facade elements. The close cousins of the EMS, building management systems (BMS) and building automation systems (BAS), can serve the same energy functions as an EMS, but also control non-energy systems such as for building security and life safety.

An EMS works by polling a set of sensors that retrieve data about external environmental conditions, internal building conditions, HVAC system conditions, and other equipment conditions. The sensor data become input variables for the EMS control algorithms. These algorithms are specified by using a simple programming language based on IF-THEN-ELSE statements and other logic structures (or the equivalent, if the EMS is equipped with a graphical user interface). After the EMS passes judgment, remote actuators make changes to the system operation; for example, they turn equipment on or off, change thermostat set points, and open and close valves and dampers. The future infrastructure of energy system appears as a complex system in which the improved monitoring and control of energy generation and / or consuming entities in the system is possible. In this system, these entities will no longer be considered as black boxes but interconnected to provide information regarding their energy behaviour. This will result in several approaches that will boost energy efficiency. A simulation of a dynamic ecosystem such as the smart city will enable us to test new concepts for reducing energy consumption. Thus, for reasons of cost and time, an Energy Management System (EMS) of a smart city cannot be designed specifically for each building, so we will look at a Building EMS (BEMS).This work is focused on modelling and simulation of a BEMS using the characteristics of the formalism

ESP-r is an energy simulation program which permits an assessment of the performance of existing or proposed building designs, incorporating traditional and/or advanced energy features. ESP-r uses numerical methods to solve the various equation types (algebraic, ordinary differential and partial differential) which can be used to represent the heat and mass balances within buildings. The system is not building type specific and can handle any plant system as long as the necessary component models are installed in the plant components' database. The system offers a way to rigorously analyse the energy performance of a building and its environmental control systems. For each real-world energy flow-path, ESP-r has a corresponding mathematical structure. The numerical engine of ESP-r was researched between 1974 and 1977 when the various techniques for modelling energy flow in buildings were investigated and compared. This seminal work led to a prototype model which used state-space equations and a numerical processing scheme to represent all building heat flux exchanges and dynamic interactions. Building and plant modelling approaches are theoretically compatible. Central to the model is its customised matrix equation processor which is designed to accommodate variable time-stepping, complex distributed control and treatment of stiff systems (i.e. systems with a large range of time constants).

REVIEW OF LITERATURES

The electricity consumption of the U.S. grew 1.7% annually from 1996 to 2006, and the total growth will reach 26% until 2030. Among that consumption, buildings are responsible for over 70% of electricity consumption in the U.S.

Around 30% of the energy used in building is consumed by heating, ventilating and air conditioning (HVAC). Studies have shown that most of the commercial and residential buildings have equipment and operational problem that reduce the comfort and waste more energy. For example, 4% to 20% of energy used in HVAC and lighting system was wasted due to equipment and operation problem.

Another study pointed out that faults or non-optimal control schemes could cause the malfunction of equipment or performance degradation from 15% to 30% in commercial buildings.

There is a great need to develop better building control and operation strategies to improve building energy efficiency and occupant comfort. Moreover, it is estimated by the National Energy Technology Laboratory that more than one-fourth of the 713 GW of U.S. electricity demand in 2010 could be dispatchable if only buildings could respond to that dispatch through advanced building energy control and operation strategies and smart grid infrastructure.

The general data flow and main procedure of white-box model development and simulation are summarized.

The parameters for weather condition, building structure, building systems and building equipment need to be obtained from their physical characteristics, usually from design plan, manufacture catalog or on-site measurement.

The simulation engine is a group of mathematical equations which simulate the building operation and calculate the building energy consumption.

A lot of mature white box software tools, such as EnergyPlus, ESP-r, and TRNSYS have been widely used to analyze energy consumption and determine building control and operation schemes.

RESEARCH METHODOLOGY

2.1 Managers of energy

Before giving the architecture and mechanism of energy management, we will quote some energy managers: G. J. Levermore and D. Kolokotsa presented related works to energy management and cost strategies and forecasting energy consumption while F. Calvino and N. Morel focused on fuzzy logic, neural networks and the optimal or predictive control of thermal conditions in homes. Analyses of management techniques of the load have been detailed. According to K. Wacks, a EMS contains methods that coordinate the activities of consumers and energy providers to better adapt the capacity of energy production with the needs of consumers to avoid peaks of energy demand and their negative effects. Over the past three years, most researches focus on the management and control of loads by the technologies of Smart Grid. These technologies can reduce domestic energy consumption (electricity and heating) and optimize the import export of electricity through smoothing of the load curve. All this research can be divided into two categories: predictive control (anticipative) and adaptive control (reactive: real time). Most recent developments on EMS use the concept of predictive control. This control uses a model with measured data to predict the optimal control strategy to implement. The predictive control is used, an error of forecasting in short term (10-20 min) or long term (days) for the control of temperature or humidity. Both are within acceptable limits for the control of temperature and humidity.

2.2 The multi layer and multi scale control system

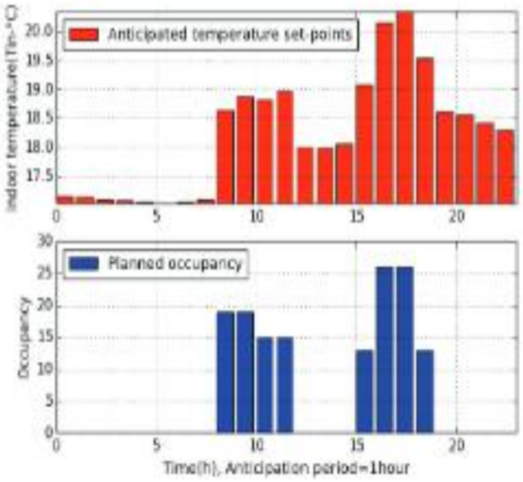
Several levels of modelling are used in this architecture. They correspond to several layers of command to divide the overall problem into sub problems to be more responsive to uncertainties. Between these layers, a flow of information is used to exchange instructions and emergency messages. These levels of management correspond to prioritized algorithms for solving according to different time scales. An optimization solution is calculated at the highest level, that is to say, with the longer sampling period, considering the relatively inaccurate predictions. The solution obtained is then refined in a lower level of management that fits the solution already calculated taking into account more detailed information for a smaller sampling period. The solution should converge towards real instructions to equipment's in the building, or towards advices to occupants.

Experiments and Simulations

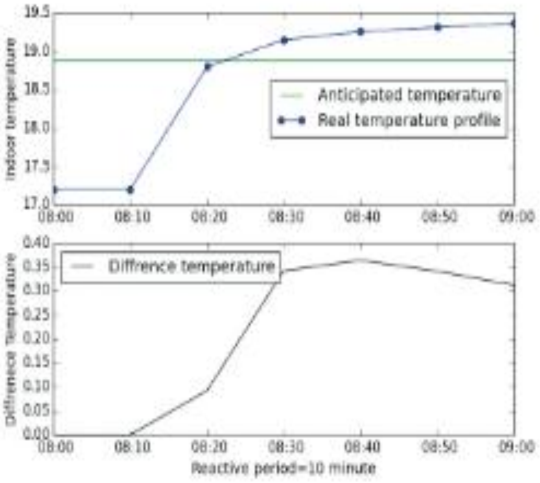
In previous section, reactive energy management with short-term models has been discussed. Following sub-sections discuss the discrepancy detection in indoor thermal comfort and indoor air quality, using these models. However, the scope is not limited to only these two, there could be more discrepancies and causes, for example discrepancy in anticipated cost profile due to unplanned appliances or system failure.

Discrepancy in Indoor Temperature

Indoor thermal discomfort symptom is measured as indoor temperature. The anticipated temperature is derived from anticipative model focusing on slow dynamics; it uses planned occupancy and hourly weather predictions. Shows how the long-term anticipated temperature profile is different from short-term measurement in between 8h and 9h hour of the day, because of the change in occupancy. The simulations shows, in case of discrepancy, it is necessary to take corrective action before the last reactive period so that temperature discrepancy could not reach to an discomfort area. Meanwhile reactive energy management tries to reach what was planned before the next hour or re-compute a new anticipative plan



(a) Anticipated temperature



(b) Real-time temperature

RESULTS AND DISCUSSIONS

Reactive Building Energy Management

[1] As aforementioned, there may exist gaps because of discrepancy between anticipated plan and reality. To fill this gap a reactive energy management strategy is proposed. Before going into detail working of reactive energy management, it is important to answer the question what should be the nature of the reactive management (Heuristic based or model based). Regarding this problem, two possible approaches could be used. First, a heuristic approach which is rule (if condition then action) based. However there are several pros and cons with this approach for example on the one hand rules are quite easy to implement and compatible with the available commercial controller on the other hand, a set of rules lead to a large decision tree. It becomes therefore difficult to ensure desired comfort level because of large number of actions.

[2] In addition, the major problem with rule based approach is its difficulty to handle varying price tariff production and storage. The other promising approaches are based on optimization. The optimization algorithm tries to compromise between long-term plans (strategies) and short-term comfort performance between predictions and real measurement. Proposed energy management scheme uses both approaches i.e. heuristics and optimization. It performs heuristic search for actions, in case of different failures and involve human actor to resolve the issue. An optimization algorithm is used to preserve the comfort in case of unexpected events such as unplanned occupancy. Reactive energy management works on one-hour time horizon considering 10-minute as reactive period.

[3] The new EMS capabilities have multiple applications for whole-building simulation. In general, the EMS module has applications for any advanced control scenario that requires flexibility beyond the standard controls. A major advantage of the EMS is that it can span system boundaries and allow control algorithms to integrate air system, plant system, and other objects such as electric lights and equipment. This type of coupling is not currently possible with the standard Energy Plus controls. One specific application that can require flexibility and system-spanning control is for demand management and load shedding. Although the standard controls do provide the DEMAND MANAGER objects, the control strategies are limited to a few fixed options.

[4] The EMS controls can provide additional flexibility. Because the

EMS module uses a simple programming language to define the control algorithms, another application is to test real-world EMS programs in simulation before they are used on a real building. Simulation, in general, provides a way to test a design concept before it is constructed. But for the EMS module there is a parallel here between input and reality that is rarely observed in building simulation. For most real-world EMS programs, whether they are defined by a programming language or a graphical user interface, the real-world control logic should be directly translatable to the ERL syntax. For simulation to be of use in the present context, it must be possible to represent the building/HVAC system and the imposed control as an integrated sys-tem. Within ESP-r a control system is implemented as a set of closed or open control loops acting jointly or individually. Each loop comprises a sensor linked to an actuator via an algorithm; in certain cases loops may be cascaded. ESP-r offers an extensive library of sensors, actuators and algorithms representing both idealised and realistic components, ranging from basic "ideal" control, through PID control to global sequence control (MacQueen 1997).

[5] As part of a design evaluation, the usual practice is to firstly employ idealised components to constrain system states (required temperatures, available heating capacity, mechanical ventilation rates etc) in order to facilitate the inter comparison of control options. Later, in support of detailed design, these idealised components may be substituted by more realistic counterparts to facilitate the study of control system stability and efficacy. By arranging that different sets of control loops can be activated over different periods, it is possible to implement any conceivable control regime (even conceptual regimes for which no actual hardware is available) The energy saving potentials and performance of BEMS control strategies on hydronic heating and air-conditioning systems were evaluated. This evaluation indicated that the emulation of building, HVAC and BEMS is a powerful method of developing BEMS strategies In order for ESP-r to participate in emulation studies, a hardware interface would be required, the principal function of which is to couple the BEMS to the sensors and actuators of the simulated plant. Analogue-to-digital converters (ADCs) are connected to the analogue outputs of the BEMS, which would normally be connected to the plant actuators. The digital-to-analogue converters (DACs) are connected to the BEMS in place of the plant sensors. As with the hardware interface device used in the IEA project [Haves and Dexter 1989], a

special component model would be required to read the simulation clock and control the data transfer in both directions. In the case of HVACSIM+, the component model is configured so that it does not participate in the iterative solution of the simulation equations; a similar facility would be required to synchronise the hardware interface and ESP-r numerical solvers

CONCLUSION

This article we presented the modelling and the simulation of an energy management system of a multisource and a multi load building. Our contribution lies in the modelling and the simulation of this system with DEVS. We proposed a model that describes the studied system. Based on this model, we have developed an application using the tool of modelling and simulation JDEVS to simulate the behaviour of the BEMS. The simulation of this BEMS gives good results for the reduction of energy consumption.

The continuation of this work will focus on several points. First, considering the implementation of the proposal work on more complex systems. The new EMS module adds advanced control capabilities to Energy Plus. The new EMS controls and the flexibility of ERL allow Energy Plus to simulate many novel control strategies that are not possible with standard Energy Plus control objects. The high-level scope of the EMS module allows control algorithms to span system boundaries and provide whole-building controls for a true whole- building simulation. The ability to selectively re simulate a time step allows the EMS Manager to make instantaneous control decisions, instead of having a lag of one time step. Controls that closely mimic a programmable EMS are unprecedented for building energy simulation programs. The EMS controls add a new level of flexibility for modelling innovative control strategies that will likely become a critical part of tomorrow’s low-energy buildings. This paper introduces a reactive energy management detailed modelling, focusing on fast dynamics, easier to initialize than more complex models. The experiments show how it is important to identify the discrepancies in anticipative period, so that it will be possible to correct before next hour anticipative plan. Future prospective of this work is to introduce different possible reactive actions and their consequences in context of energy management. An early detection may reflect huge savings of energy and cost as well. There could be various scenarios and possibilities for different causes and corresponding actions. A wrong action may cause discomfort to occupants. Defining a global reactive optimization for maximizing comfort is also considered as future work.

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