TWO LAYER CONTROL STRATEGY APPLIED TO BUILDING AUTOMATION

João Figueiredo
Universidade de Évora,CEM-IDMEC, R. Romão Ramalho, 59, 7000 Évora, Portugal

José Sá da Costa
Instituto Superior Técnico, IDMEC, Av. Rovisco Pais, 1049-001 Lisboa, Portugal

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Abstract: A two level hierarchical control strategy is developed over a network of distributed systems. This paper shows the great potential of a control strategy over two layers - distributed local controls which are connected with an intelligent centralized control, which has a global view over the system, and permits an actualization of the local references, knowing the complete state of the entire system The tested prototype worked perfectly showing the huge potential of communication systems between distributed processes. These communication systems allow intelligent centralized algorithms to manage decision making problems in real-time environments. The system presented in this paper combines several technologies (local PLCs, SCADA systems and network communications) to reach the goal of efficient management of distributed processes.

1 INTRODUCTION

Today with the worldwide communications development it is more and more usual the decentralized management of systems. This strategy reaches different fields, from agriculture, to industry, domotics ... (Christensen, 2002), (Dey, 1999), (Figueiredo, 2005a).

In the economic field the big companies locate plants in low-cost lands and research and commercial activities close to customer industrialized lands.

In engineering, especially in the industrial field, the motivation to optimize resources, forces the communication between decentralized systems in order to reach better allocation of resources, minimizing the waste of raw materials, reducing production costs…

In this context the communication between distant systems is increasing tremendously, not only in new built systems but also when reengineering is brought to old systems. The reengineering of old plants brings new intelligence to these systems by introducing automation solutions in their processes. These new instrumentation systems (intelligent sensors and actuators) allow the plants to communicate their actual state to the centralized control unit, allowing a real-time decision making (Neto et al., 2004), (Ratinho, 2002).

In this paper an urban application of decentralized control strategy is presented. A control and monitoring platform for an Intelligent building is developed using a SCADA system (Supervisory Control And Data Acquisition). The control strategy developed in this paper develops a two-level architecture where inner-loops are performed by local PLCs (Programmable Logic Controller), and the outer-loop is managed by the centralized SCADA system that interacts with the entire local PLC network. The outer loop has the potential to develop a more heavy control algorithm as the current low-level control actions are managed by the local PLCs. Tests on a prototype are shown. The prototype represents a multi-input/output parking place, composed by several gates distributed by different building floors, and having a centralized control unit that manages and monitors the complete state of the parking place (current number of free places, gates state, utilization percentage of each

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gate, overall power consumption, fire and smoke alarms… All the instrumentation in place is controlled by the industrial PLC network. Each PLC unit controls a set of sensors and actuators, responsible for the proper actuation of the input and output gates located in a multi input-output parking place.

2 SYSTEM MODEL

The studied building is modeled as tree-structure, composed by two main sub-structures: Floors and Rooms (Figueiredo, 2005b).

This structure provides flexibility to the model as it can deal with both small/simple and big/complex buildings (Fig. 1). Following this modular model structure, each room is considered as an autonomous unit with its independent monitoring and control activities. The SCADA application is developed according the model-tree structure presented above, allowing the user to go down from the general state view of the entire Building to each floor, descending continuously to each room and reaching the final elementary chain devices such as sensors or actuators.

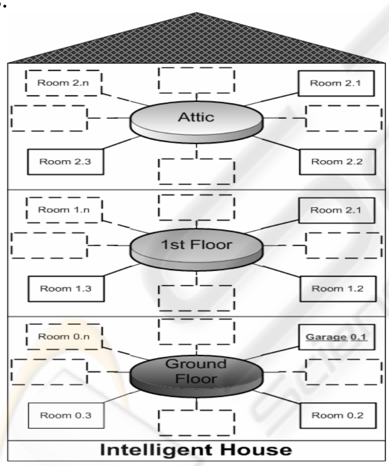


Figure 1: Intelligent Home as a tree-structure Model.

Each floor is modeled as a set of rooms and each room has several sensors and actuators.

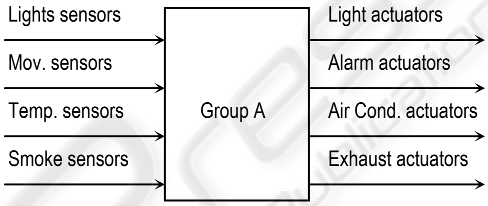
The set of actuators and sensors considered in each room are mainly grouped into 2 groups:

- Group A: leaving rooms, bedrooms;
- Group B: kitchens, toilets, parking place.

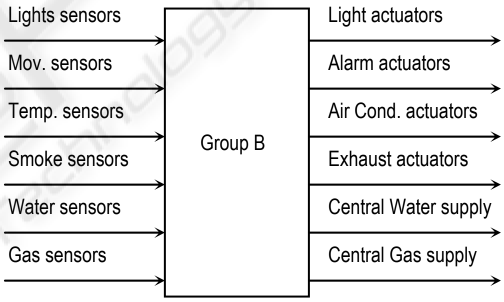
The set of sensors and actuators considered in both groups are shown in fig. 2.

An additional feature of this model that provides the system huge accessibility to their users is the SCADA platform where this model was implemented which allows the system to be connected trough the internet. This feature will be presented in chapter 3.

Concerning the prototype tested in this paper, the multi-input multi-output parking place, the inputs/outputs considered in each gate are illustrated in fig. 3. Additionally to the specific gate inputs/outputs showed in fig. 3, there are also, in the parking place all the sensors/actuators illustrated in Group B, fig. 2.



Group A: sensors and actuators



Group B: sensors and actuators

Figure 2: Intelligent Home: Sensors and Actuators.

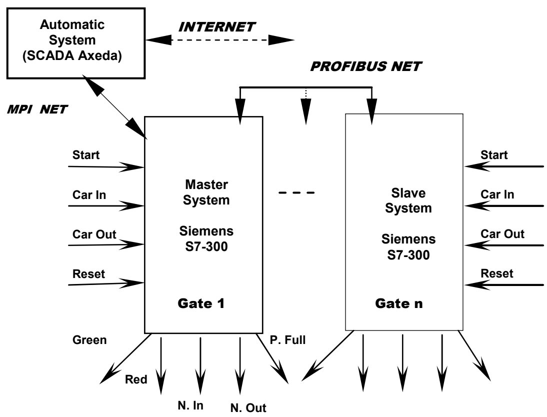


Figure 3: Parking Place Gate inputs/Outputs.

3 MONITORING AND CONTROL STRATEGY

3.1 Control Strategy

The strategy developed in this paper is commonly known as a two-level hierarchical control model as it integrates a first control loop that is managed by local PLCs with a second loop which is performed by a SCADA supervisory system that monitors globally the several distributed local systems (Figueiredo, 2005b). Figures 4 and 5 illustrate this control strategy: The inner control (first loop) and the outer control loop.

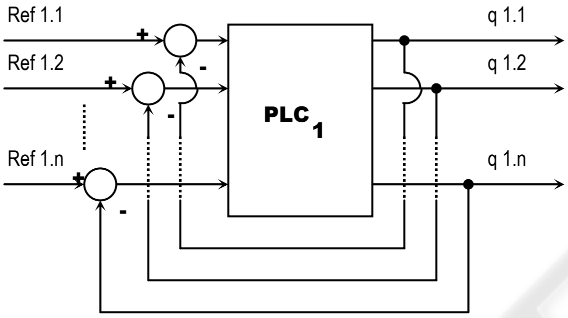


Figure 4: First Loop Control – PLC Local Control.

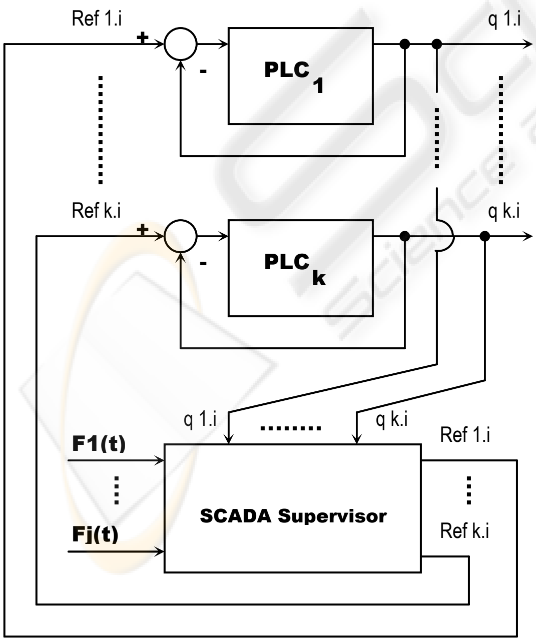


Figure 5: Second Loop Control – SCADA Supervisor Control.

Applying this strategy to a complex building that is instrumented and monitored through a SCADA supervisory system, we can manage globally the entire net of field PLCs that control locally each own process.

The upper level control law, having a global system overview, generates the set of references for each local process (PLC) avoiding possible conflicts in emergency situations. The input functions for the upper control loop are mentioned as comfort laws, safety laws (F1(t), … ,Fj(t)).

3.2 PLC Network and SCADA Supervisor

The developed strategy to cope with complex buildings with a huge set of geographically distributed actuators and sensors is implemented through a PLC network (fig. 6) consisting of several slaves PLCs connected to a master PLC via Profibus/ DP network.

Each slave PLC hosts several control programs which selection is made either locally, via an HMI (Human Machine Interface) or remotely, via the master PLC (PLC 0), which is connected to the server PC, via RS232/ MPI Siemens protocol, where the SCADA application is running.

The server PC is simultaneous a SCADA server and an internet server, as the implemented SCADA application is web enabled. All process variables are available at the SCADA PC as these variables are on-line available through the Profibus/ DP Master-Slave network.

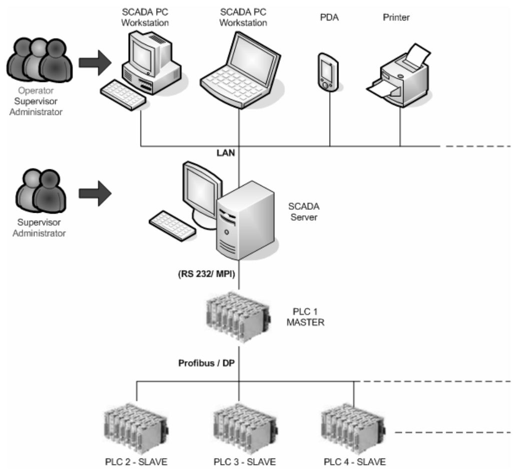


Figure 6: PLC Network and SCADA supervisor.

3.3 SCADA Supervisory Control Loop

System Description: The SCADA system used to implement this monitoring and control strategy was a commercial platform: Axeda Supervisor Wizcon for Windows & Internet V 8.2.
The Driver used in this application to establish the communication Scada system – Master-PLC was the Siemens RS232/MPI interface, via the Siemens software Simatic S7 Prodave. According to this communication Protocol, a PLC digital variable address must be defined as NNTXAAAABB, where:

NN = PLC address (from 0 to 32);
T = memory area type (I for Input, Q for Output and M for memory);
X = variable type (B for Byte, W for Word);
AAAA = slot address (from 0000 to 9999);
BB = variable address (00 to 17).

In the specific case of the prototype tested in this paper, it is necessary to exchange integer values between the several local PLCs in order to update the system overall capacity (actual number of free places in the park).

The SCADA system receives continuously the information from all PLCs in the network through the master-PLC and calculates the number of free places available in the parking place. This integer values is on-line updated to the PLC network and according this value the corresponding state of the entrance lights (red/ green) is determined. When the number of free places equals zero, the entrance red lights in all the park gates are set on, until a car exits the park. This car exit can take place from one of the several available gates in the parking place.

The transfer of integer values between the SCADA system, the master-PLC, and forward, to all slave-PLCs, it is possible through Data Base transfer. According to the MPI protocol, an integer value to be transferred from the PLC to the SCADA system and vice versa, it must be addressed as NNTXDDDAAAA, where:

NN = PLC address (from 0 to 32);
T = memory area type (D for Data Block, I for Input, Q for Output and M for memory);
X = variable type (B for Byte, W for Word);
DDD = Data Block identification (from 000 to 999);
AAAA = variable byte address in Data Block.

Among the main functionalities of a SCADA system there is the so called “Tag”. A “Tag” is a defined variable that permits the exchange of information between the PLC network and the SCADA system, in a real-time environment. There are usually three types of Tags: PLC, Dummy and Compound. In the PLC Tags the PLC sets the variable values that are directly transferred to the Scada program. In the Dummy Tags the value is set by the user on the Scada interface and transferred to the PLC address. Finally Compound Tags are set by the Scada program, following the programmed operations.

When defining the Tags a set of information is required, namely: Tag name, Description, Tag source, Driver, Sample rate, Address and Tag Type. An example of such Tag definition is illustrated in Fig. 7.

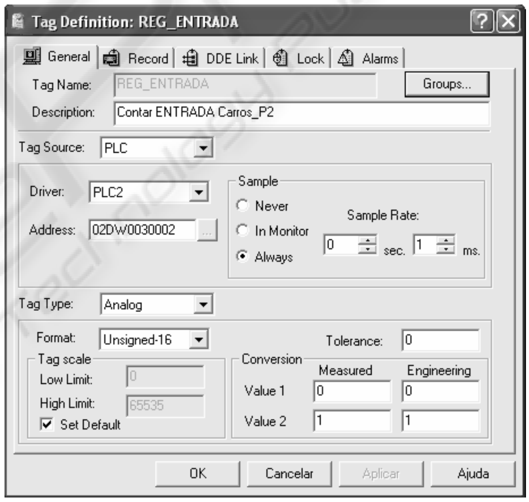


Figure 7: Tag definition.

The Scada main interface between the system and the user are the application images. The image building is a functionality of all SCADA systems and its main function is to permit the user a quick visual identification of all system functional characteristics. An easy identification of the system Inputs and Outputs permits the user an effective monitoring and a quick actuation on the process, when it is necessary.

The developed application used important features that we named animated images. These images change geometry characteristics and colours when their digital variables change the state (on/ off).

3.4 PLC Master-Slave Network

System Description: The PLCs used to implement the local control strategy were the Siemens S7-3**.

The Siemens software used to implement the PLC application was the Simatic Manager. The program language used was the Ladder Diagram (LAD).

A PLC master-slave network was established through a Profibus protocol (Siemens, 2001).

The main characteristics of the PLC master-slave network implemented in the prototype is shown in fig 8. In fig. 9 the overall PLC network implemented in this paper is presented.

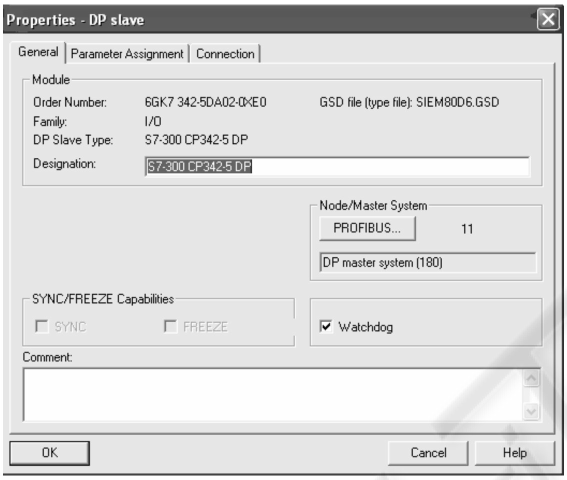


Figure 8: Main characteristics of PLC Master-Slave network.

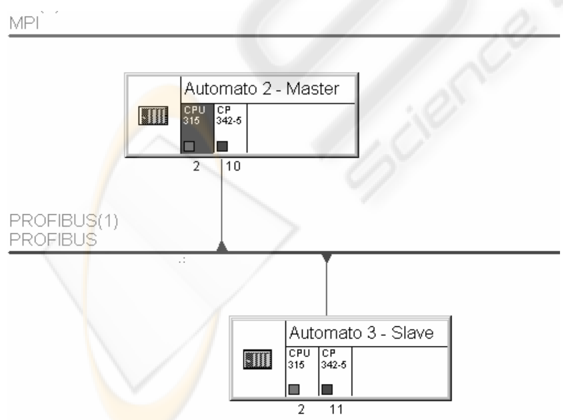


Figure 9: Profibus Master-Slave network.

Local Control Strategy: At the local control level, several algorithms have been developed for the intelligent building: Property Violation, Temperature control, Gas and Water leakages, parking gate management…

Using the Grafcet methodology, the main characteristics developed for the parking gate management is presented below (fig. 10).

The input variables referred in fig. 10 represent:

Out = binary sensor indicating a vehicle that wants to exit the park;

IN = binary sensor indicating a vehicle that wants to enter in the park;

Free Place = integer value representing the actual free places available in the park, at each time.

The output variables referred in fig. 10 represent:

Green = Green light at the parking gate;

Red = Red light at the parking gate;

Gate = Gate actuator that closes and opens the parking gate;

FP = Function Block that calculates the actual Free Places in the Park. This Function Block is associated with a Data Base Block, which is accessed by all PLCs connected in the PROFIBUS network.

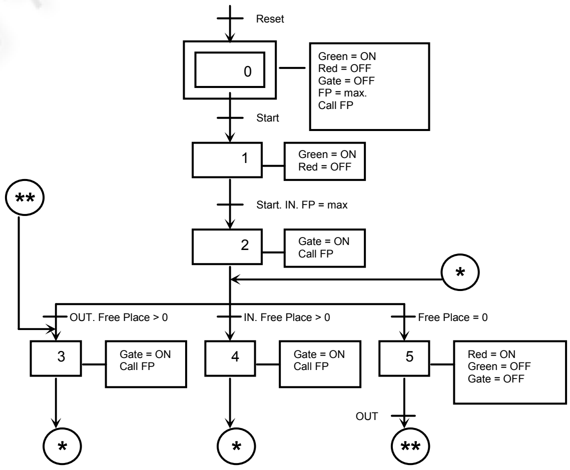


Figure 10: Grafcet for Parking gate management.

Together with this gate management system, there are also other automatic systems running in the local PLCs: property violation control, temperature control…

4 EXPERIMENTAL SETUP

The developed application to monitor and control intelligent buildings has been implemented in an experimental setup to control a parking place with multiple distributed entrances/exits.

The prototype developed has the following software and hardware requirements.

4.1 Software Requirements

The Scada system was developed over the platform Axeda Supervisor Wizcon for Windows & Internet V8.2.

Siemens Simatic Manager V5.2 and Siemens Simatic S7 Prodave V5.5 were used to program the PLCs and to establish communication between the Scada system and the Master-PLC, respectively.

The Siemens NCM S7 for Profibus was used to configure the Profibus Master-Slave PLC network. (Siemens, 2001)

4.2 Hardware Requirements

The PLC network implemented had two PLCs Siemens S7-3** (one PLC controlling each gate). The PLC which controls the gate 1 was set as the master PLC and it was connected to the Scada System via the Siemens RS232/MPI protocol.

The gate sensors and actuators were simulated through the FESTO interface SYSLINK (fig. 11).

4.3 Experimental Results

Developed Application Menus:

Several Scada menus had been built. The main characteristic of a Scada Menu is to be simple, explicit and quick on transmitting the information to the system operator. The first Menu developed is a general overview Menu, named "Main Menu" which gives us access to the several sections of the intelligent house and permits the operator to leave the Scada control and monitoring application (fig. 12). Climbing the tree structure from the main menu we can reach anyone of the floors that compose the house. In Fig. 13, the parking place is shown. This Menu informs about the number of vehicles that entered or left the park at each gate and the number of actual free places in the park. Additionally it shows the state of all sensors and actuators in the parking place (lights, smoke, gas, water…). From this Menu we can return to the main Menu, or to jump into the overview menu.

Specially referring the sensors: lights, water and gas leakages, the programmed animated images characterize the binary sensor states by a change of colour: green indicates the sensor is activated and red indicates the sensor is inactive.

Concerning the property violation system, this application developed an alarm that actuates when the corresponding sensors are actuated (in fig. 13, sensors s16 and s26 are movement sensors).

Figure 11: Experimental Setup for gate management.

Figure 12: Scada: Main Menu.

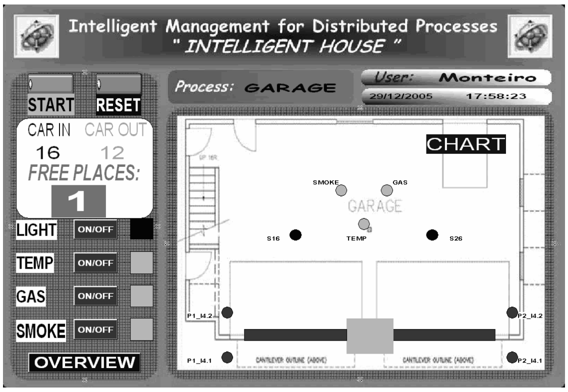


Figure 13: Scada: Parking place menu.

The park overview menu is shown in fig. 14. It gives the system operator a quick overview over the parking place capacity (number of cars that entered or left the park at each gate, actual number of free places, gates state…)

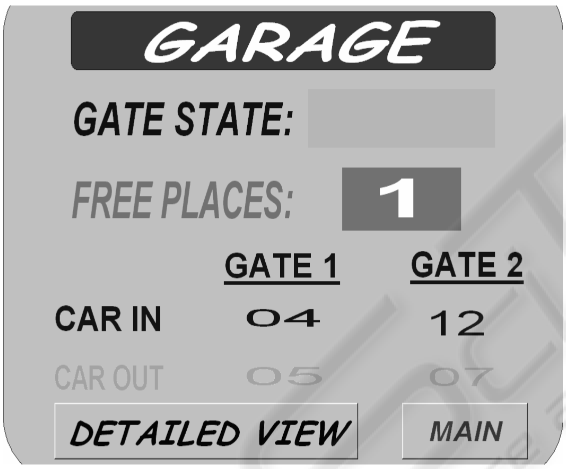


Figure 14: Scada: Park Overview Menu.

5 CONCLUSIONS

This paper shows the great potential of a control strategy over two lawyers - distributed local controls which are connected with an intelligent centralized control, which has a global view over the system, and permits an actualization of the local references, knowing the complete state of the entire system.

The tested prototype worked perfectly showing the huge potential of communication systems between distributed processes. These communication systems allow intelligent centralized algorithms to manage decision making problems in real-time environments. The system presented in this paper combines several technologies (local PLCs, SCADA systems and network communications) to reach the goal of efficient management of distributed processes.

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