Benefits of Permanently Installed Monitors

By: Brian Prokuda, P.E.
Keweenaw Power Systems, Inc.

Abstract

Temporary versus permanent meter use will be discussed. This discussion will include common goals of users including billing, reliability and other power quality concerns. Case studies will be presented illustrating the benefits of permanently installed meters.

Overview

The best reason that can be argued for permanently installed meters is that they are connected when problems occur. Many power quality issues are intermittent and non-predictable. It is typical to get an expert involved after the problem occurs, followed by installing temporary metering. Quite often the problem doesn't reoccur until the temporary meters are removed, starting the cycle all over. By installing and monitoring the data from permanently installed meters it is possible to have coverage of the electrical system 24 hours a day and 365 days per year. By having permanently installed meters at all of the utilization transformers and the main distribution level will provide a broad picture of an event throughout the facility. While it is likely that permanently installed monitors will not provide the total solution, the information that they provide will make it possible to narrow the source of the problem and allow a more effective use of portable monitoring.

It is common to use portable monitoring for determining load capacity, energy consumption, power factor analysis and harmonic analysis. While this can be effectively done by monitoring over one or more plant cycles, the period in which the process of the facility repeats itself, it isn't always the most effective. In many cases it is desired to measure the power system before and after a solution is provided. If the cost of installing portable monitoring equipment for a sustained period, more than a week, on multiple buses for simultaneous monitoring is compared to permanently installed meters the premium is about four times the cost. The premium is even less if PT's and CT's exist for the switchgear, as is often the case. If monitoring is to be done before and after a change is made, the premium has now been reduced to two times. It is easy to see that over the life of a plant permanently installed monitors could be cost effective just on the basis of simple monitoring that is commonly performed. More importantly, this information can be trended over longer periods of time and simultaneously with other utilization points throughout a facility.

Other topics to be discussed are Revenue, Preventative Maintenance and Reliability. Each of these topics is discussed in their own section with examples to demonstrate the benefits of each.

Revenue

When talking about revenue and metering, the first thing that comes to mind is Real Time Pricing because it is a hot topic with deregulation. Several schemes for rate structures in a deregulated market have been seen and it is difficult to say how a particular contract with an energy supplier may be written. In the deregulated programs that have been studied, a customer will unlikely be changing energy providers real time. The plan is for the customer to negotiate a flexible contract with a single provider. The reason permanent monitors are going to be advantageous is because that provider will be brokering for the best price which could mean variable energy costs in very small increments of time. In general, it is safe to say that electric billing is going to be more complicated and the user is going to want a more sophisticated energy monitor than reading a Watt-Hour meter once a month.

In areas with limited distribution capacity, a common rate structure is an interruptible rate. Interruptible rates are used to provide an incentive for customers to lower their consumption during periods of peak demands. The customer chooses a portion of their energy consumption to be on a floating energy cost. This cost may be a few cents during periods of high capacity and be tens of dollars during periods of low capacity. The risk is that plant production may need to be ceased if the cost of electrical power becomes too high. Without monitoring it is impossible to put a cost on shutting down a production area. The benefit to monitoring is that areas of large electrical consumption may be targeted and a cost can be assigned to allow that area to continue to operate. A production manager may hesitate to alter their production schedule to accommodate an interruptible rate structure unless they know what the true energy cost of continuing to operate is. In many cases, areas of production are shutdown that has little or no impact on the energy consumption. With the use of permanently installed monitors, not only can real time information be used to aid in load shedding but statistically it is possible to optimize how much of the energy consumption should be put on the interruptible rate.

System capacity is another issue that can benefit from permanent monitors. With long-term data collection, it is possible to determine the loading characteristics of a transformer or bus. With this information it is possible to load the system closer to its capacity without being concerned that it will be overloaded. Many times this will try to be done using portable metering over a one week or month period. In many cases this doesn't show the complete picture due to seasonal or workload variations. By loading the system closer to its capacity, capital costs are reduced by purchasing fewer electrical panels and transformers.

Of recent interest is the use of permanently installed monitoring to determine and reduce the cost per part being produced. By optimizing process cycles and knowing what impact they have on the energy consumption of a machine can determine improvements that are beneficial. Electrical characteristics are also being used to determine tool life. Ideally a cutting tool will be used for every possible cut before it becomes dull and produces cuts out of spec. Without monitoring, a tool may be replaced well before its useful life is up increasing the cost per part. The concept is to develop electrical thumbprints to determine when the cutter will make cuts out of spec.

Preventative Maintenance

It is difficult to know what the general quality of a facilities power is without monitoring. A case in point is the Lam Research Corporate facility that was able to notify their electric supplier to a problem on the distribution circuit before the supplier knew about it. The electric supplier found a problem with a distribution transformer and was able to replace it before Lam had an unexpected shutdown.[3]

Among quantities of common interest are: voltage magnitude, voltage unbalance, harmonic distortion, etc. From these, voltage unbalance can be the most detrimental. Several cases have been seen where refrigeration equipment has failed or the protection system has continuously shut it down due to voltage unbalance. Three phase motors are sensitive to voltage unbalance because negative sequence currents are created that produce heat within the motor. In the last ten years a surge of large home construction has occurred increasing the single-phase air-conditioning load. This creates a situation where it is easy for utility voltage unbalance to occur. For reasons stated above, this can be a problem for facilities with three-phase loads connected to those circuits. Voltage unbalance can also occur from within a facility. If large single-phase loads are utilized and are not connected or operated in a way to minimize unbalanced current, the voltage will become unbalanced. This is very common on three-phase, four wire delta systems where most of the load is single phase and HVAC may be the only three phase equipment. On both the utility and customer buses, three-phase capacitors can loose a phase and create a large unbalance of reactive current. This results in significant voltage unbalance.

One of the advantages of having permanently installed meters is the ability to determine characteristics for the facility electrical system. When those characteristics change, the meter itself may alert personnel or a facility observer to detect it. For example, lets say a power factor correction capacitor goes off line. It will take one billing cycle before the problem will show on the utility bill. By the time the utility bill is seen by a facility engineer, it is likely that a second billing cycle is nearly complete. Depending on a facilities staffing, the problem may or may not be detected before the utility bill reveals it. So in most cases, at least two months of power factor penalty will be incurred prior to knowing about the problem. With permanently installed monitoring the problem would be known within seconds of occurring.

Erratic Controls Due to Harmonic Distortion Case Study:
One case that could have easily been solved with permanently installed meters was the erratic operation of a gage monitor. Plant operations personnel discovered that during various periods, a gage monitor used for the quality control of parts would determine parts that were within specification as bad. This went on for several weeks when plant personnel determined that the problem must be on the power system. The first observation was that two induction furnaces were fed from the same bus. A portable monitor was used at the gage monitor and showed that the voltage distortion was near 5%Vthd with one furnace operating and near 10%Vthd with two operating. Furthermore, most of this distortion was at the 13^{th} harmonic so resonance was suspected. After inspecting the bus, two 75kVAr capacitors were found which created a parallel resonance condition near the 14^{th} harmonic. The distortion, which was seen by the control circuit, caused the sensors gauging the part to give false readings.

It is true that this problem was found very quickly using portable monitoring, so one may ask why is this an argument for permanent monitors. The quickest and most effective solution for the facility was to take one capacitor off line, which moved the resonance point, and kept the voltage distortion to less than 5%Vthd. This solved the control problem, but plant personnel were concerned that this may impact their power factor and result in a utility penalty as well as reduce the bus capacity. Additional monitoring than had to be done to determine the impact on power factor and bus capacity. Another less tangible cost is that of the plant personnel trying to identify the problem with the gage monitor. If a trained person would have been observing the power on the bus and saw periods with near 10%Vthd, they could have at least queried production to see if any unexplained problems were occurring. This could have reduced the time that production personnel had to live with the problem.

Rectifier Case Study:
Figure 1 shows the voltage and current for a rectifier during peak power draw. The first observation is that the current (shown in gray) is not symmetrical which results in even harmonics. A closer look shows that only the positive cycle for the phase C current has the characteristic double hump of current for a six-pulse rectifier. This indicates that not all of the SCR's are gating properly. Due to the nature of the process, the improper gating didn't affect the quality of the product enough to indicate a problem. Further inspection found a loose connection on the driver board and a broken lead to one of the SCR gates. These problems were repaired and the rectifier then functioned as expected.

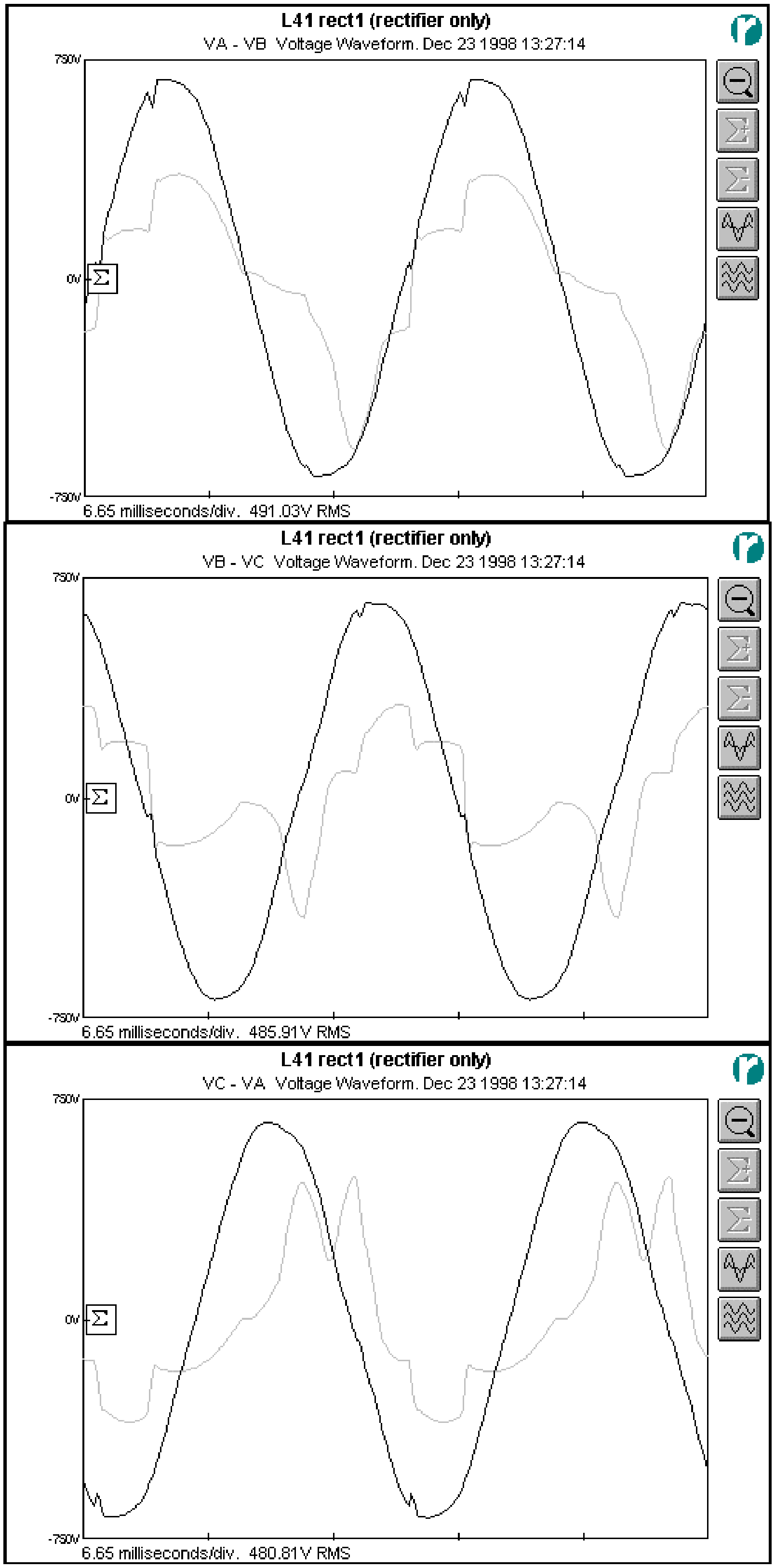

Figure 1 - Rectifier Maximum Recorded Power (Voltage Line to Line)

This is a good example of a problem that could have been detected and resolved with the help of permanently installed meters. It is unknown how long this condition had existed and was only detected because a harmonic study was being performed. The condition created stress on the rectifier system as well as creating even harmonic current that was amplified by existing harmonic filters which often shutdown due to over load. As mentioned above, by having permanently installed monitors one can develop a sense for what a facilities characteristics are. When they change, the monitoring system can alert personnel. Even if a condition exists that the monitor is not able to detect it self, an observer may see a change. For instance, in this case the unsymmetrical waveform or presence of even harmonics.

Reliability

Reliability studies are needed to determine the appropriate type and size of protection for a facility process, such as a UPS system. These studies require statistical data to characterize a facilities power system, which requires long term monitoring. Figure 8 shows all of the events for a facility, normalized to one year, in a reliability graph. The shading shows the anticipated number of events on a per year basis that will be at or below the particular level of voltage and duration. For example, within the voltage reliability graph (Figure 8) there is an equipment sensitivity curve that shows that if the voltage is below 69% of nominal for more than 13 cycles the equipment will shut down. With the data from Figure 7, it is expected that the critical equipment would go down 2 to 4 times per year. The 2 to 4 event area is so large in Figure 8 that it is likely that most sensitive equipment at the facility would fall in this range. So even without specific sensitivity curves, it can be expected that all or part of this facility will go down 2 to 4 times a year. The goal in implementing a solution is to maximize the white area in the graph or to improve equipment reliability to a point where it falls into the white area.

Reliability Study Example:

Figure 9 shows the events at the facility that would be protected with a Westinghouse Dynamic Voltage Restorer (DVR). The connected DVR is a 2.0MVA unit with 660kJ of stored energy. The graphs assume that the load is at unity power factor and that the fault is three-phase with no phase shift from the original voltage. The maximum injection voltage is 100% times the ratio of DVR MVA and load MVA. For instance, a 2MVA DVR applied to a 4MVA load has a maximum injection of 50% rated voltage.

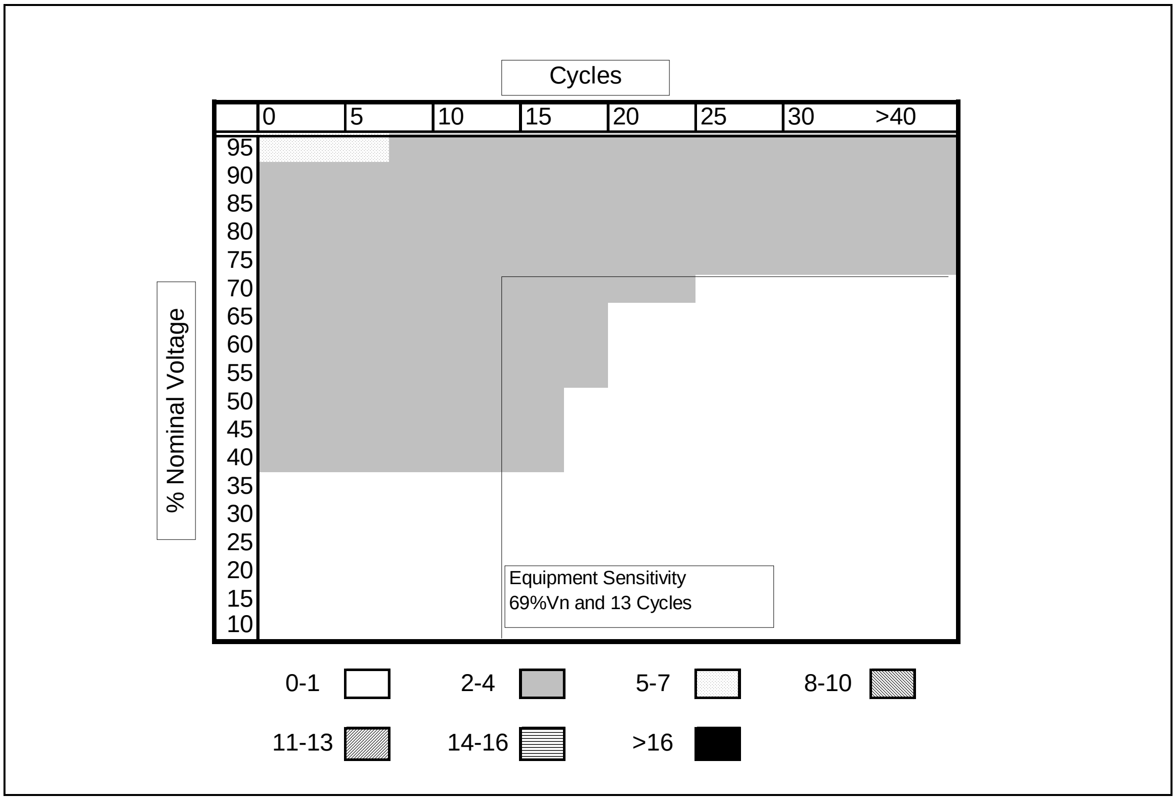

Figure 8 - Facility Voltage Reliability Graph Normalized to a per Year Basis

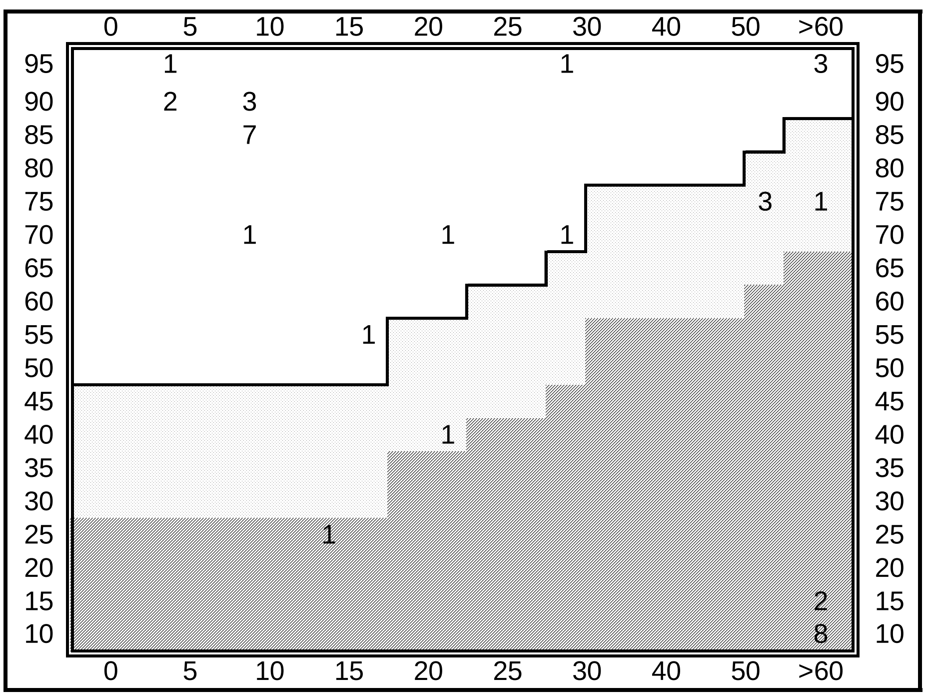

Figure 9 - Facility Events Covered with a 2MVA DVR with 660kJ of Stored Energy And 4.0MVA of Load

Figure 9 shows all the events recorded by the facility from 1990 through 1997. Events in the white area are those that the DVR will restore 100%. Events in the hatched area are those that the facility will likely not be able to ride through with the specified DVR. Events in the gray area are those that will not be restored 100%, but it is likely that the facility will be able to ride through. Without specific ride through curves for critical equipment it is not possible to determine the depth and duration of sag that the facility will be able to ride through. From past work in this area, it is surmised that sags down to 80% of nominal voltage will not cause a problem in most cases. This is the criterion used for the gray area. This area is created because the DVR will inject as much voltage for as long as possible, even if 100% voltage restoration isn't possible.

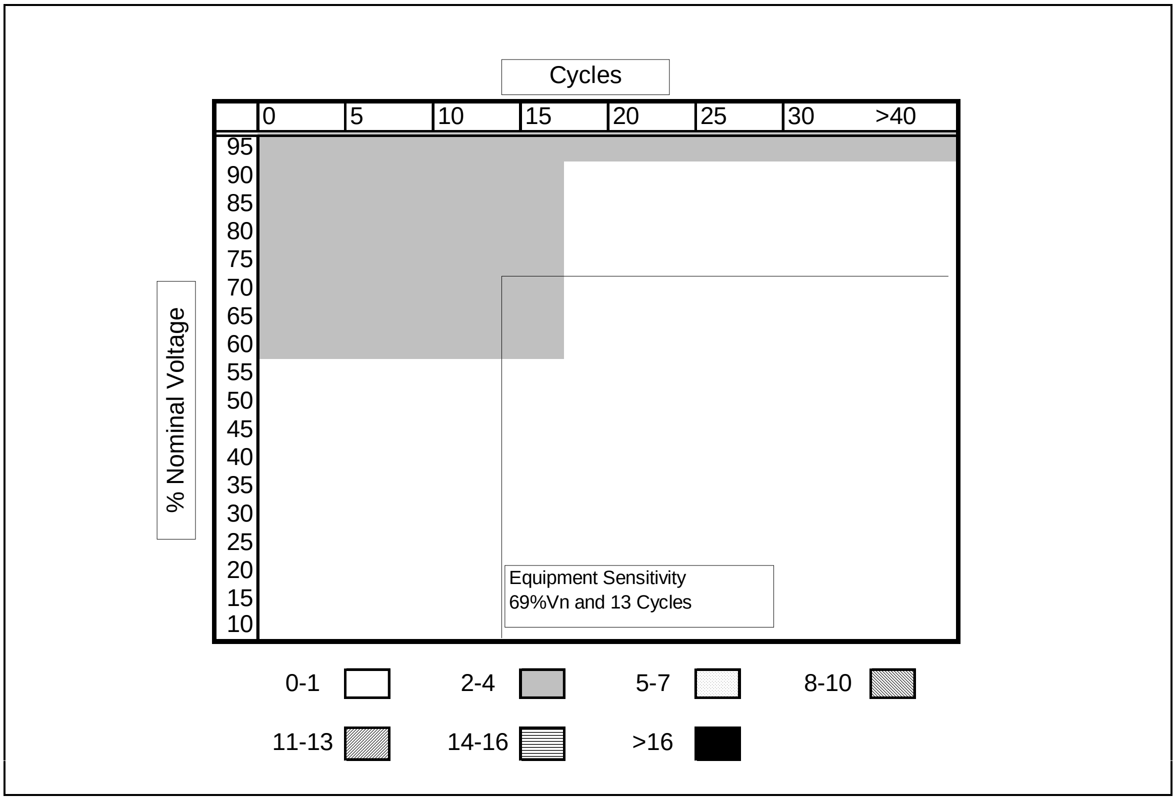

Figure 10 - Facility Voltage Reliability Graph Normalized to a per Year Basis With a 2MVA 660kJ DVR

Figure 10 shows the modified reliability graph for the facility with a 2 MVA DVR. For the purpose of this graph, the events shown in the gray area of Figure 9 have been moved to the likely magnitude and duration with the specified DVR. It is seen that there is a great improvement, but the specific equipment shown in the figure will still go down 2 to 4 times per year. This is why it is important to understand both the ride through capability of facility equipment as well as the number, depth and duration of sags per year.

This example shows that it would have been impossible to determine the benefit of a DVR installation without data collected over a long time. In this case, a very expensive solution may have been implemented without reducing the number of interruptions each year.

Reliability Case Study:
A facility with four 2000HP DC drives was fed from a very weak utility circuit. Complaints from neighboring customers fed from the same distribution circuit resulted in the utility investigating and determining that the plant with four, 2000HP DC drives were the source of the problem. The utility investigation showed that the plant didn't meet the flicker requirements as discussed in the contract between the utility and customer. This led to an investigation by the facility, which

included the installation of a permanently installed monitor at the service entrance. While the data from the monitoring showed that the operation of the DC drives did exceed the utilities flicker limits, it also showed that over a four month period that five events occurred that were long enough and deep enough to take the plants process off line. It was also found that high frequency noise was propagated onto the utility system from the drives and that some of the complaints were due to this problem and not the flicker. With this information it was possible to create a situation where the utility and facility worked together to solve the problem instead of the facility being solely responsible. Monitoring is on going to create a statistically valid database of events. This information along with the above-described method will be used to determine the best solution as well as to determine the performance of the solution.

Conclusions

Many examples have been shown where it was beneficial to use permanently installed monitors. In short, information is power. The power to reduce energy costs, the power to resolve problems before they cause unexpected down time and the power to cost effectively implement solutions. The key is to implement a monitoring strategy that uses permanent monitors to get a general picture and uses portable monitoring for detailed information.

References

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