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Visualization Techniques in Smart Grid

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Abstract. Visualization is an established methodology in scientific computing. It has been used in many fields because of its strong capability in large data management and information display. However, its applications in power systems, especially in Smart Grid are still in infancy stage. In this paper, proposed techniques to visualize the Smart Grid data are classified in two categories, which are Traditional techniques and Geographical techniques.

Keywords: Smart Grid, Visualization Techniques, Google Earth, GIS, QGIS, AMI, SCADA, Spatial, Temporal, Animation

1. Introduction

A large number of novel information visualization techniques have been developed over the past decade, allowing visualizations of larger and more complex such as multidimensional, multivariate, multi temporal, and spatial data sets. They are listed in many research publications [1][2][3] .

In earlier researches, there are a lot of researches which had been worked on visualizing data in transmission power system [8][9]. Some traditional methods, such as graph, histogram, bar chart, pie chart, single line diagram, are mandatory for visualizing power data. Besides, Geographic visualization has become quite famous technique in displaying data in transmission grid, such as contour [18][19], GDV (graphical data view) [14], GreenGrid [10]. AREVA's Energy Management System (EMS) [16] and Power World's Simulator [17] are two widely used visualization tools in this industry. There are also some research works on animated visualization for power grid data such line flow [13] or power flow [18]. Nevertheless, the numbers of research on displaying distribution power system data were still limited. Yixin Cai in his research proposed GIS as a technique for visualizing fault locations in distribution system based on spatial-temporal dataset [15].

In this paper, proposed techniques to visualize the Smart Grid data are classified in two categories, which are traditional techniques, and Geographical Information System (GIS). Traditional methods consist of some traditional techniques such as single line diagram, real-time 2D chart and 3D surface with contour. Spatial analysis and spatial-temporal analysis are two geographical techniques that are used in GIS for analyze and visualize Smart Grid data. The data to visualize was focused only on AMI and SCADA/RTU.

This project concentrates on Uniten-TNBR Smart Grid Testbed. There are 16 substations located in this area which divided into 3 main substations such as TNBSSU, TNB SSU1 and TNB SSU2. This testbed will implement 7 RTU/SCADA and 50 AMI devices. The detail of AMI and SCADA network diagram is shown in Figure 1.

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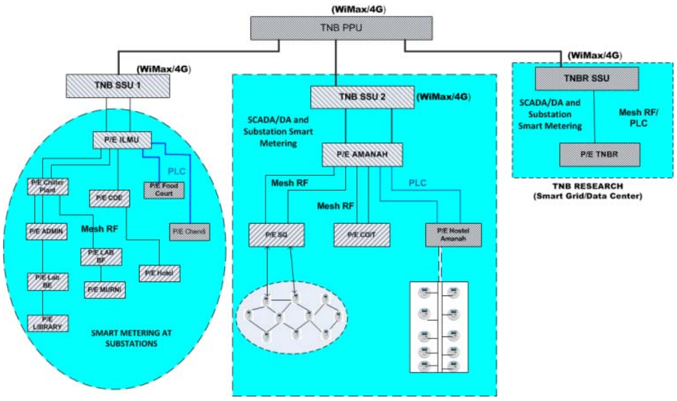


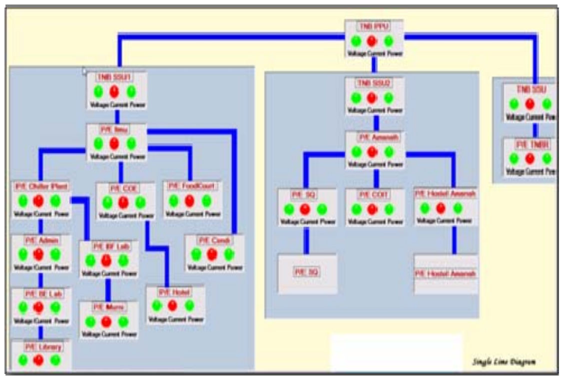


Fig. 1: AMI and SCADA network diagram for Uniten-TNBR Smart Grid Testbed.

Fig. 2: Singe line diagram

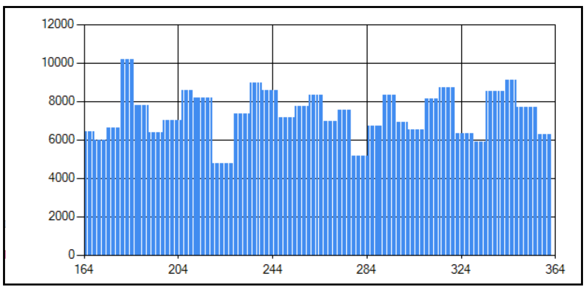
2. Traditional Visualization Techniques

2.1. Single Line Diagram

The operators use single line diagrams to get an overview of the AMI/SCADA network system. Single line diagrams display the interconnection between substations and some critical parameters such as line status, AMI energized status. Hence, the diagram allows the operators to have a macro level view of the system as shown in Figure 2.

2.2. Real Time 2D Bar Chart

Bar chart is one of traditional techniques to visualize data in many fields. However, instead of static data, dynamic data is displayed in form of bar chart. The x-axis represents number of data points while the y-axis represents total power consumption of all substations, as shown in Figure 3. Since a data point was added in every 5 minutes and the maximum of point displaying in x-axis are 200, the chart can visualize the changing of total power consumption over 1000 minutes time interval. When the new data point adds to the chart, the data at the most left of the horizontal axis will be removed.



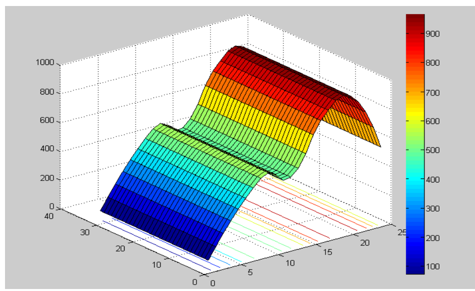


Fig. 3: Real time bar chart

Fig. 4: 3D surface with contour

2.3. 3D Surface with Contour [19]

The grid operators use the 3-D displays to visualize the power consumption or load in every 1hour interval over a month period. A 3-D illustration of the demand in the studied area is shown in the Figure 4. One hour intervals are shown on x-axis from 1 to 24 and the dates of month are shown on the y-axis from 1 to 31. The power magnitude is represented on the z-axis. The colour contouring is applied to enhance the display, as shown in the colour bar at the right of the plot. As we can see from the figure, the peak (morning and evening) and off-peak (day and night) variation over a month can be clearly brought out.

To visualize the change of power load over a year, the x-axis can represent the dates of months (1-31) while the y-axis can represent the months in years (1-12).

3. Geographical Techniques

3.1. Spatial Analysis

Spatial analysis uses spatial information to extract new and additional meaning from GIS data. GIS Applications normally have spatial analysis tools for feature statistics (e.g. how many vertices make up this polyline) and geoprocessing tools such as buffer, intersect, union, symmetric difference and so on [11].

3.1.1. Zoom and Brush

Each AMI/SCADA device is represented by a point or a placemark which can be created by using Google Earth API, The detail information of each substation such as power consumption, voltage, current from are displayed on AMI balloon. Real-time measurements of voltage, current, real power, reactive power, transformer taps from SCADA are displayed in balloon callout corresponding to each SCADA placemark. The color of each placemark represents the energized state of AMI and breaker status of SCADA, e.g. green is energized and red is not (Figure 5).

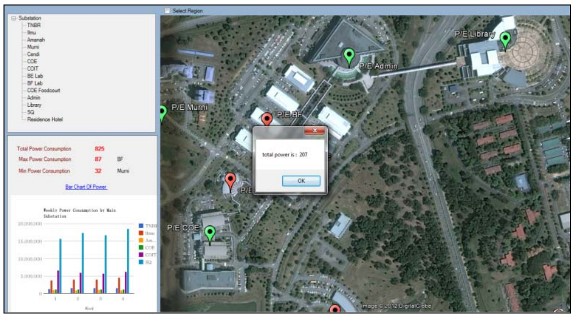


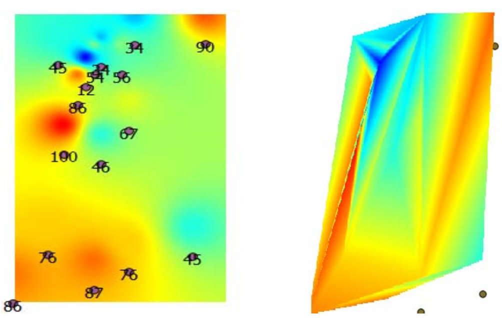
Fig. 5: Zoom   Fig. 6: Brush

As shown in Figure 5, the left pane of the GUI is the list of all the 15 substations. Clicking on any one of these will result in flying into each point where detail parameters are displayed.

Another benefit of this application is to allow user select the region of interest by dragging the mouse in GE browser to define the area and subsequently displaying the total power as new window message, as shown in Figure 6.

3.1.2. Interpolation Analysis

Spatial interpolation is the process of using points with known values to estimate values at other unknown points [7]. There are many interpolation methods. In this paper, two widely used interpolation methods called Inverse Distance Weighting (IDW) and Triangulated Irregular Networks (TIN) are presented [7].



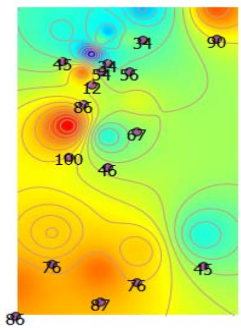


Fig. 7: Interpolation using IDW (left)and TIN (right)   Fig. 8: Contour line

The application of interpolation in Smart Grid is to visualize the contour demand power, current or billing information in whole Uniten-TNBR area based on these values at 16 substations (Figure 7).

3.1.3. Contour Line

Contour lines are lines drawn on a map connecting points of equal elevation. Contouring has been used very effectively to represent spatially distributed continuous data e.g., temperature. However, power system data is not spatially continuous for example, power or current exist only at specified substation. Thus to use contouring for power system data, virtual values must be assigned to the entire region. The operators have used contouring to represent the load power in the system. An illustration showing load power for the studied region is shown in Figure 8. From the contour line, we can predict quite accurately the load power at different desired location.

3.2. Spatial-Temporal Analysis

Almost everything in the world changes over time. It is necessary to incorporate time into geographical information systems. This is known as spatio-temporal analysis which is capable of handling temporal as well as spatial information. This greatly expands current GIS applications and allows new information to be obtained [5][6]. Spatio-temporal data can be classified into two categories: movement and static data [1].

3.2.1. Time Plot

Time plot in MultiView plugin in QGIS allow users to plot multivariate and multi-temporal data at different locations. The x-axis of the plot represents the date time in dd-mm-yy hr:min:sec format. The y-axis represents the value of selected variables in the left panel. The different variables are displayed by different colour for better visual. For example, the variation of power over time line graph is coloured by red while the variation of phase angle over time is coloured by blue, as shown in Figure 9. The advantage of this time plot is the ability to visualize multi variables at different locations versus time in one graph. Since each field has their own scale, it must be normalized before displaying in the plot. However, the disadvantage of this plug-in is not utilizing the time stamp variable. If the users want to display data over long time period, the numbers of generated raster data will be very big.

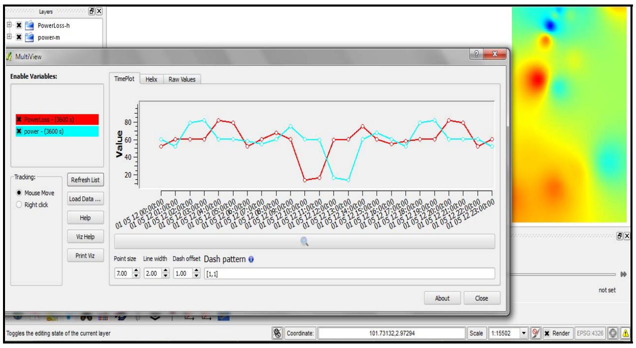


Fig. 9: Time plot

3.2.2. Animation

While time plot is useful for visualizing static (no movement) data versus time, animation is used for displaying the movement data versus time. In Smart Grid, this could help to show the change of fault locations over time period. Animation can be achieved by using QGIS with Timer Manager plug-in (Figure 10) or Google Earth with Time Slider (Figure 11).

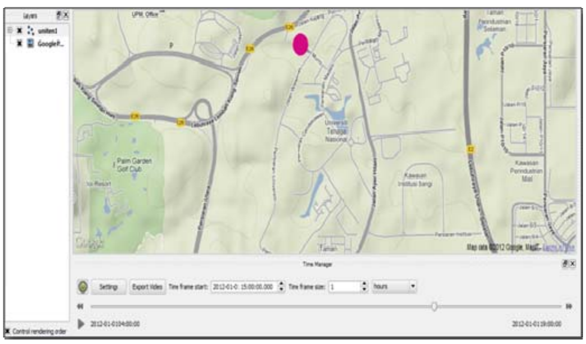


Fig. 10: Animation with QGIS

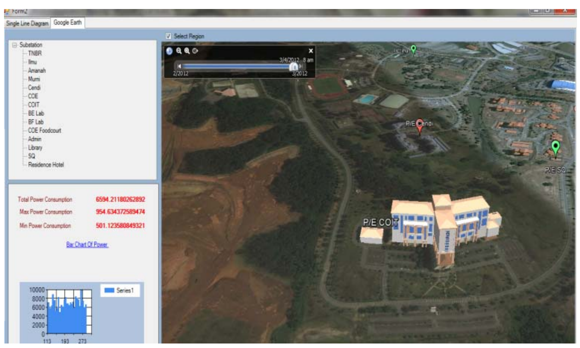


Fig. 11: Animation with GE

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