Using Key Performance Indicators (KPIs) to Manage Power System Reliability

by John Van Gorp

Executive summary

Businesses are finding themselves drowning in a sea of power monitoring data. Today's systems collect too much data — managers have trouble extracting the critical "nuggets" of useful information on power reliability. This paper discusses how taking a key performance indicator (KPI)–based approach to power monitoring allows personnel to focus more on strategic goals, translate data into actionable intelligence, and get more comprehensive insight into power reliability and "see the forest for the trees."

998-2095-07-11-14AR0

Schneider Electric

Introduction

Managing power reliability means effectively monitoring power quality. Today's power monitoring systems provide a wealth of data about power quality — often too much data. Power system managers would be well served by drawing upon the experience of business system managers, who have faced similar challenges of "data overload." They tackled the problem by taking a four-step approach to managing data:

- articulating top business goals
- translating those goals into a select few key performance indicators (KPIs)
- focusing on measuring those KPIs with data
- communicating results broadly, so data can become actionable intelligence

With today's systems able to provide so much more power quality data than traditional tools, this KPI approach helps businesses better "see the forest for the trees."

Reliability = availability + quality

Power reliability is a measure of combined **power availability** and **power quality** to determine how well the power source can provide suitable power for specific uses. (Poor power quality could result in some equipment being unusable, even if power is technically available.)

Traditionally, equipment such as power quality analyzers, fault recorders, and sequence-of-event recorders have been the primary tools used to maintain a reliable power system. This equipment typically monitors a handful of select points within a power system and captures a detailed "snapshot" of the electrical activity occurring around disturbances. In the hands of an expert user, this equipment can prove invaluable in determining the root cause of a disturbance. However, the cost of such specialized equipment has often limited its use to only a handful of select points within the system. The software used with such equipment is similarly specialized (normally being restricted to one or two computers) and was not designed to integrate with an organization's IT infrastructure.

Today's power monitoring systems, on the other hand, rely on a modern IT approach to track performance and communicate results. They capture and report a tremendous amount of detailed data about the health of the power system. In fact, these modern power monitoring information systems comprise much the same architecture as modern business information systems:

- intelligent, microprocessor-based devices designed to monitor equipment and key points within the system
- a network for data communications among system components
- one or more servers running software that processes, archives, and presents data to a variety of client computers and devices

These three components fit together to form a cohesive information system (**Figure 1**). The intelligent devices in this system may be advanced power meters, protective relays, or programmable logic controllers located at several facilities throughout an organization. The communications network might be a facility's local area network (LAN), a corporate wide area network (WAN), or the Internet. The software typically runs on Microsoft Windows on standard server-class computers, and clients range from standard PCs running web browsers to wireless devices capable of receiving text, data, and email.

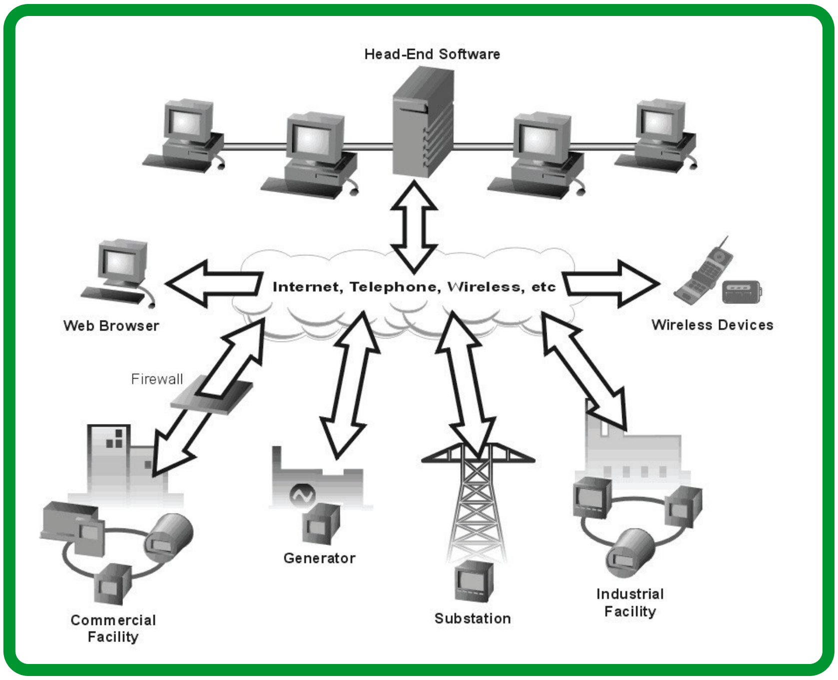

Figure 1
How components of a typical power monitoring system work together

But today's power monitoring systems present businesses with a paradox: while it is now cost-effective to collect much more data than ever before, users find themselves drowning in the volume of data generated.

While it is now cost-effective to collect much more data than ever before, users find themselves drowning in the volume of data generated.

Business information system users face a similar challenge, and they have addressed the issue by boiling down the overwhelming amount of data into a few critical "nuggets" of actionable information. Business management practice calls these nuggets **key performance indicators (KPIs)**. These KPIs provide both the metrics that will be used to determine the success of a business plan and the timely information managers need to track performance and make adjustments.

A similar approach can be adopted to manage power system reliability, whereby KPIs are designed to provide engineering and maintenance managers with the timely "nuggets" of information they need to maximize reliability.

This paper describes best practices for using KPIs to manage the reliability of a power system. It discusses how to define KPIs, what data to collect, and how to present the data.

The problem of data overload

Although modern power monitoring systems clearly can play an important role in improving power reliability, they can also overwhelm users with the sheer volume of data. With today's systems steadily lowering the cost per monitored point, it has become increasingly more cost-effective to build systems with hundreds or even thousands of monitored points.

Such systems can become unusable without careful consideration of what data to collect, how often to collect it, and how to present it. All too often a power monitoring system is simply configured to capture as much data as possible, as quickly as possible — "just in case it is needed." If only a handful of monitored points are involved, this "catch everything" approach simply makes finding the useful nuggets of information inconvenient. If there are hundreds or thousands of monitored points, it becomes impossible to find anything of value at all.

How to define KPIs

The first step is to articulate goals & covert them into KPIs — not dive right in to deciding what data to collect.

It is often tempting to start planning a power monitoring system by considering what data to collect. However, it is more effective (and usually more difficult) to start by taking a step back to consider the primary goals of managing power reliability, and how the power monitoring system supports those goals. If these goals best articulate what an organization hopes to achieve in managing power system reliability, then the first step is to convert those goals into key performance indicators (KPIs) that can be measured and tracked.

There are a number of international standards that can be drawn upon to assist in creating KPIs. Energy suppliers have long faced the challenge of monitoring their transmission and distribution systems, and standards such as EN 50160, IEC 61000-4-30 and IEEE 1159 offer "best practices" for measuring and quantifying power system reliability. Energy consumers have not typically tracked the reliability of their power systems to the extent that electric utilities have, but relevant standards do exist, including SEMI F47 (for the semiconductor industry) and the ITI (CBEMA) curve (for information technology equipment). Both standards describe the tolerance that specific types of equipment have to variations in the power supplied to them, effectively delineating the kind of power system reliability required for normal operations.

To see how such standards such might be applied to create KPIs, consider the example of a manufacturer that wishes to track the reliability of its power system and the impact that this reliability has on the IT equipment controlling its processes.

The ITI (CBEMA) Curve [1] (and associated Application Note) describes "an AC input voltage envelope which typically can be tolerated (no interruption in function) by most Information Technology Equipment (ITE)"[1].

Using standards to define power quality

A common challenge is how to describe power problems in a standard way.

The Schneider Electric white paper The Seven Types of Power Problems discusses the most common types of power disturbances, using the IEEE standards for defining power quality problems.

If data for the magnitude and duration of voltage disturbances were available for the IT equipment used by this manufacturer, the following sample KPI definition could be used:

1. The *All Voltage Disturbances* metric will log and timestamp all disturbances that exceed ±10% of nominal voltage. This metric will be represented by a count of total disturbances over a defined time range. In addition to the timestamp, this metric will have the following monitoring location data associated with it: building location, circuit tag, and IT equipment asset tag.
2. The *All Voltage Disturbances* metric will be broken down into two separate metrics: *ITI Curve Compliant* and *ITI Curve Non-Compliant*. The first tracks the number of disturbances that fall within the ITI Curve, and the second tracks the number of disturbances that do not (and which may affect IT equipment operation).
3. All IT equipment noted as critical to manufacturing operations will be monitored to generate these KPI metrics.

Although this sample KPI definition is relatively simplistic for the purposes of illustration, a monitoring system that can support these KPI metrics would be a powerful tool in the pursuit of increased power system reliability. These metrics can be organized into a variety of information views to give engineering staff a comprehensive understanding of power system operation and how that operation impacts IT equipment and manufacturing operations. (See **Tables 1–3**.)

A power monitoring system that supports KPI reporting can provide additional value if it also gathers additional "supporting" data when exceptions occur. Again using the manufacturing example, a power monitoring system could be configured to capture voltage and current waveforms for disturbances that fall outside of the ITI Curve. Information about IT equipment

[1] ITI (CBEMA) Curve (revised 2000), Information Technology Industry Council. The application note is reprinted in the Appendix to Schneider Electric's Important Aspects of a Healthcare Metering System.

status (such as whether or not it is functioning normally) could also be collected. This supporting data could be used to gain a more detailed understanding of disturbance events and the impact they have on correct equipment operation. Once performance metrics have been defined and any supporting detailed measurements selected, the next step is to determine how the required data will be collected.

How to collect KPI data

Compared with the potential volume of data that many power monitoring systems can generate, what is required to support defined KPIs can easily be much less. This is not to say that power monitoring systems should never collect detailed data at all. Rather, the system should be designed to capture just the right amount of detailed data to measure the primary goals on which the KPIs are based.

The data that supports defined KPIs tends to fall into one of two main categories:

- **Static data,** such as one-line diagrams and equipment ratings, is often collected as part of an initial power system audit of a facility and is useful in organizing and presenting performance metrics.
- **Dynamic data,** such as the equipment status and key operating measurements, needs to be collected regularly and processed to generate the desired performance metrics.

Unless the data supports the KPIs, collecting it only consumes cost and effort unnecessarily.

Although both types of data need to be collected, it is more expensive to manage parameters for dynamic data because there is some continuous effort involved in acquiring and processing the data. Dynamic data will also take up the vast majority of the total storage space in a power monitoring system. The cost and effort associated with dynamic data would suggest that defining what data to collect should be done with care. The capabilities of modern intelligent devices and information systems may make it tempting to measure a large number of parameters “just in case they are needed.” But unless the data supports the KPIs, collecting it only consumes cost and effort unnecessarily.

Once the required parameters to measure have been defined, there are a variety of potential data sources to consider:

- *Advanced power meters.* These devices monitor a wide range of power system parameters, including comprehensive electrical measurements, waveform capture, and digital/analog signals indicating equipment status and health.
- *Protective relays.* Modern microprocessor-based relays communicate the current status of the equipment they protect, and indicate the conditions under which they trip.
- *Power system equipment.* Equipment such as motors, generators, and transformers is often capable of reporting current status, indicated as digital contacts or analog sensors, or transmitted via digital communications.
- *Facility or process information systems.* Environmental control systems, process automation systems, and utility supervisory control and data acquisition (SCADA) systems can all report on the status of equipment affected by the reliability of a power system.
- *Maintenance records.* These records can be correlated with power system disturbance data to gauge what impact the disturbances may have to the normal operations of an organization.

How to display KPI data

Defining KPIs and collecting parameters to measure will not improve power system reliability if the data cannot be turned into actionable intelligence — if system managers are not able to track performance and make adjustments accordingly. Therefore, how the data is displayed and presented is just as important as how it is collected. Data displays typically fall into two main categories:

- **High-level overviews of a KPI.** These concise views are designed to help engineering staff "see the forest for the trees" and are meant to provide a general indication of power system reliability.
- **Detailed drill-down view of the KPI data.** These views work in concert with high-level overviews but provide additional details about the behavior of the data behind the KPIs. These details can help engineering staff understand which portions of the power system are the most vulnerable and determine the root causes of these vulnerabilities.

There are a variety of ways to display performance metric information and detailed data, and a number of key concepts can be leveraged to create views and a process for uncovering useful "nuggets" of information from a sea of data. Some of these concepts include:

How the data is displayed and presented is just as important as how it is collected.

- *Displaying data in tables, charts, and time-series trends*. A table is often the best way to organize and display high-level KPI metrics, and bar graphs or pie charts are useful to visually compare different KPI values (e.g., one metric against a reference metric). A time-series trend displays changes in the KPI, or more detailed supporting data (such as waveform captures), over time.
- *Organizing data by key attributes.* Attaching a number of key attributes to each monitored point in a power system (such as physical location, circuit, and load type) gives an information system the ability to organize (or "pivot") KPIs around these attributes. For example, summary KPI values can be generated for all monitored points at one facility site, for all points connected to a particular circuit, or by type of load.
- *Organizing data by time range.* Most people are familiar with creating time-series plots over a defined period of time, but modern information systems can also group data into several compelling views by applying a more comprehensive understanding of "time." One view might start with a total KPI metric for one month and then break the data down into totals by day of week, weekday vs. weekend, or more specialized divisions of time (e.g., different shifts in a day).

To illustrate, **Tables 1–3** show different ways to display the sample *All Voltage Disturbances* KPI. **Table 1** provides a summary of the metric (by month) for Facility A of XYZ Corporation. A quick scan of this table shows that this facility experienced the greatest number of disturbances during the month of May.

Table 1
Summary of all voltage disturbances for Facility A by month

All voltage disturbances
XYZ Corporation: Facility A

month	count
January	10
February	12
March	8
April	7
May	22
June	15
July	13
August	10
September	8
October	16
November	15
December	10

Table 2 provides additional detail about the voltage disturbances that occurred during this month, breaking them down into a grid that is organized by magnitude and duration. Each cell in the grid shows a count of the number of disturbances that occurred within a particular magnitude range (1 through 5) and duration range (A through E); cells with a darker background are outside of the ITI Curve compliance area.

Table 2
KPI grid for all voltage disturbances in May

All voltage disturbances
XYZ Corporation: Facility A

magnitude	duration				
	A	B	C	D	E
1	0	0	0	0	0
2	1	2	2	0	0
3	0	3	0	0	1
4	1	2	2	3	1
5	2	1	1	0	0

Finally, **Table 3** provides additional details about the three disturbances that occurred in cell D4 of Table 2, listing the timestamp, duration (in ms), and per-phase voltage magnitude (as a fraction of nominal) for each disturbance.

Table 3
Event table for three voltage disturbances in May

All voltage disturbances
XYZ Corporation: Facility A

Time	Duration	Phase A	Phase B	Phase C
03-may-2003 10:23:01.147	82 ms	0.65	0.70	0.68
10-may-2003 22:01:17.450	145 ms	0.51	0.55	0.54
11-may-2003 08:19:55.011	52 ms	0.68	0.65	0.58

The three displays of information progress from a high-level overview of power system performance down to increasingly more granular levels of detail. By reviewing high-level KPIs first and drilling down only into events of interest, engineering staff can avoid searching through thousands of data points to find the few that are of interest. However, the data captured while KPIs are on track are not without value. Such data can be used for a variety of other tasks, including the development of operating “profiles” for monitored equipment.

Conclusion

Information tools that support power system reliability have traditionally focused more on detailed analyses of electrical measurements than on comprehensive power monitoring and management. Traditional power quality analysis after disturbances unquestionably plays an important role in determining the root causes. But modern power monitoring information systems enable businesses to more proactively manage reliability before a disturbance occurs.

Power monitoring information systems are becoming a key part of maintaining power reliability, especially as the hardware and software components become more widely available. In the past such information systems were often prohibitively expensive, but recent technological advances have steadily driven down the cost to monitor an increasing number of data points within a power system. As the costs involved in automating data collection continue to drop, the total cost of ownership for these systems will increase on the data management and information processing side of the equation.

Yet the ability to capture ever more power monitoring data is both a blessing and a curse. Businesses have found that they are drowning in a sea of collected data — with hundreds or even thousands of data points now instead of just a handful, it has become almost impossible to sift through the volume of data to find the “nuggets” of useful information they need. Power monitoring information systems that are designed to extract these nuggets of data as key performance indicators can help an organization “see the forest for the trees.”

The value of future power monitoring systems will not be in the quantity of data they can collect but rather in the quality of insight they can deliver.

About the author

John Van Gorp is the Local Patent Coordinator for the Power Solutions teams in North America. John gained his experience designing energy monitoring systems for the Power Smart program at BC Hydro and for utility and industrial customers as an Applications Engineer at Power Measurement. He received his B.A.Sc. in Electrical Engineering from the University of British Columbia, and his Certified Energy Manager designation from the Association of Energy Engineers.