

PACRAT

What is PACRAT?

*Performance And Continuous
Re-commissioning Analysis
Tool*

*PACRAT is the first
comprehensive automated
diagnostic tool for HVAC
system performance*

*PACRAT sets a new standard
in monitoring and verification
and energy accounting*

*PACRAT enables you to use
true historical data rather
than estimates when planning
future work such as
expansion, renovations or
energy projects*

*PACRAT allows you to weave
together the historical data of
different automation systems
that cannot communicate.*

*PACRAT lets you "see" the
building performance so that
you can operate it more
effectively*

PACRAT is a tool for “mining” recorded meter and system operational data to improve facility operations and planning. PACRAT serves the following basic functions

1. It diagnoses system problems and poor performance and identifies energy wastes. In a typical building system, poor or inefficient operation can occur even when it is maintaining adequate space temperature. Therefore, it can go unnoticed for years while building occupants perceive the system as working fine.
2. It manages and summarizes meter data and automates monitoring and verification tasks for energy projects and building optimization. Meters can be physical or "virtual" (calculated from a characteristic curve based on another recorded variable) thus saving metering costs while allowing extensive detail in energy accounting. It uses a multi-parameter batched approach to characterizing base periods and then recreating the base for savings calculations. Extensive reporting and visualization is provided.
3. It documents important system operational parameters such as loads, energy use, indoor air quality (IAQ), etc. This documentation is essential to effective planning for dynamic facilities. Typical design estimates on system requirements are necessarily conservative in their nature. Using reality as opposed to estimates as the basis for facility planning allows more effective decisions.
4. PACRAT provides “Enterprise Historical Data” interoperability for different automation systems. Many people incorrectly assume that if their automation systems cannot communicate, they cannot be interoperable. However, with PACRAT weaving their data together, you get one of the most valuable and usable aspects of interoperability (the ability to integrate and use the historical data gathered by these different systems) at a small fraction of the cost of the next level of interoperability (real time enterprise communication).
5. It summarizes and formats the data for effective visualization. This allows facilities personnel to better understand the facility and its characteristics and needs. This allows them to make more informed decisions on its operation.

PACRAT processes data that has been recorded and stored by a computerized control/automation system, data loggers, or an energy metering system (local or via a utility company). It allows access to almost any system. It also automatically accesses and processes NCDC weather data as necessary.

Who can benefit from PACRAT?

Why can't this unit maintain temperature?

There must be an easier way to review the history from different automation systems.

Why is my energy bill so high?

Am I providing an acceptable indoor environment to my occupants at all times?

Do I need another chiller with this expansion?

Is adding an air-side economizer a cost effective investment?

Facility Operators

PACRAT assists the operators by automatically diagnosing common problems that can occur in the system without being readily evident. It includes some “expert” system advice as to what might be the cause of the anomaly and how to resolve it. It documents system anomalies that may be temporary in nature. The summaries and visualization helps operators better understand the facility.

PACRAT also allows operators to combine historical data from multiple automation and monitoring systems into one common data format and interface. This provides a key aspect of interoperability without the cost, hassle and performance hit of making systems communicate real time.

Facility Managers

PACRAT provides valuable management information to the facility managers so that they will know if the facility is being operated as effectively as possible. As the managers are usually fiscally responsible for the facility operation, they need to know when energy is being wasted. Since they are also responsible for ensuring proper indoor environments, they need to know when the system is lacking. PACRAT provides this management information in concise summaries.

Relative to the energy monitoring of the facility, PACRAT far surpasses the functionality of more traditional “macroscopic” energy consumption analysis tools as they pertain to system operation. With those tools, you find out at the end of the month that an energy waste has developed. However, you then have to figure out, on your own, why it occurred. In many cases this will involve manually pouring through trend data, or extensively surveying the systems to find out why. PACRAT will not only identify the waste much earlier, but also tell you specifically why it is occurring and suggest how to remedy it.

Facility Planners

With the reality characterization functionality provided by PACRAT, planners can have a much more solid foundation for planning facility expansions, modifications, and upgrades. PACRAT makes the system operational parameters readily available and formats them for convenience.

Energy Managers

PACRAT not only provides direct energy saving opportunity information, but it also provides the data necessary to make more informed and accurate energy cost and savings projections. Actual facility use can vary dramatically from that assumed in “standard assumptions” used to project energy savings. PACRAT provides detailed information that will facilitate more accurate “baseline models” of the facility to a resolution that can not be obtained from energy bill calibration.

The "monitoring and verification" functionality allows energy managers to easily document and track the results of energy projects. The hierarchical meter configuration allows you to penetrate into the utility uses to summarize and visualize the consumption patterns. This provides a powerful analytical tool.

What is the actual split on the chilled water system under different loading conditions?

Facility Designers

Designers can use the reality characterization functionality of PACRAT to fine tune the selection parameters of new systems. Frequently invalid design assumptions are applied to renovations of a new facility. As an example that occurs frequently, designers assume that the chilled water temperature difference typical for the system is what the coils were designed for (typically around 12°F). Data typically documents that it is much lower. This leads to less than optimum chiller and pump selection. This can lead to inappropriate equipment selection and operational problems. Even if the data is recorded in some fashion it is typically so cumbersome to find, it is usually ignored.

In general, the design industry is on the horizon of a better way of doing business. In general, now that we have computers controlling our facilities, we can "listen to what are facilities are telling us" by recording actual parameters and using them to make better design decisions. PACRAT supports this approach.

Energy Service Contractors (ESCOs)

PACRAT can be implemented remotely. Data can be downloaded to the remote site for processing. Energy service companies usually have a financial interest in making sure the facility is operated optimally. Frequently energy measures are disabled or bypassed due to a temporary or mis-diagnosed problem. Even if the disable was justified for the temporary condition, it frequently is left disabled. PACRAT will keep the ESCO apprised of the inefficient operation or when their energy performance measures are not be applied optimally.

Why am I not achieving the projected savings?

Isn't there an easier way to compile and report these savings?

PACRAT also facilitates Monitoring and Verification (M&V). In some cases savings payments are based on "microscopic" calculations relating to the use of a specific component as opposed to the "macroscopic" comparison of the energy bills to a baseline. PACRAT supports both approaches. PACRAT can process the data and specifically report the savings based on actual data compared to the baseline. "Actual" data can be actual recorded consumption, or calculated consumption based on a components part load characteristic. With sufficient baseline data, PACRAT will create a baseline based on multi-dimensional parameters. Any recorded parameter can be used as a "dimension". For instance, a typical baseline will be created based on typical use at a particular time of day, on a particular type of day, at a particular outside air condition. Once the baseline is created, PACRAT can recreate what the energy would have been with baseline conditions and calculate the savings, and summarize it in a report with one click of the mouse.

What Specifically Does PACRAT Tell Me?

Diagnostics

The list of diagnostics is growing daily. Example diagnostics that PACRAT performs includes:

- Mis-calibrated sensors

- Leaking Valves and associated wasted cost and false load
- Out of sequence coils and associated wasted cost and false load
- Fighting Coils and associated wasted cost and false load
- Suspect or failed sensors
- Failed outputs or those with a poor performance characteristic
- Unoccupied period operation (fan and ventilation) and associated wasted cost
- Inadequate ventilation rates along with the associated parameter statistics
- Excess outside air flow along with associated wasted cost.
- Missed free cooling opportunities (lack of economizer) and associated wasted cost
- Struggling system capacities and terminal outputs. This identifies the "tail wagging the dog" scenarios that often leads to very poor performance
- Outside Air temperature and humidity sensor deviation from local weather stations and assessment of whether it is being influenced by relief or exhaust air
- Deviations from defined set-point and/or profile ranges
- Unstable control
- Degrading heat exchange surfaces
- Inefficient chiller sequencing
- Poor Efficiency
- Excessive Cycling
- Low temperature difference in decoupled hydronic systems
- Excess energy use from defined baseline
- Reverse flow in hydronic decouplers
- Load mis-match in associated but decoupled systems
- Unlimited customizable analyses
- Fighting terminal zones with associated wasted cost
- Struggling VAV zones distinguishing between flow limits and system/terminal capacity
- Over-conditioning of spaces with associated wasted costs
- Fighting terminal control loops with associated wasted cost

Note that when applicable, PACRAT calculates the energy cost waste of the anomaly (with full time of day rate schedule capabilities). This is crucial information for the typical facility professional and acknowledges the reality of facility operations today. Facility staffs are frequently undersized and the operators "to-do-list" is never ending. PACRAT not only indicates the anomaly, but indicates the consequences of it so that operator can prioritize it effectively. To further facilitate prioritizing issues, PACRAT allows a fully customizable "Priority" to be applied to anomalies. This allows PACRAT to present information in the order it is important to your organization.

Documentation and System Characterization

PACRAT calculates and documents the following (again only examples):

- Indoor environment statistics including highs, lows, and averages of space temperature, humidity, CO2, ventilation rate, and load
- Space load profiles with time of day by type of daily period (occupied and unoccupied)
- Space load with outdoor air temperature by type of daily period
- Component energy uses and costs
- Output performance characteristics along with an associated histogram
- Hydronic system loads, temperature, and heating and cooling costs differences
- Chiller efficiencies (chiller only as well as with associated ancillary equipment)
- Energy use or point information profiles
- Chiller efficiencies
- Histograms of energy use or point information.
- Peak period documentation
- Outside air statistics including the daily high, low and average dry bulb temperature, relative humidity and enthalpy as well as heating and cooling degree days on a variable (definable) base.

Monitoring and Verification

PACRAT sets a new standard in monitoring and verification. Features of this module include:

- Group meters in a hierarchical fashion to allow penetration into the details of the consumption
- Create "virtual meters" for well defined operation of equipment. This saves the expense of installing a meter on a device for which you can accurately calculate the energy use based on a recorded parameter such as output to the device. It also allows aggregation of different meters that can not be physically metered. The aggregate virtual meter data is saved as if it were an actual meter.
- Create multi-dimensional baselines (which is analogous to a "neural" approach). Any recorded parameter can be used as a dimension. PACRAT automatically recreates baseline use from current data and calculates and summarizes the data. There is no need to apply the typical linear regression over-simplification popular in many savings calculations tools. Two baselines can be created. One baseline is the pre-retrofit baseline which is the basis for the savings. The other can be the post retrofit baseline which is the basis for "lack of savings" diagnostics.
- Create a "fabricated baseline". This is useful for energy projects based on predefined or assumed baseline operation and a "microscopic" savings calculation approach.
- Determine an equation that characterizes system/equipment performance and check statistics on the accuracy of the characterization.
- PACRAT has the ability to recreate costs of most utility rate schedules.

PACRAT uses a complex algorithm to fill holes on the historical data and expand its range

- PACRAT includes typical reports to summarize typical interval demand histories available from most utility companies. These can be used to analyze the facility demand profiles.

PACRAT is unmatched not only at its suite of visualization facilities, but also at the ease by which graphs are generated

Data Visualization

PACRAT provides a host of facilities for visualizing the data. The basic visualization tool is the ability to view the raw data graphically. You can define default views for frequently used graphs or you can define totally custom graphs. You have got to see the easy and intuitive custom graph definition facilities where all graph parameters are defined from a system object tree. You can assign the data to graphs and view them by date range with dynamic zooming and panning or time slicing, zoom in, zoom out, move ahead and move back facilities on each graph. One very effective form of visualization is the way PACRAT records when anomalies occurred. When it reports them it presents the range of time over which the anomaly occurred and allows you to jump directly to the visual representation of the data so you can immediately see the context in which the anomaly occurred.

You can navigate the control system I/O structure or the “meter” hierarchy and define graphs by clicking on items on the tree. You can then also define the type of graph and type of aggregation right from the tree view. Types of graphs include plot, bar, stacking bar, area, candle plot, and radar. You can do a time-wise aggregation with the aggregate operator (hour, day, month, quarter, season, year, etc.) definable right on the tree view. You can also do value-wise aggregation again with the aggregate operator (sum, average, min, max, std dev, etc.) definable right from the tree view.

Other visualization tools include graphing of the system characterization summaries, visual pivot graphs of efficiencies, 3D surface and scatter plots of efficiencies, time series 3D surface plots, output device characteristic plots, histograms of meter demand, daily load profiles by day type, pie charts of subordinate meter use and demand, and other custom two and three dimensional data scatter and surface plots.

Action Item Tracking

So you got some anomalies that are worth fixing? PACRAT does not stop there. PACRAT provides a powerful action tracking tool that lets you manage the remedy. It allows linking to supporting information and allows maintaining a threaded discussion on an issue. Responsibility and status are tracked till closure. Send a pre-addressed and formatted email based on the action item with any link information included as an attachment. Track the action item by having people respond via the link in the email. Their response will then be emailed to those involved in the discussion.

How Does PACRAT Work?

Data Access

How does it access data?

PACRAT accesses data recorded from a computerized energy management and control system (**EMCS**) or a data logging system (**DLS**). These systems sense the key performance parameters. Control systems then use the **sensed variables** to control the systems. All of this data can be trended and recorded by the EMCS or DLS. The EMCS's or data loggers store the **trend data** in different formats. Some are standard accessible formats and others are formats that are proprietary and hard to access. However they usually provide facilities to expose this data in one of a few industry standard formats. **PACRAT Snatcher** module gets the data output by the EMCS or logging system and puts it in PACRAT format so PACRAT can analyze the data. PACRAT then processes that data and stores the results. PACRAT can then archive the system data if so desired. This batch process of "snatching" and analyzing data can be initiated manually or automatically.

A byproduct of PACRAT is consolidated data that may be integrated from many different sources; different control vendors, metering systems, utility companies, data loggers. We call this Enterprise Historical Data Interoperability which is generally the most valuable aspect of interoperability. Two different buildings with two different control vendors rarely need to share real time data. However, consolidating historical data is useful.

Will PACRAT affect my control system?

One important point to note about how PACRAT handles the data flow; it uses the native system to do the raw data acquisition. Therefore it is **NON-INVASIVE** unlike integration systems that must poll the points externally one point at a time. This puts a large load on all levels of the control network that are typically not designed for that volume of data flow. This can cause problems with your control communications. Native system trending and archiving approaches typically buffer the trends in the field controller and periodically upload the data to the server in a more efficient flat block that minimizes bandwidth requirements. The native system will make this communication lower in priority than real time control information that must be delivered. Remember that for this level of data mining, you must get most points in the system. Therefore, while you must always consider the impact of anything you do to your control system, PACRAT's approach will have the least impact on your system, using it in a way the original manufacturer intended it to be used.

Data Structure

Can it handle different types of equipment with different formats for the data?.

PACRAT allows extreme flexibility in the data structure. You apply PACRAT to your data structure and not visa versa. It does not require you to force your data into a rigid structure. PACRAT adapts to varying data structures "on-the-fly" as it processes data. It provides you with the facilities to easily select the applicable fields from a list once you tell it where the source is.

So it is not live and on line?

No. PACRAT is designed to complement an EMCS and not duplicate its functionality. Critical alarms or ones that typically need immediate attention need to be identified by the EMCS and those alarms need to be enunciated such that the operator will know that these are alarms that need immediate attention. The first

priority needs to be keeping the system functional and the occupants satisfied. EMCS's are already well designed to provide this functionality. The optimization of the systems is and should be secondary to maintaining basic functionality. PACRAT identifies anomalies that are more subtle than a component failure, even though they can be very expensive. Since the operator is already quite busy maintaining the basic functionality of the systems, he usually does not have time to stare at the terminal or pour through trend data to look for poor performance.

If the heating and cooling valve start fighting because the positioners on the valves drift, unless it causes the space temperature to go beyond the comfort range, it does not require immediate attention. If the ventilation air quantity falls below the prescriptive value for a few hours, this is not a high priority for immediate action. If over a longer term these anomalies continue, this means the remedy should be added to the operators "to do" list. These are the kinds of anomalies PACRAT identifies. To help prioritization of the remedies, it calculates the cost penalty where applicable and a customized priority value that is matched to your needs.

What about bogus data?

This issue is two-fold. There is bogus data due to sensor failure or failure of the EMCS to get the data. There is also bad data due to sensor mis-calibration.

On the first issue, PACRAT allows you to set reasonableness limits for all applicable fields in the data. If the value falls outside this range, PACRAT won't consider it. Therefore, it will not affect the statistics reported or the calculated values other than not including those values in them.

Concerning sensor mis-calibration, there is a bit of an iterative process involved. In a "perfect world" all your sensors would be calibrated before you applied PACRAT. In reality they won't be. Since you will probably not have time to go through and calibrate all your sensors, the typical procedure is to apply PACRAT and use it to identify and prioritize sensors in need of calibration. If you do not want PACRAT to report anomalies that are really the result of sensor mis-calibration, or if you don't want the calculations to have any error in them due to the sensor, you can enter adjustments or simply turn off the affected modules for that system/component.

It automatically "brushes" "outliers" in statistical terminology.

The chicken or the egg?

What Do I Need to Apply PACRAT?

PACRAT Architectures

What you need will depend on what architecture is used for running PACRAT. The architecture boils down to where the main PACRAT modules reside; either locally referred to as **Site Server**; or remotely referred to as **Internet Server**. A description of each platform along with the associated requirements follow.

Site Server

The Site Server refers to an architecture in which all data resides on the same computer or Local Area Network that is connected to the control or energy monitoring/metering system that is acquiring the data. The PACRAT Snatcher component gets the data from the control/monitoring system and puts it in PACRAT format where the PACRAT **Expert** and the **Viewers** can access it. With this architecture, the following are the requirements

Site Server Hardware

PACRAT modules run in the Microsoft PC environment. They will run in Windows 95 or 98, Windows NT, Windows 2000 professional and ME, or Windows XP. Any computer that runs these environments will run PACRAT. Practically, however, you will want at least a Pentium processor with at least 128 megs of RAM and plenty of disc CACHE.

PACRAT typically deals with an extraordinary amount of data and performs extensive calculations on it. Therefore don't be "penny-wise and dollar-foolish". A muscle machine will execute the data much faster.

You will also obviously need plenty of disk space to hold the foundation software (Microsoft Access or MS-SQL Server) and the data you will need for processing, and especially if you intend to archive the data. You should practically have at least 1 gig available.

The OI is typically where the EMCS stores the long term trended data.

You will also need some way of transporting data from the EMCS or DLS to the PC running PACRAT. If PACRAT is installed on the PC that is the **Operator Interface (OI)** then you will have full access to the data. Next in priority would be a network connection between the PACRAT PC and the operator interface. That way PACRAT can access the data over the network. If none of these is an option, of course you can always transport it manually using disks. Just be advised that the data can require very large file sizes even on systems moderate in size. A CD burner will be a requirement on the source system if you are transporting it manually.

Site Server Software

PACRAT is an application written for Microsoft Access and as such allows you to store data in mdb format or in more powerful backend systems like MS-SQL server, Oracle, or IBM DB2. For large enterprises, one of the more powerful backends will be required. PACRAT was designed to allow you to use Microsoft Access to do your own data manipulation if you wish as MS Access provides intuitive and extensive functionality for custom data analysis via a powerful and user friendly interface. You can use this powerful software package to develop you own custom data analysis and reporting without being an IT professional. The does not however prevent you from connecting to and using the more powerful client server systems for data storage.

Internet Server

The Internet Server refers to an architecture in which all but the **Snatcher** and **PIMp** components of PACRAT reside on an Internet Server computer removed from the site. The **Snatcher** module "snatches" the data from the control and energy monitoring system and **PIMp** sends it across the internet to the Internet server. The **Expert** and **Viewer** components can then be accessed and run by a remote client computer via the internet. Another option is to simply view the results/generate reports and mange the action list items through the Facility Dynamics Project Portal. The Portal only requires Microsoft Internet Explorer. With this platform, the following are the minimum requirements.

Snatcher Hardware

PACRAT **Snatcher** and **PIMp** run in the Microsoft PC environment. It will run in Windows 95 or 98, Windows NT, Windows 2000 professional and ME, or Windows XP. Any computer that runs these environments will run **Snatcher** and **PIMp**. Practically, however, you will want at least a Pentium processor with at least 64 megs of RAM and plenty of disc CACHE.

Client Requirements

The client computers simply need to be able to run an internet browser. With the proper password, the client machines can access the Portal or run either the **Expert** or the **Viewer**.

EMCS or DLS

You will obviously need a system to record data. This will typically be an EMCS. Beyond having the EMCS, it must have the capability of storing the data. It must either store the data in a standard accessible format, or be able to output the data to a standard format. Some systems will require you to do additional setup to have the trends archived to disk. Typically trends set up through the normal procedure on an EMCS are only retained in the controller memory and older data is lost when the controller is full. A routine must be established to grab the data from the controller and store it to the PC running the operator interface.

Web Services

*Your application can be
"Powered by PACRAT".*

PACRAT now provides the results of diagnostic information as a series of **Web Services** in **xml** format. This allows you to use PACRAT as an analysis engine and present the results in your own software or web application. It also makes it extremely easy to integrate results/data with maintenance management systems or any other vertical market system that might want to manage or integrate this extensive data analysis.

Summary

PACRAT defines a new category of software targeted at mining data available from a facility. Though it may only be the whisper of electrons flowing around, this data speaks volumes. It is time for us start listening to what our buildings are telling us.

Our buildings are talking! Shouldn't we be listening?