The Ateneo SCADA Project

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A proactive and productive management approach wants real-time business productivity information compared with profitability indices, allowing production to be redirected towards better profitability now and not later.

Abstract : *The Ateneo SCADA Project (Supervisory Control and Data Acquisition) prepares students to become more aware of profitability as the primordial goal of a business enterprise and that the technology that they bring with them are supportive of this goal. The setting is the conversion of Room F-311 into an intelligent room. The "ingress and egress" function allows access only to authorized personnel. The illumination function maintains the lighting conditions at the working surface at a constant level. The air-conditioning function controls the amount of energy removed from the room. The air-circulation function achieves almost uniform temperature within the room. Each of these functions reside in independent computers (as in "distributed control systems" or DCS), which are managed by a "local master" through the computer's communication ports. Failure in this communication system would make the independent computers perform their respective "fail safe" functions. The "local master" is under the direct supervision of a "remote master", but operates in accordance with pre-determined algorithms if the remote master is not available. Communication with the "remote master", which can be anywhere in the world, is by telephone. This provides added security to the system, since the communication protocol is proprietary and does not follow any standard. Dynamic plots and graphs of profitability and cost indices are based at the "remote master". Under normal conditions, all control parameters ("set points") originate from the "remote master". This simulates the active control, which the Head Office wields over the production function.*

In implementing the Project, students build and commission computer-based interfacing circuits for the control of devices and the subsequent generation of feedback information for the controls algorithms. Specific areas are (1) control of power electronic devices, (2) the measurement and control of analog-based devices, (3) the measurement and control of digital-based devices, (4) the design and implementation of proprietary communication protocols, and (5) the graphical representations of profitability parameters.

As an added feature, illumination and temperature sensors are designed and built by the project and not procured.

I. Introduction

The Information Age. A business concern manages profitability essentially through revenues and cost items. Profitability is decreased as the cost of producing a unit of product increases. This condition could go on undetected until the next management review process, which could be daily, weekly, etc. In the meantime, however, profitability is eroded by the minute.

One of the agenda of the review process may be the assessment of variances, such as “the past week” VS “the week before last”, or “month to date” VS “month to date last month (or last year)”, and so on. This kind of review process looks at the history of the business, whose profitability may or may not been improving lately.

Students of Ateneo’s ECCE Program enter the professional world prepared for the challenge of “on-line”, “real-time” business information. He is prepared to transcend the traditional “variance” review process, and introduce “rate of change of variance” as an information management tool. He is also prepared to automatically send "accurate, relevant, and timely information" to a responsible official of the company at any time that bands, or limits of technical or business parameters are crossed.

This means that the company need not wait until the next management review for it to realize that the company “has already lost” substantial profitability points. When the “rate of change of variance” becomes the guiding principle, profitability trends that can become disadvantageous can be spotted and immediately corrected. At the same time, trends that are advantageous could lead the company to ask the question, “what did we do right?” so that it can be assessed and replicated.

II. Project Description

1. Overview

A strong commitment of the participants of the Ateneo CE 150 (Computer Interfacing) class to the project, was the reason for the project's success. The class designed and commissioned a system which mimicked a "distributed control system" (DCS). Some of the more significant features of this pseudo-DCS are the following:

- In a DCS, each control and/or monitoring function is performed by relatively independent microcomputers, with common communication lines to a “master”, which is able to communicate with the outside world.

- In the project, each function is controlled by independently running Personal Computers, which are linked by a communication system to a “local master”, which is also capable of communicating with the a “remote master”, anywhere in the world, to receive “set-point” values for each of the control functions, and to transmit data to that “remote master” as required.

- Control philosophy is that all systems will "fail" on the safe side. Each function is provided with arbitrary fail-safe control philosophy that are appropriate to the equipment being controlled. In case of the failure of the local master, for example, the air-conditioning system will shut down, but the lighting system will continue to be operational. However, failure of the control computer of the lighting system will case the lighting banks and the fans to shut down.

Its course framework was derived from three sessions of class planning, and this is: *Supervisory Control and Data Acquisition (SCADA) Project : Automation of Room F311*. The broad outline of the course is as follows.

Introduction
Module 1 - Overview
Module 2 - Inventory of Competencies
Module 3 - Parallel Port for Interfacing
Module 4 - Serial Port Interfacing
Module 5 - Serial Data Transfer (PC-to-PC)
Module 6 - Serial Data Transfer (PC-to-PC using Modems)
Module 7 - Remote Control of the SCADA Project Via Telephone
Module 8 - Conversion of the one-to-one RS232 into a Multi-drop System
Module 9 - Thyristors
Module 10 - Stepper Motors

2. Features

A. Management of Project

The project also simulated a contract project. This included quality, milestones and project acceptance, which was in the form of a functional presentation of the project to the members of the Ateneo ECCE Faculty on October 5, 2000. Listed below are other information related to the management side of the project.

Project Leaders
Project Manager -- Albert Causo
Assistant Project Manager -- John Paul Fajardo
Logistics and Documentation -- Tyrone Tai
Quality Assurance -- Joanne Dy

B. Project Components and Milestones

a) Lights - Lights and fans will be individually controlled using set points given by the "local master controller". (John Paul Fajardo, Maritoni Rose Lee, Mimienne Celemin)
SCR, RS232, ADC - Jul 25
DAC - Aug 1
Dimmer Function - Aug 15
Algorithms - Sep 1
System Commissioning - Sep 21

b) Air Conditioner - Compressor operation will be controlled ON/OFF to maintain temperature. (Ryan Chong, Thomas Edison Yu)
Relay, RS232, ADC, DAC - Aug 1
Compressor Control - Aug 15
Algorithms - September 1

System Commissioning - Sep 21

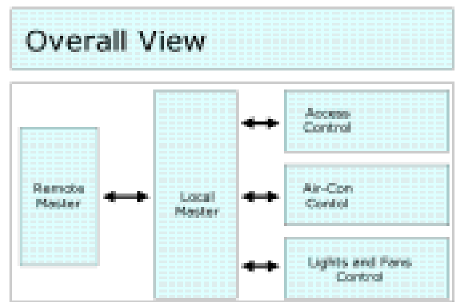
c) Access Control - Specific people are allowed or disallowed ingress and/or egress. (Rommel Castillo, Albert Causo)
Concept and Block Diagram - Jul 25
Procurement of Materials - Aug 1
RS232, Algorithms - Sep 1
System Commissioning - Sep 21

d) Local Master Controller - Gathers operating parameters from A through C, sends them to the "remote master" via telephone and receives set-point values for each of the operating parameters. (Tyrone Tai, Joanne Dy)
RS232 (4 slaves to 1 master) - Jul 25
Local Algorithm - Sep 1
Remote Algorithm and Modem - Sep 21

e) Remote Master Controller - Analyze operating parameters according to specific algorithms and send set points back to the local master. Calculates operating cost of F311 and plots this against time. It will also plot "rate of change of variance" from operating costs. (Rosby Quiambao, Antonio Ganzon)
Concept, Block Diagram, RS232 - Jul 25
Procure Materials - Aug 1
Algorithms - Sep 1
System Commissioning - Sep 21

3. Block Diagrams

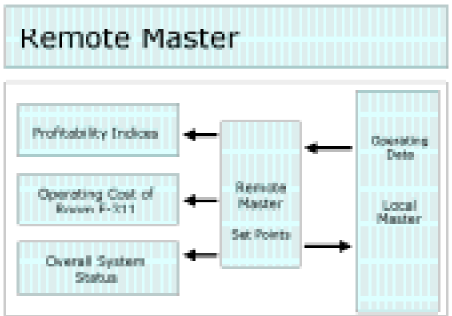
A. Overall View



The block diagram shows the local master as the hub of the operation of the SCADA. The design is such that any of the communication links (indicated by arrows) may be broken at any time without adverse effect on the operation of Room F-311. The *local master* manages the affairs of the SCADA, and the *remote master* may "dial-in" through a telephone line. For this project, the preferred interface between the *local master* and the *remote master* is via the conventional telephone, and not the internet, in order to demonstrate a way of safeguarding confidentiality. This is implemented through proprietary software, which the project also built.

Each block are run by independent personal computers.

B. Remote Master (The ***IT*** component)

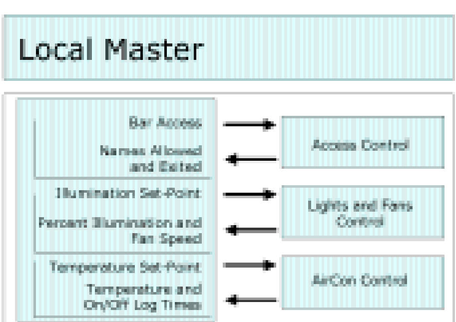


The *remote master* is the interface between the operating unit, which is Room F-311 and the "business" side of an operating concern.

It is the ***IT*** side. It deals with profitability indices, operating costs and overall system status.

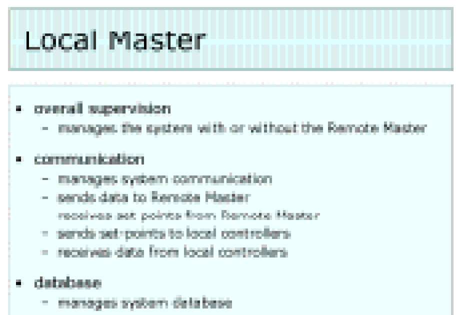
The *remote master* is provided with the ability to automatically dial the pager, the cell phone, or the land line of a responsible official at any time that a limit of a "business parameter" is crossed.

C. Local Master Overview



The *Local Master* is also capable of directly communicating with a company's responsible official in the event that a limit of the "technical parameters" is crossed.

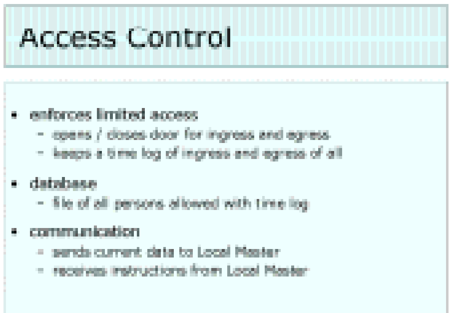
Local Master Detailed Function



It is at the *local master's* communication line with the various functions that the PC's one-to-one serial RS232 system is converted into one-to-many, without procuring an expensive converter.

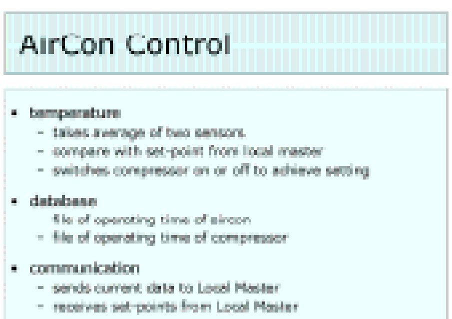
All data from each of the controllers are shown on the screen of the *local master* in real-time while it continues to collect data. It also has the ability to override the controllers by changing the set-point remotely. The purpose is to demonstrate a centralized management scenario.

D. Access Control



The *access control* system serves the business ***IT*** function by granting or denying access to individuals. Names of those granted access are stored in a database, together with the time they came in and the time they left the room. Each individual is assigned a "billing rate", and the cost to the system of the presence of an individual is also considered in the cost of operating Room F-311, and thus, finds itself at the profitability statements.

E. AirCon Control



The *AirCon Control* averages the readings of two sensors and compares this average with the set-point sent by the local master. A band of plus/minus 0.5 degree Celsius from the average is normal. An actual condition crossing this band initiates a routine.

The logic of the system shuts off the compressor of the aircon when the average temperature is 0.5 degree below the set-point.

However, the converse does not turn on the compressor. The program is equipped with an elapsed time monitor that "allows" the compressor to be turned on after three minutes of having been turned off. However, it "disallows" any command to turn on the compressor before three minutes has elapsed.

The mechanical reason for this logic demand is as follows:

a) the compressor operates at a high discharge pressure and a low intake pressure, such that the pressure difference between the discharge and the suction ports is highest when it is running.

b) upon its shutdown, the compressor slowly discharges the pressure at its discharge port to its suction port through the aircon's expansion valve.

c) the starting current of the compressor motor is smallest at the time that the discharge and intake pressures are equalized, and industry practice put this elapsed time between two and three minutes.

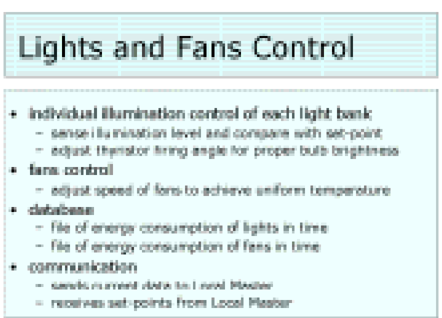
d) starting the compressor motor before the pressure difference has equalized provides it with an initial load against which to start.

e) if this pressure difference is too high for the motor, it may not be able to overcome it. Engineers say that this motor has a "locked rotor".

f) a motor in this condition presents a very low impedance to the line, and may burn itself, or raise the temperature of line connectors potentially triggering a fire.

The system uses a 10-ampere solid state relay for turning the fan on, and a 75-ampere solid state relay for the 2-hp compressor motor. This solid-state relay is capable of continuous operation at 10 times the compressor motor's operating current.

G. Lights and Fans

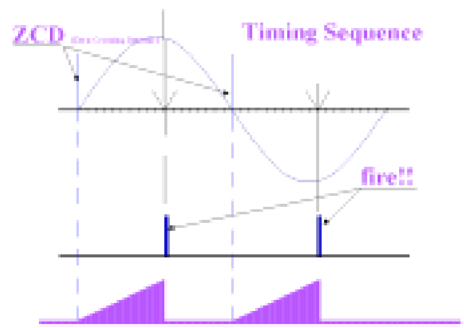


The *lights and fans* system controls three subsystems, namely, two banks of incandescent lamps, each rated at 200 watts and 230 volts, and one bank of AC ceiling fans with a load of about 100 watts.

a) Two light sensors monitor the ambient light at the surface of working table. Deviation beyond a certain band from the set-points trigger an adjustment in the firing angle of each of the thyristors controlling the two light banks and the ceiling fan bank.

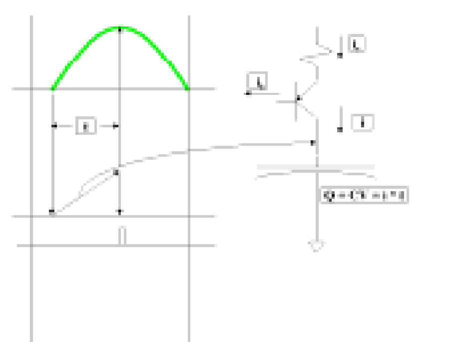
b) This system had to develop mathematical algorithms to compensate for the fact that the behavior of its light-sensitive resistor is not linear, nor does the brightness of the incandescent bulb change in a linear manner with energy or firing angle.

c) The first of the two charts that follow shows the "firing" of the Thyristor in relation to the "zero-crossing" detector ZCD. The second chart shows how to generate a "linear ramp" to generate the appropriate timing point after "zero-crossing".



Firing Chart

Ramp Generator Chart



H. Some Highlights

a) Except for the solid-state devices, the project used surplus materials from past experiments. This includes the keypads from a discarded computer keyboard, as well as, the motor to drive the deadbolt for the security function. Even the thyristors were procured from a surplus store in Marikina.
b) The temperature sensing elements are the *base-emitter* junction of a 2N2222 general purpose transistor.
c) The light sensing elements are the inexpensive light sensitive resistors readily available from Alexan and other stores.
d) The project confined components, mostly to the readily available LM555, LM741, and the general purpose transistors and opto-isolators.
e) Functions as intricate as the ones performed by the project could easily be implemented in lower level computers, such as an XT, AT, 386, 486, Pentium, or higher.

III. Conclusion

Some ask the question: *why do you have to re-invent the wheel?*

This author's answer is that we Filipinos must learn to *re-invent* and to *create* for our technology to mature.

It is very strongly suggested that the country should have a very strong program that puts value to initiatives that *unleash* the Filipino's *creative* potentials.

At the Ateneo de Manila University, it is our desire to send graduates out there who can introduce value, be happy for the feeling, and take pride that he has done so.

IV. Appendix

Outline of Learning Elements

Precaution section - Since this is an interface project between the PC and various other devices, a precaution was made that all interconnections be done through an opto-isolator IC (4N25)

Analog section
- the LM555, LM741, 2N2222, 2N2907 and several other electronic components proved formed the platform for the learning process
- the ability to use potentiometers in designing circuits proved to be effective time-savers for adjusting the quiescent state “zero” levels, and the required “span”

Analog sensors
- the base-emitter junction of the 2N2222 was utilized as the sensing element for temperature
- the light-sensitive resistor was utilized as the sensing element for illumination
- as a matter of policy, the project deliberately avoided purchasing calibrated, ready-made sensors
- this enabled the project to “create” sensors, in contrast to “using” sensors

Microcomputer and software section
- show outline of software to directly control hardware ports
- single-step each assembler mnemonic command
- in the case of “output” commands to see how the hexadecimal code at the

microprocessor's AX register is reflected at each of the pins of the specified computer port, whose address is contained in the DX register
- in the case of input commands, to see if the content of the microprocessor's AL register reflects the digital code presented at each of the pins of the input port, whose address is contained in the DX register

Digital output hardware section
- this section is composed of logic gates (74LS00, 74LS02, 74LS04), multiplexers (74LS258), latches (74LS273), and other TTL-compatible devices
- an output command, which is intended for a digital function is sent to an 8-bit latch, which is duly enabled in time
- similarly, an output command, which is intended for an function is sent to an 8-bit latch, duly enabled, and sent to a digital-to-analog converter (DAC)
- this analog signal would become one of the following set-point values: (a) the set-point for the illumination, (b) the set-point for the temperature control, and (c) the set-point for the fan speed.
- input function

Digital input hardware section
- this section is composed of the same TTL and TTL-compatible devices as the digital output hardware section
- in this case, an input command takes data from an analog value, which has been digitized at the analog-to-digital converter (DAC), whose output is stored in a latch
- the multiplexer (74LS258) takes the higher four bits (nibble) and sends it to four status pins of the printer port
- the software reads this value into the microcomputer's AL register and is shifted to the AH register
- the multiplexer then takes the lower four bits and sends it to the same four status pins of the printer port
- the software again reads it into the AL register
- the combination becomes the value of the digital code presented to the computer

Interface between the analog and digital signals - the LM555, LM741, 2N2222 and the 2N2907 have proven to be among the most convenient interface devices for shifting between analog to TTL and vice-versa

The communication interface between computers
- the serial port of the PC is designed for one machine communicating with another machine
- this design is for exclusive one-to-one communication
- a one-to-many, or a many-to-many, communication is often done with the use of hardware converters that could become quite expensive
- a one-to-many communication was achieved by the project with the use of very inexpensive hardware, consisting of opto-isolators to convert voltage levels found in RS232 ports into current loops and vice versa with the use of the opto-isolator 4N25.

The communication interface with a remote computer
- interface with a remote computer was via a 56K modem
- the use of non-standard communication protocols and software is one way of changing communication encoding algorithms at will
- this means that secure data transfer can be achieved without going for the purchase of software that can be rather expensive or engage consultant/vendor assistance to achieve the purpose
- the remote computer (or "remote master") has the specific function of

gathering business information so that it can plot trends in profitability.

- it assigns costs to the energy consumed in the electrical appliances in the room
- it also assigns hourly costs to each individual present in the room

The security section

- a person seeking access to the room will enter his unique code
- he also enters the same unique code when he leaves the room
- the system acknowledges a valid code, opens the door's dead bolt, and keeps track of the time the person stayed in the room

The power section - power is controlled at six (6) points, namely

1) the "on/off" switch of the airconditioner for a maximum instantaneous current of about 1 ampere at 230 volts for the coils of a pilot relay
2) the compressor of the airconditioner with a maximum instantaneous current of about 120 amperes at 230 volts
3) one bank of light bulbs with 200 watts with independent variable energy control to achieve the desired illumination levels
4) another bank of light bulbs with 200 watts, also with independent variable energy control to achieve the desired illumination levels
5) a bank of two ceiling fans with an approximate maximum load of about 100 watts, also provided with independent variable energy speed control to provide the necessary air circulation to make the temperature readings a around the room as uniform as possible
6) power to a 2-ampere reversible DC motor that controls the "dead bolt lock" of the door