INTEGRAL SYSTEM FOR REMOTE CONTROL OF BUILDINGS & SERVICES (SITES)

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Abstract: SITES provides a system to maintain, administer and control industrial plants. Keeping in mind the installation's maintenance cost. To obtain a system with optimum and versatile control, several Master modules that control a series of Slave modules are provided; the Slaves acquire data at the field level. In each installation there is only one Master and a certain number of Slaves (according to the installation's size). All these modules are connected through RS-485 network, ideal for industrial facilities. To increase reliability, two separate communication lines are used, if the Master doesn't receive any response from a line, it will try the other one.

Keywords: industrial, installation, control, administration, maintenance, Master, Slave, Personal Computer, RS-232, RS-485.

1. INTRODUCTION

The main goal of SITES project is to develop a complete system to maintain, administer and control industrial plants, or any other installation, susceptible of maintenance. Also keeping in mind the installation's maintenance cost.

To obtain a system with optimum and versatile control, several Master modules that control a series of Slave modules have been developed (up to 62 slaves for each Master); the Slaves are the one which acquire data at the field level.

In each installation there is only one Master module and a certain number of Slave modules (according to the installation's size), between 1 and 31 or 62 depending on the type of network used. All these modules are connected to a balanced communication network of type RS-485, ideal for industrial facilities as it avoids the interference produced by the industrial machinery. To increase reliability, two separate communication lines are used (main and redundant), in such a way that, if the Master doesn't receive answer from a line, it will try the other one. The Slave always responds on the same line from which it was being interrogated. The general architecture of the SITES system is shown in figure 1.

For years the automation of the processes has been a strong tendency, which reduces the cost of manpower and finally obtaining more profit. Nevertheless, the existence of personal, in charge of the maintenance of these equipments continues being indispensable. The SITES (Integral System for Remote control of Buildings & Services) project arises as a solution to solve the requirements of a system capable of distance supervision of the status of a specific installation and able to perform changes on it when required. This will allow a reduced number of staff, providing at the same time more security to the system, on warning immediately on any anomaly that could occur in the installation, which decreases the repair time, providing in result more benefit for the company. Among other of its advantages is the centralisation, historial of events and the reliability of the information obtained. The Slaves are responsible for obtaining this information and later to send it when being interrogated by the Master. The Master stores in its memory the data obtained by different Slaves. The memory is organised so that in the maximum configuration (62 slaves), the Master is able to retain the data at least during 8 or 12 hours in its memory. In smaller installations the duration is increased, as there is more memory available. On being able to communicate through RS-232 interface to a PC, all the information is passed as a block from the Master to the PC in the next communication, directly or through a Modem. The Master does not require to be connected always to the PC or the modem. Although the Master governs the installation, it can be programmed from the PC, the same is true for any Slave in the same installation even it is not connected directly to the PC. In addition, even special commands can be sent to the Master or any Slave.

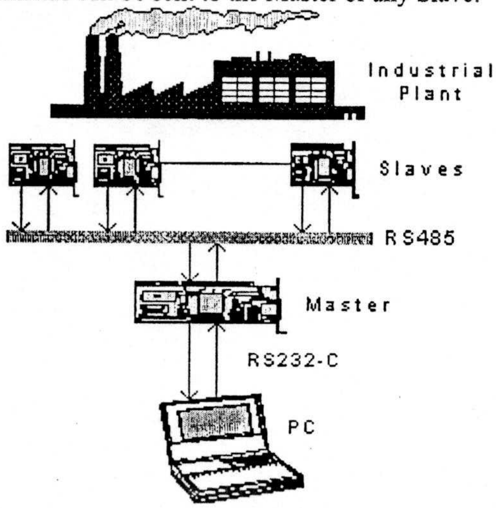

Figure 1. General Architecture of SITES

Therefore in any moment you can connect a portable computer to a Master and supervise or program the installation using the visual possibilities provided by the software in PC. Once the data reaches the PC, the software processes it, well to carry out reports basing on the historical data or to analyse shortcomings in the installation or any other analysis that may be required to be carried out.

1.1 Characteristics.

Initially, the field defined for SITES project is limited to facilities with relatively high response time, mainly the control of temperature and illumination facilities of the buildings, as well as the control of the irrigation of the gardens in their environment. The control system must fulfil these requirements, although certainly its final characteristics will permit it to broaden its field to other facilities where the response time is not so high. Due to the requirements previously exposed, the system was developed with the following characteristics:

- *Flexible,* so that it can be adapted to any installation, through the appropriate transducers.
- *Modular,* it implies that it can be configurable in number, allowing their adaptation to facilities of different sizes.
- *Economic,* it may offer a good price relationship with the benefits that it can offer.
- Must allow the *maintenance administration* of an installation, which means it, may provide information about the installation's status.
- *Control* over its elements, in such a way that it can have autonomy in the absence of the staff and always controlled by a software program previously configured.

1.2 Components.

The SITES system can be divided in 4 parts:

- *Master* module along with the communication network to administer the communication with Slaves.
- *Slave* module for data acquisition, acquires information about the system's behaviour, such as, its name indicates.
- A modular system for *signal adaptation* that converts different signals managed by the Slave module to actual signal values present in the installation.
- PC Software for the final interpretation of the information and making decisions to act on the system, as well as for the whole initial system programming.

For the development of the complete system two types of Application Specific Integrated Circuits (ASIC) were built using Standard Cell technique, these ASICs were developed in the GAME Project of the EEC.

- Communication ASIC, is responsible for administering RS-485 communication network, detecting and fixing errors that occur in the Master-Slave communication, and therefore, they are located in both modules.
- Data Acquisition ASIC, serves as the interface between the Slave modules and the field signals, implanting different types of digital and analogical, both inputs and outputs in a single integrated circuit that will be controlled by the CPU of the Slaves. Each Slave can be configured to have from 1 to 6 ASICs and each one of them can govern 32 digital inputs, 32 digital outputs, 4 analogical inputs, 1 analogical output and alarms.

1.3 Communications

The communication PC-Master and Master-Slave will be carried out in asynchronous half duplex serial mode. The connection PC-Master is based on point to point connection model, characteristic of the standard RS-232-C, where two data treatment terminal equipment (DTTE) are connected. In this case, the initiative in any moment can be taken by any of them. Whereas, in the Master-Slave communication, the communication will be carried out following the interrogation method which is a centralised multipoint connection procedure. A data treatment terminal equipment (Master DTTE) connects to various secondary DTTE's (Slaves), in such a manner that the central station decides always with which station it may communicate. Thus the slaves will only respond on being interrogated by the Master without taking the initiative by themselves, so there is no need to implement collision detection and concurrent access resolution.

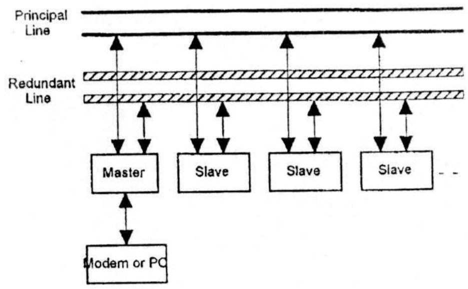

Figure 2. Communication Structure

To improve the reliability, two separate communication lines will be used (main and redundant), in such a way that, if the Master doesn't receive response from a line, it will try it from the other one; the slave will always respond from the line that it received the interrogation. The communications structure is described in the figure 2.

For the Master-slaves communication, a system is required with more quality and immunity to interference. Since the different Slave modules will be distributed at different data acquisition sites within the installation. So the communication distance and the possibility of interference will be greater. For these reasons, this communication is done using RS-485 standard, which permits to communicate through a cable upto 1200 meters, with enough immunity to noise and is especially suitable for industrial facilities.

2. MASTER MODULE

Each Master module has the characteristics described below:

- Must administer the network communication with Slaves, deciding always with which Slave it needs to communicate with.
- Possibility of connecting to a PC through RS-232 interface. This connection doesn't needs to be continuous but periodic as the Master will store the data and transfer it later as a data block.
- Possibility of substituting the computer by a modem, so that different installations can be controlled from a single remote site through a telephone line.
- It is responsible for bypassing different configuration changes generated by the computer to the corresponding slave, in this way redefining its operation.
- Periodic storage of not only the installation's status but also the incidences produced in every moment, through sampling, where the time interval can be configured through the PC. This data will be obtained by different Slaves and later passed on to the computer. Once stored in the computer they are erased from the Master's memory, which will start once again to collect data.
- It must be able to establish a modem connection by itself to a central computer, or at least capable of making an alarm call to it, so that if a dangerous situation is created within the facility, the control centre must be aware of it.
- Each Master module must be capable of controlling two communication ASICs and thus two different networks, so it is able to control twice the number of Slaves.

2.1 Structure of the Master Module.

The different parts of the Master can be identified as shown in figure 3:

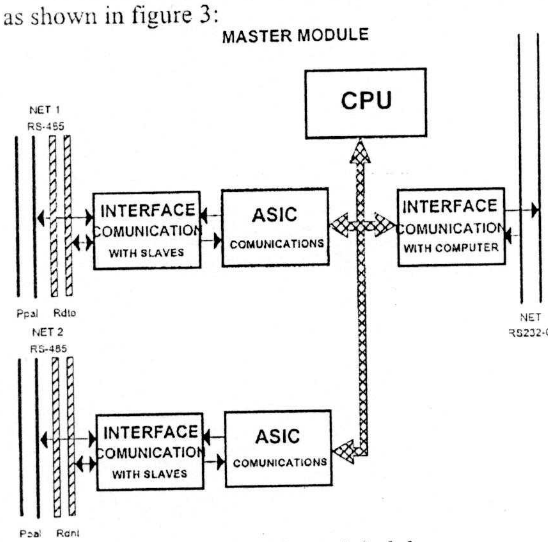

Figure 3. Master Module

The first thing to observe is that there are two communication procedures.

- It has the possibility to communicate with a PC through the microcontroller's UART.
- It can communicate through one of its communication ASICs. For every ASIC there are two physical lines (principal & redundant). The Master decides from which channel, and from which of its line it wants to send the interrogation command. The Slave must respond from the same line that it received the interrogation.

The modules are identified by five address bits (A0-A4), and the Master-Slave communication by 2 bits (V1 & V0), all of them can be configured externally through jumpers. The message generated by the Master module, includes in its header the Slave's address to which it is send, whereas the response messages created by the Slave module include their own address. A single bit in the message's header identifies if the message circulating on the line, is delivered for a Master or a Slave. The messages can have a variable number of bytes, identified by two header bits. Each byte contains a parity bit. The data words are followed by two BCH coded words for error detection.

The communication speed with the PC is configured by software, and the following speeds are allowed: 1200, 2400, 9600 y 19200 bauds. Whereas the communication speed with the Slave modules, as mentioned earlier, can be selected by an external switch to communications AISC to one of the following values: 1200, 2400, 4800, 9600 bps.

The Master module's CPU has the following characteristics:

- It is responsible for sending different commands generated by the PC for the Slaves, administering their automatic retransmission in case of error, and generating error messages for the PC in case it is not possible to communicate with them. These transmissions will be made when the master is in *command mode*.
- In *autonomous mode*, it periodically performs sampling of the active Slaves recording the installation's status, where the time interval is previously adjusted by a command. On the other hand, whenever it is not busy with sampling, it will ask for incidences to the active Slaves, generating alarms in case there is any communication problem. In the moment it has any type of data, it will take the initiative to send it, except when this option may have been cancelled by software. Once transmitted to the computer and acknowledged correctly by the computer, the data is removed from the Master's memory, which will start to collect the data again. If no response is received from the computer, the data is retained in the memory, so that it can be transmitted later when the connection is possible. If for any reason, the master is found to be in autonomous mode, when it receives an instruction, it will temporarily pass to the command mode to execute it. Returning later to its previous state, except when the received instruction is "change to command mode", in this case it will be left in command mode until it receives a "change to autonomous mode" command.
- Another CPU function is to manage not only one but two communications network (as described in the previous figure), each of them with its own principal and secondary network, deciding in every moment with which Slave it wants to communicate. So as to communicate it will have to employ both communications ASICs and software in the CPU, which converts commands, sent from the PC to the adequate network and reconverts it after the message has been received. This will permit the Master to be configured on both networks, or to any one of them, giving more flexibility to the system. In consequence it allows to duplicate the number of active Slaves too, from 31 to 62.
- On the other hand, it also permits RS-232 standard serial communication to a PC or a Modem. In addition software is included to modify the communication speed. For more security, a speed confirmation command will be included in the software, so that, if the Master doesn't acknowledges a correct response to this command, it will reject the speed change command from the PC returning to the previous speed.

3. SLAVE MODULE

The principal characteristics of each Slave module are described below:

- It has certain autonomy, for that it possesses a versatile programming system, similar to a programmable automaton, so that a program can be created in Slave module's own language, transferred to it and executed whenever it is desired.
- It constantly revises different input signals and, in case there are variations, acts in consequence according to the program it has been given.
- It governs different output signals according to predefined values or the status of input signals, that is, the outputs can have values that are constant or depend on inputs, and always they can be programmed.
- It stores in non-volatile memory all the incidences of interest that occur in the input signals, to send them later to the Master on which they depend, and only when they are asked.
- Store and manage all the watchwords (configuration values) of the inputs and the outputs, which are received from the Master, which in turn receive them from a computer.
- It will always be monitoring the RS-485 network, waiting if the Master requires their service both for giving the information it has and to reorganise its configuration.
- Deliver the current status of different corresponding inputs and outputs to the Master when it requires them.

Possibility to connect with a computer through RS-232. This possibility is included in the Slave module due to various essential reasons: Due to installation problems, the communication with the Master through RS-485 may result inaccessible, so the Slave is left incomunicated. On including this RS-232 interface, when a Master detects a Slave has disappeared, it can send an alarm to the PC, and once the user receives this alarm, he can go directly to the corresponding Slave and communicate directly with it. On the other hand, if one needs to extend the installation, it is not necessary to program the new Slave through RS-485. But one can install it at his working site, program it directly from the RS-232 serial port, and once prepared and having passed all the necessary tests, connect it to the RS-485 network and leave it to be managed by the Master module. Moreover, it lets the Slave to be installed in absence of the Master module when it is not necessary to elaborate reports about the continuous state of the installation, as it works with its own internal programme and it is also capable of being configured directly from the RS-232. So for small facilities, where there is no need to control it from different points of the same facility, such as temperature control system of a building or neighbourhood community, installing a single Slave module, the control requirements will be perfectly covered.

3.1 General Description of the Slave Module.

If we need flexibility so as to adapt to different applications in higher layers of the protocol, it is absolutely necessary to implement layers above the 2nd layer of OSI through a micorcontroller. It will interpret the messages received by the communications ASIC, generate response messages to the interrogations, and passes it on to the communication ASIC to transmit it through the line. The microcontroller, in the case of Slave module, also controls functions for data acquisition & external devices through a second type of ASIC (data acquisition). There may be several of them in a Slave, so as to allow modularity in the field inputs and outputs which can be controlled by the module.

Within the microprocessor systems are the programmable automatons, which include a monitor programme in an EPROM memory which lets the user or the programmer, to perform direct operations on system's different outputs and reading and decision making depending on the values presented at the inputs. These upper level operations are joined in a sequence forming a program called a cycle, and are stored in a second memory of the automaton. In this way, when the equipment is started, the microprocessor's monitoring programme starts loading sequentially the instructions included in this programme and goes on translating them to microprocessor's basic instructions to execute them. With this type of system, it is very easy to change the system's functioning logic, as it provides a series of input variables, a series of internal variables, and a series of output variables, and all of them are managed directly from the instructions provided by the monitoring programme. Thus, only a programme has to be created in a level much more higher than the one used by the microprocessor and transfer it to the equipment by any communication system.

Additionally, the fact that system inputs and outputs are easily managed by this programme, lets the hardware equipment to adapt in a simple manner to any installation, with only creating a small programme adapted for it. Definitively, the programmable automatons, are not more than small computers dedicated exclusively to manage digital or analogical signals as prescribed by a preestablished programme.

The automatons, execute the introduced programmes in a particular form, called the cycle programme. This is due to the fact that an automaton is not dedicated permanently to the established programme, but in its execution there are three clearly differentiable phases:

a) Data acquisition phase:- During this phase, the automaton performs a sampling of all of its inputs so as to process the obtained information later.

b) Cycle execution phase:- In this phase, all the instructions included in the preestablished programme are executed, starting from the first and finishing on the last one. During the execution of a cycle, not a single output is affected directly by the instructions, but their copy is used in the memory. Similarly, none of the inputs used in the programme will change its state during the programme's execution, as they are only read once in the cycle (Phase A).

c) Data download phase:- This phase is performed once after each time the cycle finishes, so that each output will change to the value it was assigned by the cycle programme.

3.2 Structure of the Slave Module

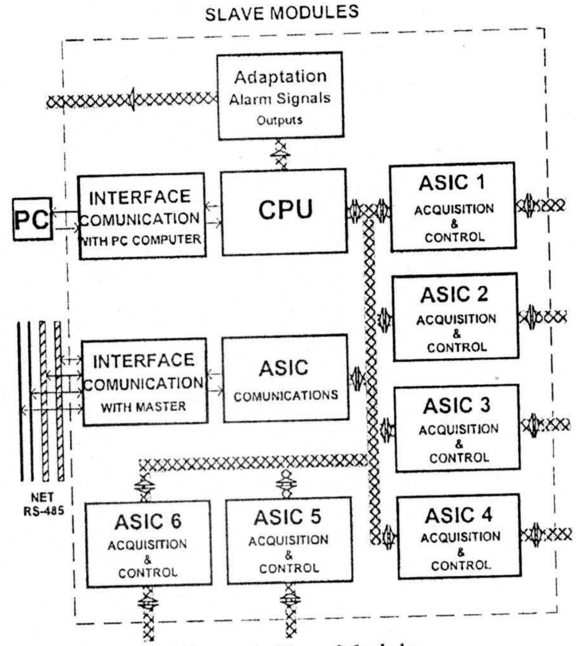

Figure 4. Slave Module

This part of the project has been oriented to the format used by the existing systems, where programmable automatons are used. So that's why each Slave module is based on a system similar to a programmable automaton capable of managing all the inputs and outputs of a data acquisition and control ASIC. In addition, each Slave module also governs a communication ASIC through which it will maintain contact with the Master module that manages the RS-485 network to which the Slave is connected.

The Slave module is based on the block diagram described in the figure. In this diagram one can see, the Central Processing Unit that governs the module, and the included non-volatile memory that will serve to store both the cyclic program to execute and the data required to manage the module alongwith the different incidences that occur.

There are two communication procedures:

- Through the microcontroller's UART, it is provided with the facility to communicate directly to a computer through RS-232.
- Through a communication ASIC it can communicate to the Master module which manages the network. For each communication channel there are two physical lines (principal & redundant). The Master is the one who decides from which channel and which of its line
- it may send the interrogation, the Slave must respond on the same line from which it was interrogated.

3. PC SOFTWARE

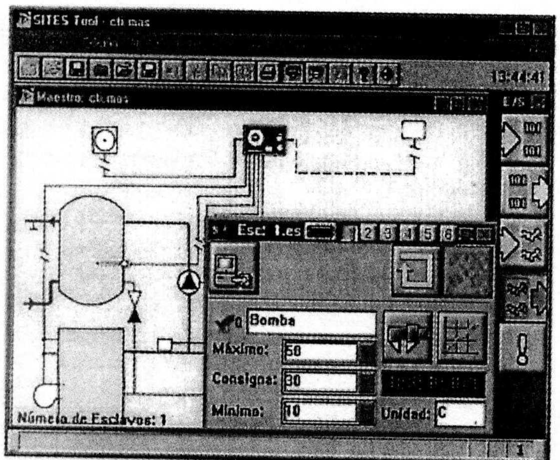

Figure 2. Example from the PC Software

The software will provide a graphic interface to the installation, allowing weather to supervise it or to program it. It is capable of working with multiple installations. For security reasons it restricts access to a particular installation until the privileges are granted, different user levels can be defined to maintain the installation.

Function Mode: There are two main function modes, Supervision and Programming. In Supervision one can only watch the installation status (Master and Slaves). Whereas in Programming Mode, it allows to make changes in the installation and one can even program the Master or the Slaves. The application is designed to work in background mode so that the PC can use any other software while the installation is being supervised or to process the data obtained from the installation by any other software. To access the Programming mode one needs to know the installation password to access this mode, as some security is required. The software uses Multiple Documents Interface (MDI) to show the Master and the Slaves present in the installation. The window, which represents the Master, shows the installation's diagram from where the general parameters of the installation and Master are controlled. On the other hand the Slave windows represent the information specific for every Slave. The Slave window has five different views representing digital inputs, digital outputs, analogical inputs, analogical outputs and alarms, alongwith the possibility to choose between any of the six possible ASICs.

4. SIGNAL ADAPTATION MODULE

Some signal adapters are provided, which adapt different electrical levels present in the installation to levels which can be used in the Slaves, in turn these signals are used by acquisition and control ASICs

The signal adaptation module has the following characteristics:

- The system must be modular, so that to every input or output a corresponding adapter can be connected to the real external signal to be controlled or supervised.
- It must be of reduced dimensions, as every slave module can govern a lot of input and output lines, and each of these requires an adapter, the overall size grows quickly.
- It must provide signal adapters for standard signal levels used commonly both digital and analogical, so that the system may adapt to sensors and actuators normally used.

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