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6.6. PLANT PROCESS COMPUTER SYSTEM REPLACEMENT

The Plant Process Computer equips some Nuclear Power Plants, like CANDU-600, with Centralized Control performed by an assembly of two computers known as Digital Control Computers (DCC) and working in parallel for safely driving of the plan at steady state and during normal maneuvers but also during abnormal transients when the plant is automatically steered to a safe state. The Centralized Control means both hardware and software with obligatory presence in the frame of the Full Scope Simulator and subject to changing its configuration with specific requirements during the plant and simulator life and covered by this subsection.

6.6.1. Description of the project

Plant Process Computer has a wide variety for both software and hardware solution. At Cernavoda NPP the Varian-72 System made by "Varian Data Machine" in 1972, was selected and implemented. The Varian-72 System is a system-oriented, general-purpose minicomputer and it is designed for maximum performance in instrumentation, data acquisition, and communications systems. Now it is an obsolete computer but in 1972 was a revolutionary one. The Varian-72 features are:

- **Efficient Operation** - Operates on 16-bit words with a full-cycle execution time of 660 nanoseconds.
- **Large Instruction Set** - Recognizes 160 arithmetic, decision, and control instructions, may of which can be micro-coded to extend the effective instruction repertoire into the hundreds.
- **Modular Core Memory** - Can be expanded in 8,192 words (8 K) increments, from the minimum of 8 K to a maximum of 256 K with the memory expansion chassis and memory map option. Cycle time is 660 nanoseconds.
- **Multiple Addressing Modes** - Including direct, multilevel indirect, immediate, indexed/indirect, relative, and extended with pre-indexing and post-indexing.
- **Effective Input/Output** - Includes a full complement of peripheral controllers and devices and three types of I/O operations: program-controlled, direct memory access, and priority memory access.

The above-mentioned features assure a very important characteristic of this computer: the control programs can be modified and tested and in the same time the plant control is performed by the same system. The technique is to write an orphan code on the backup machine, which runs in parallel the same control program, but without action, and after this, to connect this code to respective control program, which was checked on the full-scope simulator. This characteristic is very important for operation because the control program changing does not ask the DCC and plant shutdown.

The DCC assures the interface between plant processes and Main Control Rooms (MCR) operators through some monitors. Trends, bar-chards, status displays and alarms are displayed on these monitors. Also, the DCC checks the operators' commands and performs automatically maneuver for reactor and turbine power. Starting from these reasons we can conclude the DCC is an important piece of the simulator with a great role in the training process.

Another aspect refers to simulator development. Parts from the control programs were *simulated* in the frame of simulation modules in first phase of the simulator progress. This simulator for a part of DCC control programs is needed to test the model stability when the whole control program cannot be used because the complete model is not available, and represents a first phase of the Plant Process Computer (PPC). The simulator for a part of PPC is very simple and only the main control function of the simulated precesses is included. This stage is obligatory for simulation manufacturing and useful for simulator-upgrading process but, unfortunately, needs time and is not cheap.

The second stage refers to PPC for training process using full-scope simulator. Is possible to use the PPC simulators? The answer is negative because the training requirements asks the control program *as it is* in the plant and a first solution is to use in the frame of the full-scope simulator the same computer like in the plant. This was the choice for Cernavoda U1 Simulator and the possibility to use a program very close to plant control program was its main advantage. Now, when computers are very powerful, this first solution is obsolete and asks the old hardware replacement with a modern one and equipped with an emulator fitting the real device from the software point of view. This is the actual situation at Cernavoda U1 Simulator with numerous and various problems because who know and has the possibility to write this emulator? The ex-"CAE" (Canadian Aerospace Electronics) and now MAPPS division of the "L-3 Communications" (see http://www.mapps.l-3com.com/), which is the supplier for Cernavoda U1 Simulator, bought the DCC emulator from other company, the Simulator Department of the Point Leprous NPP and cannot sell to a third part the emulator sources. The supplier did only the emulator integration in the frame of full-scope simulator. The simulator user must accept what it is on the market or to develop itself and in a similar way as above-mentioned Canadian NPP.

6.6.2. Reasons for upgrade

Why to upgrade the Plant Process Computer? Good question because many problems appears in this process.

In the case of Cernavoda U1 Simulator the main reason was the Full-Scope Simulator (FSS) re-host. The simulation computer, VAX 4000-500, is an old one, made by Digital Company, now included in the frame of HP, and must be replaced from the maintenance reasons. This is the origin of modernization process for Cernavoda U1 Simulator. The old DCC hardware becomes obsolete in the frame of the new simulation system and the supplier proposed a new solution: the emulator. The user (purchaser) accepted this solution from the following reasons:

- The full-scope simulator supplier, with good achievements in this field, suggests this solution.

- When the real DCC will be changed in the plant with a new hardware (in the next future this process will happen at Cernavoda U1 NPP) only the emulator software shall be upgraded.

- The emulator is able to perform itself the simulation functions: freeze, store, restore and so on. This characteristic permits to be used the *as it is* in the plant version of the control programs - very important now when o lot of modification and improvements are already done by the DCC department and implemented in the plant. The problem is the keyboards and displays that must run during frozen state of the simulator to respect the training request. It is a problem because the emulator must know to run in background the respective part of control program belonging to keyboards and displays.

- Evolution of the respective simulator in the world generates emulators for many types of control devices and the PPC is one of them. These emulators are tested during years of continuous operation in many NPP-simulators and became a new solution for PPC. In the Cernavoda case, the Point-Leprous emulator, which was written by the simulator modelers of this plant, has some year of operating-experience.

The PPC upgrading means emulation of the old hardware in a new and modern computer, running on the powerful operating system, and written using Rapid Applications Development (RAD) Platforms. The problem is the emulator fidelity versus real device. All the above-mentioned advantages fall in this big problem: emulator fidelity.

6.6.3. Difficulties experienced

For a young team, the replacement of the real PPC with an emulator is a problem, and for experienced teams too. To emulate the PPC is a provocation for the NPP specialized staff. At Cernavoda NPP two persons developed separately DCC emulators to verify the control software before to be implemented in the plan. These programs are used one by U1 and another by U2 under construction. Also, the staff of Point Leprous NPP from Canada developed a DCC emulator bought later by MAPPS. Because the company that made the real computer does not certify this software, many difficulties move up at the PPC replacement.

The possible difficulties raised by the PCC replacement can be classified considering the following problems:

- The main difficulty is the replacement type: an emulator replaces the real PPC.

  The fidelity is guaranteed and the control programs will run in the same environment when the Full-Scope Simulator is equipped with the same PPC hardware like in the plant. Also, the real PPC is connected to plant processes through the special electronic devices replaced by other types in the case of Full-Scope Simulator where the connection must be done between two computers, the PPC computer and the PC running simulator models. Replacement of the real PPC means to replace the PPC hardware

and also the connection between this hardware and the PC running simulator models. The last item means to replace the hardware and its software for data transfer to and from the PPC with Ethernet connection and adequate software for data transfer.

At Cernavoda Full-Scope Simulator the initial PPC hardware is the real DCC of the plant connected to simulation process running on the simulator computer VAX 4000-500 through the DUSC, a special computer for data converting and transferring. Data converting is necessary because the DCC works with integers and the simulator computes with real numbers. The DUSC converts the real number of the simulator labels into DCC integer using a scale and in the same way the DCC integers into real numbers for simulator labels. A similar process is happen in the plant and in the frame of the instrument loops where the process value is measured by the element (for example: temperature or pressure element) converted by its transmitter in one current between 4 and 20 mA, 4 mA for lowest value and 20 mA for greatest value, and this current is converted into 8-bits integer by the Data Acquisition Board. This 8-bits integer is transmitted to DCC Control Programs. The hardware upgrading process will replace this initial system of data converting and transfer between computer for simulation and PPC with another one based on common PC's, Ethernet connection and new software for data converting and transferring. The MAPPS solution includes a special program, DataPath, developed by this company in order to connect different control-devices geographically distributed.

- The real device manufacturer did not certify the emulator.

Now, the fabricant of control devices offers adequate and certified software for simulation purpose. This practice is new and was not adopted by Varian vendor and for Cernavoda the emulator writer was the Simulator Department from another NPP, Point Leprous. This software was developed on the basis of general information having the main scope to allow the computer user to exploit the computer and not to provide all the technical information referring to how the computing and communicating process is performed. The emulator development was done without any official implication of the real device manufacturer. Despite the number of years of tests passed without major malfunctions, it is expected to appear differences between the real device and the emulator. But the main problem is the lack of documentation referring to this software, about how it was developed and for what scope and what is out-of-scope. The emulator is delivered as it is and, excluding a short user-guide, without any comment or description. Also, the emulator is delivered without the source-files and the client cannot resolve the possible future deficiencies that would be very probable for new software.

- Acceptance Test Procedures must be developed for the first time. The purchaser has no experience for this and must accept the procedures written by the emulator provider.

To proof the emulator fidelity vs. real device, the common method is to pass the Acceptance Test Procedure (ATP) developed special for this type of equipment. The basis for ATP would be the vendor experience. In general the vendor only integrates the emulator in the frame of Full-Scope Simulator and he is motivated to add no more tests than referring to this integration process. In the Cernavoda case, the ATP written by MAPPS for DCC has included only items referring to DataPath and nothing referring to DCC emulator because the vendor activity was only to integrate the DCC emulator machine in the frame of the Full-Scope Simulator. The respective team of the simulator purchaser asked the team of the emulator vendor, which is responsible with DCC integration, about procedure improvement with specific test for DDC emulation but this action was very difficult to be implemented by a staff not experienced in this field.

- The emulator sources are not provided from various reasons and difficulties to fix the bugs can appear.

  The emulator is delivered as it is, without source-files and documents, excepting the User-Guide. All the documents describe how the emulator was integrated in the frame of Full-Scope Simulator because that activity was performed by the vendor. The emulator is delivered as a black-box without any information referring to how its transfer-functions are built. In this case, the purchaser must accept the emulator as perfect software, without any deficiencies.

- The emulator writer is another company, in general unknown by purchaser, and a direct collaboration is not possible in order to solve possible future deficiencies.

  The vendor doesn't provide officially the author of the emulator and a direct collaboration will be impossible. It is expected the vendor wants to intermediate this collaboration that asks additional payments.

The Full-Scope Simulator provider considers the Plant Process Computer (PPC) only an item of his project with intention to find quickly a good enough solution, which means to work properly in the simulator environment and pass a number of acceptance tests. The Full-Scope Simulator purchaser has a more realistic perception of the Plant Process Computer because he knows the role in the frame of the training process and wants to obtain a new device with a similar response vs. the real device and simulating all the components of the real device. From the purchaser point of view, the PPC emulator must be more complex and able to reproduce with a great fidelity the real device functions because it will be used with a great impact in the training process and also to test the new solutions of the control programs developed by the PPC-team of the plant - at Cernavoda NPP, the plant procedures ask tests on simulator for each major modification of the control programs. There are two different and antagonist points of views, one of provider, which wants to simplify the problem, and another one of the purchaser, which wants to obtain a realistic and complex emulated-device able to reproduce with great, validated and controlled fidelity the real-device. In general, the purchaser does not agree something that works only a little close to real-device, which is the provider-rule for his development in the Full-Scope Simulators field. Finally, a

common area for the emulator characteristics must be found, common area where both purchaser and provider will accept and respectively provide most of the items. Unfortunately international documents or guides do not exist to define this common area and this can be a theme for a future AIEA's works dedicated to this subject.

6.6.4. Reasons and considerations to determine the solution

During the Full-Scope Simulator development, the PPC was initially simulated in order to have a response from control programs used to verify the models of the simulated processes. Simulation means to replace the real control program with another one, more simply and including only the major functions. This new control program is developed in programming-language of the models. The role of this phase is restricted to development of the models but, in general, the simulator provider delivers to purchaser these simulations for control programs.

When all the models are ready, the real computer replaces initially the simulated PPC. The real PPC will have the executive program modified to include special instructions needed by the simulation functions: freeze and unfreeze, store and restore, and so on. Unfortunately this means that the real computer will run another software like in the plant. It is the case of Cernavoda Full-Scope Simulator from 1996 up today. During nine years of operation, the DCC software was improved by major changes by the specialized team of the plant. These modifications were done without any consideration accorded to simulator's PPC-software and now the control programs have a new appearance in Main Control Room (MCR) of the real plan with major impact for training process. The impact for training asks updating process for simulator PPC-programs. The updating process appears to have a hard and complicated implementation because the area of memory used by special functions of simulator was used by the improved control-programs. Finally, we can conclude: to keep the real computer in the frame of simulating environment is not a very good solution from the reasons and consideration described below.

- The real computer equipping the PPC is obsolete from the training point of view.

  Reasons and considerations used to choose the PPC for real plant differ in comparison with those for the training-simulator. The real plant PPC needs high performance for safe and efficient operation, data security, instruction set, core memory, addressing mode and input/output operations. For training purpose and referring to safe operation and data security, the emulated PPC does not need special performance but should be built on the common operating systems, running on the widespread computers and should have a friendly and modern Human-Machine Interface (HMI).

  The real PPC is, in general, an old machine, obsolete now for many IT fields, but mature and assuring the above-mentioned requirements as follows: (1) the data security is hardware assured through special memory units equipped with dedicated switches for read-only access; (2) efficient operation is assured by the 16-bit words with a small full-cycle execution time (around of 660 nanoseconds) and large instruction set recognizing 160 arithmetic, decision, and control

instructions, may of which can be micro-coded to extend the effective instruction repertoire into the hundreds; (3) core memory is expandable in steps of 8,192 words (8 K), from the minimum of 8 K to a maximum of 256 K with the memory expansion chassis and memory map option. Cycle time is 660 nanoseconds; (4) multiple addressing modes include direct, multilevel indirect, immediate, indexed/indirect, relative, and extended with pre-indexing and post-indexing addressing; (5) effective input/output includes a full complement of peripheral controllers and devices and three types of I/O operations: program-controlled, direct memory access, and priority memory access. Unfortunately the control programs running on the real PPC are written to work only with integers and using a special concept for the exponent named "B-Scaling" because the computing-time needed by the arithmetic operators is shorter for integers comparing with real numbers. The memory savings, realized through the integers and B-Scaling concept, are an obsolete concept and not used in the frame of new and modern control computers. Also, the programming technique, developed through the assembler programming language directly in the machine instruction set without any friendly and modern interface, is out of use now for many IT applications.

Comparing with the real PPC requirements, the emulated PPC does not need these characteristics to be really present as a quality of its hardware and only to be replicated by the dedicated programs running in the frame of the emulator software. The new computers now are usually equipped with gigabytes of memory running with gigahertz frequency and values of 256 K with 1.5 MHz are completely out of date. The scope of PPC emulator is to be frequently maneuvered by the simulator developers, managers and users in order to verify, test or study/investigate the control programs of the plant and to fulfill all these requirements the emulator program must be provided with modern and friendly-to-use interface.

· The real computer equipping the PPC cannot run for training purpose the software fully identical with the plant.

It is not economically and practically to include two PPC teams in the frame of the plant staff, one team for real PPC and the second for simulator PPC because the control program problems have their specific difficulties that can be resolved only by specialized people. Also, the control programs have a major impact for training process because these programs receive and process the operator commands and inform the operators, through the monitoring function, about what is happen in the plant. These are the reasons for what it is required a great fidelity for the simulator PPC. To achieve this great fidelity the best solution is to run in the simulator framework the control program *as it is* in the plant. Because the computer used by the real PPC is not provided with hardware or software facilities able to assure the running of the specific simulation function referring to freeze/unfreeze, store/restore, backtrack and so on, the PPC executive must be changed in order to respect these requirements of simulators. Unfortunately this process alters the PPC software, becoming unacceptable for the *as it is in the plant* implementation and asks for an expensive solution, which includes

specialized people working only for simulator in the frame of the second PPC team. Better is to assure, through the emulator software, the *as it is in the plant* implementation of the control software. This assuring means to include dedicated subroutines to perform simulator special function and that action needs a best knowing of the real computer equipping the plant, requirement in general satisfied, inside the staff of the plant, by the PPC team.

- For training-purposes, the PPC software from the plant must be adapted to become usable.

The PPC software cannot be used in the frame of Full-Scope Simulator *as it is in the plant*. The causes are the special function needed by the simulation process: freeze/unfreeze, store/restore, backtrack and so on. These functions cannot be implemented in the real PPC controlling the plant as *orphan codes*, which would be active only during the training and keep reserved the segment of memory during the control process in the real plant. In general, the Regulatory Body and plant procedures do not admit orphan codes in the real PPC software. In conclusion, to execute these functions, special subprograms must be added to the executive program of the real PPC software and only for its training version.

To realize the freeze/unfreeze status asked by the training process, the added code to the *as in the plant* executive will bypass all the control programs and execute other function referring to keyboards and ramteck - special device to show trends, barcharts and status display. In this mode, during freeze status of the simulator, the operator has the possibility to change the trends, barcharts and status displays, and to modify addresses from core and disk memory. This feature is used by the PPC staff during the control program improvement and is not present in the real plant. It is not clear up now if this characteristic is a progress and must be kept or induces negative training and must be removed. Instructors and PPC staff want to be kept but simultaneously the operators, during the training process, use these facility that is unusable in the real Control Room (MCR) and it is a negative training.

For store/restore and backtrack, the added code must record in dedicated addresses of the PPC memory the important variables of the control programs in order to memorize the status of the PPC software at one moment of time. The value for these variables will be restored in the frame of the restore and backtrack process and it is essential for simulator operation. The store/restore and backtrack code must keep into account the addresses for all restorable variables of the control programs and, unfortunately, these addresses are changed by the PPC staff to correct the plant control and this process asks to be adapted these store/restore and backtrack code. Specialized staff similar with the PPC staff must do periodically this fitting with additional expense and time.

The Cernavoda practice shows the training process works with old version of the PPC software because of the difficulties raised by the implementation of the new version.

- In the plant, the real PPC is subject of upgrading and replacing with new and modern equipment.

  During plant life, the PPC computer is upgraded with new types. For example, at Unit 2 of Cernavoda NPP, the SSCI-125 equipping Unit 1 was replaced with the new type, SSCI-890, and the intention is to purchase this new type for Unit 1 too. The new computer includes new instructions used by the control programs and it is necessary to be provided also for the simulator environment making expensive the upgrading process. If the simulator is equipped with PPC emulator, only the emulator needs modifications to become able to process the new instructions and this action is inexpensive.

- From the hardware point of view, the real PPC has a complex and growing structure.

  The real PPC includes three computers: two computers working in parallel to control the plant's processes and the third is provided for PPC staff to test the new versions of the control programs before their implementation. This system comprises other devices, ones of them for data acquisition and recording for future analysis. These *other devices* grow during the life of the plant following the operating needing. For example, at Cernavoda Unit 1, initially, the PPC was not provided with SCADA system utilized to acquire all analog and digital inputs coming from field into the system of control computers. This system includes new computers connected in a special network and it is not present in the frame of the Full-Scope Simulator.

- Hardware maintenance.

  The real PPC counts many pieces of hardware and all of them need specific activities of maintenance. The emulator puts together all these equipments in a single one and uses software to reproduce their functions. This single equipment saves a lot of time for maintenance activity.

- PPC emulator accepts usefully debugging tools with advanced and friendly user interface.

  Computer for the real PPC is designed and fabricated only for process control purposes and does not include enough hardware resources for debugger programs with advanced and friendly user interface. The PPC emulator is developed on the platform of the *Personal Computers (PC)* with new and advanced operating system (Windows-2000 or Linux), assuring enough memory and computing speed called for running the programs with advanced and friendly user interface.

Replacement, in the frame of simulator environment, of the real PPC computer with an emulator developed on PC platform with modern operating system is an improvements that should be considered when the simulator hardware must be upgraded.

6.6.5. Experience during specification, implementation and validation phase

To obtain the working properly equipment it is necessary to write correct specification, to implement appropriately all the specified items and to perform a real validation. The experience achieved is important and includes the following points:

- PPC requirements to be included in the frame of its specification result only from the real manufacturer documents and from the user practice.

  During the real PPC computers purchasing, the manufacturer delivers all the documents specified by the contract and these document are very important because will be used as information source for emulator development. These documents must explain enough how the processor works and the instruction set should be included and described because this information is the basis of emulator development. The purchaser must be very attentively with the content of these documents, which must include enough details, referring to processor functions and how these functions work, capable to assure all data needed by the emulator development.

  Documentation of the control computer, equipping the plant PPC, is important factor but experience shows the information provided is not enough and the operation experience and user practice must be added. The processor functions and its mode of work must be analyzed through specials programs performed by specialized staff using the real computer.

- The lack of feedback for PPC specification from the real manufacturer of this computer.

  Computer type for PPC is old but specialized to control safely the industrial processes and was developed for special requirements. It is not a common computer about everybody know how it works. From various reasons it is not possible to obtain information directly from its manufacturer or to have a feedback referring to the processor functions or working mode.

- Third Company implemented PPC functions.

  The PPC emulator is special software needed only by few clients and the simulator manufacturer has not a strong motivation to develop itself and prefers to buy it from another company. It is the case of the Cernavoda Unit 1 Full-Scope Simulator where the DCC emulator was made by the simulator staff from a Canadian NPP. The role of simulator manufacturer is only to integrate the emulator in the frame of Full-Scope Simulator and provide documentation and tests only for this activity.

- Acceptance Test Procedures (ATP) must be developed for the first time.

  The replacement of the real PPC with its emulator will happen only one time during the simulator life and the ATP must be developed for the first and last time without any previous experience because it is not expected to come back to initial solution, the real PPC, and after this again to emulator. This means a lot of works done in difficult conditions and deficient in previous experience and information. A Guide developed by the AEIA would be an excellent idea.

- The lack of people specialized and experienced for this type of control computer.

  Computers equipping the real PPC are old and specialized for the safe control of the industrial processes and are different from the common computers. They are manufactured by specialized team working in the frame of companies focused on this type of computers and their knowledge is not widely shared.

The experience attained during these phases is a value for the company but, unfortunately, it is not needful in future because a second replacement is not expected. From this reason, this experience should be shared through the international organizations and the good practices should be highlighted.

6.6.6. Key points

The real PPC replacement with one emulator running on the common computer under modern operating systems like Windows-2000 or Linux is a real improvement for the Full-Scope Simulator and it is able to assure a modern and user friendly facilities for operating, upgrading and debugging but this solution become possible if the following key points are fulfilled.

- The PPC emulator software achievement.

  In general, the manufacturer of the Full-Scope Simulator is not motivated to develop PPC emulators because this software asks a lot of specialized works with application limited to the respective client. Specialized teams working in the companies that use this type of control computers make the PPC emulators for other purposes like control programs developing, testing and debugging. The Full-Scope Simulator manufacturer only acquires and integrates this software in the frame of simulator environment and this is possible only if the emulator software is realized and purchasable from the manufacturer with all documents.

  The emulator must be recognized and accepted by the simulator manufacturer. For example, the PPC staff from Cernavoda Unit 1 and Unit 2 realized their own DCC emulator in order to develop, improve, debug and test the control programs. Unfortunately the simulator provider does not recognize these emulators. In conclusion, achievement of the PPC emulator depends by the relation with simulator manufacturer

and here the international cooperation should be a must in order to share the obtained knowledge, positive experience and good solution referring to this subject.

- PPC emulator simplifies the structure of the PPC hardware utilized for training purpose.

  The real PPC system equipping the plant has complex structure consisting of many computers, in general two computers working in parallel and a third for software development, connected to special devices for data acquisition, communication of the commands and transfer of the control. Initially, the simulator hardware-structure includes a minimal part from the structure of the real PPC able to reproduce all the PPC functions required by training process. Unfortunately this solution increases the simulator cost and its hardware structure. Respecting the simulation principle to simulate all involved pieces of hardware, these equipments must be emulated by special programs in the same way with the simulation of the technological equipments like nuclear reactor, steam generators, turbo-generator and so on, assuring an important simplification of the simulator hardware. Where emulators for different control devices exist, their presence in the frame of Full-Scope Simulator simplifies considerably the hardware requirements with positive influence for simulator cost and maintenance.

- PPC emulator acceptance tests.

  The PPC emulator is designed to reproduce the real product but a difference will remain and it is expected the response will not meet completely response of the real PPC. This difference must be checked through the acceptance test (ATP). This ATP must include the entire key of the real PPC functioning. This needs a best knowledge of the real machine and a good experience of operation and are difficult to be attained. The practice shows the simulator provider, which highlights only the integration process of emulator, proposes the ATP and this proposal is sent to simulator purchaser to be corrected and, finally, accepted. Unfortunately the purchaser has enough power to impose his version and a good ATP, and good from the purchaser point of view, is an important key point. The problems raised by this ATP are already discussed.

We can conclude the real PPC replacement with PPC emulator would be possible only when these three key-points are fulfilled and the emulation program appears on the marked, it asks a simplified hardware, and Acceptance Test Procedures are written from the purchaser point of view. Unfortunately, the experience shows that only first item is satisfied, the second item is partially satisfied because the emulator is installed on one dedicated computer connected through the LAN with the simulator computer, and the third is partially satisfied because the ATP is written from the purchaser point of view highlighting only the integration process.

6.6.7. Main recommendations for management and technical aspects

The experience of real PPC replacement with emulator brings to light the following five main recommendations referring to management and technical aspects, and they are, in general, aspects that have been missing in the Cernavoda case.

- Emulation of the entire structure of PPC.

  The PPC structure is complex and the emulation must cover this entire structure. Initially, the Full-Scope Simulator (FSS) is equipped with a part from the real PPC structure, which is indispensable for training process. The simulator purchaser, when upgrades the FSS, proposes an emulator only for the previous structure of the PPC equipping the simulator and not for the PPC equipping the real plant. This solution keeps the deficiencies initially accepted from reasons of cost, space and maintenance asked by complex hardware.

- Emulator software must run the PPC software as it is in the plant.

  For special functions asked by the simulation requirements (freeze/unfreeze, store/restore, backtrack, snapshot, and so on), dedicated subprograms are added to initial PPC executive, which was identical with the PPC of the plant. This modification of the PPC executive is the source of many problems already discussed. To avoid these problems the best solution is to design the PPC emulator able to run the software *as it is in the plant*. In this way, all the development of the PPC staff will be directly loaded in the PPC emulator, ready for testing, debugging or running in the training process with minimum of effort.

  In the Cernavoda case, the simulator provider received from purchaser the simulator version of the PPC software and, after this, the plant version only for information purpose. The simulator version was loaded in the PPC emulator and all efforts of the simulator provider were to integrate correctly this software in the frame of FSS. All these were done because the initial intention was to replace the old simulation hardware with a new one and not to improve the simulation facilities, which are accepted as the simulator purchaser proposed them.

- Emulator software must be certified, validated and approved by real machine manufacturer.

  A feedback from manufacturer of the real machine is useful for emulator developing process. Also, his validation and approval would certificate the emulator works in a similar way with the real machine.

- The emulator must be delivered fully documented.

  The purchaser must know what he buys and only the executables files without their sources and documents are not enough and this situation is not acceptable. The missing of the emulator source files will have negative implications for the deficiencies fixing or repairing. Without sources, purchaser cannot execute this process. The Cernavoda experience shows the provider is not authorized to supply the emulator

sources, written by another company, and, unfortunately, this situation was accepted by the buyer administration with the hope that emulator will work properly without any notable deficiency.

The emulator documentation is another point of this item. The purchaser must know how the product was developed and this knowledge must be attained in short time from the emulator documents and not investigating the emulator software functions.

- PPC emulator must run close to simulation.

The PPC emulator sends and receives a lot of data from the simulation models and, to be done properly, the both programs must run on the same machine, if possible, or, if not, on two machines directly connected through the simulator LAN (Local Area Network). In general, the first solution is preferable and possible because the both are programs and now the common computers are able to run in real time a big amount of instructions. From the point of view of the simulator provider, it is easier to run these two pieces of software on different machines and to resolve the communication problems with specialized programs (see DataPath of the *L-3 Communications / MAPPS*) developed as common tool for many other projects. A new hardware for PPC emulator is the solution forced by simulator provider and accepted by purchaser with supplementary problems referring to simulator space, configuration management and hardware maintenance.

Few years ago, the parallel computing and multi-processor machines appeared on the computers market and simulation is one field where these machines can be utilized. They would be the simulator future considering the number of computing techniques already introduced in control and monitoring of the Nuclear Power Plants with immediate impact to Main Control Room and operators training.

It is expected other reasons determine the replacement of the PPC solution and not the emulator advantages. In the Cernavoda case, the reason was the replacement of the old computer used for simulation (VAX 4000-500). In general, when an important part of the simulator system is replaced with a new solution including new and advanced techniques, all the pieces directly connected with this part are predisposed to be changed. The PPC is one of them and not considered by purchaser at its real importance comparing with the cause of the simulator improvement (VAX replacing in Cernavoda case) and all above-mentioned recommendation are partially or fully neglected.

6.6.8. Maintainability

Maintainability of the PPC emulator asks a quickly and easily updating of the control plant programs, fast fixing of the deficiencies and permanent contact with real manufacturer for correct information referring to real PPC.

- Emulator ability to run the PPC software as it is in the plant is a key for its maintainability.

It is very important from the maintainability point of view to update easy and fast the PPC software as it is in the plant. A lot of time and effort will be saved. This is an important key to reduce the maintainability effort and to keep the simulator configuration close to the real plant. The Cernavoda experience proved it.

- The fully documented emulator permits to be fixed quickly all future deficiencies.

  In general a fully documented product is useful to be maintained. For PPC emulators the Cernavoda experience shows the fully documented product, in the emulator case, is a problem because in many cases the simulator provider is not the emulator builder and this is a conditions for writing down a completed documentation.

- The feedback from real manufacturer assures the correct information referring to processor functions.

  It is very important for purchaser to know what works properly and what does not work in the same mode with the real PPC. This information is necessary to establish what is *in scope* and what is *out of scope* for the respective simulator and the real manufacturer of the emulator is the best source. The simulator maintainability is discussed only for its *in scope*.

A correct replacement of the real PPC with emulator can be a real improvement from the maintainability point of view if this emulator assures a great fidelity versus real equipment. All documents, contracts and efforts of the simulator purchaser must be done in order to fulfill these requirements discussed in the frame of this document.

6.6.9. References

	Varian 72 System Handbook Machine 2772 Michelson Drive Irvine, California 92664 1974 USA.	Varian Data
Operation and Service Manual	Buffer Interlace Controller Model 7X-3102 (F3024-02) Irvine, California 92664 April 1981 - USA	Sperry-Univac 2772 Michelson Drive