Development and Implementation of PMAX® On-Line Performance Monitoring at Entergy's Michoud Power Plant

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DEVELOPMENT AND IMPLEMENTATION OF PMAX ON-LINE PERFORMANCE MONITORING AT ENTERGY'S MICHOUD POWER PLANT

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ABSTRACT

During 1992, Entergy Corporation's Michoud Plant, located in New Orleans, Louisiana, was successful in acquiring and implementing a real-time performance monitoring system. The new system utilizes a recently implemented Westinghouse WDPF data acquisition system, a new Digital Equipment MicroVAX computer, and NUS Corporation's PMAX on-line performance monitoring software package. For the first time in the history of the Michoud Plant, the plant operator now has available to him a real-time performance monitoring tool which continuously displays the effects of his operation on unit performance in terms of dollars per hour. Numerous other performance screens have been implemented and others are presently under development utilizing computer interfaces which simultaneously link the WDPF data acquisition system, the MicroVAX computer, the PMAX performance monitoring software and the plant personal computers to provide the plant operator and technical support staff with desktop flexibility in real-time performance monitoring and trending capability. This new system greatly enhances the ability of the plant operator and technical support staff to make day to day, moment by moment decisions regarding unit performance and will, in time, provide a significant return to overall heat rate savings and the capability of trending and providing early detection of equipment problems. The intent of this paper is to assist others in their plant performance monitoring development plan by providing insight as to how a system such as Michoud's can be developed and implemented cost effectively and with limited plant technical resources.

INTRODUCTION

Recently, a group of Michoud control room operators were observed discussing the proper action to take in order to resolve a high back pressure condition on Unit No. 3. At first thought, it seemed an appropriate action to place a second circulating water pump in service which would, by experience, force more circulating water through the condenser, improve the heat transfer capability of the condenser and thus lower the turbine exhaust temperature and back pressure. Prior to taking this action, they first calculated their net cost ($/Hour) for operating with the high back pressure plus the auxiliary power of one circulating water pump. After placing the second circulating water pump in service, they did indeed experience a significant drop in back pressure, however, to their surprise, taking into account the added auxiliary power for the second pump, the new cost ($/Hour) had increased. From this brief exercise, the operators had reached a valuable decision - operate with one circulating water pump with the consequence being a higher back pressure, but with an overall net savings ($/Hour) in performance.

But, how had the plant operators been able to arrive at a decision of this nature in such a short period of time and without the assistance of the plant technical staff, test gear or other traditional plant test and diagnostic arrangements used in the past to help the operator optimize unit performance? The operators had been able to accomplish this feat by using a new PMAX® on-line performance monitoring system implemented into Michoud operations . To say the least, to those of us who had observed this exercise, it was exciting to know that the operators had endorsed the new on-line monitoring system and had experienced first-hand its potential as a valuable performance improvement and decision making tool.

The implementation of this new on-line performance monitoring system represented a major achievement at Michoud and provided a great sense of satisfaction to those individuals who have shared in this achievement. In retrospect, it is now apparent that the successful completion of this project would have been difficult, if not impossible to achieve, had there not been certain essential elements present, namely, a vision, a strategic plan, proper budgeting, plant management direction and support, vendor participation, teamwork, operator buy-in, commitment and a desire to champion an idea and see it to completion. A brochure recently circulated at Michoud contained an interesting quotation which sums up these necessary ingredients. It reads, "Planning - Where the Present Meets the Future!". Performance and heat rate improvement projects have always been and will probably continue to be difficult to justify for some time; but, the tide is changing and the demands may soon be upon us to provide a more accurate accountability for the way we operate our units and methods we use to optimize performance. For anyone anticipating this need in your plant any time in the near future, now is the time to begin formulating your ideas and getting the ball moving in the right direction. We appreciate this opportunity to share our achievements at Michoud and hope that this report will provide you with a foundation from which to build and also stimulate some useful ideas as how to best plan and achieve your goals for an on-line monitoring system. Please feel free to call

Gerald Lagarde, Farin Schwartz or myself should you have any questions or if we can be of assistance to you in your project.

BACKGROUND

There have been some interesting developments and significant milestones met at both a company and plant level during the past several years that have eventually led to our ability to support an on-line performance monitoring development and implementation plan at Michoud. These accomplishments have been aided by input from the Little Gypsy and Ninemile Point power plants. These plants are both part of Entergy.

The following is a brief historical account of these events:

- Louisiana Power and Light (LP&L is part of Entergy) Productivity Improvement Program (PIP) - The LP&L PIP Task Force submitted a list of Specific Programs from the Ninemile Point power plant to the PIP Steering Committee in January 1985. The Unit Efficiency Task Force portion of this committee was charged with the responsibility for developing the functional requirements for a performance package and evaluating the on-line packages, instrumentation and controls for Ninemile No. 4 and 5. This activity stimulated the interest of other LP&L plants, including Michoud.

- During the 1980's, the Michoud Plant had endorsed the 5-year budgeting process. One of the projects added to the 5-year plan was a 3-year phase-in project for an on-line performance monitoring system using the existing IBM plant process computer and data acquisition system.

- During the late 1980's, it was recognized that the outmoded Edison Omniguard system for measuring critical temperatures on Michoud No. 1 and 2 would have to be replaced and a decision was made to budget for a new Westinghouse WDPF to meet this need.

- In 1990, a new WDPF DAS was implemented on Michoud No. 2 as a replacement for the Edison Omniguard system. An earlier decision had been made to postpone the upgrade of the Unit 1 system due to its lower service factor.

- In 1991, through a joint effort with Little Gypsy, the Michoud Plant purchased a used MicroVAX system through Digital Equipment Corporation (DEC). This system which had been used by the U. S. Census Bureau was in exceptionally good shape and was obtained at an extraordinary savings compared to new list prices for the same equipment. The new VAX was installed and implemented in late 1991 in conjunction with a previously budgeted project for upgrading the DAS on Michoud No. 3 with WDPF.

- In early 1992, the number of Michoud engineering personnel was reduced by one and along with a plant reorganization, the remaining group was organized under the new Michoud Technical Support Group. It was during this time that Gerald Lagarde, who had previously been assigned to the Michoud Maintenance Department, now assumed added responsibilities over the plant performance activities.

- In early 1992, Michoud was introduced to the capabilities of the PMAX on-line monitoring software through the efforts of the E&TS Technology Development Group; and a decision was made to incorporate PMAX into our new WDPF/VAX system. To support our ambitious goal to have a new on-line performance monitoring system implemented into plant operations by the end of 1992 with our limited engineering resources, the following plan of action was undertaken:

    - Provide an accelerated training effort for Gerald Lagarde in the use of WDPF, VAX and PMAX.

    - Contract the services of NUS to install and implement PMAX on our WDPF/VAX system and also to develop and implement PMAX on-line modules for monitoring Unit No. 2 & 3 controllable losses, Unit No. 3 turbine, condenser and feedwater heaters and to provide turbine cycle prediction for Unit No. 3. The Technology Development Group, due to their interest in seeing the PMAX package introduced to our system, shared in the cost of the controllable losses module for Unit No. 2. This support was a great encouragement to our group during this phase of the project.

- By the end of 1992, the new WDPF/PMAX on-line performance monitoring system had been successfully implemented and plans were made to proceed with training of the plant operators in the use of the new monitoring capability in early 1993.

Gerald Lagarde, who has since been reassigned to the E&TS Principal Design Group and Farin Schwartz, engineer for the NUS PMAX Development Group who were both instrumental in developing and implementing the new on-line performance monitoring system at Michoud, will share in the remainder of this paper, covering in greater detail their personal and most valuable contributions to the project.

DEVELOPMENT and IMPLEMENTATION - Gerald Lagarde

In May of 1992, our Michoud Technical Support Group established a plan of attack to accomplish an ambitious goal to have a new on-line performance monitoring system in place and available to the plant operator by the end of 1992. This plan consisted of my personal training in the following:

- VAX/VMS System Management
- WDPF System User
- PMAX Modeling

Over a four month period, all three of these training goals were accomplished. All three training programs were essential in allowing myself to interact with the related software and hardware.

On-line monitoring begins with a data acquisition system (DAS). See Attachments for illustration of how this system is configured. We were fortunate to have an existing WDPF (Westinghouse Distributed Processing Family) data acquisition system on site. We had all essential points available for Unit No. 3 and a limited number of points available for Unit No. 2 (still we had enough to continue our efforts).

The next piece of the on-line monitoring system is a computer with multi-task and number crunching capabilities. A VAX computer was chosen because it has these capabilities.

Another essential piece of hardware needed for on-line monitoring is an interface between the WDPF and the VAX computer. This is accomplished by using a VAX Highway Interlink (VXI). The VXI allows the VAX access to point data from other drops on the highway (RECEIVE points) and also allows the VAX to return data to the highway (ORIGINATE points).

It should be noted here that all the aforementioned equipment was in place prior to the selection of the on-line performance monitoring software. Here the choice was between EPRI's Performance Monitoring Workstation (PMW) and NUS's PMAX Performance Monitoring System.

We chose NUS's PMAX software. PMAX is totally menu driven. PMAX database information resides on a PC as well as the VAX and can be downloaded and uploaded as necessary between the two. PMAX is totally supported by the NUS PMAX Development Group whose headquarters is in Idaho Falls, Idaho. Along with the PMAX software, the PMAX system comes equipped with a Kermit software package to allow the PC to emulate the VAX terminal. We originally purchased the TIW IMAGE software package to allow the PC to emulate an Intercolor graphics terminal. We have since upgraded our display capabilities using NUS's X-Windows based R*TIME display and trending package. The upgrade gave us better networking capabilities and distributed the information throughout the plant using our local area network. Now, most interested parties have current and archived information concerning the operation of the plant at their finger tips.

The PMAX software was installed and verified by the NUS PMAX Development Group. NUS also assisted in setting up the VAX computer with various VMS command programs and VXI receive and originate point files for the VXI.

Due to organizational changes that occurred at Michoud in early 1992, our plant technical support staff was reduced in size; and it became apparent that our group would not be able to dedicate a person full time to the development of the various PMAX modules needed to meet our goals for a new on-line monitoring system. Therefore, a decision was made to contract the services of NUS to develop the following modules:

- Controllable Losses - Units 2 & 3
- Monitor Turbine Cycle Performance - Unit 3
- Predict Turbine Cycle Response - Unit 3

Upon completion, we worked with the NUS PMAX Development Group to install and tune-up the developed PMAX modules for Michoud.

The next step was to identify those calculated values that we were interested in monitoring. PMAX uses an EU (Engineering Units) TABLE that is nothing more than a series of storage locations in which a received or originated value resides. Using these locations, we create a point name for that EU TABLE location to be used by the WDPF system. From there we then establish that point name for the VXI by updating the previously created received and originated point files (short and long) on the VAX computer. After the files have been updated and the VXI mass memory rebuilt, we then establish the created point names in the WDPF point directory and download them to each op-cons' mass memory. Once downloaded to the op-cons, the PMAX generated value can be used by WDPF graphics. These steps must be performed whenever a new PMAX value is used. It should be noted that if an existing WDPF point name (one that is used by PMAX) is changed these steps are taken in the reverse order.

Now that the points reside on the WDPF data highway, they can be used in any WDPF graphical display. In an effort not to recreate the wheel, we were fortunate to have access to existing WDPF graphical displays from the Little Gypsy and Ninemile plants. We were able to modify them as necessary to accommodate the Michoud Operations Department.

Once the graphical displays had been created and made available on the WDPF graphic terminals, it was then necessary to train the ultimate user, the control room operator, how to interpret the performance information being displayed. Our goal was to make the control room operator become aware of PMAX and how it can help him in his daily duties and decision making process. We especially emphasized the benefits of the controllable losses graphical display.

After successful installation of the initial PMAX work for Michoud Unit No. 3, we decided to have a boiler and turbine cycle model constructed for Michoud Unit No. 2. Although the available input points for Unit No. 2 were limited, we knew that the information would be made available in the future. It will be just a matter of assigning the WDPF point name to the already designated EU TABLE location as the points become available.

Because the performance calculations are based on field instrumentation, the chance of loss of data because of instrumentation failure is always a concern. Loss of key data can interrupt calculations and invalidate others. We have configured our system using PMAX's Input Validation Module to validate most of the input points coming from the WDPF. The PMAX validation process allows the performance calculations to continue uninterrupted by substituting an acceptable value for a bad or unacceptable (out of range) field value. The substituted value can be either one of the following:

- Constant value
- Value obtained from another point in the EU TABLE
- Clipped value from the user supplied min/max values
- Value obtained from a bogey curve
- Bad value to be tagged as invalidated (no substitution)

Points that fail their validity checks can be viewed through the report option of the data base compiler. This information can be made available to the Instrument and Controls shop to help them prioritize their instrumentation maintenance.

In closing, to those plants that may be considering an approach similar to Michoud's, we would like to emphasize the cooperation between stations that use PMAX. Currently Michoud, Little Gypsy, Ninemile Point, and Waterford stations all use PMAX to monitor plant performance. My training and experience in PMAX and WDPF is now available on a system level through our E&TS Department. I can support any of the plants needs concerning utilization of their performance monitoring system.

NUS SUPPORT - Farin Schwartz

HISTORY OF PMAX

The on-line performance software PMAX was developed in 1981 by the software and engineering staff at NUS's Idaho Center (formerly Energy Incorporated). The original development staff are still active in the on-going enhancements to the product and in providing solutions to applications problems.

PMAX is based on ASME approved methods for calculating power plant performance. It also employs several calculational techniques used by the General Electric Company to evaluate steam turbine performance. The widely used steady state thermo-dynamic analysis tool PEPSE® was used as a model for the PMAX calculations. The PEPSE calculational process was not capable of handling the inconsistencies of plant instrumentation. Therefore, a rigorous error checking routine was implemented into PMAX to handle the sometimes errant data. With this error checking, PMAX is able to provide, even with bad input data, uninterrupted calculational results. PMAX calculational results mirror those produced by PEPSE.

PMAX has over fifty installations throughout the United States in both fossil, combined cycle, and nuclear power plants.

PMAX Power Plant Modeling

PMAX uses calculational modules and user defined calculations to provide performance information for various power plant components. The data provided by the plants data acquisition system (DAS) are used as inputs to the calculations. The calculational results are displayed on PMAX's own display system, or sent back to the DAS to be displayed on its display terminal.

The PMAX model, or "arming plan" as it is called, consists of several sub-models. The sub-models are listed and defined as follows:

1. **Controllable Loss Model**. Identified when specified operating parameters have deviated from their target or design values. It also calculates the associated costs and heat rate penalties. This on-line information aids the operator in keeping the controllable losses to a minimum.

2. **On-Line (What Is) Turbine Model**. Performance results for the turbines, condensers, feedwater heaters, and pumps. These results can be trended and used to identify degradation of the plant components. The model also calculates on-line heat rate.

3. **Predictive (What If) Turbine Model**. This is a separate model of the plant's turbine cycle used to conduct predictive analyses. The user can make hypothetical changes in plant equipment or operating parameters and calculate the effect on gross generation and heat rate. This calculation runs independent of the on-line turbine model, but can use the on-line results as starting values. For example, "if you increase the intermediate turbine efficiency by one percent, what would be the impact in gross generation and heat rate?".

4. **On-Line (What Is) Boiler Model**. The PMAX boiler model determines the fouling of individual boiler stages, providing valuable information to the operator for optimizing boiler sootblowing. Boiler efficiency is calculated using the ASME Heat Loss and the Input/Output method. Air heater calculation results include air and gas side efficiencies and leakage.

5. **Predictive (What If) Boiler Model**. This is a separate model of the plants boiler cycle used to conduct predictive analyses. The user can make hypothetical changes to operating parameters and calculate the affect on other parameters. This calculation runs independent of the on-line boiler model, but can use the on-line results as starting values. For example, if you improve the cleanliness of an individual boiler stage, what will be the affect on the steam temperature.

6. **Replay Model.**. This is a separate model of the plant that allows the user to retrieve data from an archive file and "replay" it in a model and study the results of the calculated outputs. This model, which runs independent from the on-line model, is used for test data reduction and plant event studies.

PMAX Calculational Processing

The construction of a PMAX model is a three layer process. The layers are the cycle, sequence, and the individual calculational module or user defined calculations. All calculations defined in PMAX are specified through a menu-driven user interface. This allows a model to be constructed without having to do any computer programming.

PMAX contains a library of calculational modules that produce performance results for most major power plant components. In addition, most algorithms and custom calculations can be implemented using the Composed Point (C-Point) Processor. The calculational capability of the Composed Point Processor range from a simple addition to steam and gas table calls and sixth order polynomials. In the construction of a PMAX arming plan, the user defines a calculational module or custom calculation for each plant component to be modeled. These modules are constructed individually, however, the outputs of one calculation might be specified as the input to another.

Once the modules have been constructed, the sequence of executions for the modules is defined. The PMAX sequence determines the order in which modules will execute, and is defined by the user. Logical branching allows for conditional execution of each module, group of modules, or of the entire sequence of modules. An example of the steps and order of a sequence is shown in Figure 1.

As the calculational modules are ordered and executed in a sequence, so the sequences are ordered and executed by the PMAX cycle. The PMAX software is staged on a multi-tasking operating system. This allows up to six PMAX cycles to be running at the same time. With multiple cycle operation, the user can group the sequences in such a way as to minimize the delay time between certain calculations. For example, the sequences containing the controllable loss calculations might be grouped in their own cycle. This would cause the results to be updated more often than if the controllable sequences were included with the turbine and boiler sequences.

The results of the calculations are saved in PMAX storage locations. There are 30,000 storage locations available in the PMAX system. These 30,000 locations make up the PMAX "Engineering Units Table". The values stored in the locations can be displayed, used in trends, archived, plotted, used to generate plant logs, or used as inputs to other calculations.

PMAX User Interface

As previously noted, all PMAX calculations are defined with a menu-driven user interface. This user interface is located on a personal computer (PC) and uses the data base manager dBASE IV. The user defines the calculation instructions on the PC and then transfers these instructions to the processing computer for calculating. Once the model has been completed, the user may printout the calculational instructions from dBASE thus documenting the model.

The PC that is used for building the PMAX model on dBASE can also be used as a display terminal to view graphics results of the calculations. The Intecolor graphic terminal emulation software IMAGE 8820 from T.I.W. Computer Inc. is used to display the PMAX graphics. The transfer of the PMAX model and the graphics is accomplished via a serial link between the PMAX process computer and the PC. In addition to the IMAGE display package, NUS has recently developed the X-Windows base R*TIME display and trending system for the VMS operating system. This package provides advanced graphics and trending capabilities to the plant. It can also be easily networked throughout the plant using its existing local area network. The interface usually utilizes an existing plant PC. An illustration of the interface configuration being used at the Michoud Plant is shown in Figure 2.

PMAX Sequence
Turbine Model (Simplified)

Step	Module Type	Description
1	C-Point	Data preparation (units conversion, pressure drops, etc.)
2	C-Point	Flow calculations
3	Turbine	High pressure turbine performance
4	Turbine	Intermediate pressure turbine performance
5	Turbine	Low pressure turbine performance
6	Condenser	Condenser cleanliness
7	FW Heater	FW Heater 1 TTD and DCA, extraction flow
8	FW Heater	FW Heater 2 TTD and DCA, extraction flow
9	FW Heater	FW Heater 3 TTD and DCA, extraction flow
10	FW Heater	Deaerator extraction flow
11	FW Heater	FW Heater 5 TTD and DCA, extraction flow
12	FW Heater	FW Heater 6 TTD and DCA, extraction flow
13	C-Point	Net unit heat rate calculation

Figure 1

PMAX INTERFACE CONFIGURATION
MICHOUD PLANT

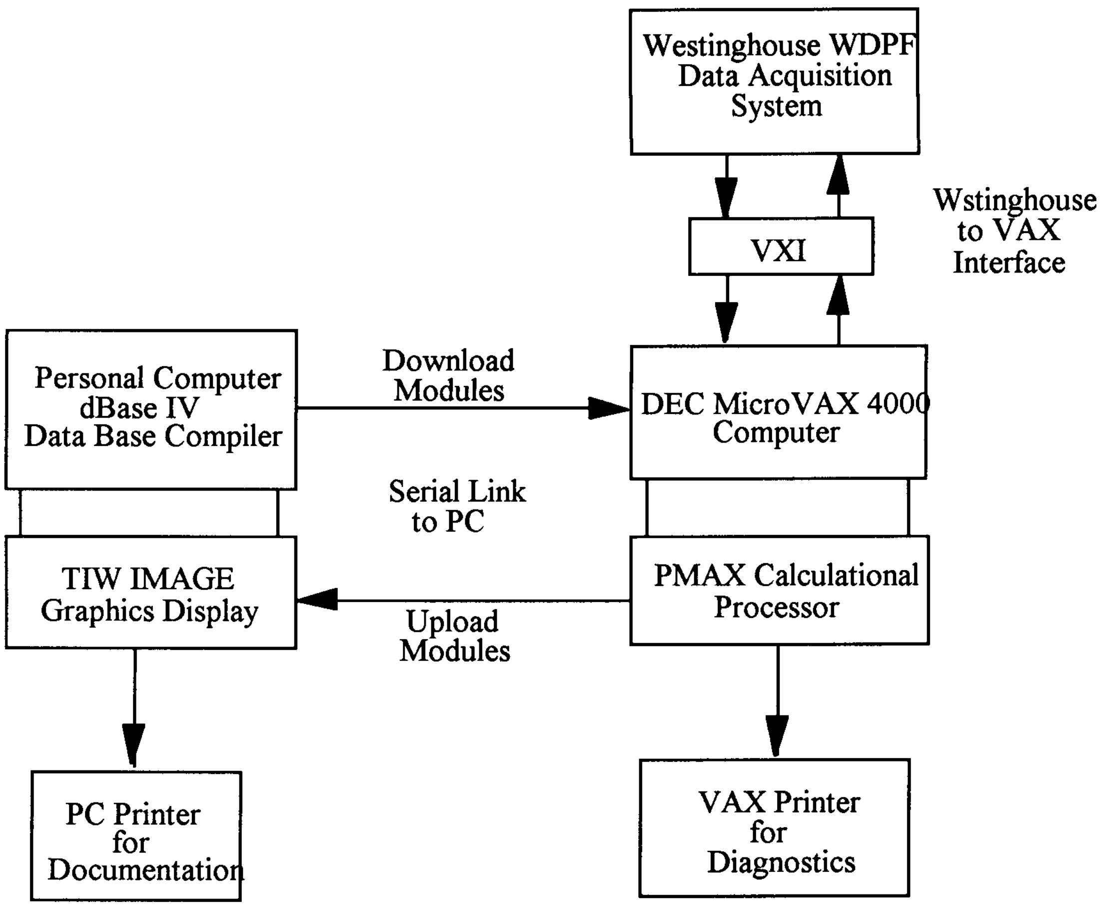

Figure 2

Construction of Michoud PMAX Arming Plan

NUS was contracted to build the PMAX arming plan for the LP&L Michoud Generating station located in New Orleans, LA. The arming plan for the Michoud Units 2 and 3 were to include an on-line and predictive turbine model and a controllable loss model. A boiler model was constructed and installed after the initial contract. Instrumentation lists and thermal kits for both units were sent to the NUS engineering staff for work to begin.

The DAS at Michoud Units 2 and 3 is a Westinghouse WDPF. After a review of the instrumentation list, it was determined that there were some key instruments that were not available on the WDPF. However, the model was constructed with the understanding the instrumentation would be made available at a later time. In place of the missing DAS points, bogey curves were temporarily used to supply the missing information. The curves would simply be deactivated once the DAS points became available. During the modeling process, the staff at Michoud was contacted regularly to answer questions that arose. Their input during the construction of the model was key in arriving at a final service that met their expectations. The PMAX software was installed on a Digital Equipment VAX by a member of the NUS software staff. After the installation, the Michoud staff established communication between the WDPF and PMAX and sent the staff at NUS a representative set of plant data. These data are used as input to the PMAX calculations simulating real-time data acquisition. PMAX results indicated some bad data points coming from the WDPF. NUS identified the bad points to the staff at Michoud, who were able to quickly solve the problems. With the communications complete and accurate and the model finished, it was time for the installation.

Installation and Implementation at Michoud

The installation and implementation of the arming plan at the Michoud plant was accomplished in one week. Values from a few problematic instruments were clipped and tagged by the Input Validation Module and the arming plan was shown to produce correct results. During the installation, several graphics were constructed to display the results of the PMAX calculations. Calculated results of interest, including the controllable loss results, were sent back to the WDPF and displayed to the operations staff on WDPF graphics.

Additional Work Done at Michoud

In upon completion of all items on the original contract, additional work has been completed at the Michoud plant including a PMAX boiler and turbine model for Unit 2. The boiler model includes both on-line and predictive modes for boiler stage monitoring, boiler efficiency using the ASME Heat Loss method, and air heater leakage and performance. The boiler model has been installed.

Additional Enhancements to Michoud

In talking with the staff at Michoud, it was agreed that there were several additional applications for PMAX at the plant. In general, almost any calculation based on plant instrumentation data or manual inputs can be accomplished using PMAX. Some of the topics for enhancement were as follows:

Performance test data reduction. Michoud currently uses a test trailer to set up and gather plant test data. Upon completion of the test, they receive the printout of the compilation of test data. They must then reduce the test data to produce meaningful performance information. We discussed gathering the data in the test trailer and then making it available to PMAX. PMAX could be configured to reduce the test data and provide the test results. This could be done while the test trailer was still on site. If there were any problems with the test data it could be identified immediately. This could save time and money to by avoiding re-testing due to bad test data. Money could also be saved by reducing man power for test data reduction.

Fuel gas flow and analysis. Michoud currently has an on-line gas chromatograph. Sending the information from the chromatograph to PMAX would greatly enhance the boiler efficiency and combustion calculations by providing on-line fuel analysis and a redundant fuel flow calculation.

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TECHNOLOGY TRANSFER DAY

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Gerald Lagarde is presently assigned to the E&TS Principal Design Group as a mechanical engineer. In this capacity, Mr. Lagarde supports the Energy Supply - Fossil plants in their capital and O&M engineering projects. He began his career with LP&L in 1984 as a plant maintenance engineer at the Ninemile Point Plant and in 1988 moved to the Michoud Plant to assume the plant maintenance engineering position. In 1992, he was reassigned to the Michoud Technical Support Group and assumed added responsibilities over plant performance activities. He has received formal training the Westinghouse WDPF, DEC MicroVAX and PMAX/PEPSE Modeling. Mr. Lagarde received a B.S. Degree in Mechanical Engineering from Tulane University.

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Farin D. Schwartz is an engineer for the Performance Systems Department of NUS Corporation. The department develops and applies the power plant performance software PMAX and PEPSE. As a member of the engineering staff Mr. Schwartz designs, constructs and implements both on-line and steady state performance models. He has developed over twenty PMAX models at both fossil and nuclear power plants. In addition to power plant modeling. Mr. Schwartz aids in software development and testing. Mr. Schwartz received a B.S. Degree in Engineering from Idaho State University.

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Don Sanders is presently assigned to the Michoud Plant as Technical Support Coordinator. In this capacity, he is responsible for supervising the plant technical support staff and water chemistry technicians and for coordinating engineering and technical support activities for the plant. Mr. Sanders began his career with the NOPSI Power Department in 1974 as plant mechanical engineer at the Michoud Plant. Since that time, he has also worked as engineer in the former NOPSI Results Department and has served the role of Plant Betterment Supervisor, Operations Superintendent and Technical Support Superintendent at the Michoud Plant. Mr. Sanders received his B.S. Degree in Mechanical Engineering from the University of Texas - Arlington. He is also a registered professional engineer in Pennsylvania and Louisiana.