Application of Intelligent Systems

Many advanced power quality monitoring systems are equipped with either off-line or on-line intelligent systems to evaluate disturbances and system conditions so as to make conclusions about the cause of the problem or even predict problems before they occur. The applications of intelligent systems or autonomous expert systems in monitoring instruments help engineers determine the system condition rapidly.

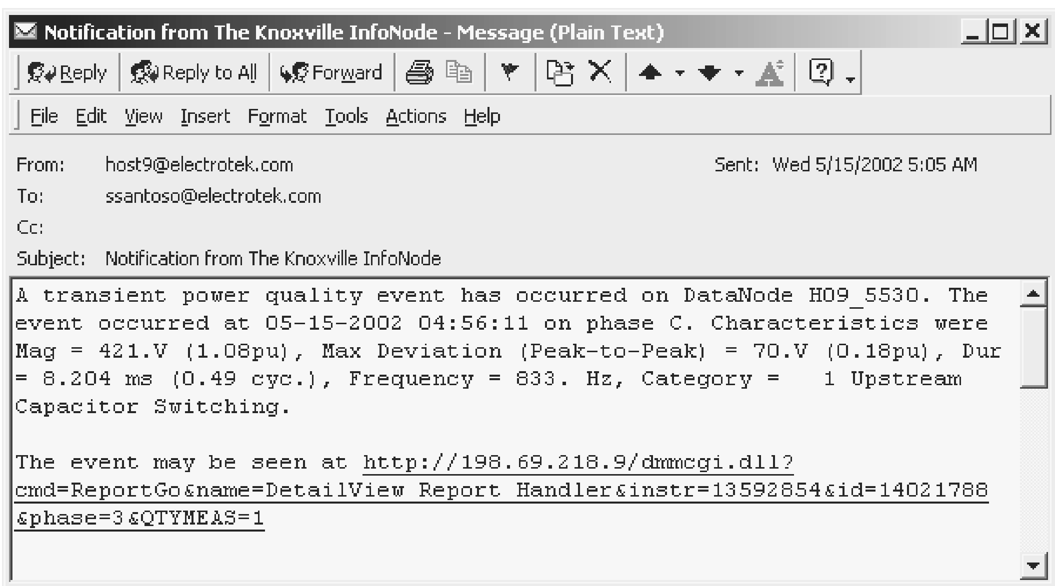

Figure 5.12 On-line data analysis can send e-mail notifications to users about the occurrence of specific events

This is especially important when restoring service following major disturbances. The implementation of intelligent systems within a monitoring instrument can significantly increase the value of a monitoring application since it can generate information rather than just collect data. The intelligent systems are packaged as individual autonomous expert system modules, where each module performs specific functions.

Examples include an expert system module that analyzes capacitor switching transients and determines the relative location of the capacitor bank, and an expert system module to determine the relative location of the fault causing a voltage sag.

5.4.1 Basic design of an expert system for monitoring applications

The development of an autonomous expert system calls for many approaches such as signal processing and rule-based techniques along with the knowledge-discovery approach commonly known as data mining. Before the expert system module is designed, the functionalities or objectives of the module must be clearly defined. In other words, the designers or developers of the expert system module must have a clear understanding about what knowledge they are trying to discover from volumes of raw measurement data. This is very important since they will ultimately determine the overall design of the expert system module.

The process of turning raw measurement data into knowledge involves data selection and preparation, information extraction from selected data, information assimilation, and report presentation. These steps (illustrated in Fig. 5.14) are commonly known as knowledge discovery or data mining.

The first step in the knowledge discovery is to select appropriate measurement quantities and disregard other types of measurements that do not provide relevant information. In addition, during the data selection process preliminary analyses are usually carried out to ensure the quality of the measurement. For example, an expert system module is developed to retrieve a specific answer, and it requires measurements of instantaneous three-phase voltage and current waveforms to be available. The data-selection task is responsible for ensuring that all required phase voltage and current waveform data are available before proceeding to the next step. In some instances, it might be necessary to interpolate or extrapolate data in this step. Other preliminary examinations include checking any outlier magnitudes, missing data sequences, corrupted data, etc. Examination on data quality is important as the accuracy of the knowledge discovered is determined by the quality of data.

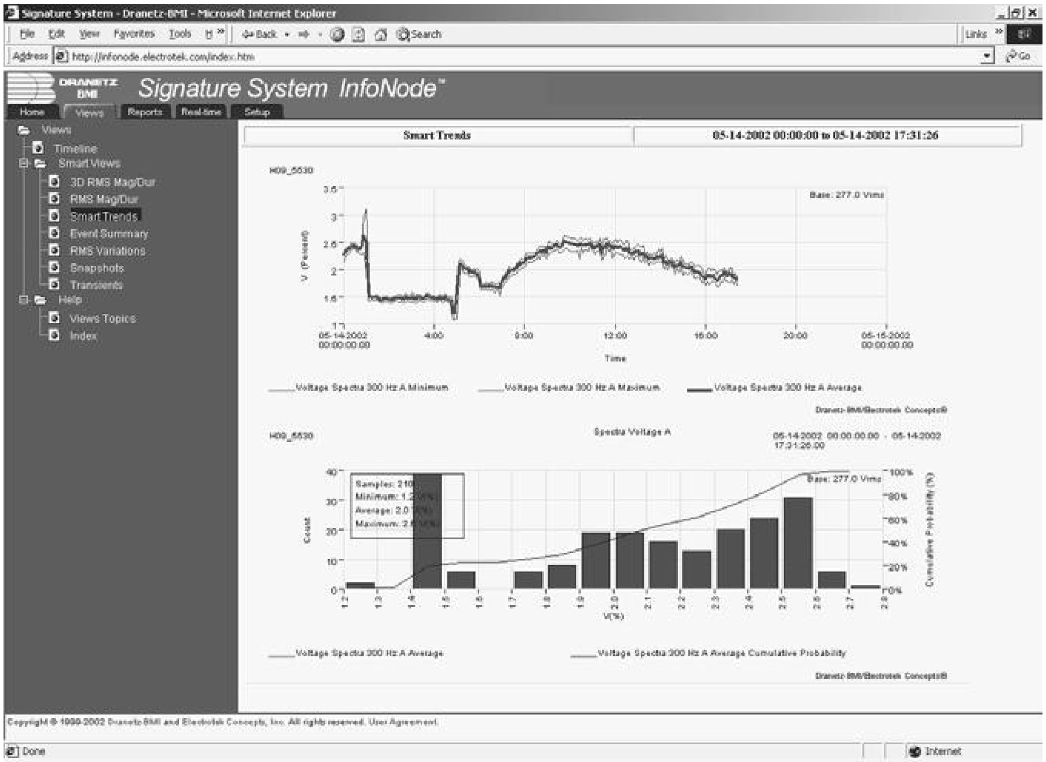

Figure 5.13 On-line data analysis displayed on a standard Web browser. The analysis includes the trend of minimum, maximum, and average values of the fifth-harmonic voltage distortion along with a statistical distribution of the average values.

The second step attempts to represent the data and project them onto domains in which a solution is more favorable to discover. Signal-processing techniques and power system analysis are applied. An example of this step is to transform data into another domain where the information might be located. The Fourier transform is performed to uncover frequency information for steady-state signals, the wavelet transform is performed to find the temporal and frequency information for transient signals, and other transforms maybe performed as well.

Now that the data are already projected onto other spaces or domains, we are ready to extract the desired information. Techniques to extract the information vary from sophisticated ones, such as pattern recognition, neural networks, and machine learning, to simple ones, such as finding the maximum value in the transformed signal or counting the number of points in which the magnitude of a voltage waveform is above a predetermined threshold value. One example is looking for harmonic frequencies of a distorted waveform. In the second step the waveform is transformed using the Fourier transform, resulting in a frequency domain signal. A simple harmonic frequency extraction process might be accomplished by first computing the noise level in the frequency domain signal, and subsequently setting a threshold number to several fold that of the noise level. Any magnitude higher than the threshold number may indicate the presence of harmonic frequencies.

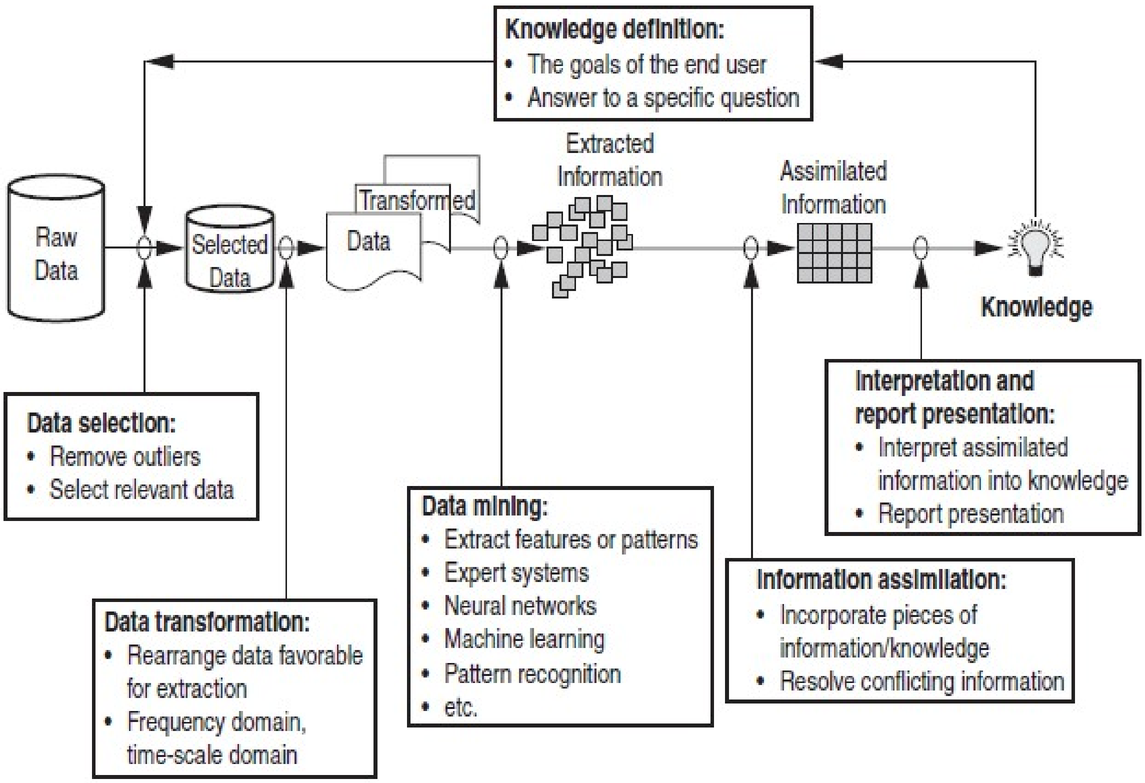

Figure 5.14 Process of turning raw data into answers or knowledge

The data mining step usually results in scattered pieces of information. These pieces of information are assimilated to form knowledge. In some instances assimilation of information is not readily possible since some pieces of information conflict with each other. If the conflicting information cannot be resolved, the quality of the answer provided might have limited use. The last step in the chain is interpretation of knowledge and report presentation.

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