New Publicly-Accessible Online Power Quality Monitoring Databases

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ABSTRACT

While performing power system studies, it can be difficult to find real-world data to supplement and/or reinforce experimental data. This paper provides information on how four databases can be obtained through a new online power quality monitoring system accessible via the Internet and how the data in these databases can be used. The available data includes NOAA Space Weather, NREL Wind, the DOE/EPRI Disturbance Library, and the PQSoft PQ Waveform Library. The cloud-based databases are available at no cost to educational institutions worldwide for the purpose of training electric power engineering students.

INTRODUCTION

A new cloud-based online system has been developed for sharing power systems measurements via the Internet at www.pqweb.com. The measurements that can be accessed from the website include recordings by power quality monitors, microprocessor relays, digital fault recorders, wind turbine simulations, and geomagnetic sensors. Measurements include long-term data log trend data, waveforms of voltage and current, rms samples from voltage sag events, and more. Measurements can be downloaded in graphical format, IEEE Std 1159.3 PQDIF format, and in comma-separated variable (CSV) format.

This paper describes four different data sources available on the online power quality monitoring database: NOAA Space Weather geomagnetic data, the Eastern Wind Dataset from the National Renewable Energy Laboratory (NREL), the DOE/EPRI Disturbance Library, and the PQSoft PQ Waveform Library. The type of data contained in these databases is covered along with some examples of how the data can be used.

NOAA SPACE WEATHER DATABASE

Background

The sun has an eleven-year cycle with changes in levels of solar radiation and ejection of solar material. The last solar maximum occurred during 2012 to 2013. Sun spots produce Coronal Mass Ejections (CMEs) which occur more frequently during solar maximums. CMEs propagate from the solar corona to the orbit of the Earth in one to three days. The bulk of CME material is blocked by Earth's magnetic field, but magnetic reconnection at the magnetopause allows for some of the CME mass, momentum, and energy to enter the magnetosphere. During peak periods of solar activity, electric currents in the magnetosphere and ionosphere experience large variations. These variations induce currents in electrical conductors located on the surface of the Earth, observed as DC currents on electric transmission lines. The electromagnetic field produced by these DC currents may cause power transformers to enter into half-cycle saturation. The effects include increased heating, system voltage collapse, higher harmonics, higher reactive power demand, and possibly cause relays to not operate properly [1].

K Index from US NOAA

Numerous indices are available for estimating solar CME activity, one of which is the "K" index. The K index quantifies disturbances in the horizontal component of Earth's magnetic field [2]. The value is derived from the maximum fluctuations of horizontal components observed on a magnetometer during a three-hour interval. The K value ranges from 0 to 9. Calm solar conditions result in a K of 1, and a geomagnetic storm would produce a K of approximately 5. The planetary (K_P) index is derived by calculating a weighted average of K indices from a network of geomagnetic observatories worldwide [3].

Table I. Estimated Power System Impact by K_P Index

K_P Index Reference	Estimate of Effect on Power Systems
K_P = 5 (Minor)	Weak power grid fluctuations.
K_P = 6 (Moderate)	High-latitude power systems may experience voltage alarms. Long-duration storms may cause transformer damage.
K_P = 7 (Strong)	Voltage corrections may be required. False alarms triggered on some protection devices.
Kp = 8 (Severe)	Possible widespread voltage control problems. Some protective systems will mistakenly isolate key assets from the grid.
K_P = 9 (Extreme)	Widespread voltage control problems. Protective system problems can occur. Some grid systems may experience complete collapse or blackouts. Transformers may experience damage.

Using Solar Data

The solar data available on PQWeb.com is presented in the format of the K_P index obtained from NOAA's Space Weather web site. These values are available as 3-hour

interval values, but using PQWeb.com, this data can be presented in minimum, average, and maximum format over different time frames. For example, in Figure 1 it is presented as monthly minimum, average, and maximum values. Figure 2 presents a histogram showing the distribution of K_P indices throughout the year of 2013.

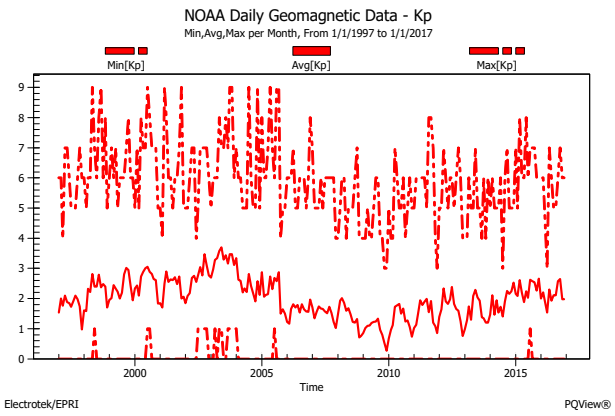


Figure 1. Monthly Min/Avg/Max KP Values

This data can be used in conjunction with other data sources such as system voltage, DC neutral current, transformer temperature, etc. as a means of measuring the impact of solar CMEs on a power system.

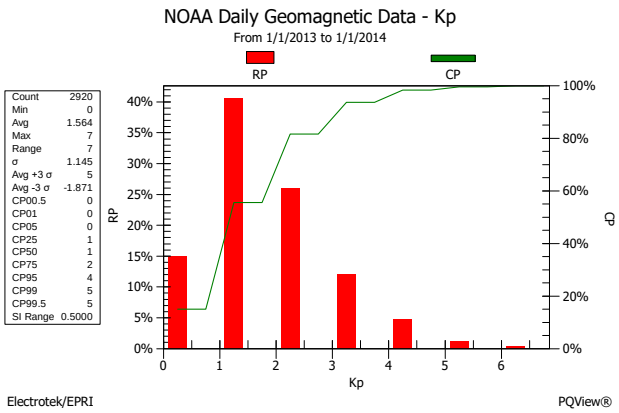


Figure 2. Histogram of KP Indices during 2013

Figure 3 shows the maximum value of K index by week during 2016 for the planetary average (K_P), for Fredericksburg, Virginia (K_F), and College, Alaska (K_C).

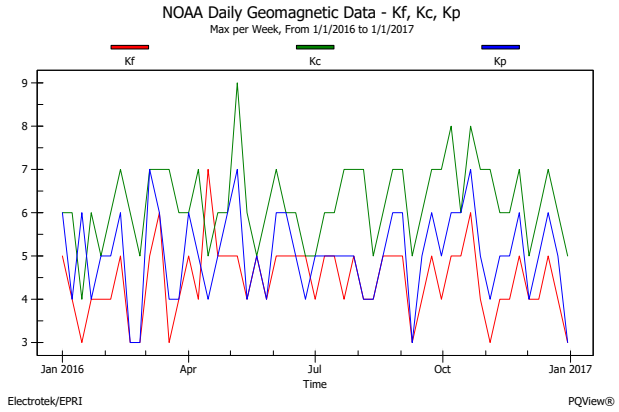


Figure 3: Maximum K Indices by Week during 2016

NREL WIND DATA

Background

The NREL Wind Database contains thousands of simulated wind farm data points in the United States for 2004 to 2006. This data includes wind speeds at locations throughout the Eastern United States. Associated with these locations are estimates of power output for hypothetical wind turbines at these locations. The online data was compiled from a project funded by the National Renewable Energy Laboratory (NREL), which is operated by the Alliance for Sustainable Energy, (ALLIANCE) for the United States Department of Energy (DOE) [4].

In addition to the data log measurements for kW output and wind speed, properties are stored for each simulated wind turbine site, including its rated capacity, IEC 61400-1 class [5], and losses. The latitude and longitude for the wind turbine is also available, making it possible to display the data geographically on interactive maps.

Using the NREL Eastern Wind Dataset

Used in conjunction with PQWeb.com, the simulated data points can be seen geographically (Figure 4) or in a tabular format. The data can then be plotted over time in order to perform wind integration studies and/or estimate power production from turbines placed at the simulated locations. Figure 4 provides an example trend of the wind speed and wind turbine output data available in the NREL Eastern Wind Dataset Database. The data is divided into two databases: one for onshore locations, and one for offshore.

Figure 4. Geographic Locations of NREL Eastern Wind Data

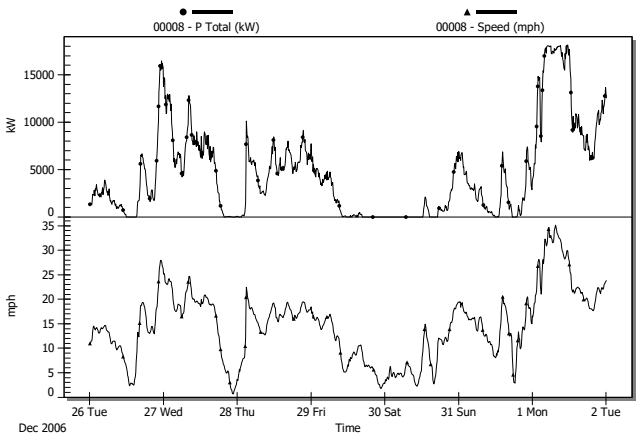


Figure 5. Wind Speed and Simulated Power Production

DOE/EPRI DISTURBANCE LIBRARY

Background

From 2005 to 2007, the Electric Power Research Institute (EPRI) collaborated with a group of U.S. electric utilities to produce a database of electric system disturbances that includes the cause of the corresponding disturbance. This collaboration was made possible through a grant from the U.S. Department of Energy (Instrument # DE-FC02-05CH11348). Data was provided from a mix of power quality monitors, digital fault recorders, microprocessor relays, and remote terminal unit systems (RTUs). Participating utilities included American Electric Power, the Consolidated Edison Company of New York, Progress Energy Carolina (now Duke Energy), San Diego Gas & Electric, Southern Company, Tennessee Valley Authority, TXU Electric, and the United Illuminating Company. Nearly three hundred disturbances were documented.

Using the DOE/EPRI Disturbance Library

The value of this disturbance library is that it is not just a library of waveforms from power systems. The associated cause of the events allows for waveform analysis while knowing what type of disturbance is being analysed. This database could be used to test and/or develop algorithms that determine the cause of an event based on the wave shape. For example, Figure 6 and Figure 7 show the waveform samples and rms samples due to a similar cause code (vegetation contact with a distribution system conductor). The online database from PQWeb.com allows researchers to analyse the data in detail and export it into other formats such as IEEE Std 1159.3 PQDIF for more advanced analysis. Figure 8 shows a feeder inrush during energizing after an interruption that is followed by a single-phase fault.

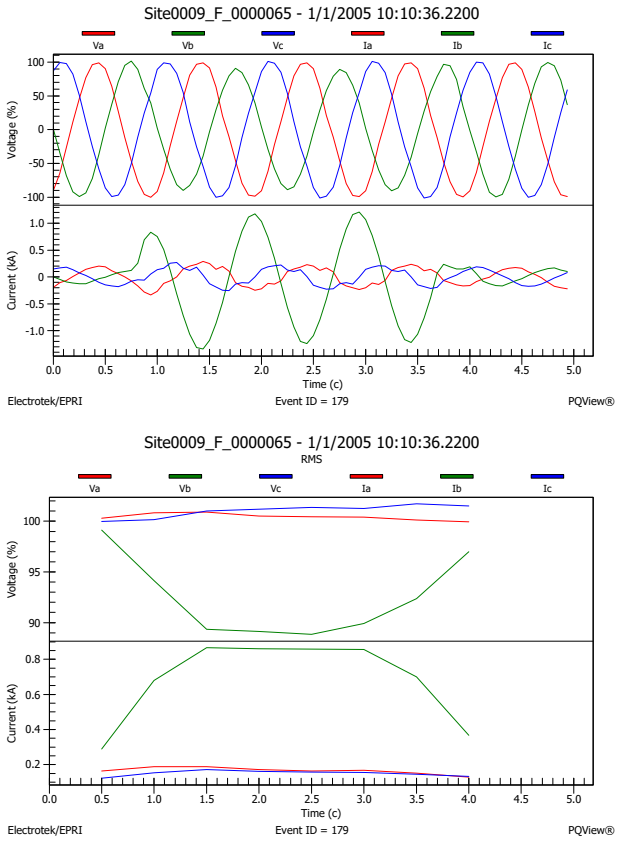


Figure 6. Downstream Tree Contact at Site 1

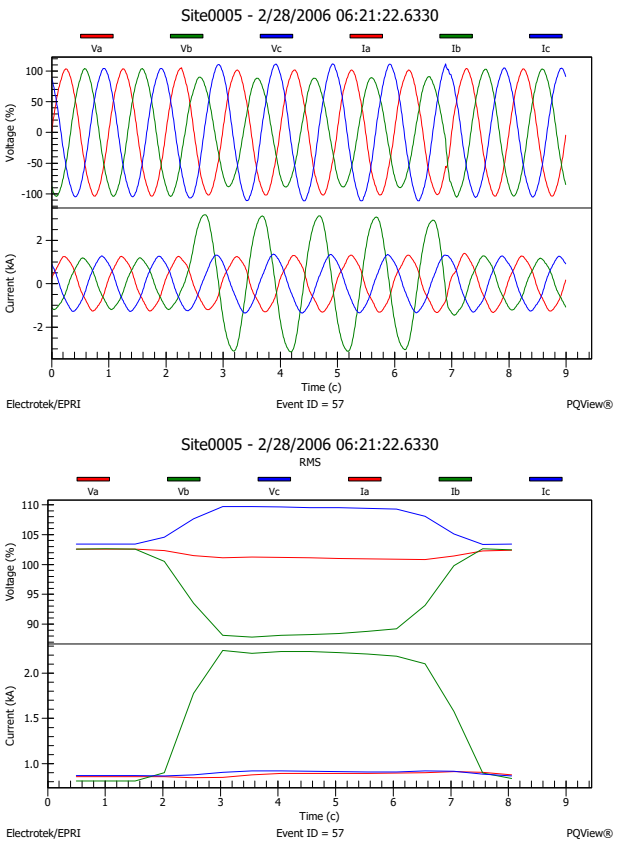
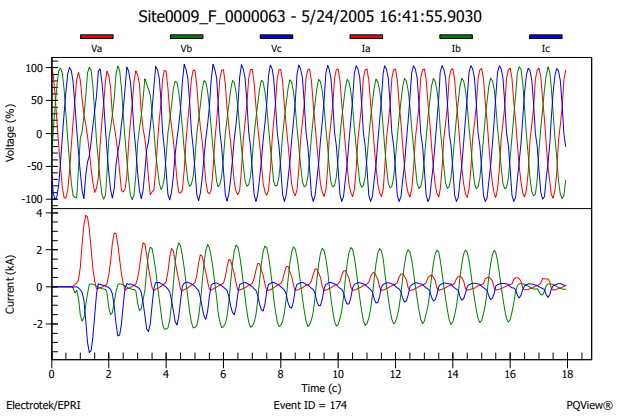


Figure 7. Downstream Tree Contact at Site 2



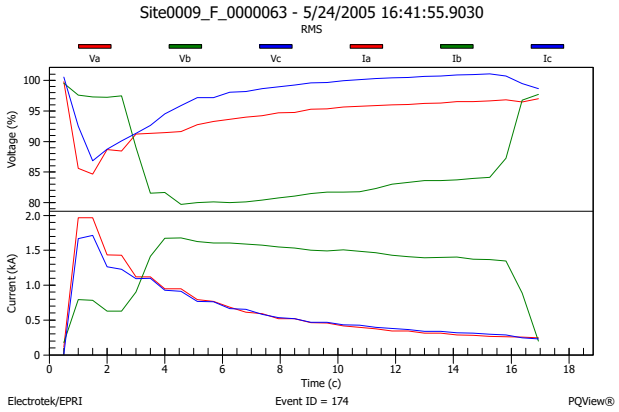


Figure 8: Feeder Inrush Measurement Followed by Single-Phase Fault

PQSOFT POWER QUALITY WAVEFORM LIBRARY

Background

The PQSoft PQ Waveform Library is a collection of waveforms and RMS records displaying common power quality conditions and events from arcing faults to long-term RMS variations and transformer energizations. This data was obtained via case studies and power quality investigations performed by the authors of this paper over a period of approximately fifteen years. Figure 9 is an example of a capacitor switching transient waveform measurement that can be found in this database.

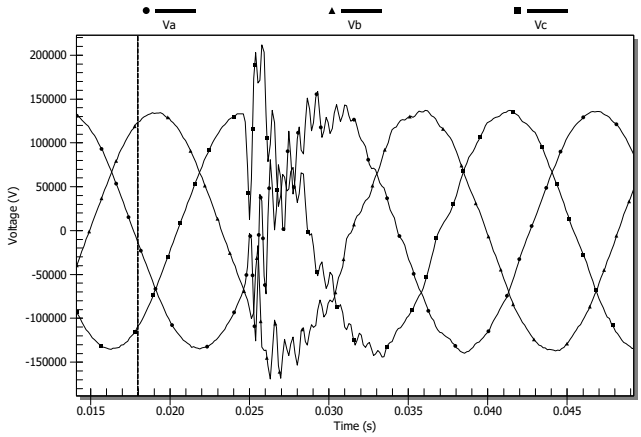


Figure 9. PQSoft Sample Waveform (Switching Transient)

Using the PQSoft Waveform Library

The waveforms in the PQSoft Waveform Library can be used in multiple ways. The waveforms can be used in presentations when discussing different types of power quality events and phenomena. The waveforms could also be used to develop and/or test a disturbance characterizer that categorizes events by type based only on the waveform or rms samples of the event. For example, if a researcher needed a voltage sag waveform, Figure 1 can be obtained from the PQSoft Waveform Library.

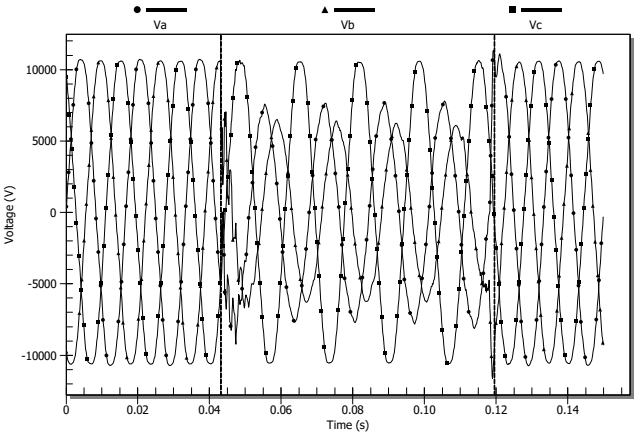


Figure 10. PQSoft Sample Waveform(Two-Phase Voltage Sag)

ONLINE ACCESS TO DATABASES

Access to these data sources described in this paper can be obtained by visiting www.pqweb.com/sample-data/. This data will be available via the PQWeb.com interface at no cost to educational institutions worldwide for the purpose of training engineering students.

BIOGRAPHIES

Kevin M. Kittredge is a Senior Power Systems Engineer with Electrotek Concepts in Beverly, Massachusetts, USA. He has been in the power quality field since August of 2000. At Electrotek, he provides support and training for both PQView 3 and PQView 4, including the provisioning of new systems. Prior to working at Electrotek, Kevin was a Senior Engineer at Salt River Project (SRP) in Phoenix, Arizona from 2000 to 2015. While at SRP, his primary responsibility was maintaining, expanding, and collecting data from SRP's power quality monitoring system. This included monthly and annual reporting on the health and performance of the power system. He also developed tools to display data in a geographically visual format and assisted in the implementation of notification systems and administered the procedure SRP developed to track the root cause of all transmission disturbances. Kevin has a Bachelor of Science degree in Electrical Engineering from Arizona State University in Tempe, Arizona. He is the former secretary and president of the Arizona Power Quality Association and is still currently involved with this organization as their webmaster.

Daniel D. Sabin (M 1992, SM 2001, Fellow 2016) is a Principal Engineer and Software Architect with Electrotek Concepts, Inc. in Beverly, Massachusetts, USA. He is currently the chief application architect of PQView. This software database application is used by electric utilities worldwide for managing and analyzing the gigabytes of measurements recorded by power quality monitors, digital fault recorders, and electronic relays. He has developed automatic fault location systems used by the Consolidated Edison Company of New York, the United Illuminating Company, and Detroit Edison. He was a project manager with the Electric Power Research Institute, Inc. (EPRI) and its subsidiary EPRI Solutions, Inc. from 2005 to 2008. He managed and completed power quality monitoring and distribution fault location projects. He has a Bachelor of Science degree in Electrical Engineering from Worcester Polytechnic Institute in Massachusetts and a Master of Engineering degree in Electric Power Engineering from Rensselaer Polytechnic Institute in New York. Dan is registered as a Professional Engineer in the State of Tennessee. He is the vice chair for the IEEE Transmission & Distribution Committee, former chair of the IEEE PES Power Quality Subcommittee, and chair of the IEEE P1159.3 Power Quality Interchanged Format (PQDIF) Task Force of the IEEE Power & Energy Society.

Brian W Todd is a Vice President/General Manager with Electrotek Concepts in Edison, New Jersey, USA. He was involved in the power quality field in the early 1990s and again from August 2015. At Electrotek, he provides Senior Management oversite to both the PQView software development team in Beverly, Massachusetts, as well as the Electrotek Consulting Services business in Knoxville, Tennessee. Prior to working at Electrotek, Brian has held senior positions in a number of technology based companies in the field of energy management and conservation in the United Kingdom, Scandinavia, Canada and the USA. These companies had a global reach, consequently he has significant international experience in the Americas, Europe, Middle East and Asia. Brian has an HNC in Industrial Measurement & Control from Falkirk College of Technology and an EMBA from Queens University.

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