SMARTBUILDINGS as Autonomous Distributed Systems

Arliones Hoeller Jr. and Antônio Augusto Fröhlich

[1]Software/Hardware Integration Lab
Federal University of Santa Catarina (UFSC)
P.O. Box 476 – 89.040-900 – Florianópolis – SC

{arliones,guto}@lisha.ufsc.br

Abstract. *The* SMARTGRID *has come to describe a next-generation electric power system that is typified by the increased use of communications and information technology in the generation, transmission, distribution, and consumption of electric energy. As on the start-points of the energy chain, that already integrate power plants and transmission lines, the intelligent end-points (i.e.,* SMARTHOMES, SMARTBUILDINGS*) may decrease their energy footprint as they become able to reduce power, use alternative power sources, and/or schedule their energy demands to take the best advantage from energy availability and cost. From a computer systems perspective, these buildings have become complex distributed systems. As they must adapt to variations on energy availability and demands, they also need to feature autonomous operation. By adequately monitoring and controlling devices distributed in a control network,* SMARTBUILDINGS *are able to impelent a multitude of services in more efficient ways. In this paper we describe the approach that is being used to raise UFSC's first* SMARTBUILDINGS. *An overview of such buildings is given, and the current status of the project is shown along with its preliminary results.*

1. Contextualization

SMARTBUILDINGS are automated buildings where, by the deployment of some sort of intelligence, it is possible to monitor and manage the buildings' equipments providing efficient and reliable operation of building services. Integration of services is, however, an intricate task as different systems usually implement different communication protocols and require distinct security or comfort regulations to be fulfilled. Usual building services include lighting, HVAC[1], access control, and fire detection systems, for which standardized protocols exist (e.g., BACNET). Smarter management of such systems, however, require more sophisticate sensing mechanisms, such as accurate and distributed temperature, lighting, and presence sensors. Moreover, SMARTBUILDINGS are increasingly deploying alternate energy sources such as solar or wind energy systems. Such systems include other equipments that need to be integrated to the building's automation network. For this, other application-level protocols need to be deployed.

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[1]Heating, Ventilation, and Air-Conditioning

Several standards exist for building automation networks. BACNET is a data communication protocol for building automation and control networks [ASHRAE/ANSI 2012]. It supports applications such as HVAC control, lighting control, access control, and fire detection systems. Its lower network layers may be Ethernet, BACNET/IP, point-to-point RS-232, token-passing RS-485, or LONWORKS. LONWORKS is another standard that defines a networking platform for control applications. It is mostly used in building automation applications under the BACNET standard for HVAC and lighting applications. The IEEE 802.15.4 [IEEE 2011] standard is also used in building automation. It specifies a physical layer and a media access control protocol of a low-rate wireless personal area network (LR-WPAN).

Narrow-band power line communications (NB-PLC) [Oksman and Zhang 2011] is also widely deployed in building automation. In a PLC network, low-power signals are transmitted at high frequencies over the power lines. It is a good choice for building automation because it does not require extra cabling nor wireless network infrastructure. ITU-T's G.HNEM standard defines the physical and data link layers of an interoperability model for NB-PLC solutions. Its addressing mechanism allows the devices to be separated into domains. Some nodes may be deployed for bridging distinct domains. Also, special nodes may be used for bridging G.HNEM to alien protocols. Each domain has a master, which is responsible for performing administrative tasks such as node admission and resignation. Such actions are usually implemented by using a standardized security module (AES-128). Beacon packets are employed to keep the network synchronized.

One of the main objectives of a SMARTBUILDING is to be energy-efficient. Building "intelligent" management rules, however, is not a trivial task. Defining which sections or devices in the network are critical still depend on user interaction. Information related to renewable energy availability may depend on weather and solar irradiation predictions that present high error rates. Finally, building user or room specific energy consumption profiles and estimating the energy to be consumed by devices or building sectors require the collection of historical information and the deployment of heuristic or artificial intelligence methods able to efficiently take management decisions. This paper presents an approach to address these issues.

2. UFSC's SMARTBUILDINGS

Since early 2011, an inter-departmental team of the Federal University of Santa Catarina (UFSC) have been working to raise UFSC's first SMARTBUILDINGS. The team is formed by professors and students from several departments, including civil, electrical, and automation engineering, architecture, and computer science. The building, besides serving as workplace for the research team, will also serve as a prototype and showroom for new technologies in the SMARTGRID and renewable energy research topics.

Figure 1 shows a 3D view of the buildings. The architectural project has carefully deployed windows and water mirrors to increase lighting efficiency and humidification. Both buildings will be covered by photovoltaic panels. As a research prototype, different types of photovoltaic panels are being deployed to address specific research needs. This includes technologies based on both amorph and crystalline silicon. The total power generation of the facility is projected to be of 50,153 kWp (kilowatts peak), what may allow the buildings to operate autonomously most of the time.

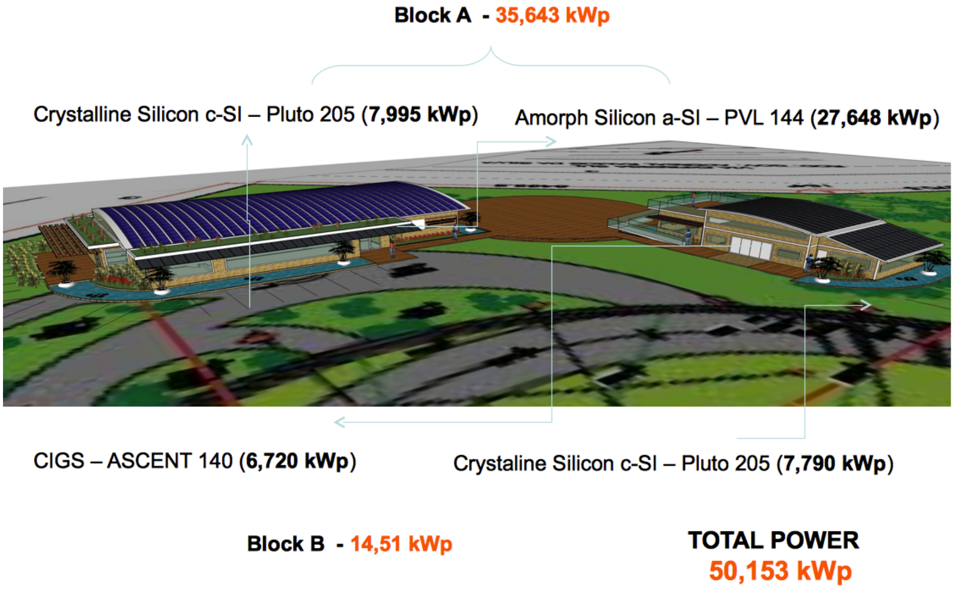

Figure 1. 3D view of UFSC's SMARTBUILDINGS.

UFSC's SMARTBUILDINGS include a set of smart components that will allow for better management of the buildings' energy consumption. One of these components is a smart wall socket with NB-PLC communication capabilities and an energy consumption meter. The smart socket reports to the system the energy consumption of the equipments connected to it. Also, the smart socket receives commands to either block or release power to the equipments or, in specific cases, to communicate to the equipments' specific command interfaces. This allows for the integration of, virtually, any smart equipment to the buildings' PLC network. The smart socket prototype based on the EPOSMOTE project [LISHA 2012a] was deployed in three versions: one to serve as a dimmer for LED lamps (low power), one to serve as a generic switch for any wall socket (high power), and a third implementing a command interface to an air-conditioning system.

A Supervisory Control And Data Acquisition (SCADA) system was built using the SCADABR project [MCA Sistemas 2012]. The system stores data received from the devices in the network in a database, and provides interfaces so that actions may be performed in the network and data may be made available to graphic interfaces. The system uses the concept of "data points", which represent variables either monitored or controlled by the system. The system reads data from devices and feeds these into specific *input* data points. The SCADA system then processes data either when they change or periodically, and set new values to *output* data points. Finally, the system sends these output data points to their respective devices in order to make management decisions effective.

Control rules were implemented in two levels: global level and room level. Scripts implement decision trees to configure devices in the network. Figure 2 shows the global level decision tree. The global decisions focus, specially, on the energy sources. Depending on the status of the external energy source, batteries, 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 critically out of energy and everything is shutdown. At level 5, energy availability is normal and the building may operate adequately.

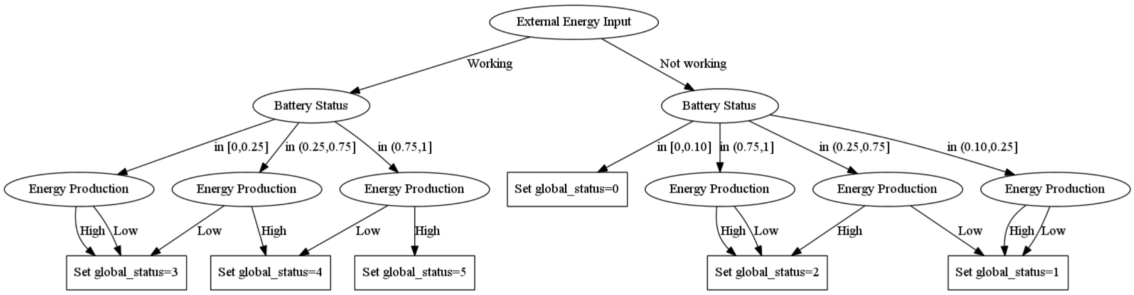

Figure 2. Decision tree with global building management rules.

Another set of rules controls rooms' energy consumption. Status for each room is defined by the sum of the global status and the room priority. Room priority is also assigned a value between 0 and 5. The lower the status, the lower the allowed energy consumption, and the fewer the services operating in that room. A complete room decision tree is available online [LISHA 2012b].

3. Conclusion

This paper presented the status of a project in the Federal University of Santa Catarina that is building UFSC's first SMARTBUILDINGS with the goal of integrating novel technologies. These technologies include alternative energy sources, new building automation approaches, and new energy management policies, making these buildings complex distributed systems. So far, work focused on building the system's infrastructure, there is still research to be performed regarding autonomous distributed systems. One of the open issues is scalability. Future work intend to explore the security infrastructure defined by the G.HNEM standard to implement secure admission and resignation of privileges within the network. Another open issue is the currently centralized decision structure. As the number of interconnected equipments grows, the PLC network will, inevitably, build a hierarchy. In such hierarchal topology, the centralized decision-making process may pose undesirable communication delay on buildings' services. In this scenario, the decision process may need to be spread across the network, making room for an autonomous decision structure in the buildings' distributed system. More information on these developments are available at the project's website [LISHA 2012b].

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