A System Controller Update and its Tendency of Information Deployment at a Control Center: a Study Case and Practical Application

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Abstract— **This article presents a study case and practical application of a system controller update for a power control center. This system was designed and developed by Simulation Department of the Instituto de Investigaciones Eléctricas and it is one more of the technological developments carried out here. The technology of the system controller has operated for several years and worked properly providing, in a reliable way and with high availability, information to the operators at a control center, the state of the feeder switches and the substations of the Electric Power Network of the main metropolitan zone of the country, therefore guaranteeing the supervision of safe and reliable operations. Final results during functional tests are also analyzed and tendencies of this development within operators' scope are also presented.**

Index Terms— **Control center, control room, communication protocol, controller, power plant.**

I. Introduction

THE Instituto de Investigaciones Eléctricas (IIE*, Mexican Electric Research Institute, http://vmwl1.iie.org.mx/sitioIIE/site/indice.php) was founded on 1975 and started its operations. It has been the right hand as R&D institution of the Mexican electrical utility, offering technical innovations. The Simulation Department (SD), one of the technical areas of the IIE, has developed, installed, and integrated computer software and hardware systems in order to put on service and support new and advanced technical platforms of simulators for training personnel that operates power plants in control rooms. It also provided technical equipment for operators that supervise and control different electric power networks in a control center of the electrical utility companies. In this paper, a system controller conversion of an operation control area is presented and its different parts are described within the supervisory and control purposes. The developed system controller technology involves several areas and to reach these goals, different specialists were required. Engineers of software, control, communications network, maintenance and tests and faults have shared the same commitment.

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* Some acronyms are after the name or phrase spelling in Spanish.

II. Background

In 1994-95, the IIE's Electronic Department put on operation a new platform SAC IBUS-III of control and data acquisition system, known as controller system for dynamic mimic panel (CSDMP®), used to act as a monitoring interface of the feeder switches and the substations (SS) of the electric power network (EPN) of Mexico City's metropolitan zone, between a supervisory master station (MS) and a dynamic mimic panel (DMP) installed in a control center (CC). Preliminary tests were carried out at Siemens™ (provider of the Empros™ Master Station) in Minneapolis, USA; where engineers form the control center were trained to use, operate and put the CSDMP on service. The CSDMP worked properly and continuously during the next nine years though at the beginning of 2003, an electric fault in the CC appeared and the CSDMP began presenting instability during the process of starting operation. The CSDMP was re-established and put back on service to guarantee its availability and continued full functionality

At the present, the CC, Fig. 1, is operated by Comisión Federal de Electricidad (CFE, The Mexican utility company) [3] which is the manager of offering the electrical service in the whole country.

III. Problem

Foreseeing the term of useful life of the CSDMP and going towards the expiration of technology that was used for the development of the CSDMP, the IIE proposed its substitution in the briefest term.

The challenge was to obtain the same requirements as well as the same hardware and software functionality of the original system.

In 2004-05 the SD developed a project with the purpose of substituting the SAC IBUS-III [1] old platform for a modern, compact and robust one, avoiding the long interruptions of service to the CC's operators were supervising, achieving a high availability of the CSDMP.

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Fig. 1 Center of Control and Operation of the metropolitan zone at Mexico City

IV. PROBLEM

As shown in Fig. 1, the DMP measures 46x23 feet and it has been constructed with hundreds of 1x1 inch mosaics on which a set of lamps are dynamically distributed around it. All together represent the behavior of the EPN.

The CSDMP was settled on a serial network connected between a MS and a DMP as shown in Fig. 2.

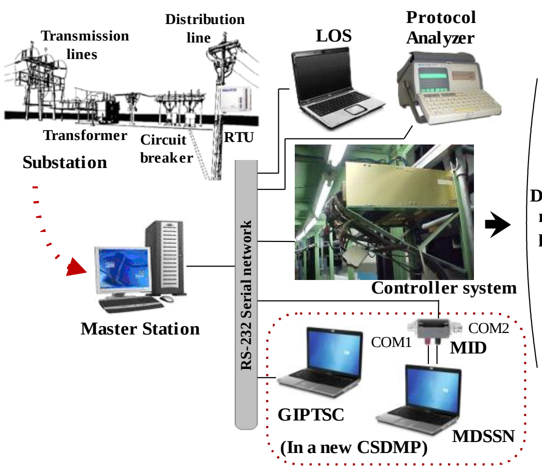

Fig 2 CSDMP configuration in an RS-232 serial network

The MS receives/sends information to/from remote terminal units (RTU). The information consists of the logical state of the feeders' switches and the SS of the EPN and some analogical data as time schedule, current, voltage, and phases of different points around the EPN in the metropolitan zone. The MS, processes all concerning data, putting it into a data base, updates a set of one-line diagrams, fills the proper protocol formats, and sends the message to the controller by means of an RS-232 serial communication channel. The controller receives the message, processes all data and through its digital outputs set values (on, off and blinking) to a lamps on a DMP. The states and the colors (red, green and yellow) of the lamps, represent different states (connected, disconnected, fault, and right operation) that are supervised and interpreted by the operators at the CCO to take a particular action when necessary. In addition to the visualization in the DMP, the operators can observe, in a redundant way, the behavior of the EPN in monitors at their Station Operator.

Additionally, there is a system diagnostic tool, for the old CSDMP, the local operation station (LOS), and for the new CSDMP, a graphic interface for protocol test in serial communication (GIPTSC®) was used, both capable to emulate MS commands by operator request and send it to the controller.

The following sections describe the transition process occurred from the old CSDMP platform to the new one.

V. CSDMP PLATFORM VERSION SAC IBUS-III

A. Hardware

SAC IBUS-III was a Control and Data Acquisition System generation of a family of I/O analog and digital electronic boards [1]-[2], communication interface, synchronization module, and microprocessor, among others, plugged to a common electric bus contained on a card cage which was designed and developed by IIE's Electronic Department with the purpose of offering computer electronic

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equipment for monitoring and handling devices of the real world.

The CSDMP formed by SAC IBUS-III platform, shown in Fig, 3, consisted of one master controller (MC) which acts as the front end to the MS and three more slave controllers, known as logic controllers (LC) that receive data, transfer the final values to a DMP, and answer with a fault code to its MC. The LC are always communicating and synchronizing a real time clock (RTC) with its MC through internal RS-485 networks.

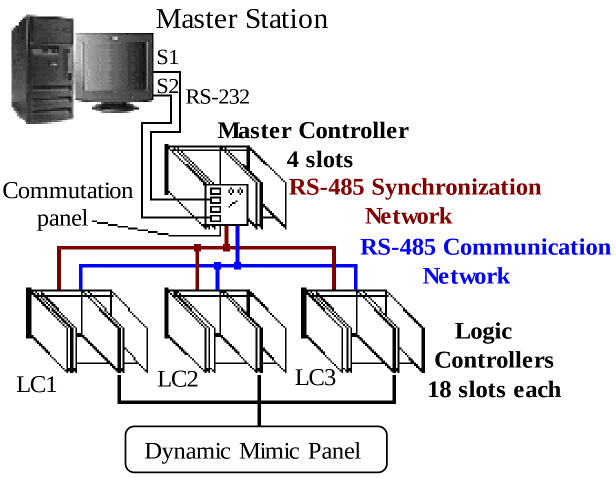

Fig. 3 CSDMP SAC IBUS-III physical configuration

Both the MC and the LC had in common some important characteristics as: IBUS-III backplane for electrical interconnection of digital outputs boards, +5V DC power supply, SAC-1887 CPU, synchronization module, RS-485 communication and communication module for LOS.

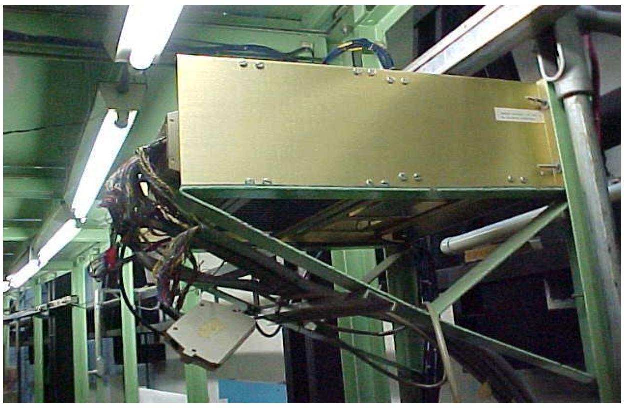

Fig. 4 Logic Controller SAC IBUS-III installed on the rear of Dynamic Mimic Panel

Additionally, in the MC there was a commutation panel with RS-232 channels for communication with two Servers of the MS, and in every LC there were 13 SAC-617/64 digital output boards with 64 channels each. A view of one LC is shown in Fig. 4

This CSDMP has been designed to drive 2,304 single digital outputs plus 12 Binary Code Decimal modules.

B. Software

Concerning software, it has implemented over a Concurrent Processes Operating System (CPOS). All communications programs have been written on Intel™ assembler for the 8088 uP and 8039 microcontroller, and the concurrent processes have been written on PLM86™ programming language. All programs together work as the supervisory application at CCO. Each program has different purpose: to initialize all necessary hardware, to read/write messages on serial channels from LC, to write data to buffer status, to decode protocol CIS (Computer Inquiry Systems) [6] messages from ME, including update of digital output signals (DO) and BCD modules, as well as verification the controller status and to generate error code.

VI. NEW SCTM PLATFORM VERSION VMIC

A. Hardware

The new CSDMP, as shown in Fig. 5 and 6, is an embedded and generic system of I/O VMIC™ [7] electronic boards manufactured by GE™ Fanuc as follows.

- VMIVME-0404 VMEbus backplane 21 slot computer chassis
- +/- 12V DC Power supply
- VMIVME-7805 Single Board Computer Intel Pentium 4 uP based on the VMEbus standard
- VMIVME-7459 VMEbus CD-RW 20 GB Hard Disk
- 18 VMIVME-2128 128 bit high voltage DO board
- 18 VMIACC-BT04 Dual 96-pin transition panel
- RS-232 network and RS-485 network converters

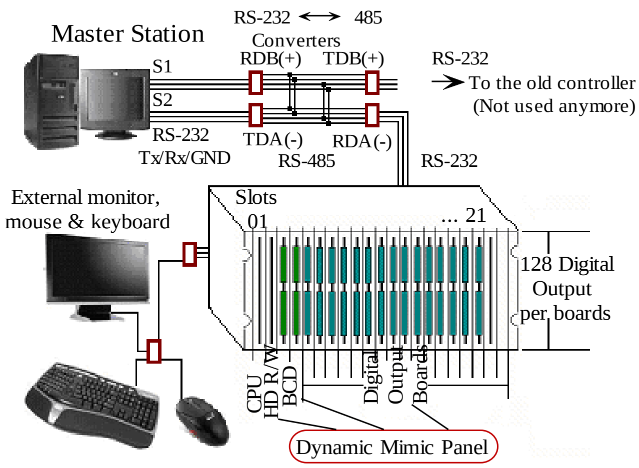

Fig. 5 CSDMP VMIC GE Fanuc physical configuration

B. Software

The software of the VMIC CSDMP consists of a group of programs written on C++ using the following packages:

- VMISFT/SW-7431 Windows 2000 operating system
- VMISFT-9420 VMEbus IOWorks software
- Visual Studio.net™ 2003

And different programs, as block diagram on Fig. 7 shows, were designed in order to get the same application as before: to initialize all serial ports, to initialize ports and threads, to decode protocol CIS messages from M, to update digital output signals and BCD modules, and to verify the

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controller status and to generate error code.

Fig. 6 VMIC GE Fanuc CSDMP

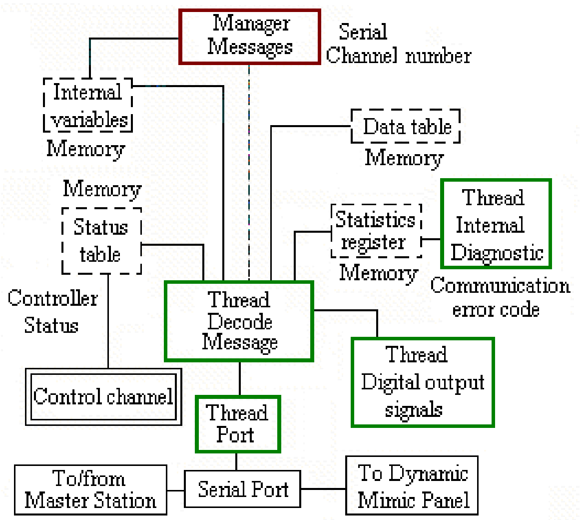

Fig. 7 Interconnection of the new programs and threads

TABLE I
HW/SW of different CSDMP versions

Parameter	SCTM SAC IBUS-III	SCTM VMIC GE Fanuc
Hardware		
Controllers	4	1
Digital output	2,304	2,304
Network	RS-232 RS-485	RS-232 Ethernet
uP	8088	Intel™ Pentium 4
Software		
Operating system	SOPCO owner	Windows 2000
Programming	Assembler PLM86™	C++ on Visual Studio.Net

The new CSDMP consists of a unique controller working exactly as before; however, with renovated hardware and software which main differences are summarized in Table I.

VII. AUXILIARY TOOLS FOR THE CSDMP

For the operative and functional tests of the new CSDMP, it was specified a tool of diagnosis supporting the development, testing and putting in operation of it.

This new interface, named GIPTSC [4], was intended to test any communication serial protocols and is based on the previous development: the LOS. Originally the protocol CIS but now it has been improved aspects of its functionality and would provide the user with additional abilities of diagnosis of the system but using the GIPTSC. An operator is capable to arm a CIS message, to send and receive commands emulating the Main Station across the communication channel series. See Table II.

TABLE II
CIS protocol commands

Command	Description
Tests	Manual/Automatic point (lamp) Even/odd (red/green) bits Even/odd bytes BDC segment display All points and BCD displays Status system reestablishment
Update on line	Point's state (up to 20 points) BCD display (RTC, Voltage, Current, and Frequency) Group points (up to 20 groups) Group point assignment (up to 80 points)
Diagnostic	Point state/system status
*Diagnostic	Points' states recover
*Message simulation fault	Incomplete
	Without terminator
	Additional data
	Wrong header
	Point out of range
	Fault reestablishment

The two commands, diagnostic and simulation fault, are exclusive of the GIPTSC for testing and fault simulation serial network purposes.

Additional to the functional tests, another diagnostic tool: a monitor for data supervision in serial network, known as MDSSN [5] was required to validate the messages that circulate around a serial communication network connected between a MS and the peripheral CSDMP with a physical adapter (MID) to serial communication ports, processing and updating of data, displaying the data obtained in a graphical way focused to users who process a particular data of this application. MDSSN is capable to substitute a commercial protocol analyzer.

Both the GIPTSC and MDSSN were developed using the software platform Visual Studio.net® and written on C++ programming language.

VIII.CDSMP CONVERSION

The migration to the new platform was realized with the previous platform still working, see Fig. 8.

During the coexistence of both platforms, the messages originated from the Master Station had to be sent peer to

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peer, and though the messages were directed to both CSDMP. To avoid conflicts in the communication network, only the new CSDMP was enabled to answer to these messages and the digital output signals were migrated one by one.

The LOS and a Protocol Analyzer were used as auxiliary tools to put on line the new CSDMP.

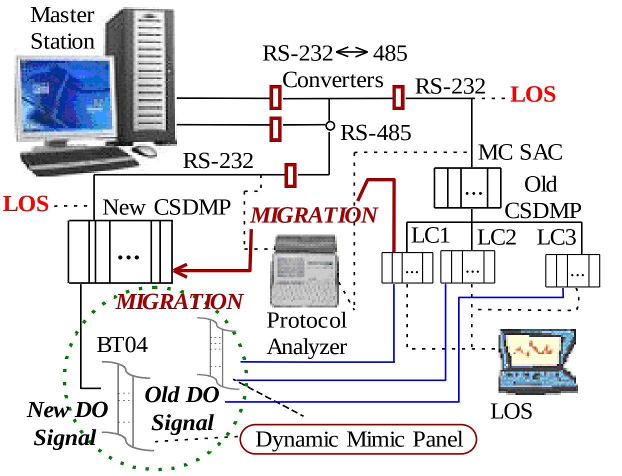

Fig. 8 Coexistence of both CSDMP during migration of one by one digital output signals

This extremely important and delicate activity was carried out by the coexistence in line of both platforms due to the need, partially by the operators of the system, of being provided with the visualization in real-time of the information originated from diverse SS and switches associated in field, in the mimic panel. See Fig. 9.

Fig. 9 IIE's Technicians connecting signals from the old CSDMP to the new CSDMP

IX. CONCLUSIONS

The former CSDMP validation was carried out at Minneapolis and the control center facilities by specialized personnel under rigorous acceptance controller testing procedures, and with a lot of experience in the use of SCADA applications, to ensure that this controller would fulfill the performance specified by the end user in order to have one more useful tool to supervise the correct operation of the Electric Power Network.

The new platform developed by the IIE provides a lot of certitude and robustness to the new CSDMP behavior and this one reproduces correctly the same behavior that the previous CSDMP. See Fig. 10.

Where tp < te, considering that

te = 25 msec, MS waiting time
tp = 20 msec, processing received message time and responds to MS

Last behavior (red):
RXa = identification and message processing
TXa = answer to the previous received message

Actual behavior (blue):
RXb = identification and message processing
TXb = answer to the previous received message
PSD = updating digital outputs before receiving next command from the MS

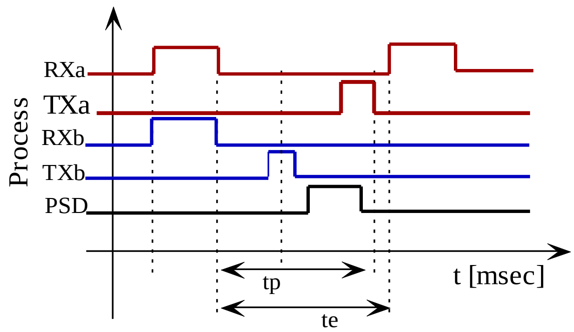

Fig. 10 RX/TX validation time of the CSDMP

In a similar way, using GIPTSC and MDSSN auxiliary tools, during real time operation, an exploration of 12,000 message series was observed by 11 hours lapse, and the obtained statistics results demonstrated that the fault index was reduced to zero. See Table III.

TABLE III
Statistics messages

Message	Statistic
Sent by Master Station to the CSDMP	
Update point status	11,194
Turn off points	60
Subtotal updated points	12,000
Turn on all points +BCD	4
Turn on BCD	6
State reestablishment	2
Subtotal manual test	12
Point status	44
System status	328
Subtotal status request	372
BCD block update	45
Group update	8784
Group assignment	578
Errors on CSDMP messages sent to Master Station	
Point status response	**0**
System status response	**0**

A robust fault tolerance scheme was prepared in the software of the CSDMP foreseeing any risk during the mailing and reception messages, supporting high reliability of the system operation.

With the development and the commissioning of this new CSDMP, the IIE has demonstrated the capacity to penetrate into new technologies and once again it has supported our national utility companies, as enterprises hard linked to the electrical sector.

In the opinion of the final user, the evolution of the CSDMP has been satisfactory, since it classifies to this development in very good position inside the state-of-the-art technology.

Finally it is necessary to mention that this technological development have been worked since 2005 uninterruptedly neither reported faults.

X.FUTURE WORKS AS TENDENCY OF INFORMATION DEPLOYMENT

Because the control center is the fundamental part of the supervision and control of the EPN, there is a proposed project that consists in modernizing the projection technology for a more modern one [10], [11], [12] that offers at least the same service to the system operators. This means, to substitute steeply the visualized mosaic mimic panel by representative diagram images on Plasma Display (PDP) or Liquid Crystal Display (LCD) panels [8]. See Fig. 11.

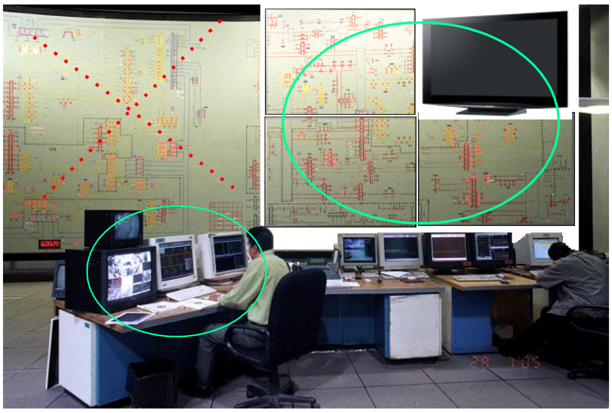

Fig. 11 Modern projection of the representative mimic panel diagrams on PDP or LCD panels

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