ELECTRIC POWER RESEARCH INSTITUTE

Combustion Turbine/Combined Cycle Monitoring Platform

ORAP® LINK™ and Combustion Turbine Reliability Analysis

Combustion Turbine/Combined Cycle Monitoring Platform

ORAP® LINK™ and Combustion Turbine Reliability Analysis

TR-113984

Interim Report, December 1999

Project Manager
J. Scheibel

EPRIGEN • 3412 Hillview Avenue, Palo Alto, California 94304 • PO Box 10416, Palo Alto, California 94303 USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

DISCLAIMER OF WARRANTIES AND LIMITATION OF LIABILITIES

ORGANIZATION(S) THAT PREPARED THIS REPORT

Strategic Power Systems, Inc.®

ORDERING INFORMATION

Requests for copies of this report should be directed to the EPRI Distribution Center, 207 Coggins Drive, P.O. Box 23205, Pleasant Hill, CA 94523, (800) 313-3774.

CITATIONS

This report was prepared by

Strategic Power Systems, Inc.
11301 Carmel Commons Blvd. – Suite 308
Charlotte, North Carolina 28226

Principal Investigator
T. Christiansen

This report describes research sponsored by EPRIGEN.

The report is a corporate document that should be cited in the literature in the following manner:

Combustion Turbine/Combined Cycle Monitoring Platform: ORAP® LINK™ and Combustion Turbine Reliability Analysis, EPRIGEN, Palo Alto, CA: 1999. TR-113984.

REPORT SUMMARY

As a result of the overall business environment surrounding deregulation and the technologically advanced machinery being installed in power plants, the power generation industry has a need for timely, accurate information on the performance of equipment. The capability of today's control systems to generate thousands of data points at millisecond intervals provides the basis for meeting this need, but the output of these systems requires manipulation to be translated into usable business information. This report presents information on a control system interface that facilitates this process.

Background

EPRI has conducted projects and developed products that require the automated retrieval of control system data in order to be effective. This experience has resulted in the use of many different types of data collection systems. These systems are typically customized for individual companies and/or control systems, and they are usually expensive. While effective for their specific purposes, they are not generically suitable for wide-scale use on all of the EPRI products and projects that may require control system output.

ORAP® LINK™ is a product that has been developed by Strategic Power Systems, Inc.® (SPS) for the purpose of extracting power plant control system data and transforming this data into business information. The ORAP LINK product utilizes a generic, configurable control system interface to obtain data directly from the control system. The generic nature of the ORAP LINK system allows for a common system to be deployed to plants that have different control system architecture, generation equipment, and plant configurations. This common interface approach results in a robust product that can be provided at significant economies of scale when compared to the custom-built interfaces available today.

EPRI and SPS are working together to integrate the data requirements of EPRI products and projects with the capabilities of ORAP LINK. This effort is initially focused on developing a specification for the integration process. Future EPRI products can be built based upon the generic specification so that access to control system data will be achievable and a product-specific user interface will not always be required.

Objective

To provide a generic guideline for integrating ORAP LINK with EPRI monitoring and diagnostic products that are enhanced by input taken directly from a control system.

Approach

Utilizing the experience gained during the integration of the EPRI compressor monitoring product with ORAP LINK, a set of guidelines will be developed to provide the basis for integrating additional EPRI products with the ORAP LINK system.

Results

The expected result of this effort is the ability to quickly integrate current and future EPRI products with the ORAP LINK product as system modules. These modules can then be provided as options to all ORAP LINK users.

EPRI Perspective

Reliable, timely business information represents a significant advantage in a competitive environment such as the power generation industry. The ability to generate this information is dependent on the amount of raw data available and the analytical techniques used to transform this data into meaningful information. In today's power generation industry, access to an abundant amount of raw data exists, but the integration of data with analytical tools is still highly specialized. Through this project EPRI plans to develop a methodology for integrating its analytical tools with a generic control system interface (ORAP LINK) that can be used as a data collection and reporting platform for all standard power plant instrumentation. This activity is related to the combustion turbine axial compressor monitor described in TR-113985.

TR-113984

Keywords

Combustion turbines
Control systems
Data collection and reporting
Diagnostic monitoring
Predictive maintenance

CONTENTS

LIST OF FIGURES

1
ORAP LINK PRODUCT OVERVIEW

1.1 Basic System Features

The ORAP® LINK™ product was designed and developed by Strategic Power Systems, Inc. (SPS). The genesis of the ORAP LINK system came from specific experience with ORAP, a system for collecting monthly operational data, event, and maintenance information from over 1400 units worldwide. This system depends on individual plant personnel to manually record the required information and highlights the need to move the effort of data collection and reporting to a more automated process. An automated process reduces the burden placed on power plant personnel while at the same time providing a more uniform reporting standard. The ORAP LINK application automatically produces approximately 80% of the monthly input required by the ORAP system.

ORAP LINK is specifically designed to address productivity issues associated with data capture and its subsequent conversion to business information. These productivity issues are a result of the inherent conflict between the personnel time required for data collection and reporting and the need for "more" information to drive a company's market competitiveness. ORAP LINK reduces the personnel time required in the collection and transformation of data while enhancing the quality and timeliness of business information flowing to management.

ORAP LINK obtains data from up to three (3) different sources;

- Power plant control system(s)
- Maintenance management system
- Manual input

ORAP LINK transforms the data obtained from these sources into relevant business information for availability and reliability assessment, equipment condition and parts tracking, operating considerations, and other relevant management reporting output.

The primary objectives of the ORAP LINK system are as follows:

- Establish a standard for the collection and organization of data on equipment function (reliability), availability, usage, durability, and life.
- Cost effectively improve the usefulness, quality, and completeness of such data to the operations, maintenance, and management levels.

- Substantially reduce the manpower effort required to collect and apply this data to planning, decision making, and managing plant operations

Figure 1-1 provides a schematic overview of the ORAP LINK system.

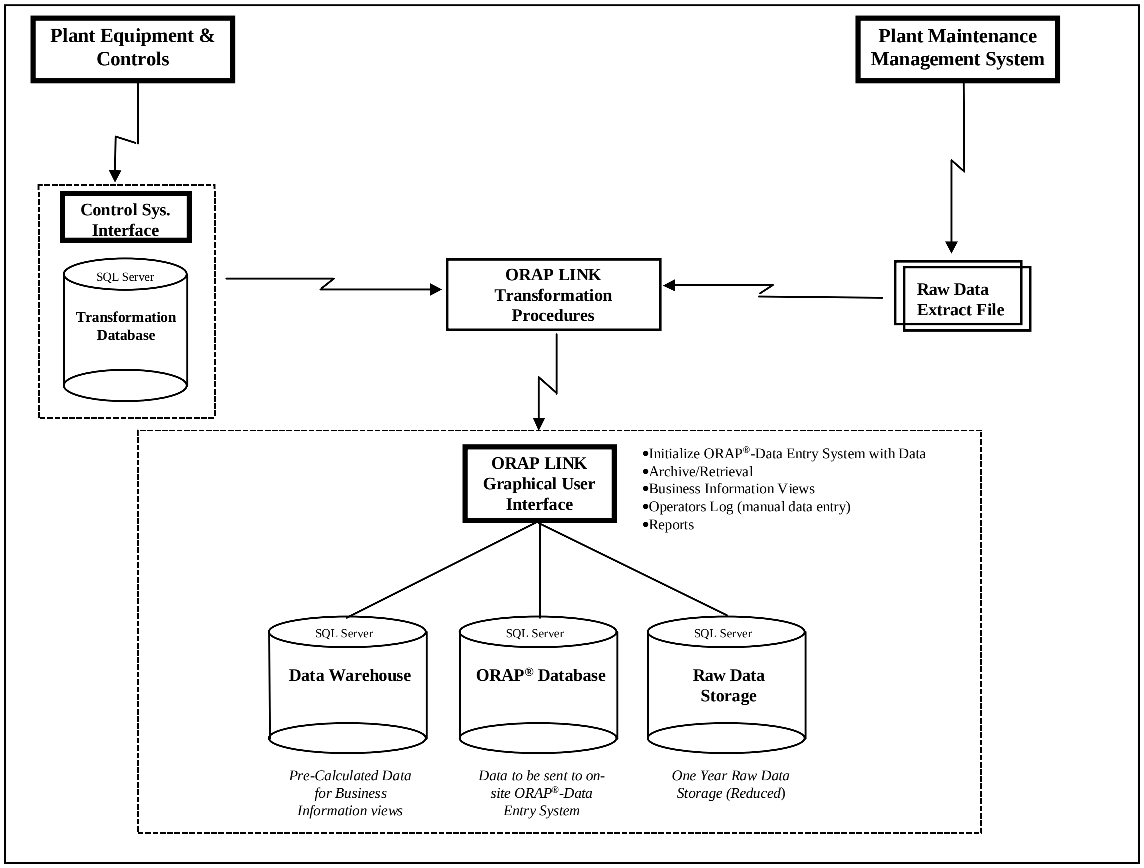

Figure 1-1
Schematic of ORAP LINK

The basic design concept for the ORAP LINK system included the following high-level features that were incorporated as a part of the overall system design:

- A format that is considered user-friendly and “simple” to use.
- A MS Windows “look and feel” (i.e. GUI with standard Windows functionality).
- The ability to monitor information on multiple units within a single plant.
- The flexibility to allow for future additions to; the data points being collected, the required data transformations, the “triggers”, and the business information views.
- The capability to define the module pieces (i.e. data points, data transformations and triggers) that are applicable to a specific user.

- A security process which, at a minimum, limits access to areas by user name and password.
- Year 2000 compliant.

As described above in Figure 1-1, the ORAP LINK system is comprised of several major functions; the control system interface, the maintenance management system interface, the transformation logic, and the database areas. Each of these is described in the following subsections.

1.1.1 Control System Interface

The control system interface is the mechanism by which ORAP LINK obtains raw data from the control system. This interface is passive in nature with a ***read only*** capability that allows ORAP LINK to understand and interpret the protocol being used by a specific control system. ORAP LINK has the capability to directly interface with over 500 different control systems, including almost all of the major varieties found in power plants control systems today. For any control systems which are not currently compatible with ORAP® LINK™, the capability exists to map the protocol being used by that control system. From this mapping process an interface driver can be developed so that ORAP LINK can obtain data from that particular control system.

The ORAP LINK control interface is based on client server architecture and runs under the Windows NT operating system. This architecture allows the primary ORAP LINK database to act as a server and for other computers connected via a LAN or intranet connection to "view" the information being kept within the server. This capability allows individual plants to determine the physical location where they display the ORAP LINK system graphics. It also allows companies with multiple sites to tie all of the sites together into a central intranet setting accessible from a central facility as well as from each site.

The control system interface is configured for each site based on the number of units located at the site, the number and type of business views that are requested and the data points that are available through the plant control system. For each business information view, a specific set of data points is required. If those points exist for a given unit, or can be obtained/calculated based on the available points, the view will be available for selection. Once the desired business views have been selected, the specific control system data point nomenclature is mapped via a series of virtual data points to the chosen ORAP LINK information views. This configuration process is performed by SPS engineers and is included in the standard package price.

As an example of the configuration process, suppose that the information view shown in Figure 1-2 below is selected for inclusion in the ORAP LINK system. The collection of data for this Alarm Summary view is "triggered" based on a unit tripping off-line. The specific control system data point that designates a trip from a normal shutdown will vary from control system to control system. However, the ability to distinguish a trip from a normal shutdown will always exist. The single point, or combination of point conditions, which designate a trip are routed through a virtual point designated unit_trip in ORAP LINK. Whenever that specific point or combination of points occurs, the unit_trip virtual point will cause the system to begin collecting the information that is shown in Figure 1-2. Once this information is collected, time stamped, and transformed, it is placed in the data warehouse for viewing through the ORAP LINK business view interface.

Alarm Summary - Unit 14		
Mission 4: 11/08/1997 14:32 - 11/09/1997 04:15 *Mission Termination: Trip occurred at 11/09/1997 3:18*		
Alarm Tag	**Alarm Designation**	**Time**
ANN025	***GAS FUEL NOZ PURGE SYSTEM TROUBLE TRIP***	***11/09/1997 03:17***
ANN133	HIGH VIBRATION TRIP OR SHUTDOWN	11/09/1997 03:18:01
ANN055	EXHAUST DUCT BACK PRESSURE HIGH TRIP	11/09/1997 03:18:04
ANN112	COMBUSTION TROUBLE	11/09/1997 03:18:06
ANN103	AA CPRSR AIR TEMP HIGH SHUTDOWN	11/09/1997 03:18:09
ANN109	CHAMBER FLAMED OUT DURING SHUTDOWN	11/09/1997 03:18:11
ANN110	LOSS OF FLAME TRIP	11/09/1997 03:18:13
ANN175	GENERATOR BREAKER TRIPPED	11/09/1997 03:18:16
ANN147	MASTER PROTECTIVE LOCKOUT STARTUP	11/09/1997 03:18:18

Figure 1-2
Sample ORAP LINK Information View: Alarm Summary

The configuration of the virtual points required by the information views is only performed once at the initial on-site product installation. Once this configuration process has been completed, the ORAP LINK system will continue to collect the raw control system data based on the conditions that have been specified.

The configuration process also allows for the specification of intervals at which data is collected and the amount of time that the raw information is kept in the database. All of the control system information received is being sorted through by ORAP LINK to determine if any of the specific triggers for the business information views are present. Once a determination is made as to the presence of these triggers the data is passed on to the transformation for processing and/or kept the transformation database area. The data that resides in the transformation database area is typically maintained for a specified period of a few days to a month. Any information that is required to corroborate the results of the business information views is also passed on to the raw data storage database area that is discussed later in this report. Since the majority of the data points are taken at one (1) second intervals, the size of the transformation database area is monitored and not allowed to grow beyond a specified size so as not to interfere with the capabilities of the ORAP LINK program to continue processing information.

1.1.2 Maintenance Management System Interface

Within the ORAP LINK system there also exists the capability to interface with a power plant maintenance management system (MMS). The MMS would typically provide additional information on the maintenance work that was done on the plant equipment for both forced and scheduled events. For example, if gas turbine compressor efficiency is being tracked, then ORAP LINK will also expect information on water washes and major overhaul work on the compressor. This information cannot be obtained from the control system so it must be entered either through the manual entry portion of ORAP LINK or through the MMS. If this information is already being placed in a MMS, then the objective would be to import this detailed data into ORAP LINK and reduce the need for duplicate, manual data entry.

There is a tremendous variety of maintenance management systems installed in power plants today. These systems range from fairly inexpensive and simplistic work order tracking programs to expensive, enterprise systems which track everything from inventory levels to taxable income. In order to build a generic interface with the MMS that is similar to the control system interface concept described above, a standard export/import procedure has been developed. This procedure allows for a fixed definition of data values that are to be exported from an MMS to a delimited ASCII file. Since the definition of this file is generically defined, the ORAP LINK system can read the available information and place it in the appropriate area of the database for use in the views.

It should be noted that several data pieces contained in the MMS are typically company or plant specific. As an example the definition of equipment in the MMS is typically developed internally and will vary across companies. Since the goal of the ORAP LINK system is to maintain a generic interface, these specific data pieces will need to be translated into a standard set of information that is universally recognized by the ORAP LINK system. To use the example above, the EPRI Equipment Breakdown Structure (EBS) is utilized within the ORAP LINK system to define equipment. Therefore, a translation table must be built for the equipment codes in any MMS system that does not utilize the EPRI EBS. Other site-specific data collection and storage conventions will also have to be treated through a translation process. The translation requirements will need to be defined as part of the up-front configuration process.

1.1.3 Transformation Programs

The heart of the ORAP LINK system is the transformation programs. These programs take the raw control system data that is being collected and “transform” it into the data format required by the various business information views. Each information view has a specified set of transformation programs that constantly run in the background, checking the data points sent by the control system and waiting for their “trigger” point(s) to appear. These trigger point(s) are a specific event, or series of events that will execute the transformation procedure (e.g. base load operation, trips, unit start, etc.). Once a triggering event is encountered, the transformation program begins taking data from the control system interface and via calculations or other forms of mathematical data manipulation (e.g. integration, summation, etc.) returns data values that are placed in the data warehouse for the business information views.

An example of the transformation process would be the collection of the time to start a unit. The triggering event may be a combination of the start button being pushed and the unit being below 10 rpm. Once this triggering event happens a transformation program sets up a start time for the specified mission and assigns it a mission number. Transformation programs then look for another triggering event that indicates that the unit has completed the start, the start has failed, or the operator aborted the start. The triggering event for a successful start is typically that the pre-set load level was reached (i.e. base load, spinning reserve, etc.). When this second triggering event is achieved, a transformation program closes the current start and stores the begin time and end time for the start in the data warehouse along with the type of start (i.e. successful, failed, or aborted).

All of the transformation programs in ORAP LINK perform a specific function and may be required by one or more business information view. The transformation programs are part of the generic ORAP LINK product and cannot be modified on a site-by-site basis. The structure of the transformation is also tied to the configuration of the control system interface and the business information views. While modifications and additions to the transformation programs are possible, they should not be undertaken lightly.

1.1.4 Database Areas

1.1.4.1 Data Warehouse

The data warehouse area of the ORAP LINK database is designed to maintain data for each of the business information views contained in the specific application. The intent of this area is to maintain pre-calculated statistics and data values so that the user has instantaneous access to all information once a view has been selected. This area of the database is fed by the transformations and therefore only those tables that contain information required by the views that have been selected by a specific plant are actually populated.

1.1.4.2 ORAP Data Entry

The ORAP Data Entry area of the ORAP LINK database contains the information required to update approximately 80% of the manual input currently required by the ORAP system. The ORAP system is a worldwide power generation database encompassing over 1,400 units submitting operational, failure, and maintenance information to Strategic Power Systems on a continuing basis. The ORAP program allows participants to “share” fleet level information and experience with equipment and plant designs similar to their own.

In order to populate the ORAP Data Entry database tables, an ORAP LINK user needs to be configured as an ORAP participant. If this information is contained in the ORAP LINK system, then a series of transformation programs are included which automatically feed the database format required by ORAP Data Entry. This information is placed in this area of the ORAP LINK database where it can then be transferred to the ORAP Data Entry program for editing, the addition of any required manual input (e.g. event descriptions), and submittal to the ORAP program. The use of ORAP LINK as a front-end data gathering tools significantly reduces the amount of time required to participate in the ORAP program. The data that is gathered through this part of the application includes a history of the counter readings, operational data (i.e. hours, starts, etc.), and available event data (trips, failed starts, etc.) that can be retrieved from the control system.

Once information is provided to the ORAP Data Entry program, this system is also capable of translating the ORAP data format to the NERC GADS data format and building the export ASCII file required by NERC GADS for data submittals. The ORAP Data Entry Program can also export information to any common software interface (i.e. MS Excel, MS Access, Dbase, etc.) and will be capable of sharing information back to the ORAP LINK system.

1.1.4.3 Raw Data Storage

The Raw Data Storage area of the ORAP LINK database contains the raw control system data that is required to corroborate specific calculations made in the transformation procedures. As an example, the recorded compressor inlet and outlet temperatures and pressures would be maintained in this area. These values would support the compressor efficiency calculations made for the gas turbine compressor efficiency view. The intent of keeping this data is to provide the user with the capability to understand the data that goes into complex calculations so that the information can be further investigated in the event that a potential issue is highlighted.

1.2 Customization Features

The ORAP LINK software is designed to be flexible with respect to the future addition of modules that enhance the capabilities of the system. Modules include the addition of third party products, instrumentation, and business information views. Additionally, the software was built to allow users to modify some of the calculations that are built into the transformation programs. All of these customization features are discussed in further detail in the following subsections.

1.2.1 Integration of Third Party Products

ORAP LINK was designed to be a data collection and viewing platform that can act as both a front-end (data collection and dissemination) and/or a back-end (data display) for third party products. These products can be developed with ORAP LINK as an integral part of the application, added as a custom, fully integrated feature on a site-by-site basis, or merely fed raw data from the ORAP LINK system with no display feedback provided.

The fully integrated third party products will typically have a separate calculation process that is fed pre-specified input data from the ORAP LINK transformation procedures. These products can then perform some independent manipulation of that data to derive a set of output that is then passed back to ORAP LINK for display and reporting purposes. This maintains a common interface for the user, reduces the amount of manual input required for the third party product, and allows for this information to be tied into the other data that is contained within the ORAP LINK system.

As an example of the fully integrated process described above, SPS is currently working closely with EPRI to integrate several of their monitoring and diagnostics products. These products have been previously developed for their membership and are enhanced by the provision of information directly from the control system. Specific examples of EPRI tools that can be integrated with the ORAP LINK application are SCAMP, a gas turbine compressor efficiency monitoring program and EPRI COATLIFE, a tool for determining the remaining life on gas turbine blade coatings. The integration process for these EPRI products is described in detail under Section 3 of this report

The site specific, fully integrated third party product follows the same general integration guidelines that are described in Section 3 of this document. However, the major differentiation from the generic integration process would be that the third party product is either specific to the site and therefore has no generic value to other ORAP LINK users, or the site wishes to maintain the rights to the integration of this particular product.

Finally, if a user has a particular system that would benefit from receiving automated data directly from the control system, a data pipeline can be set up so that ORAP LINK provides the data to this third party product at a pre-defined interval and in a pre-defined format. This pipeline would be a one-way transfer, with no information provided back to ORAP LINK for display and integration purposes. Virtually all of this integration process would be customized and specific to a given user.

1.2.2 Addition of Instrumentation

During the design effort, it was recognized that after the ORAP LINK system is initially installed and configured, additional instrumentation may be added to the unit. Provisions were made in the configuration process that allow for this instrumentation to be added to the data collection process from that point forward. Additional effort would be required to build transformation programs and business information views for this instrumentation. However, this work could be directly integrated into the ORAP LINK base design without any interruption of the current system processes.

1.2.3 Addition of Business Information Views

As additional views become available, the ORAP LINK application can be updated with the new views and their associated transformation programs. In most cases the introduction of new views will require that the configuration of points also be updated to include any new control system data that is required. The intent of the ORAP LINK design is that, to the extent possible, all business information views will be designed to be backwards compatible with all previously issued ORAP LINK applications.

1.2.4 Modifications to Calculations

There are many calculations that are embedded in the ORAP LINK transformation programs. Some of these calculations may change over time and can be partially modified within the ORAP LINK system. The partial modification refers to the built-in capability for the user to modify equation constants and reference table information. These modifications can be enacted through the ORAP LINK manual data entry process described in further detail under Section 2 of this report.

Examples of calculations that can be modified by the user are the ambient temperature vs. expected output curve and the equation constants for factored or equivalent hours. In the former case, the curve is entered into the ORAP LINK system as part of the initial configuration process. For each ambient temperature reading, a corresponding expected percentage output value is entered. Over time if this curve changes, or the user feels that the original values are inaccurate, any of the values can be changed through the manual data entry forms.

The equations constants for factored hours (e.g. multiplier of 6 for peak load hours) can also be modified as required by manufacturer changes or “real world” experience. These changes will not impact the ORAP LINK system in any way and will only take affect in the system from the point in time that they are entered. All historical data will continue to be calculated with the values that were valid at that point in time.

It is important to note that the user cannot implement fundamental changes to the equations because these changes will require modifications to the transformation programs and business information views.

2
ORAP LINK INFORMATION VIEWS & SUPPORTING INFORMATION

2.1 Primary Business Information Views

2.1.1 Definition

A primary business information view is a pictorial representation of data that has been obtained directly from the control system and transformed to highlight a specific area of interest. There are a number of standard business information views that are offered with the base ORAP® LINK™ software. The addition of customized business information views is also being offered provided that the business information view can be designed and developed as a generic entity that can then be offered to all ORAP LINK users.

2.1.2 Samples

The following are samples of the business information views contained within the ORAP LINK system today and also several that are being designed, developed and tested at the first commercial site for this product. These sample information views are included in this report in order to communicate the potential use of this system at end user's sites.

Some of the business information views have been filled with "test data" in order to demonstrate the capabilities of the system to track information. This test data is not meant to demonstrate the actual performance of a unit, but to provide a maximum understanding of the intent of the business information view.

All of the business information views can be selected from a main screen area. The main screen area is set up with a roll-up window menu on the left hand side of the screen. This roll-up window is similar to the MS Outlook menu bar. Each bar in the roll-up area represents a different grouping of business information views. In the sample main menu area provided in Figure 2-1 below, the bar groupings are Summary, Efficiency, EOH, and Admin. Each of these groupings may contain several business information views. Each business information view will have a separate icon and text that describes its content. In order to access the view the user just has to double click on the icon and the view will appear in presentation area of the screen.

The upper section of the screen is customized with the customer's company logo, name, and the site at which the application is installed. This is also the area where a specific unit would be selected for viewing in a multi-unit site.

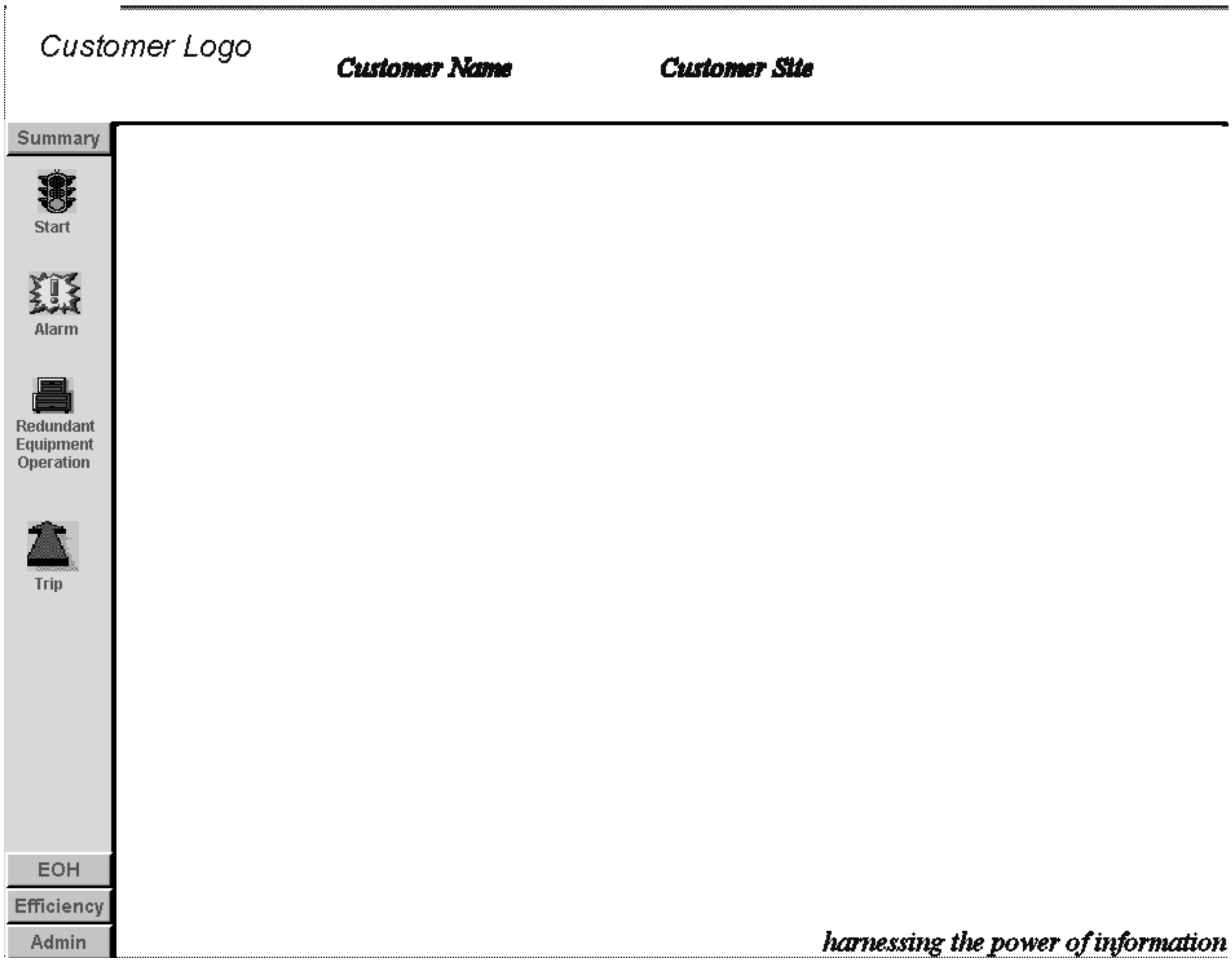

Figure 2-1
Sample ORAP LINK Main Menu Area

The business information view shown in Figure 2-2 shows the gas turbine compressor efficiency over a period of time. The solid purple horizontal line across the top of the view is a user configurable value for "new and clean" compressor condition. This line provides a benchmark against which all actual data points can be measured. The vertical lines shown in the graph are color coded to represent different events that can impact the expected compressor efficiency values. These events would include such items as on-line water washes, off-line water washes, and major overhauls.

The best-fit lines that are drawn through the compressor efficiency points calculated between each set of events that affect compressor performance are meant to show the severity of the compressor degradation during that period. Each compressor efficiency data point represents the compressor efficiency calculated by the EPRI SCAMP program, corrected to standard day conditions. The standard day conditions are a user input and can be defaulted to ISO standard day conditions.

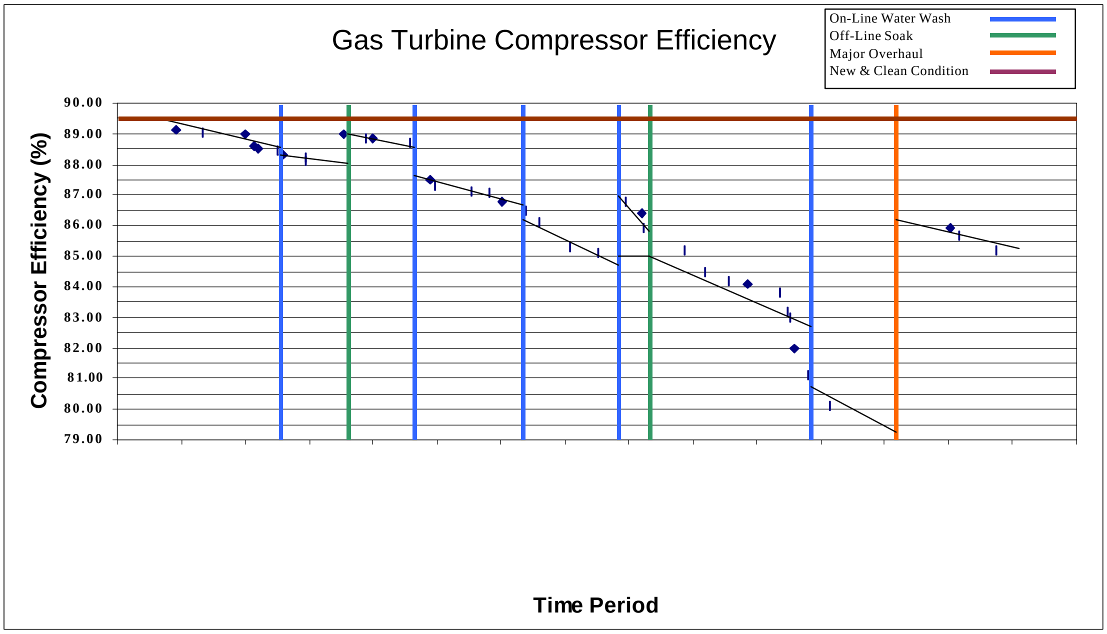

Figure 2-2
ORAP LINK Sample View: Gas Turbine Compressor Efficiency

The sample ORAP LINK data view shown in Figure 2-3 depicts the amount of time required to start a unit, from the time that the start button was pushed until the unit reached it pre-set load requirement (i.e. a successful start).

The horizontal dashed lines located at the top and bottom of the view represent the maximum and minimum starting times experienced during the selected data period. Another horizontal line labeled Avg. shows the average starting time over that same time period. A fourth horizontal line labeled Req. represents a user defined input for the required starting time for this unit. The shaded area between the required and average starting times provides a visual understanding of how the unit is performing against its requirements.

Each start is recorded as one (1) of three (3) symbols; a solid green circle denotes a successful start, a red circle with a slash through it denotes a failed start (i.e. unit tripped prior to reaching pre-set load), and a red letter ‘a’ represents a start that was aborted by the operator by invoking a normal shutdown prior to reaching the pre-set load.

Each start in the view shown in Figure 2-3 represents an individual mission that is tied to a specific starting date. All of the starts are shown in Chronological order and the dates can be selected by the user as ALL or by specifying the begin and end date for the desired period.

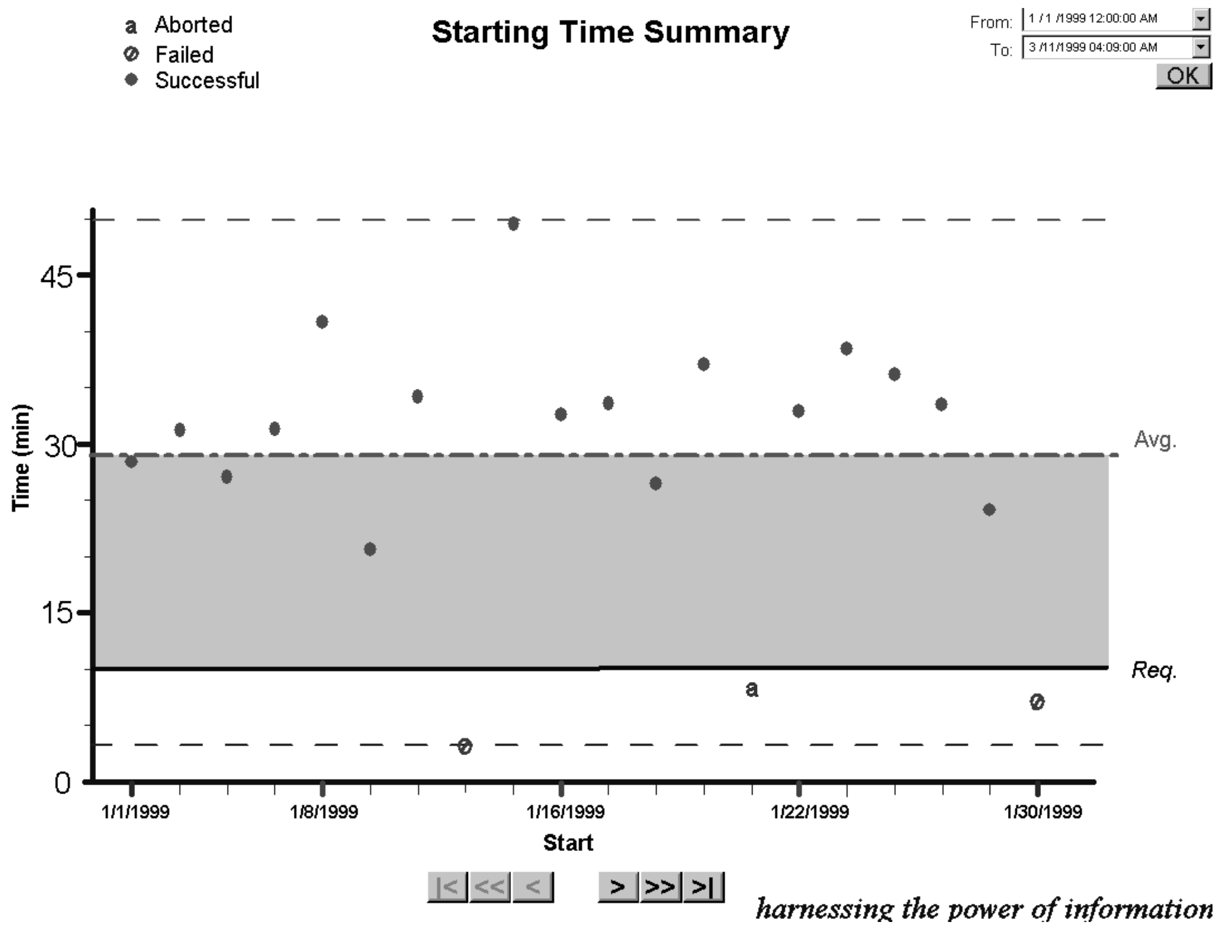

Figure 2-3
ORAP LINK Sample Data View: Starting Time Summary

Figure 2-4 provides a sample of the mission summary view. The user can look at a specific mission summary by either double clicking on one of the starts under the starting time summary view shown in Figure 2-3 or by selecting a mission directly from the main menu area. If the user clicks on a start (i.e. successful, failed, or aborted), all of the information pertaining to the mission that followed that start will be displayed in the presentation area.

The Mission Summary view is divided into four (4) distinct pieces of information. The first three (3) are displayed in the form of pie charts which summarize the time that the unit spent starting, on-line, and in shutdown. The last section is a tabular summary of the mission.

The starting time pie chart is divided into "time in state" for each part of the starting sequence. Examples of the various parts of the starting sequence would be starting permissives, starting means engaged (i.e. cranking), turbine acceleration, full speed no load, synchronizing, spinning reserve, and load to set point. These categories can be configured for each system depending on the specific starting sequence that the unit follows. The high level pie chart shown in Figure 2-4 displays a different color pie slice for each of the starting categories. The intent of this pie chart is to show how much time is required in each part of the starting sequence so that if the unit is not meeting its starting requirements, the user has information that can be used to identify potential problem areas.

The on-line pie chart is also divided into the time that the unit has spent in the various on-line states that are configured for this unit. Typically these on-line states are; loading, base load, peak load, pre-selected load (off design load control), part load (temperature control), and unloading. Again the pie is color coded to show how much of the mission was spent in each of the on-line states.

The shutdown pie is based on the same concept as the other pie charts. Each of the various shutdown states can be configured for a specific unit and then displayed as a "time in state" color-coded pie slice. These states cover the time period from when the generator breaker opens on shutdown until the unit reaches a point where the "cool down" period has ended and it is either stopped or put on some type of rotor barring service.

The tabular summary in the lower right corner of Figure 2-4 is designed to summarize the mission statistics. All missions are referenced by a mission number that is generated by the system as a means of tying together information from one view to the next. The table then shows for the indicated mission; the elapsed time from start initiation to shutdown completed, the elapsed time that the unit was fired, and the elapsed time that the breaker was closed. The mission termination is also indicated (i.e. trip, normal shutdown, etc.) as well as a summary of the total time depicted in the pie charts and information on the generation of the unit during the mission.

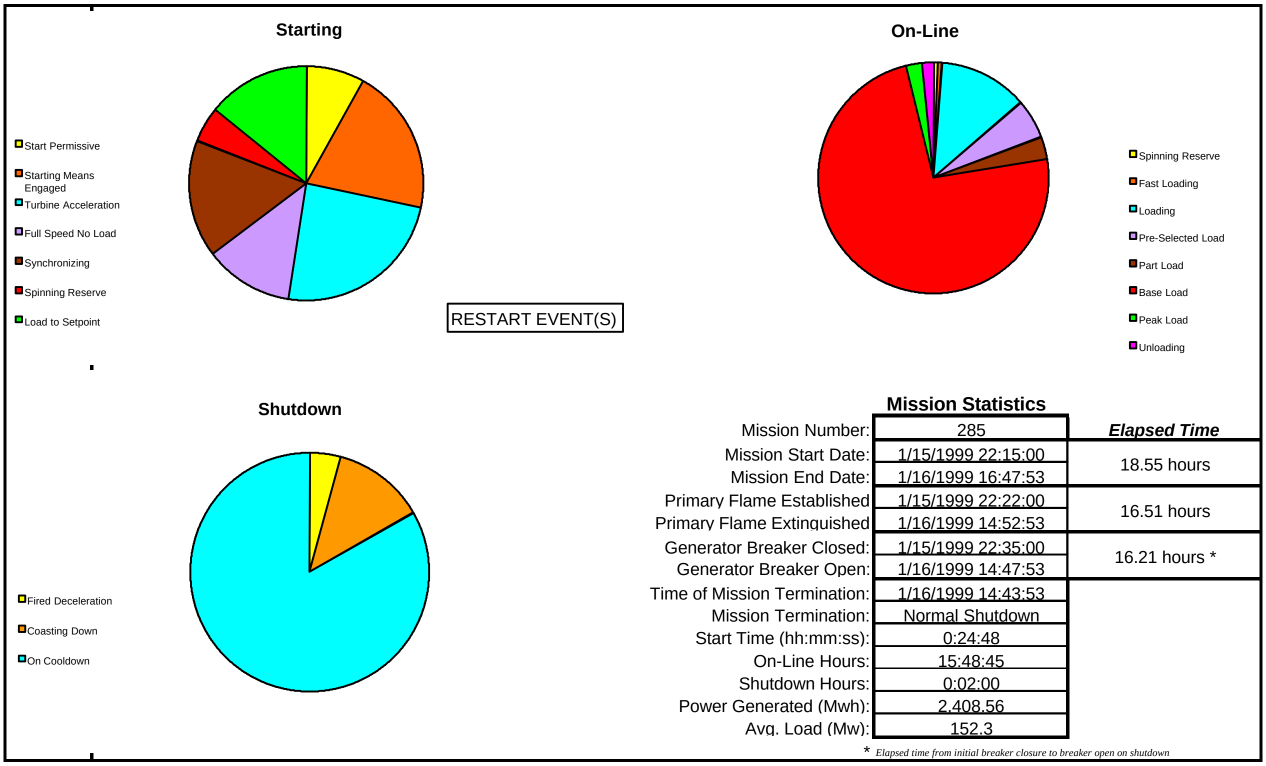

Figure 2-4
ORAP LINK Sample Data View: Mission Summary

The view shown in Figure 2-5 is a further breakdown of the Mission Summary view shown in Figure 2-4. The user can click on any of the pie chart titles shown in Figure 2-4 and get a specific tabular breakdown of each pie. This breakdown is provided in a pop-up window that can be moved around the screen and viewed along with the pie chart, if the user so desires.

For the starting and shutdown pie charts this breakdown includes; the begin and end time for state, the total elapsed time (hh:mm:ss format), and the percentage of total time spent in that state. The on-line breakdown does not show each transition, but does provide the specific time that was spent in each of the on-line states.

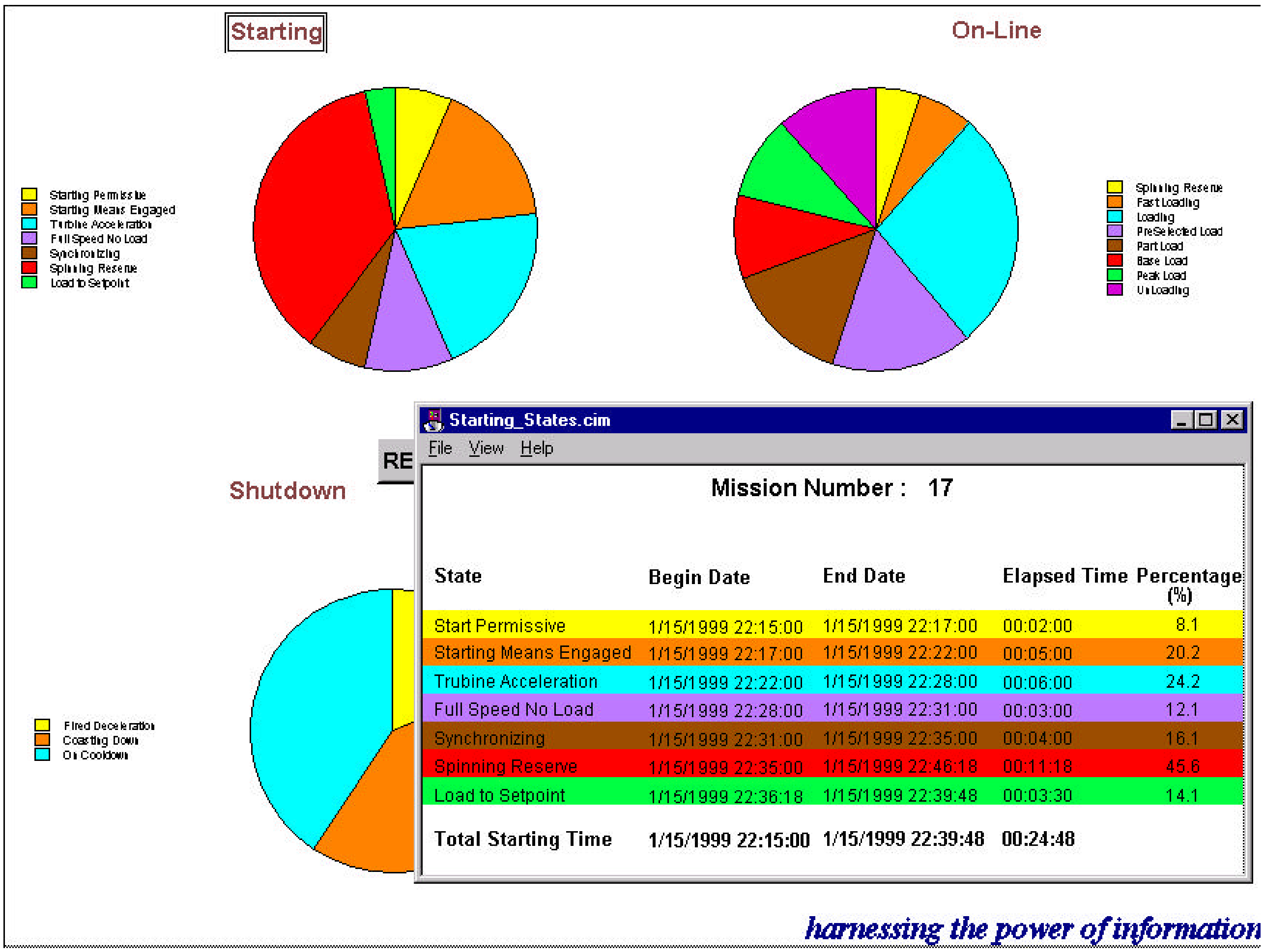

Figure 2-5
ORAP LINK Sample View: Mission Summary with Detailed Starting Summary Window

Figure 2-6 is a sample view of the GE Gas Turbine Inspection Summary Status view. This view is slightly different for each gas turbine manufacturer based on their definition of factored hours and starts or equivalent hours.

The sample view shown below summarizes the unit's current status for each major OEM (original equipment manufacturer) recommended inspection. This information is based on the equation that applies to that specific inspection type and OEM.

If an inspection was performed previously then this information is displayed with a date and the factored hours/starts at the time of the inspection. A daily average accumulation is provided for both hours and starts. This number is used in conjunction with the inspection interval (user configurable), the current factored hours/starts status, and any previous inspection information in order to provide an indication of the next projected inspection for this unit.

For manufacturers where the inspection can be driven on the basis of hours or starts, the primary driver of the next inspection is highlighted in red (i.e. the earliest chronological date for that inspection type).

GE Factored Hours							
As of:	Current	Daily Avg.		Previous		Next Projected	
07/26/1999	Status	(Last 12 Mos.)	Interval	Date	Factored Hours	Date	Factored Hours
Combustion Inspection**	30,714	15.70	6,000	05/28/1998	24,121	**10/23/1999**	**32,121**
Hot Gas Path Inspection	30,714	15.70	24,000	05/28/1998	24,121	08/07/2002	48,121
Major Overhaul	30,714	15.70	48,000	n/a	n/a	**07/31/2002**	**48,000**
Rotor Maintenance	12,689	6.48	144,000	n/a	n/a	01/01/2055	144,000

GE Factored Starts							
As of:	Current	Daily Avg.		Previous		Next Projected	
07/26/1999	Status	(Last 12 Mos.)	Interval	Date	Factored Starts	Date	Factored Starts
Combustion Inspection**	485	0.68	200	05/28/1998	201	01/13/2000	601
Hot Gas Path Inspection	485	0.68	900	05/28/1998	201	**01/22/2002**	**1,101**
Major Overhaul	485	0.68	2,400	n/a	n/a	04/28/2007	2,400
Rotor Maintenance	501	0.70	5,000	n/a	n/a	**03/16/2017**	**5,000**

**** Combustion Inspection values are not factored per GER-3620F**

Figure 2-6
ORAP LINK Sample Data View: GE Gas Turbine Inspection Summary Status

In Figure 2-7, a timeline is provided which shows the current status of the unit with respect to factored hours and starts over a period of time. All recorded OEM inspection events are also shown as vertical lines on this view along with their respective dates.

The intent of this view is to allow the user to see any abrupt changes in the accumulation of factored hours and starts in order to investigate the underlying cause for the increase. This view also allows the user to visually understand the rate at which these factored hours and starts are being accumulated.

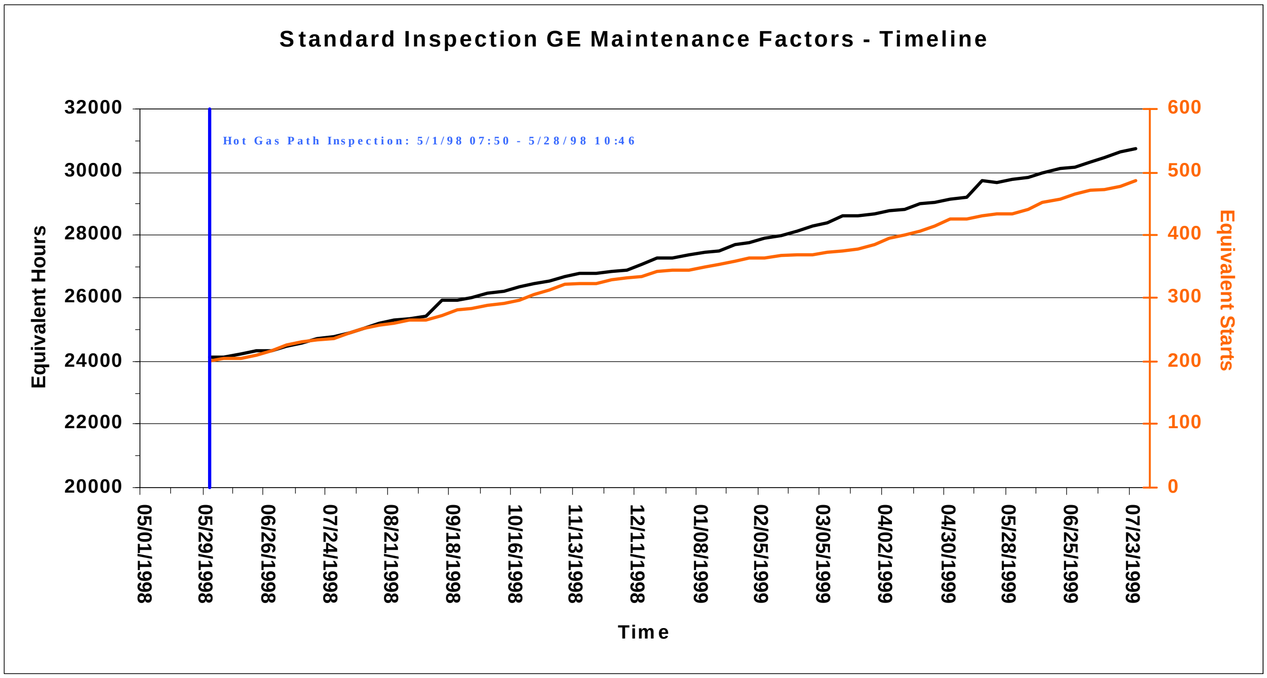

Figure 2-7
ORAP LINK Sample View: GE Factored Hours & Starts – Cumulative Timeline

In Figure 2-8, the components of the factored hours equation are broken out to show the impact that they have on the final computed values for factored hours and starts. In this sample view for the GE products, the equations are specifically derived for hot gas path inspections and major overhauls. Separate equations, and therefore views, are utilized for the other major GE inspections. Specific equations for other OEM products would be provided in a similarly formatted view.

In Figure 2-8, each part of the equation is described in the first column and then the respective values for the time since the last inspection was performed and the lifetime values (i.e. since data was first collected) are displayed. Along with each of the values is a percentage contribution to the final computed value. For example in Figure 2-8, the impact of water/steam injection is shown to comprise ~57% of the total accumulated factored hours since the last inspection was performed.

The intent of this view is to provide the user with input as to the manner in which the factored hours are being accumulated. If required, and fiscally prudent, the user can then modify their operational parameters to maximize the operating time that can be accumulated between inspections.

The most recent equation constants are also available via a button in this view (not shown in sample). As was discussed above, the equation constants used in computing the equation component values are as of the time that the data was accumulated.

Contribution to GE Factored Hours				
Equation Variable	Since Last Inspection	% of Total	Lifetime	% of Total
Effect of Water/Steam Injection (K + M x I)	3,755	56.95%	17,605	57.32%
Factored Base Load Operating Hours on Gas Fuel (FG x G)	1,860	28.21%	10,265	33.42%
Factored Base Load Operating Hours on Distillate Fuel (FD x D)	822	12.47%	2,310	7.52%
Factored Operating Hours on Heavy Fuel (Af x H)	0	0.00%	0	0.00%
Factored Peak Load Operating Hours (FP x P)	156	2.37%	534	1.74%
Total	6,593		30,714	

Equivalent Hours = (K + M x I) x [(FG x G) + (FD x D) + (Af x H) + (FP x P)]

Contribution to GE Factored Starts				
Equation Variable	Since Last Inspection	% of Total	Lifetime	% of Total
Factored Part Load Start/Stop Cycles <60% Load (FNA x NA)	11	3.87%	16	3.30%
Factored Normal Base Load Start/Stop Cycles (FNB x NB)	123	43.33%	123	25.37%
Factored Peak Load Start/Stop Cycles (FNP x NP)	8	2.75%	13	2.68%
Factored Emergency Starts (FE x E)	40	14.09%	100	20.62%
Factored Fast Load Starts (FF x F)	20	7.05%	22	4.54%
Number of Trips & Severity factor (atT)	82	28.88%	211	43.52%
Total	284		485	

$$\text{Equivalent Starts} = (FNA \times NA) + (FNB \times NB) + (FNP \times NP) + (FE \times E) + (FF \times F) + \sum_{i=1}^{n} a_{Ti} T_i$$

Date References:
Last inspection - Hot Gas Path Inspection - Ended 5/28/98 10:24
Lifetime (First Roll) - 3/1/95

Figure 2-8
ORAP LINK Sample Data View: GE Gas Turbine Inspection Status – Equation Variable Contribution

The sample view shown in Figure 2-9 provides information on the calibration status of redundant sensors. Redundant sensors are defined as any group of sensors that are measuring the same value. The user is able to use the manual data entry screens in ORAP LINK to set up a series of parameters for each redundant set of sensors specified in the configuration process. These parameters include the percentage point difference that is considered allowable between the various redundant sensors, the period over which this difference is measured, and the reset period. The reset period is the amount of time that the sensor deviation has to be within the acceptable range again before the allowable percentage deviation and time period will restart. These parameters can be fine tuned over time by the user as experience is gained with this view.

When any of the redundant sensor groups goes beyond the allowable percentage point difference between the highest and lowest value, the sensor title becomes red, alerting the user that there may be a calibration issue with these sensors, or a sensor may be bad.

As an example, if a group of sensors is set to have an allowable percentage point spread of 8 over a ten minute period, once the lowest reading deviates from the highest reading by over 8 percentage points within any ten minute period, the label will turn red. If the deviation then comes with the acceptable limits for a period of time equal to or greater than the reset period, the label will become green and the system will again begin to look at the deviation between the highest and lowest sensor. If the sensors measure within the acceptable limits, but do not do so for the time allotted for reset, the label will remain red.

Sensor Deviation

Unit 3 at 4/15/99 16:27

Inlet Guide Vane LVDT - Degrees Angle	
Transducer #1 (96DE-1)	87.76
Transducer #2 (96DE-2)	87.88
Deviation Allowance	1.0%
Allowance Period (Minutes)	0.0
Reset Period (Minutes)	0.0
Actual Maximum Deviation	**0.1%**

Fuel Gas Control Valve LVDT - % open	
LVDT#1 (96GH-1)	63.20
LVDT#1 (96GH-2)	63.10
Deviation Allowance	0.5%
Allowance Period (Minutes)	0.0
Reset Period (Minutes)	0.0
Actual Maximum Deviation	**0.2%**

Water Injection Flow Transmitter - GPM	
Transmitter #1 (96IJ-1)	7.85
Transmitter #2 (96IJ-2)	8.16
Transmitter #3 (96IJ-3)	8.32
Deviation Allowance	6.0%
Allowance Period (Minutes)	10.0
Reset Period (Minutes)	2.0
Actual Maximum Deviation	**5.9%**

Compressor Inlet Temperature - degF	
Thermocouple #1 (26AB-1)	88.20
Thermocouple #2 (26AB-2)	88.60
Thermocouple #3 (26AB-3)	82.10
Thermocouple #4 (26AB-4)	80.30
Deviation Allowance	8.0%
Allowance Period (Minutes)	3.0
Reset Period (Minutes)	0.5
Actual Maximum Deviation	**10.3%**

Compressor Discharge Thermocouples - degF	
Thermocouple #1 (26BC-1)	695.06
Thermocouple #2 (26BC-2)	694.50
Thermocouple #3 (26BC-3)	694.00
Deviation Allowance	2.0%
Allowance Period (Minutes)	5.0
Reset Period (Minutes)	1.0
Actual Maximum Deviation	**0.2%**

Magnetic Speed Pickups - rpm	
Pickup #1 (77AB-1)	3600.00
Pickup #2 (77AB-2)	3599.75
Pickup #3 (77AB-3)	3599.50
Deviation Allowance	0.2
Allowance Period (Minutes)	1.0
Reset Period (Minutes)	1.0
Actual Maximum Deviation	**0.0%**

Figure 2-9
ORAP LINK Sample Data View: Redundant Sensor Deviation

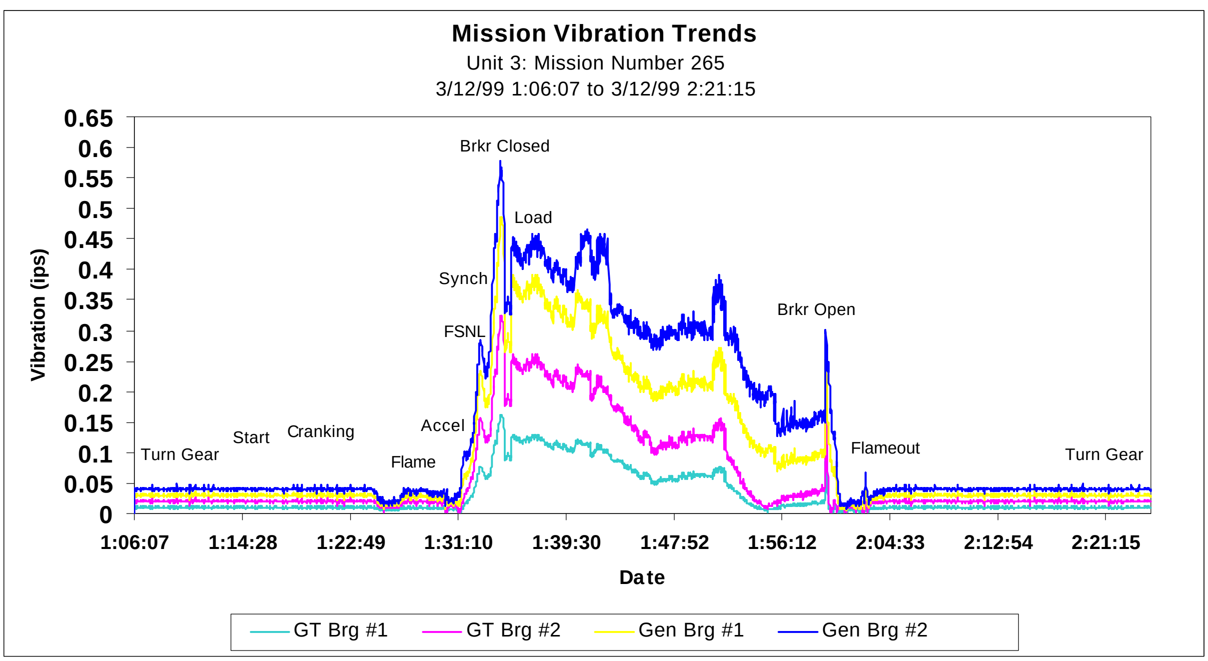

Figure 2-10
ORAP LINK Sample Data View: Mission Vibration Trends

The sample view shown in Figure 2-10 depicts the vibration levels recorded at each of the major bearings on a gas turbine/generator set over the course of a single mission. Each element of the mission is labeled in the area where it occurred chronologically. Underneath these labels are the vibration levels, in different colors, which were recorded at that point in time. The intent of this chart is to provide the user with an indication of vibration levels that are encountered over the course of a mission.

The final sample view provided in Figure 2-11 of this report shows the median gas turbine exhaust temperature reading over the MW load at that point in time. A best fit line is drawn through the points to indicate the median exhaust temperature seen on average at various MW load levels. This chart can be used for troubleshooting purposes by observing how the median exhaust temperature pattern changes over time.

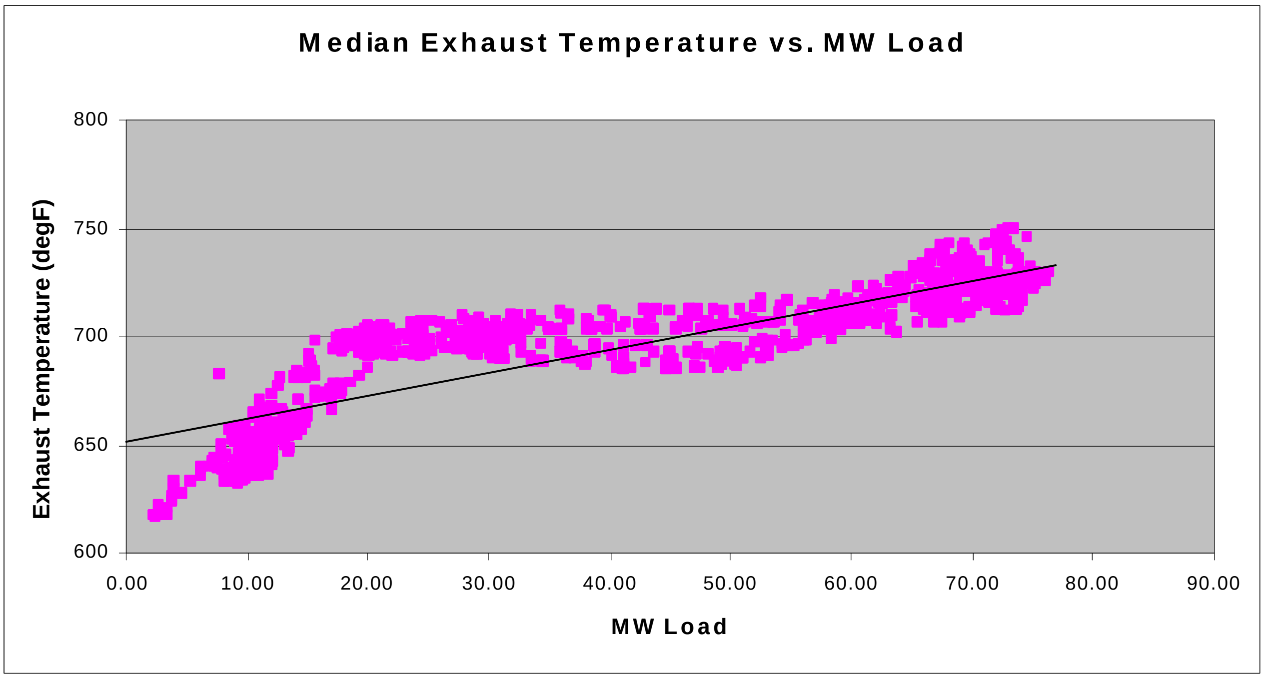

Figure 2-11
ORAP LINK Sample Information View: Median Exhaust Temperature vs. MW Load

2.2 Manual Data Entry Forms

2.2.1 Definition

The manual data entry forms in the ORAP LINK application are found in two (2) primary areas depending on the type of information views that they support. For all of the views that are considered part of the base ORAP LINK application, the manual data entry form is located under the Admin bar in the main menu area. This allows manual data entry values that are used in multiple views to be shared from a central database location.

For all third party products the manual data entry used to support those products can be accessed directly from the ORAP LINK view that displays the results to the user. This differentiation is made to simplify the attachment and detachment of the third party modules.

The intent of ORAP LINK is to minimize the need for manual data entry. Therefore, the only manual data entry that is **required** involves specific event information that cannot be ascertained by the control system. Other manual data entry forms are provided to allow the user to customize and fine-tune certain areas of the ORAP LINK system (i.e. equation constants and reference tables discussed under Section 1 of this report).

2.2.2 Samples

The view sample shown in Figure 2-13 represents a typical manual data entry form. The uppermost two (2) lines contain drop down boxes that allows the user to pick the information that they wish to add or edit. These lines are typically in hierarchical order and may have up to three (3) lines to choose from depending on the selection made in the upper lines. As an example, if the manual data entry was for gas turbine rating (first line), the user would then specify the fuel type (second line), and whether it was a base or peak load rating (third line).

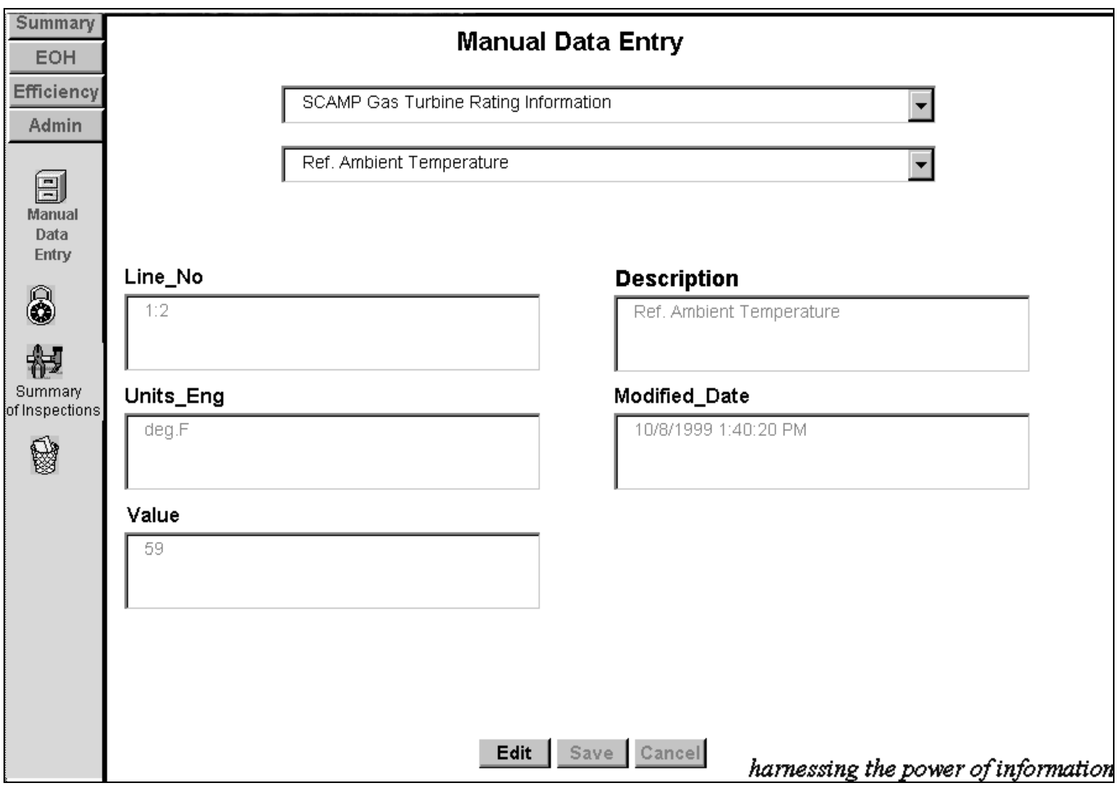

Figure 2-12
ORAP LINK Sample Information View: Manual Data Entry Form

The bottom area of the view shown in Figure 2-13 provides the user with all of the information regarding the entry and allows them to input or change a value. Each time that a value is entered, a new modified date is assigned and the previous values are stored for historical reference. It should be noted that all transformations utilize the most current records, as indicated by the modified date, for their calculations.

3 INTEGRATION OF EPRI MONITORING & DIAGNOSTIC PRODUCTS

3.1 Basic Integration Process Definition

Over time EPRI, working with its membership, has developed many power plant monitoring & diagnostic software tools. The majority of these tools require manual input of plant parameters in order for the tool to provide value added output to the end user. In general, there are two (2) basic drawbacks to tools that require manual input; the output provided is only as accurate as the manual input and someone has take the time to provide the manual input. Recognizing these facts, EPRI and SPS are working together to utilize the ORAP® LINK™ system as a data collection platform for EPRI monitoring & diagnostic tools. The integration of these EPRI products with the ORAP LINK system is intended to enhance the value of both products to the end user.

EPRI and SPS are now in the process of developing rigorous guidelines for the integration process described above. At this time the guidelines have been defined at a high level in the integration of the EPRI SCAMP product with ORAP LINK (discussed under Section 4 of this report). The lessons learned from this test integration and the initial deployment of ORAP LINK are now being accumulated and will be used to augment the basic guidelines described below in this report. The final outcome of this endeavor will be a methodology that will allow all relevant EPRI products to be seamlessly integrated with ORAP LINK in a standard, generic manner.

The ultimate goal of this integration effort is to allow EPRI members to take better advantage of the many EPRI products that have been developed and could be of value to them in the operations & maintenance of their plant(s).

3.1.1 EPRI Product Design

At a high level the EPRI product must meet certain basic design criterion in order to be integrated with the ORAP LINK application. The following paragraphs outline some of the basic design requirements.

The EPRI product will physically reside on the ORAP LINK PC which is provided to the user as part of the total package. This PC operates under the Windows NT operating system and therefore the EPRI product must also be compatible with Windows NT.

In order to maintain the appropriate level of distinction between the EPRI product and the ORAP LINK application, the EPRI product will be maintained as a separate entity with a separate directory structure. This directory structure must include provisions for input, output, reference tables, and the application.

The EPRI product must be accessible as an external process from the ORAP LINK system so that it can be run automatically once data has been provided. This type of operation requires that the EPRI product is written/compiled as a dynamic link library (.dll) or another similar type of stand-alone program that can be called directly from the ORAP LINK transformations.

At this time no specific limitations have been determined with respect to hard disk space, memory, or processor requirements. All of these areas are now being reviewed and specific guidelines will be provided in the future.

3.1.2 Division of Responsibilities

It is important to clearly delineate the responsibilities of the developer of the EPRI product, and SPS, as the ORAP LINK developer. The following outlines the general responsibilities of each party.

SPS is responsible for:

- Participating in the design process.
- Developing a functional specification of the ORAP LINK requirements.
- Obtaining raw control system information.
- Transforming raw data into the data required by the EPRI product (if required).
- Providing transformed data to designated area for EPRI product use.
- Starting the EPRI product once the data has been provided.
- Retrieving the EPRI Product output from a pre-defined location.
- Participating in the design of the ORAP LINK views which will support the EPRI product output.
- Developing the ORAP LINK view(s) that support the EPRI product.
- Maintaining the EPRI product data results in the ORAP LINK database.
- Maintaining manual data entry forms for reference data or equation constants utilized by EPRI product (if required).
- Supporting the integrated testing of the EPRI product.

The EPRI product developer is responsible for:

- Participating in the design process.
- Developing a functional specification of the EPRI product requirements; including directory structure, file formats, data requirements, etc.

- Providing the capability to retrieve input data from the specified file, format, and area as well as processing it to obtain the desired results.
- Writing output in a pre-defined format and placing it in a pre-defined area.
- Developing a feedback signal to ORAP LINK that indicates output data has been prepared.
- Participating in the design of the ORAP LINK views which will support the EPRI product output.
- Thorough documentation testing of the product as a stand-alone entity to ensure that it provides the desired results and does not adversely affect the overall performance of the ORAP LINK application (i.e. GPF or other "crash" type scenarios).
- Providing input to the ORAP LINK on-line help document in an MS Word format.
- Development of a User's Manual.
- Participation in training the end user.
- Participation in the integrated testing of the product with ORAP® LINK™.

3.2 Data Requirements

The first step in the integration process is the definition of the data requirements. The entire integration process is based on the data requirements; both input and output. The data requirements definition must address the following questions:

1. What control system data points are required for the EPRI product?
2. If the required control system data points are not available, can they be calculated or estimated using other control system data points?
3. Which control system data points are critical to the implementation of the product (i.e. cannot be implemented if they are not present)?
4. How will missing or "bad quality" control system data be handled/flagged in the process?
5. Can default values be used for any of the control system data points in the event that they are missing?
6. What units of measurement (e.g. SI, English, etc.) can be accommodated in the program?
7. If the program requires a specific unit of measurement, how will the conversion of control system data be handled?
8. What will trigger the ORAP LINK program to begin collecting and sending data to the EPRI product?
9. What are the time interval requirements for this data set?

10. Will the data be sampled on a periodic basis, averaged over time, etc?

11. How will data from multiple unit be managed?

All of the answers to the above questions should be included in the functional specification written for the EPRI product integration effort. This portion of the document will drive the integration process and will greatly assist in determining the necessary ORAP LINK configuration requirements for this EPRI product. Additionally, this information can be brought to potential users so that it can be determined if their control system data will support the product requirements.

3.3 Specification of Data Transfer

After the data requirements have been defined, the method for exchanging this data between ORAP LINK and the EPRI product must be determined. The simplest, most universally accepted method of exchanging data is through the use of ASCII files. In the integration process the ASCII information exchange will be considered the minimum requirement. However, since the ORAP LINK system is based on the MS SQL Server 7.0 database product, this tool will also be considered as a potential means of data transfer. In theory the exchange of data through this medium would be faster, more efficient and would result in a much tighter integration process as compared to the ASCII data exchange method.

Once the means by which data will be exchanged has been determined, the file structure must be defined. In the case of an ASCII file exchange a mapping of each delimited field must be developed for both the input and output files. If the MS SQL Server database format is to be used, then the specific table structure required for the data exchange must be defined in terms of column names, format, indices, etc. A specific file or database table must also be defined as a means of communication between ORAP LINK and the EPRI product specifically for flagging when an input or output file has been written.

As was discussed above, for an ASCII file exchange process to work effectively there must be a logical directory structure defined so that ORAP LINK and the EPRI product can always find the necessary data files in a separate area. This directory structure must be flexible in that it cannot designate a specific drive (i.e. c:\) and must be capable of accomodating a data exchange for multiple units.

3.4 Display Requirements

Since the ORAP LINK application will be displaying the output provided by the EPRI product, a design of the business information view(s) must be developed. These views must be consistent in format with the base ORAP LINK views. The output data provided by the EPRI product should form the basis of the view and the view should be focused on a particular topic. Any manual data entry that is required for the view(s) must also be defined at this point. The manual data entry screens will be directly accessible from the business information view that it supports.

The view(s) generated for this EPRI product will be placed in a specific group under the roll-up menu bar in the main viewing area. An appropriate name for this grouping and for each individual view will also need to be determined. Finally, icons will need to be designated to represent the specific view(s) that are generated in the definition process.

3.5 Development & Testing

The development & testing process will be performed by SPS and the EPRI product developer on the software within their respective areas of responsibility. This unit level testing should be performed against a formal test plan to ensure that the software works according to its design. This unit level testing must be completed and accepted prior to the integration of the EPRI Product. Once unit level testing has been completed an integrated test will be performed at SPS on a test version of ORAP® LINK™. Although it would be ideal to have the EPRI product developer on hand for this test, results can also be communicated by telephone and e-mail. Once the system has been rigorously tested it will be released for deployment.

3.6 User Support

Once the software has been deployed, there is a minimum level of support that must be provided to each end user. This minimum level consists of a set of on-line help topics that describe the product, how it should be used, and what it provides the end user. SPS currently uses RoboHelp to build the help files for ORAP® LINK™. This system is compatible with MS Word and therefore the EPRI product developer can submit the help file contents for this product in a Word document.

Additional support, which should be determined based on the complexity of the system, can be provided in the form of a Users Manual that can be provided to the user when the product is installed.

Finally, in some cases, on-site training on the proper use and interpretation of the EPRI product may be required. This training should be performed in conjunction with the overall ORAP LINK training that will be provided to each end user.

4
EPRI SCAMP: FIRST USE OF INTEGRATION CONCEPT

4.1 Overview

In April 1999 EPRI, Fern Engineering (SCAMP developer) and SPS began working together on the integration of the EPRI Strategic Capacity Axial-compressor Maintenance Program (SCAMP) with the ORAP® LINK™ application. The EPRI SCAMP product calculates gas turbine isentropic compressor efficiency, heat rate, and inlet airflow. The program also has the capability to compare current results against the expected values for a new and clean machine and then correct the values to standard day conditions (e.g. ISO). The SCAMP product is described in more detail in the EPRI Report titled “Compressor Monitor Report: Compressor Monitoring and Inspection Techniques” and designated as TR-113985.

One goal of this collaborative effort was to understand how EPRI products could be integrated with the ORAP LINK application. To date this integration effort has been very successful and was deployed as part of the first commercial ORAP LINK application.

Although the first commercial application of the ORAP LINK system and the EPRI SCAMP product is still undergoing testing and verification, the intent of this section of the report is to describe the manner in which the integration was performed and the initial results of the process. As testing and verification of the system is completed, more information will be added to this section of the report.

4.2 Design Process

The design process for this integration effort was conducted over the course of a one-day meeting and several exchanges of e-mail and telephone calls. The amount of time required for the up-front integration meeting(s) will vary based on the complexity of the EPRI product and the amount of views required in ORAP LINK. However, by following a rigorous integration outline the required time for the initial meeting and subsequent changes will be minimized.

The first item of discussion was the data points required by the SCAMP program. These points numbered less than twenty (20) and were verified to be present at the site where the program would be installed. Fern Engineering provided a comprehensive list of the points and their associated control system data designations so that SPS could being to build the virtual points required to support the SCAMP product. A specific customer requirement to provide an operation indication when a compressor wash was warranted (based on user defined parameters) was also discussed and designed at this point.

Once the points were determined and verified, the format of the proposed business information view (only a single view was required) was reviewed and modified accordingly. The final view design is shown above in Figure 2-2.

Based on the requirements of the SCAMP product and the defined view, a series of manual data entry requirements were also defined at this time. These manual data entry requirements provided input to SCAMP on the site-specific parameters required to correct the raw data to standard day conditions, provide default data point information, and define the point at which a water wash would be recommended. There were over 250 points that had to be organized into five (5) separate tables to satisfy the requirements of the SCAMP product and allow the customer to have sufficient information to understand and fine tune the output. The customer, typically in the form of OEM documentation, provided the majority of the input to the manual data entry tables.

Based on the configuration of the SCAMP product and the requirements of ORAP LINK, it was determined that the only viable method of data exchange was via delimited ASCII files. Each of these files was defined by Fern Engineering and provided to SPS in the design documents. The ORAP LINK system was then set up to read the ASCII files, convert them to the manual data entry screen format, and then write back to the ASCII files when the user made modifications.

Following the design meeting, Fern Engineering provided a functional specification of the SCAMP product and an integrators manual for SPS in support of the integration process. Based on these documents SPS wrote a detailed specification for how the ORAP LINK transformation programs would retrieve this data from the control system, provide it to SCAMP for processing and then retrieve the results for display in the business information view. These specifications formed the basis for all design and integration efforts and were the foundation for a very smooth development and implementation effort.

Although the design process for this integration effort went very smoothly, there were still several areas where issues with the original plan were discovered and modifications had to be made to both SCAMP and ORAP LINK. Based on the lessons learned from the initial implementation process and any issues that arise over the first few months of operation, the generic integration process for EPRI products described in this report will be modified, augmented, and strengthened.

4.3 Implementation

The initial implementation of the ORAP LINK and SCAMP product went very well. It has now been in full operation for over a month and the initial data results have been positive. At this time the unit has operated for only a small amount of time at base load conditions where the SCAMP program is executed so the full range of the integration effort has not yet been tested.

Additionally, the ability to operate for multiple units simultaneously has not yet been tested. This was a part of the original design effort, but the first site where the program was installed currently only has a single gas turbine unit. It is expected that testing for multiple units will be conducted in early 2000 when a second unit is added to this site.

4.4 Preliminary Results

As was discussed above, there has not been a large amount of compressor efficiency data collected at the first commercial site. However, the data that has been collected has been reviewed and appears to be accurate and useful.

Figure 4-1 shows a sample of the SCAMP business information view that has been taken from the commercial ORAP LINK application. Since no compressor related maintenance events have yet been entered into the system, this information is not present in the chart. Also the "new & clean" efficiency has not yet been entered into the system so it is also not present.

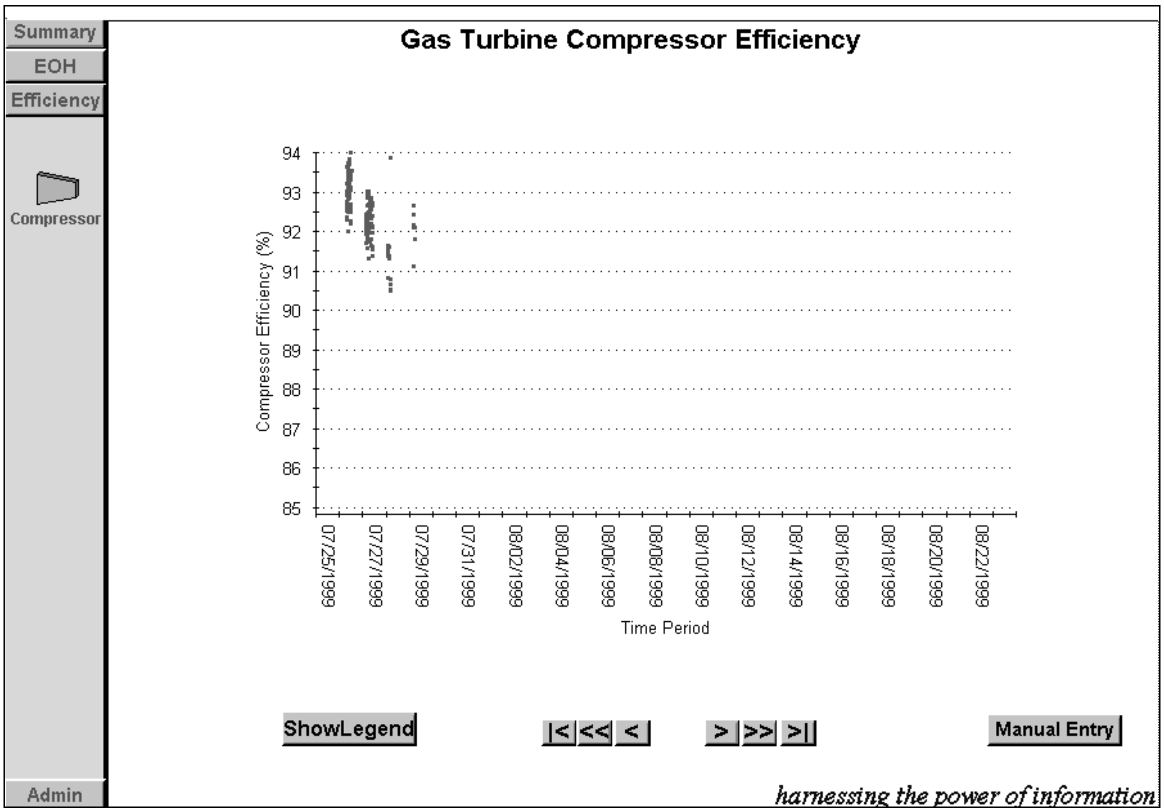

Figure 4-1
Sample of Initial SCAMP Results

There are still some minor modifications remaining on this integration effort, primarily in the interval at which the compressor efficiency is calculated. However, the initial integration effort and the resulting "lessons learned" have provided the basis for developing a generic integration process that can be extended to additional EPRI products.