2011

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2011 IEEE GCC Conference and Exhibition (GCC), February 19-22, 2011, Dubai, United Arab Emirates

doi: 10.1109/IEEEGCC.2011.5752603

THE "BIM'S 4D+" DIMENSION: REAL TIME ENERGY MONITORING

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ABSTRACT

With the current trend towards Building Information Model (BIM), facility managers have a new tool for raising efficiency. This paper discusses the integration of the BIM software with a real-time monitoring (RTM) system, as a 4D+ dimension in BIM, to track the electrical usage at every location in a building. This ability could be invaluable in identifying what unnecessary loads are connected to a device and could be disconnected. This would result in elimination of needless loads and phantom loads during non-business hours, causing significant reduction in energy consumption. A prototype of the RTM was built and the results are in support of reduction in energy consumption. Real-time awareness is a major factor in facility management and essential to meet the strict guidelines presently being adopted.

Index Terms - Real-Time Monitoring, Building Information Model, ZNETH, Building America, Sensor Network.

1. INTRODUCTION

According to United States Green Building Council (USGBC), the built environment in the United States accounts for 72% of electricity consumption, 39% of energy usage, 38% of all carbon dioxide (CO_2) emissions, 40% of raw materials use, 30% of waste output (136 million tons annually), and 14% of potable water consumption [1]. While in Europe, buildings account for approximately 40% of energy usage, contributing about 30% of all CO_2 emissions [2]. U.S. homes use about one-fifth of the total energy consumed in the nation and about 60% of that is in the form of electricity [3]. The residential sector, unlike the commercial and industrial sectors, is made up of multiple small energy users, such as houses, mobile homes, and apartments. Research has shown that these residential energy consumers waste almost 41% of the power supplied to their homes [4]. The large amount of usage and waste indicates that residential has significant energy savings potential.

With new technology making its way to the market, the role which technology can play in the development of better buildings (whether better is defined as sustainable, more energy efficient, safer or less costly) is paramount [5]. Examples of these new technologies include: real-time monitoring (RTM) devices, Building Information Modeling (BIM), and sensor network (sensing and actuation). These technologies when integrated can provide new methods to monitor energy consumption and enable conservation. The ability of BIM software to be integrated with RTM and sensor networks give a new capability at controlling preventable energy waste. From facility managers to homeowners, benefits for such technology are expected to keep up with the new, stringent policies that are being adopted. Awareness is the key. If the location for misuse is realized, appropriate actions can be taken to make the facility more efficient. Understanding what devices are wasteful and disconnecting them to limit unnecessary energy usage is one potential solution in reducing energy consumption while maintaining acceptable comfort level for the occupant. This monitoring would make it simple for a facility manger to control unwanted electrical usage during off times of operation.

Energy management and control in the residential sector lags behind technologies created for the commercial and industrial divisions. It has been estimated that application of more sophisticated management and control to residential electricity consumption has the potential to save 3% to 26% of residential electricity use [4]. The opportunity for the integration of the new technology in the residential sector will pave the way for energy savings and provide for sustainable future.

This paper will address this integration and focus the discussion on the residential sector by a case study in a new type of home, namely the Zero Net Energy Test home (ZNETH) [10]. Section two will discuss BIM, while section three will address RTM. Section four will provide information on energy and the built environment and section five will discuss BIM and RTM integration. A summary will be provided in section six.

2. BUILDING INFORMATION MODELING

Currently, computer-aided design (CAD) software range from 2D linear systems to 3D solid and surface system. The first generation of CAD software depended on individual objects that were controlled and interpreted by the user as meaningful graphic symbols. These items only represented the geometrical properties of the architectural elements not actual elements. Modern 3D CAD packages also allow rotations in three dimensions providing views of a designed object from any preferred angle and views inside the object looking out. Some CAD software is capable of advanced modeling, in which case it may be marketed as computer aided drafting and design (CADD). With the present generation of CAD systems, a new concept shifts drawing based model into a Building Information Model (BIM) with the potential of modeling true architectural objects. These CAD objects provide all related data to the designer describing the geometry, as well as any related data associated with the object.

With the appearance of the BIM, came the concept of "objects". These objects have a corresponding meaning to a real world objects which in turn give information to the designer. For example, a device such as an electrical receptacle in a BIM system represents an actual receptacle in the physical world with properties that provide information to the end user, such as expected electrical load and manufacturer rating. BIM can be used to demonstrate the entire building life cycle, including the processes of construction and facility operation. BIM provides a virtual model to be handed from design team to contractor and subcontractors and then to the owner. Each level has the ability to adding additional information that is specific to each discipline and track all changes made to this one file. The result reduces the information loss that takes place when ownership of the project is handed over. As computers and software become more proficient at handling building information, this is expected to become the standard of the future.

The ASHRAE Handbook-HVAC Applications defines Building Information Modeling as the process of using intelligent graphic and data modeling software to create optimized and integrated building design solutions. BIM encompasses the use of three dimensional, real time, intelligent, dynamic modeling and can be a valuable tool in facilitating successful coordination and collaboration. BIM is the assembly of a single database of fully integrated and interoperable information that can be used seamlessly and sequentially by all members of the design and construction team and ultimately by owners/operators throughout a facility's life cycle. The desired results is a BIM model where three-dimensional (3D) graphical images carries real-time data, and where every line and every object carries real-life intelligent physical and performance data [5]. 5-D refers to all of the current dimensions of BIM, where the 3rd dimension is considered space, the 4th dimension is considered time and the 5th dimension is considered cost. In the future, the reference will be modified to include 6-D (procurement applications) and 7-D (operational applications) [6].

3. REAL-TIME MONITORING

A solution to reduce energy usage is knowing when and the precise location unnecessary energy consumption. Energy consumption is largely unseen to most users and this contributes to wasteful behavior. Real time feedback on consumption is necessary for energy savings. Several real-time monitors (RTM) are available to consumers offering electrical monitoring and display capabilities [7]. This information is expected to prompts users to reduce their electrical power consumption. The monitors that show near instantaneous usage, cost and historic feedback have the most potential for success to influence behavior.

Currently, monitoring has limited to a single device located at the main electrical service to the building, measuring total electrical consumption. These monitors then use tools such as the Nonintrusive Load Monitoring (NILM) to predict the load throughout the building. With the recent development of wireless sensor networks, the physical measurements needed for building assessments have become far more convenient than previous. The monitoring methods based on communication networks assist answering the questions such as how much energy is consumed by appliances or HVAC. Integrating this sensor network will allow for actual data received from each location and not at a service entrance point which in turn can to be monitored and utilized for saving. This means a more accurate account of each appliance's usage and location of unnecessary usages [8]. A method for sensing and monitoring at every location where a load is present will increase usage awareness and aid in reduction of electrical consumption.

4. ENERGY & THE BUILT ENVIRONMENT

The U.S. Department of Energy has developed a research program titled "Building America", with the goal to accelerate the growth and acceptance of a variety of advanced technologies for affordable homes. The ultimate goal, while keeping cost down, is to produce new homes on a large scale that consume an average 40% to 100% less energy. Some of the items that Building America is trying to compel into the built environment are passive solar heating and cooling and solar thermal and solar electric systems. Benefits for homeowners are sustainable building, higher quality of home and reduced operating cost over the entire year no matter the climate [9].

To foster research, innovation and save energy; the Net-Zero Energy buildings, specifically Net-Zero Energy Homes (NZEH), are currently being researched and designed by research centers around the U.S. to meet the Department of Energy, Building America, Research Toward Zero Energy Homes [4]. One such house is the Zero Net Energy Test House (ZNETH) currently being built at our campus of the University of Nebraska in Omaha [10]. The ZNETH house is traditionally designed, consisting of a finished basement, main floor and second floor. Several sustainable systems were implemented in this project. Various high efficiency window types were selected to reduce solar heat gain during the summer months and heat loss during the winter months. Two 250 ft (76 m) horizontal wells were looped at 8 ft (2.4 m) deep, and six vertical wells were drilled at 150 ft (46 m) deep for the geothermal heat pump. To lower the energy consumption of the heating system, a radiant floor system was planned to eliminate the use of a furnace for heating the house. To offset the consumed energy of the household occupants, a wind turbine and solar panels were selected as the energy production resources for this project.

ZNETH will be used as an educational tool to educate the public as well as to involve students in the design, construction and as a living laboratory with ongoing research in all areas of energy consumption and conservation. This house is well suited to show how BIM integrated with RTMs can reduce unnecessary electrical usage. With the extent of existing monitoring for other utilities, a means to measure electrical usage on the same level is obvious. ZNETH, although residential, will work as a great case study to test this new technology. The implementation of this technology would benefit large consumers of electrical power but also could play a significant role in information modeling to display real time information.

5. INTEGRATING BIM AND RTM

A new type of programming called Energy Management Software (EMS) has recently emerged as a method to observe all RTM. EMS collects energy data from a range of different monitors and uses it for three main purposes of recording, monitoring and understanding. Recording electrical consumption gives feedback about when electrical energy is being wasted and when these loads can be turned off. Monitoring gives real time information about loads current usage for facility managers to watch. Understanding is the most important part of EMS in its method to reducing energy. EMS does not contain actual monitors, but gives a method to monitor all the different types of monitors at one location. This still does not give information at each load, RTM via BIM would give a central point of monitoring and information at every location. Figure 1 shows Virtual ZNETH using the Constructor program. The detailed 3D model of each location is accessible for interaction as can be seen in Figure 2. Once the sensor network is implemented, the entire building's energy can be measured and monitored at every location using actual and virtual sensors.

Figure 1. ZNETH's 3D Model.

Figure 2 gives a detailed location to monitor devices and give accurate feedback at that location, such as kitchen appliances. With the diversity of level of expertise of individuals that could be using this software, it is apparent to make it as user friendly as can be. Integrating with the easy to navigate graphical interface in BIM allows any discipline to monitor this monitoring system. The RTM equipment would be linked to BIM as shown in Figure 3.

Figure 2. ZNETH's Kitchen 3D Model.

Furthermore, BIM could be integrated in to building management systems and load monitors. With this new feature, BIM cold prove to be a very successful tool for reducing energy consumption. Building management personnel can have real time feedback on all systems so to closely monitor usage and identify systems that could set on standby or even shut off completely. Wireless communication between loads and the BIM system provides feedback needed to have a reduction in energy consumption. With accurate information between loads and the BIM software, give a whole new way to monitor buildings.

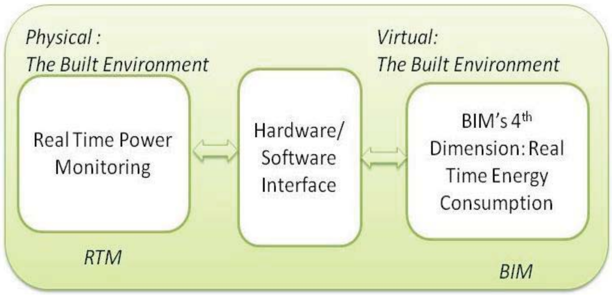

Figure 3: BIM & RTM Integration.

The amount of information that BIM models contain has the potential to equip a facility manager with means to manage the building efficiently as possible. Similar to the 4D day-lighting software used by Revit, real-time electrical consumption can be relayed from continuously updated a lookup table to show usage at every device in the building. By accessing this data, the user can monitor and control the locations that are consuming unnecessary electricity. Using existing 2D CAD drawings to create a

BIM model would give an accurate model to integrate this new technology in existing buildings as well.

A prototype of the RTM was built as a proof of concept tool to test the system. It consists of 5 modules: A load board module, voltage sensor & current transducer module, signal adjusting (i.e. resizing the signals to fit between 0-5 volt) module, power measurement, calculation and data communication module (at the load level), and a main data communication, processing, and display module. The results of tests on the prototype show that the initial objectives of the RTM system were acheived. Figure 4 shows the prototype in operation along with the load values for a small load. The load values for the voltage, current, power, and power factor are respectively displayed on the character LCD screen.

6. SUMMARY

With the intergration for new technologies, brings new methods of reducing our carbon footprint. BIM 4D+ could prove to be invaluable to faciality manangers with a large capacity for change. This work is on-going and more results will presentred at th econference.

ACKNOWLEDGEMENT

This project is funded and sponsored by the United States Environmental Protection Agency (EPA).

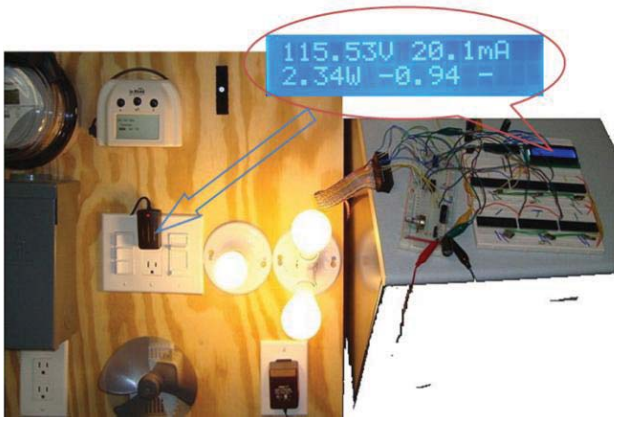

Figure 4. Proof of concept prototype board.

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