SmartBuildings as Embedded Distributed Systems

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***Abstract*—The SMARTGRID has come to describe a next-generation electrical power system that is typified by the increased use of communications and information technology in the generation, transmission, distribution, and consumption of electrical energy. All around the world, utility companies are integrating power plants in order to balance energy availability and be able to adapt to variations in consumption demands. As on the start-points of the energy chain, the intelligent end-points (i.e., SMARTHOMES, SMARTBUILDINGS) can decrease their energy footprint as they become able to reduce power, use alternative power sources, or schedule their energy demands to take the best benefit from energy's availability and cost. From a computer systems perspective, these buildings have become complex, embedded distributed systems, once they must adapt themselves to variations on energy availability and demands, and, in order to do that, they must rely on distributed sensors and actuation points. This paper describes the approach used to automate UFSC's first SMARTBUILDING. An overview of the building shows design decisions, with a special focus on the automation network technologies, topology, and control applications.**

I. INTRODUCTION

A SMARTBUILDING is a building where an intelligent automation system monitors and manages equipments to make building services more reliable and efficient. The integration of building services is, however, an intricate task as different systems implement different communication protocols and require distinct security or comfort regulations to be fulfilled. Common building services such as lighting, HVAC[1], access control, and fire detection, often implement the BACNET or LONWORKS protocols over a cabled infrastructure (e.g. Ethernet). Newer Green Buildings deploy devices to manage alternate energy sources such as solar or wind generators that implement proprietary communication protocols. The efficient integration of all these components in a single automation network, as well as the extensions to these systems to allow for adequate interaction with users, demand the development of new tools.

An infrastructure integrating all sensors and equipments in the building allow the deployment of intelligent mechanisms to manage the building services in ways that satisfy user preferences. One of the main objectives of an intelligent control system in the SMARTBUILDING is to make the building energy-efficient. There is a lesson learned from energy-aware computing systems that can be brought to this context: fine-grained information on energy consumption of the managed system enables more efficient power management methods to be deployed [1]. The more information a power manager has, the more energy it can save. Having energy meters distributed along the power network of the building can enhance the efficacy of energy-related decisions.

The information needed to make power management decisions depend on other data than the building energy consumption profile. "Intelligent" energy management rules have to take into account other restrictions. Defining which sections or devices in the building are critical, and should not be shut down, depend on user interaction. For instance, critical equipments like servers, elevators, and fire alarms must be highly reliable and cannot be shut down if the building lacks energy. Moreover, some users can have higher priority for using energy than others. Some energy-related information depends on external factors. Energy availability from solar panels depends on the solar irradiation and weather forecasts. Cost and quality of the energy provided by the power utility company is subject to season and time of the day, which are contract-dependent. Finally, building user- or room-specific energy consumption profiles and estimating the energy to be consumed by devices or sectors require the collection of historical data. With such data in hand, one can deploy heuristic or artificial intelligence methods to enhance the efficiency of energy management decisions.

In this context, this paper describes the approach used to raise UFSC's first SMARTBUILDING, including fundamental design decisions, with a special focus on the automation network's technology and control applications.

II. SMARTBUILDING PROTOTYPE

Starting in 2013, an inter-departmental team of the Federal University of Santa Catarina (UFSC) is designing and building UFSC's SMARTBUILDING prototypes. The architectural project of the building carefully deploys windows and water mirrors to increase lighting efficiency and humidification, helping the buiding's energy-efficiency. The buildings are covered with photovoltaic panels showing a peak power of 50,153 kWp. Battery arrays are used to store energy and reduce the amount of power bought from the local power utility. Eventual energy excess will be sold to the power utility network. This configuration, associated to the intelligent management of energy storage and energy load, allows the buildings to operate autonomously most of the time.

The building prototype includes a set of smart components that enable better management of energy consumption. The main component in this set is a smart wall socket. This wall socket is implemented as an extension of the EPOSMOTE

[1]HVAC: Heating, Ventilation, and Air-Conditioning

project [2]. The smart wall socket has either NB-PLC or IEEE 802.15.4 communication capability. This design decision is important because both NB-PLC and IEEE 802.15.4 can suffer from several types of interference. Having both versions in hand, the building manager can choose which version to deploy for each case.

The smart wall socket equips a hall effect sensor that measures energy consumption of connected equipment and reports it periodically to a central supervisory system. Based on pre-defined rules and on other variables for building operation, the supervisory system can command the smart wall socket to block, release, or dim power. In specific cases, the wall socket can also be connected to a digital interface of the equipment connected to it, allowing the supervisory system to issue device-specific commands through the automation network.

Three types of power actuation mechanisms were built to switch on and off low and high power devices. A Triac-based power actuation system acts on low-power equipment (up to 1A) and can serve as a dimmer for LED lamps. A relay-based circuit acts on high-power equipment (up to 10A), what covers most of the equipment in the building. An extra actuation system integrates to other devices through digital communication interfaces. An example is the serial communication interface used to command the air-conditioners.

A Supervisory Control And Data Acquisition (SCADA) system [3] stores the data acquired from the network in a database. Integration to the automation network is performed through a Modbus TCP/IP interface. The system also provides a high-level visual interface for system administrators. The SCADA operates through the manipulation of "data points". A data point represents a variable either monitored or controlled by the system. The system reads data from the devices in the network and feeds this data into specific input data points. The SCADA system then processes the data either when they change or periodically, and set new values to output data points. Finally, the system takes these output data points and send them to their respective devices in order to act on the network.

In the current prototype, system control is implemented by decision trees in two levels: global level and room level. Figure 1 shows the decision tree of the global rules. The global rules focus, mainly, on the building energy sources. Depending on the status of external energy source, battery, and incoming solar energy, the global building status is set to a priority level ranging from 0 to 5. When at level 0, the system is running out of energy and everything is shutdown. At level 5, energy availability is normal, and the building can operate without restrictions.

A set of rules controls energy consumption of individual rooms as shown in Figure 2. A variable sets the room status based on the global building status and the priority level set to each room (i.e., $room\_status = global\_status + room\_priority$). The room priority can be assigned a value between 0 and 5.

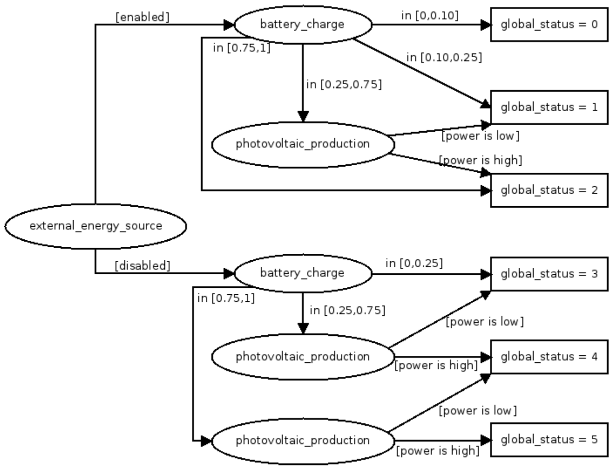

Figure 1. Decision tree with global building management rules.

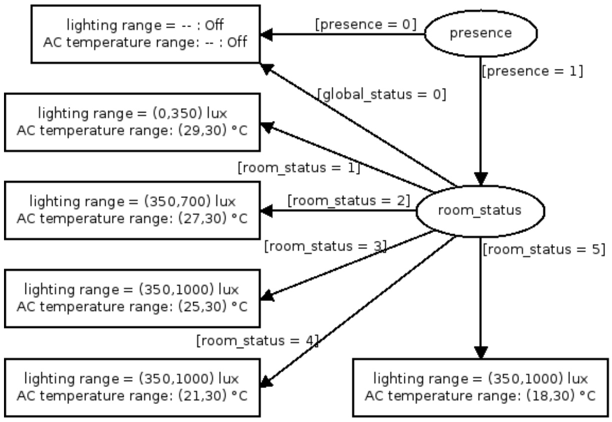

Figure 2. Decision tree with room management rules.

III. CONCLUSION

This paper presented a project at the Federal University of Santa Catarina that is building a smart, green building, and showed the current status of the development of its automation infrastructure. The project goal is to integrate a set of novel technologies in the building. These technologies include alternative, renewable energy sources, novel building automation approaches, and new intelligence systems to build a greener building. These technologies form a complex distributed system that requires adequate monitoring and control. Moreover, the buildings are expected to be energeticaly self-sufficient, demanding extra intelligence in the automation system to monitor and plan energy production, storage, and usage.

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