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RECONFIGURABLE CIRCUITS USED IN SMART HOUSES

BY

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Abstract. The wide field of intelligent buildings includes a variety of technical solutions, from the physical structure and the location of the building to the options an intelligent house can offer. We shall study the smart house type that accommodates most general use situations, with no need to modify, for instance, the physical structure of the house.

Key words: smart metering; measuring; monitoring; energy management; energetic potential.

1. Introduction

In most cases, in order to have a smart house, it is necessary to get as much information as possible from inside the house (Corbusier, 2014), as well as from outside the house (Spicer, 2012). This is done by various sensors, such as:

a) from inside the house: security sensors, fire and smoke sensors, water consumption sensors, electricity consumption sensors, oxygen sensors, light sensors, pressure sensors, temperature sensors, gas sensors ;

b) from outside the house : light, temperature, house access, wind sensors (Ramler & Donovan, 1979; Nayeem & Ullah, 2007).

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For a complete intelligent house concept, in addition to the information received from the above sensors, we also need: data communication, television and phone. The information received from the sensors is sent towards one or several command circuits that control and monitor the house.

Based on the information read by the sensors, the monitoring and control circuit makes decisions on the choice of a functioning pattern. From this perspective, there are two control concepts: temporal and behavioural control.

Temporal control refers to the analysis of the information received from the sensors in order to decide on control patterns that reach certain functioning thresholds previously set: for instance – 22 degrees minimum temperature, 24 degrees maximum temperature, etc.

In behavioural control, the data received from the sensors are processed together in order to render a general picture of the smart house. For instance, if the temperature inside the house is found to be too high, external temperature and the position of the sun are also taken into consideration in making a decision: activating the shading device outside the building and turning on the air conditioning (HVAC). The shading device will also minimize the amount of light received by the building, but the light sensors inside will insure the necessary light for the proper functioning of the house. One can say that implementing this concept is a balanced approach for using sensor data and for achieving a smart house in the broad sense of the term.

2. Smart Metering

Starting from the smart house concept, we get to the next development step – the intelligent house (Cetin & Sazak, 2009). Thus, in addition to the features presented above, there are options on increased data transfer towards the outside world, as well as access to services delivered by third party companies. The possible features belong to various fields: security, entertainment, social services, maintenance services, supply, etc. For example, in the security field, in addition to the alarm going off when the sensors detect movement inside, an intelligent house is also equipped with options such as: turning on the surveillance cameras, taking high resolution (clearer) pictures, calling the owner, calling the security firm/the police, allowing voice messages with the house, blocking the access to the safe, etc. The block diagram of such a system is presented in Fig. 1.

The Programmable Logic Controller (PLC) is the central element of the system and its main functions are to communicate with various sensors, to process and transmit data.

The reconfiguration characteristic of the programmable logic controller is that it can adapt, so that circuits (sensors, for instance) can be added to or removed from the system at any time during functioning (Erfidan *et* al., 2008; Bârleanu *et al*., 2001; Valachi *et* al., 2009).

Thus, by means of a graphic programming interface – GUI (Graphical

User Interface), we can modify the configuring parameters for each sensor, we can opt for local data processing (for example, the detection of threshold values in case of an alert), for local data transfer (to a smartphone) or remote transfer (to the cloud).

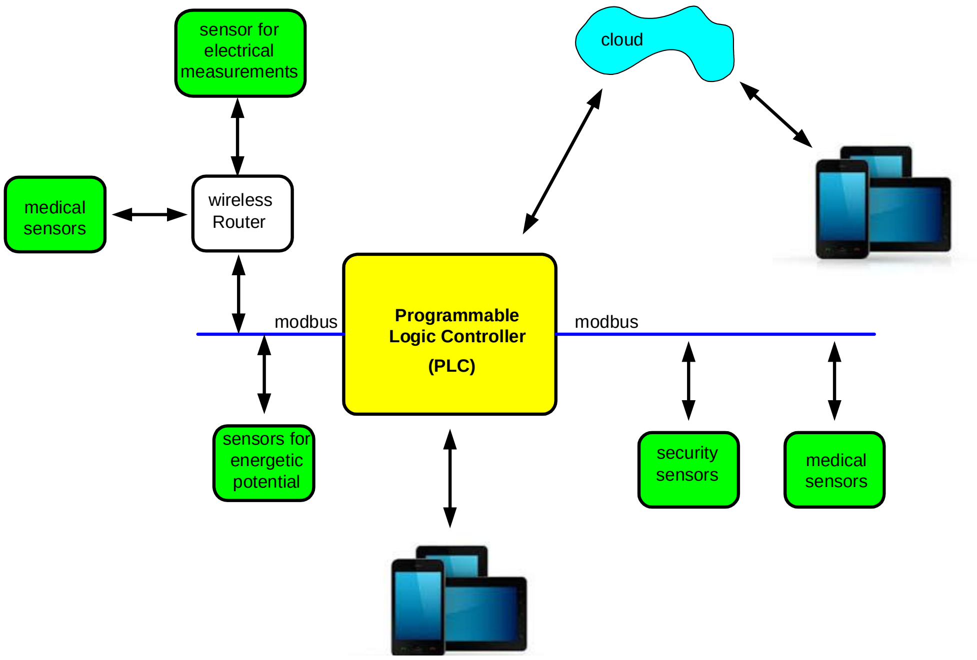

Fig. 1 – Block diagram of a reconfigurable system.

The sensors connecting to PLC belong to different categories:

a) security sensors (movement sensors, smoke sensors, vibration sensors, thermal sensors);

b) energy consumption sensors (electricity, gas, cold water, hot water, thermal energy meter);

c) energetic potential sensors (wind, light, geothermal energy);

d) medical sensors (sensors for registering the parameters of the living environment - temperature, humidity, pressure, virology, etc.).

3. The Programmable Logic Controller

The design of the programmable logic controller involves two parts: hardware and software. At hardware level, it should insure a direct connection interface with various modules, sensors and communication circuits. The software level includes the configuration of each circuit/module/sensor, local data pre-processing and remote or local data transfer.

3.1. The Software Configuration of the Programmable Logic Controller

This can be accomplished by a GUI (Graphical User Interface) programmable interface located on a mobile device (a tablet) or on a server, as shown in the block diagram in Fig. 2.

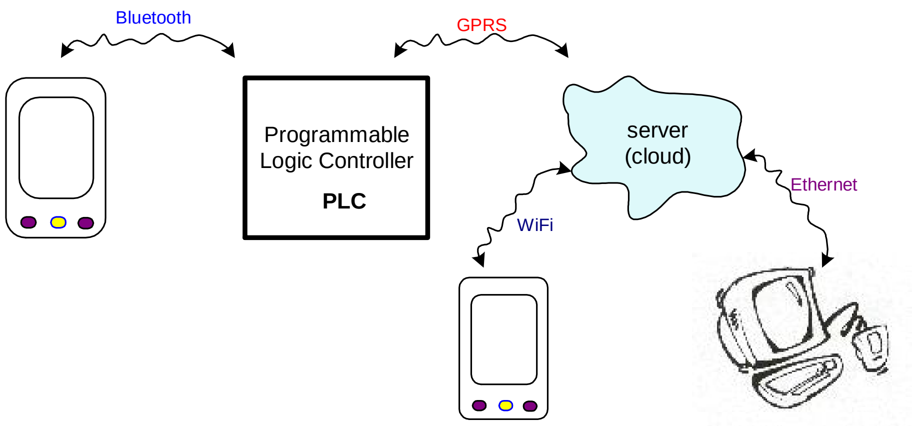

Fig. 2 – The block diagram of the interface with the control circuit.

According to Fig. 2, the programmable logic controller can be configured either locally (by smartphone/tablet) or remotely (by PC or smartphone/tablet). For remote configuration, the data transmission chain includes a server (cloud) facilitating the data exchange both ways. This server can also store data (database) resulting from various sensors connected to the PLC. This function is very useful because it helps create a log for events such as data visualization, data transfer to other interested users (for instance to water or electricity providers, etc.).

3.2. The Hardware Configuration of the Programmable Logic Controller

This level insures the electric connection interface between PLC, communication modules and various sensors. The sensors are connected to PLC through a MODBUS or CAN communication network and are identified by means of a unique ID (Fig. 3). Based on this ID, the PLC identifies data and then forwards it to the server (or locally to the smartphone/tablet). The ID also allows the PLC to send the configuration data for each sensor; the configuration is carried out based on a GUI graphical interface (installed either locally – o a smartphone/tablet or remotely – on a server).

The communication protocol MODBUS can be implemented on the communication interface (RS232/422/48/Ethernet) available of various sensors. Moreover, if it is absolutely necessary to use a special type of sensor that only has a SPI/I2C interface, this sensor will be attached a converter SPI/I2C <-> RS232/422/48/Ethernet in order to adapt it to the preexisting network.

In order to further develop this concept, an intelligent house also needs to draw on energy resulting from renewable sources (wind, solar, geothermal energy, etc.) (Saha *et* al., 2009; Kusiak *et al*., 2009; De Broe *et al*., 1999). The most popular sources are by far the wind and the sun. Fig. 4 presents a block diagram for the use of these resources.

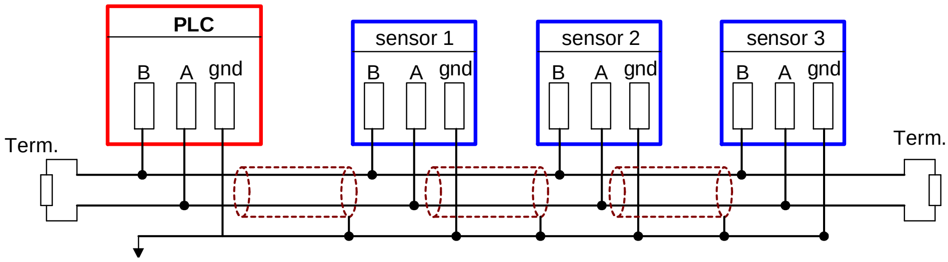

Fig. 3 – The block diagram of the interface between the PLC and various sensors.

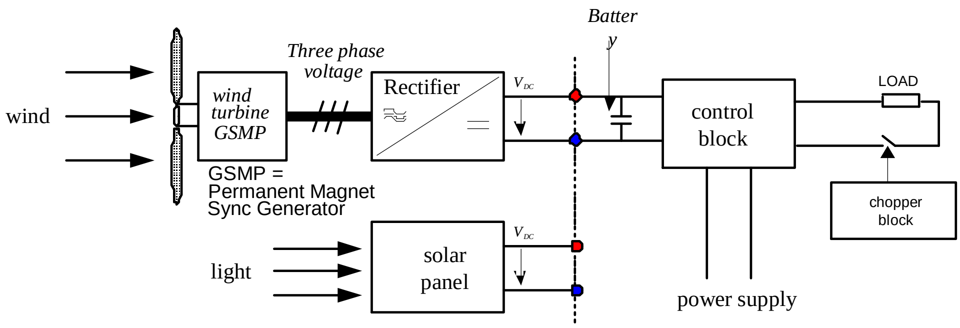

Fig. 4 – Using renewable energy sources.

According to the diagram in Fig. 4, the supply of the load resistance (for instance the electric resistance of a boiler) is controlled by the Chopper Block. Therefore, if at a certain point there are no energy resources (no light and no wind), the load resistance supply draws on the national electrical grid. However, if there is energetic potential, the control block will primarily switch the supply of the load resistance to the energy resulting either from a wind turbine or solar panels. Sometimes, there is a surplus of energy and if special circuits are used, the excess energy will be directed to the national electrical grid. Such special circuits are called synchronous inverters connected to the grid.

The wind turbine is made up of a permanent magnet synchronous generator (PMSG) functioning at variable speed. The rectifier helps transform the alternating energy produced by the turbine into direct current electricity (a.c.-c.c.).

The main block in the diagram above is the d.c.-d.c. converter, based on a buck-boost converter architecture, presented in Fig. 5.

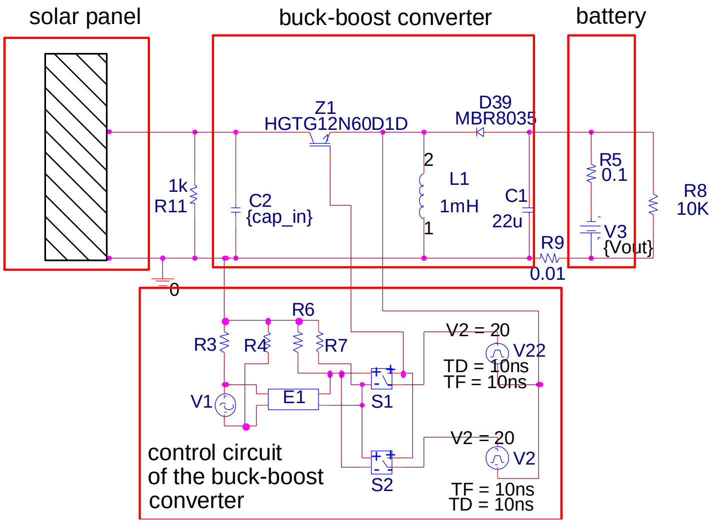

Fig. 5 – Control circuit.

The calculations made in designing the buck-boost d.c.-d.c. converter (Pletea *et al.*, 2011; Rata, 2012) are presented below. The design is based on a situation in which a voltage V_1 = 100V is applied at the input of the converter and the values intended are the following: V_2 = 200V (at the output), functioning frequency = 28 KHz, ripple current through the coil = 20% (of the maximum output current), maximum output current = 10 A.

Considering the input values above, the following equations can be written:

$$V_1 dT = V_2(1-d)T \ , \quad \frac{V_2}{V_1} = \frac{d}{1-d} \ , \quad 2 = \frac{d}{1-d}, \ d = 0.67. \qquad (1)$$

Frequency = 28 KHz , Period T = 1/Frequency = 35.71 μs, when

$$t_{\mathrm{ON}} = 23.8 \text{ us} \quad \text{and} \quad t_{\mathrm{OFF}} = 11.9 \text{ us}. \qquad (2)$$

When the transistor is blocked, the coil voltage $|e|$ is:

$$|e| = \frac{L\mathrm{d}i}{\mathrm{d}t} = 200.6\,\mathrm{V},$$

where

$$L = e\frac{\Delta t}{\Delta I} = 200.6\frac{t_{\mathrm{OFF}}}{2} = 1.19 \text{ mH}. \qquad (3)$$

By choosing the magnetic core type PM 74/59 having the following parameters

$$\begin{cases} l_e = 128 \text{ mm}, \\ A_e = 7.9 \text{ cm}^2, \\ A_{\min} = 630 \text{ mm}^2, \\ V_e = 1{,}010{,}000 \text{ mm}^2, \\ A_l \approx 10{,}000 \text{ nH}, \\ \mu_e = 1{,}290. \end{cases}$$

We can calculate:

a) the number of spires:

$$N_{\min} = \frac{L \times I_{\text{Max}} \times 10^4}{B_{\text{Max}} A_e} = \frac{1.19 \times 10^{-3} \times 10 \times 10^4}{250 \times 10^{-3} \times 7.9} = 60.25 \text{ spires}; \quad (4)$$

b) the electrical gap of the magnetic circuit selected:

$$l_g = \frac{\mu_e \mu_r N^2 A_e 10^{-1}}{L} = \frac{4\pi 10^{-7} \times 60.25^2 \times 7.9 \times 0.1}{1.19 \times 10^{-3}} = 3.02 \text{ mm}; \quad (5)$$

c) the maximum repetitive current through the coil, transistor and diode is the following :

$$I_{LM} = I_{QRM} = I_{DRM} = I_L + \frac{\Delta i_L}{2} = \frac{dV_1}{(1-d)^2 R} + \frac{dV_1}{2Lf},$$

where: $R = V_2/10A = 20\ \Omega$,

$$I_{LM} = I_{QRM} = I_{DRM} = \frac{0.67 \times 100}{(1-0.67)^2 \times 20} + \frac{67}{2L\text{Freq.}} = 30.76 + 1 = 31.76 \text{ A}; \quad (6)$$

d) the average value of the current through the transistor is:

$$I_{\text{Qavr}} = dI_L = \left(\frac{d}{1-d}\right)^2 \frac{V_1}{R} = \left(\frac{0.67}{0.33}\right)^2 \frac{100}{20} = 4.122 \times 5 = 20.61 \text{ A}; \quad (7)$$

e) the average value of the current through the coil is:

$$I_{\text{Davr}} = (1-d) I_L = \frac{d}{1-d} \cdot \frac{V_1}{R} = \frac{0.67}{0.33} \cdot \frac{100}{20} = 10.15 \text{ A}; \quad (8)$$

4. The Intelligent House Network

After the creation of intelligent houses, one step further would be connecting them into a network in order to facilitate the data exchange. For instance, the utilities (water, energy) providers can interrogate such networks and find out the consumption level at a certain point in time. This would allow them to manage consumption profiles for each client. The block diagram of such a network is presented in Fig. 6.

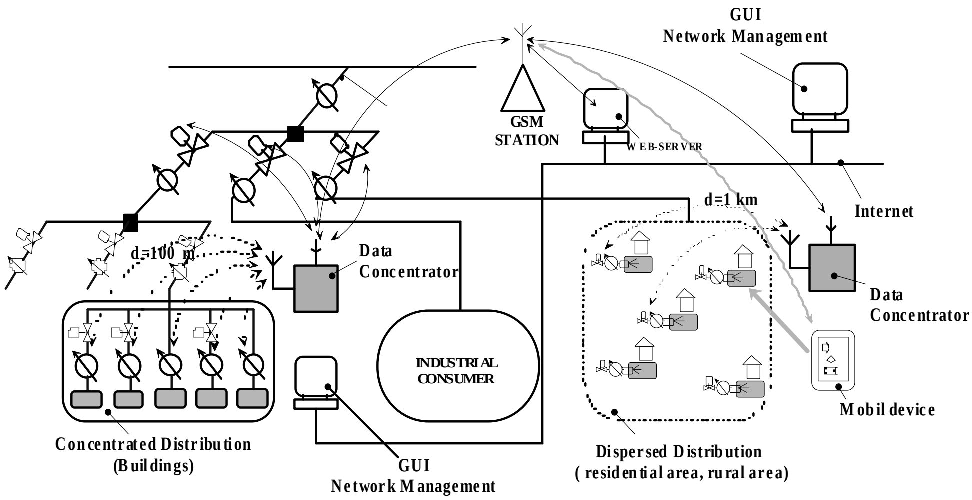

Fig. 6 – Metropolitan network of resource management.

4. Conclusions

A home can be seen both as an energy consumer and an energy producer. If it is equipped with energy generation and management devices, the users' living conditions improve and the maintenance costs diminish. The method suggested in this paper (the hybrid use of low-voltage grid electricity and of renewable energy sources) has the following benefits: reducing energy consumption costs and reducing greenhouse effect by a decrease in carbon emissions, especially in summer. An significant part of the solutions presented in this paper resulted from the implementation of the research project **SisConGes**.

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CIRCUITE RECONFIGURABILE UTILIZATE ÎN CASE INTELIGENTE

(Rezumat)

În domeniul larg al clădirilor inteligente pot fi incluse o varietate de soluţii tehnice pornind de la structura fizică a clădirii, zona de amplasament până la

dotări/opțiuni cu care este echipată casa inteligentă. În această lucrare s-a studiat soluția de tip „smart house” care se potriveste la cât mai multe situații de uz general, fără a fi nevoie ca implementarea unei soluții să modifice, de exemplu, structura fizică a casei. Pentru a completa conceptul de casă inteligentă, față de informațiile primite de la senzorii enumerați mai sus mai sunt necesare: comunicații de date, televiziune şi telefonie. Informațiile primite de la senzori sunt trimise către unul sau mai multe circuite de comandă care controlează şi monitorizează casa.