User Interface for Situational Awareness for openPDC

Nickolas Gellerman, B.S.E.E Student
Ranganath Vallakati, M.S.E.E Student
Anupam Mukherjee, M.S.E.E Student

Advisor: Dr. Prakash Ranganathan, Assistant Professor
World becoming increasingly dependent on electrical energy.
- Communication Systems
- Transportation Systems
- Medical Equipment/Devices

Situational awareness involves being aware of what is happening in the electrical grid in order to understand how information, events, and operator actions will impact goals and objectives, both immediately and in the near future.

Benefits of a situational awareness tool:
- Real-time monitoring of electrical grid status.
- Address anomalies (phase, frequency, voltage, current) as they happen, shortening downtime in the grid.
- Detect patterns and prevent future outage problems

Need for Situational Awareness in Electric Utilities Data

Phasor Measurement Units

- Measures phasor data (frequency, magnitude, phase angle, etc.) at a bus on the power grid
- Takes measurements in real time (between 30 and 240 Hz)
- Vital tool to maintain awareness of the power grid

Figure 1: Phasor Measurements using PMUs

Figure 2: PMU


Open source Phasor Data Concentrator
  - Reads and archives data streamed from PMUs
  - Supports many different data protocols
  - Has a small amount of built-in data analysis/dashboard tools

Figure 3: openPDC Dataflow
Objectives

- Create tools for more robust data monitoring
  - Email alerts upon alarm activation

- Expand upon data analysis tools
  - Give geographic representation of data
  - Prototype K-Means clustering on received data
- C# used for all coding
- Visual Studio 2012 IDE used for development
- External libraries utilized:
  - Grid Solutions Framework
  - Google Static Maps API
  - .NET Framework 4.5
- Action Adapter add-on to openPDC
- Uses SMTP protocol
  - Gmail SMTP server used during testing

**Figure 4: Email Alert Message**
- Send email/s to specified addresses, whenever any selected alarm is triggered.

- If service providers is known, email can be sent directly to cell phone as well.

Figure 5: Snapshot of email to text
- Windows Forms application

- Uses the Google Static Maps API as basis for location mapping
  - Individual PMUs placed on top of Static Map map using Mercator Projection

Geographic Representation
Geographic Representation GUI
Geographic Representation GUI

Figure 7: Geographic representation GUI verbose 1

Data to monitor selected via dropdown box

Color scale a hue between red and blue, adjustable by user

Hovering over a data circle causes a pop-up with PMU information to appear
Geographic Representation GUI

PMU devices retrieved from openPDC database and positioned on map on startup

Colored circle represents value of measurement

Map image created automatically based on PMU position via Google Static Maps API

Figure 8: Geographic representation GUI verbose 2

Cluster Formation & Data into Groups

1) Initial statistical “mean values” are randomly generated for each cluster.

2) Each data point is assigned to the cluster with the closest mean value.

3) Mean values are re-calculated using the data points contained in the clusters.

4) Repeat Step 2. If none of the data points require re-assignment, terminate the algorithm.

Figure 9: Flowchart showing PMU data analysis in OpenPDC
- Basework created to allow for K-Means clustering of data
  - Red dots represent centroid of a cluster.
  - Blue dots represent individual data points that are used to calculate centroid.

**K-Means Clustering Algorithm (Cont.)**

*Figure 10: Display of voltage data using K-means clustering*
Future Work

- Change colored circle data representation to true heat-map using openGL
- Make clustering through the GUI more flexible
  - Selectable samples, time period, etc.
- Improve general user-friendliness of GUI
- Expand data mining research using other classification/clustering algorithms.
- Displays the complex phasor data in a Unit Circle Representation.
- Length of arrow represents magnitude of voltage/current
- Direction of arrow represents the phase angle.

**Figure 11: Unit circle phase Angle representation**
• Initially, select a point $p$ arbitrarily.
• Observe all the points that are density reachable from $p$ w.r.t $\varepsilon$ (Eps) and $MinPts$.
• If point $p$ is a core point, a cluster is formed.
• If point $p$ is a border point and no points are density reachable from $p$, Then DBSCAN visits the next point of the database.
• This process from step 1 to step 5 is continued till all the points have been processed or when no new point can be added to any cluster.

Figure 12: Clustering representation through DBSCAN for openPDC data

Density-Based Spatial Clustering of Applications with Noise

- Our research explores ways to improve the **situational awareness** of the grid using OpenPDC

- **E-mail adapter** added to the OpenPDC environment to provide real-time alerts on grid status

- **K-means clustering** explored to provide more sophisticated data analysis tools


• GROUP PHOTO

Questions?
Thank You.