Detection of power quality transient disturbances classification based on complex event processing

Su-Xia Ma, Yi-Di Zhao and Ying-Long Ma

School of Control and Computer Engineering,
North China Electric Power University,
Changping, Beijing 102206, China
[†]E-mail: sma@ncepu.edu.cn

Effective and efficient classification to transient disturbance is crucial to provide reasonable decision making for solving power quality problems. Existing approaches for detecting transient disturbance classification are often centralized and procedure-oriented, which are developed in a hard code manner, and therefore possibly will face scalability and extensibility problems. In this paper, a novel approach to detecting transient disturbance classification is proposed by utilizing Complex Event Processing (CEP) technology in order to excavate features of transient disturbance effectively and efficiently from real-time, dynamic, and massive data. Each of occurrences of transient disturbance is modeled as an atomic event. A category of transient disturbance is expressed as a complex event that consists of multiple atomic events with logical operations represented by event pattern languages (EPL). The task of detecting classification of transient disturbance can be reduced to filtering and matching events from a real time event stream of transient disturbance in terms of given event patterns. The related experiments show that the CEP technology has significant advantages in the system throughput and latency event processing, and thus has strong scalability and extensibility. Our approach can provide a feasible solution for detecting classification of transient disturbance for massive real-time data with multiple sources.

Keywords: CEP; transient disturbances classification; massive data; real-time processing

1. Introduction

With the development of information technology and electric power market, advanced tools have been developed and applied to monitor and control power quality. The quickly growing amounts of power quality data call for automatic analysis methods. The power quality problems are caused by various types of power disturbances [1], especially the transient power quality problem such as transient shock, overvoltage, and neutral drift, etc. [2], which cause serious influence to industrial production and thus have received widespread attention in recent years. Power systems often need to monitor and control power quality by detecting transient disturbance data in real time.

Effective and efficient classification to transient disturbance is crucial to provide reasonable decision making for solving power quality problems. One of important problems for detecting transient disturbance is how to identify Eigen values from existing data for excavating more underlying information for better power quality prediction and more reasonable decision making together with other data sources. Some typical approaches for extraction of Eigen values have been proposed in recent years, such as S-transform [3], Wavelet Transform [4], Fast Fourier Transform (FFT) [5], etc. Based on excavated different types of Eigen values, many approaches using artificial intelligence technologies such as neural network and probabilistic reasoning, etc., have been introduced into power systems [6], and also have illustrated their potential success in addressing the problem of power quality detecting and analysis.

However, existing approaches for detecting transient disturbance classification are often procedure oriented, which are developed in a hard code manner. This means that software systems for transient disturbance detection need to adapted and recompiled once new detection requirements are considered, which is fragile to extend new system functions. In addition, most of existing approaches are to adopt centralized data processing and analysis technology, and therefore cannot satisfy the requirements of massive data processing and analysis in real time.

In this paper, we consider the problems mentioned above. We present a novel approach to detecting transient disturbance classification based on Complex Event Processing (CEP) technology. We model each of occurrences of transient disturbance as an atomic event, a category of transient disturbance as a complex event consisting of multiple atomic events with logical operations represented by event pattern languages (EPL). By utilizing CEP technology, we make full use of the CEP's advantage of data driven model, and transform the task of detecting classification of transient disturbance into filtering and matching events from a real time event stream of transient disturbance in terms of given event patterns. This also can avoid the limitation of hard coding residing in the traditional transient disturbance classification applications, and enables more flexible and extensible detection and analysis.

2. Overview of Transient Disturbances Classification based on CEP

This paper presents a method to monitor power quality by detecting transient disturbances classification based on CEP. Fig.1 is the overview of our approach. Monitoring devices sense and receive original data, and then transfer them to a control center which can extract Eigen values from data in several ways such as S-transform, Wavelet Transform, Fast Fourier Transform, etc.
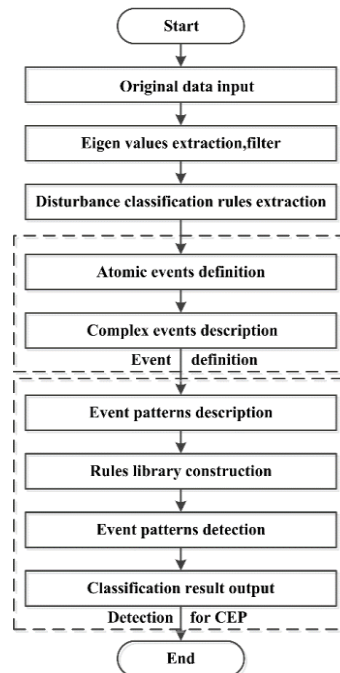
Fig. 1. Overview of our approach

In traditional methods, a procedure oriented algorithm can be specified to encode the relevant rules of the transient disturbance classification. Each of rules is detecting by a series of sequent IF-ELSE statements. For example, we first judge that the IF statement which must satisfies all the three condition judgments. The three condition judgments are to respectively decide whether the record time is no less than 8 cycles, whether the THDx value is less than <2%, and whether the maximum value of three-phase/line THD is larger than 4%. If all of them are true, then we further detect waveform distortion. Otherwise, we will judge the next IF statement until a transient disturbance is classified.

Distinguished from the traditional approaches, we use CEP technology for transforming traditional procedure oriented method into rule data. Specifically, we identify an event by detecting whether a transient disturbance is satisfying a given condition judgment of statement. If it is satisfied, then an event is identified and decided. Of course, some logical relations possibly exist between multiple identified events, which is regarded as a complex event. We use logic based method to describe the complex relationships between events. Complex events are combined by atomic event through relativity of events. An EPL based tool can be used to implement our complex event description.

Furthermore, we use EPL to obtain event patterns. According to event patterns, we can construct the corresponding disturbance classification rule base. The CEP engine uses the event patterns in the rule base to query and output the result of the transient event classification. The task of detecting classification of transient disturbance can be reduced to filter and match events from a real time event stream of transient disturbance in terms of given event patterns.

3. Definition of Event and Event Pattern

3.1. *Identification of Atomic Event*

The Condition 1"Record time>=8 cycles and THDx<2% and Maximum values of three-phase/line THD>4%", represented in procedure nodes, can be described by a complex event, it combines three atomic events by the logical operator"$\wedge$". Record time >=8 cycles define as event e_{11}, THDx<2% is defined as event e_{12}, Maximum values of three-phase/line THD>4% define as event e_{13}. Condition 1 use event E_1 to express: $E_1= e_{11} \wedge e_{12} \wedge e_{13}$.Similarly, other conditions in a process can be also described by complex events.

3.2. *Description of Complex Events*

The relationship between events is the basis of CEP. A complex event is combined by multiple atomic events corresponding to a disturbance classification rule. For example, if event $E_1$is identified, then we can detect a transient disturbance type called waveform distortion. There are different types of transient disturbance, which are numbered using different integers with an Out label. We can use EPL to describe the event's expression as [every item=E_1]. If events E_1 and E_3 do not happen, and the event E_2 occur, then we can detect a transient disturbance type called transient shock (with the label "Out=1 transient shock"). From the perspective of logics, the complex event can be represented by the logical expression$\neg E_1 \wedge E_2 \wedge \neg E_3$. It can also be represented as [every (not item1=E_1 and item2=E_2 and not item3=E_3)] by using the EPL language. Similarly, all of the remaining complex events can be represented by the above method.

From the root node to a leaf node (i.e., a path), the procedure oriented methods can detect a transient disturbance type. It is not difficult to find that atomic events in the path are connected with logic operator "and" to form a complex event during we transform procedure oriented rules to their EPL based ones. Each of complex events corresponds to a distinguished classification rule.

4. Event Classification Based on Event Pattern Matching

In the following, we give a brief procedure of detecting event classification types based on event pattern matching as follows.

Step 1: When atomic events in event stream are passed into the system, they are presented in the form of POJO, XML or Map for event processing based on Esper.

Step 2: An engine instance is constructed based on Esper.

Step 3: We use the query expression to generate a Statement object, and then register the object to the engine. A query expression can be regarded as an event pattern.

Step 4:An event listener is set up, which is bound to the statement object.

Step5: The engine instance will parse the expression and execute the statement for pattern matching.

Step 6:If a pattern is matched and detected, then the listener will output a classification type of events.

For example, in the first step, we use an EPL query expression "String expression1 = Select item1, item2, item3 from pattern [every (not item1=E1 and item2=E2 and not item3=E3)]" to generate a statement. The listener outputs the expression1's classification types. All of atomic events in expression1 are presented in the form of POJO, and are sent to the runtime environment of Esper. When a pattern is matched, the listener outputs the classification type: transient shock.

5. Experiments and Analysis

5.1. *Experimental settings*

We use CEP engineEsper-5.1.0, and the testing environment is set up with 3.30GHz CPU and 2GBMemory. The testing data is obtained from a power Grid Company, and it is the real operation data of the company. Wetest the system scalability from system throughput.

5.2. *System Throughput*

Throughput is the total amount of processed data within a unit time. Throughput of a single processing engine is shown in the Fig. 2.From the diagram, it can be seen that the system throughput is approximately linear growth; the average throughput of system is about 80000/min. If we use the high-profile machine, the throughput will be higher than the existing test results. It is also not difficult to predict that the throughput is fully able to meet the needs of practical application when we use multiple engines to realize parallel of event detection

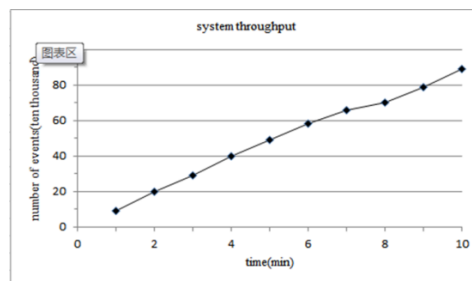because such throughput has already processed and analyzed most of transient disturbance data.

Fig. 2. System throughput

6. Conclusion

The main contributions of this paper are as follows. (1)We presented a novel approach to detect transient disturbance classification by utilizing CEP technology. (2) We also made the related experiments to illustrate that our approach has a high throughput for transient disturbance classification based on CEP, and therefore has strong operability and good scalability.

The future work is to parallelize our CEP based method for event detection of transient disturbance. In addition, more detailed experiments will be made for validating the effectiveness and efficiency of our approach.

References

1. Roger C D, Mark F M, Wayne H B, Surya S. Electrical Power Systems Quality, New York: McGraw-Hill Professional,2002.1-52
2. Tao R. Analysis of Power Quality Transient Disturbance [Master dissertation], North China Electric Power University,China,2007
3. Dash P K, Panigrahi B K, Panda G. Power quality analysis using S-transform. *IEEE Trans on Power Delivery*, 2003, 18(2):406-411
4. Hedt G T, Galli A W. Transient power quality problems analyzed using wavelets. IEEE Trans on Power Delivery,1997, 12(2) :908-915
5. Rockmore DN. The FFT: an algorithm the whole family can use. Computing in Science Engineering, 2000, 2(1):60-64.
6. Huang N T, Liu X S, XuD G, Qi J J. Power quality disturbances events recognition based on S-transform and probabilistic neural network. In: Proceedings of International Conference on Life System Modeling and Simulation. Wuxi, China: Springer 2010. 207-212.