New Presentation Method of Human-Machine-Interfaces for EMS

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HUANG Xiaoyun[1,a], HUANG Andi[2,b]

[1]Foshan Power Supply Bureau, Guangdong Power Grid Corp. China Southern Power Gird, 63, Nanguidong Rd. Guicheng, Foshan, 528000, China.

[2] Electric Power Research Institute, China Southern Power Gird, 11 Kexiang Rd. Guangzhou, 510663, China.

[a]E-mail: xiaoyunhuang@21cn.com [b]E-mail: huangad@csg.cn

Abstract. Power demand is constant increasing, so power networks are push to the operation limits. Traditional presentation of SCADA/EMS HMI(Human-Machine-Interface) is not more suitable to this situation. Various technology such as AI base alarming, dynamic coloring, contour, map based diagrams, new presentation methods are purposed. New method for indication and measurement alarm processing, measurement presentation, topology presentation, risk assessment presentation, KPI presentation, map based presentation are implemented. Through these presentation techniques, the operators can comprehend the system information easily and more accurate, then more proper action can be promptly taken to ensure the power networks operate more safely and more economically.

1. Introduction

Fast economic development make electricity demand grow rapidly. Because of various reasons, the investments of electricity facility can not always keep paces with electricity demand. Renewable energy and low carbon economic also make electricity flow in bi-directional way and make more stress on power grid operation and more grid devices are on operation near marginal points. Electric grid's Supervisory Control and Data Acquisition System(SCADA) or Energy Management System (EMS) play an important role in power grid operation. As a big utility have hundreds of power stations in transmission and tens of thousand of stations in distribution, millions of monitor and control points make the operators sometimes have difficulties to comprehensive the information of SCADA/EMS, especially in bad weather when SCADA/EMS information flooding to the operators through HMI.

Traditional HMI of SCADA/EMS is only diagram, table,alarm list,etc, and is a little bit hard to find the most valuable information in very short time and sense the grid at a glimpse. This situation has not changed much for a longtime. Recently visualization of SCADA/EMS have made progress, but still have much room to improved.

The development of HMI for SCADA/EMS mainly focus on visualization. ABB uses contour to represent voltage level and load[1]. GE's e-terra do the same as ABB, but add geographic background on one-line diagram[2]. Various software tools have been developed for HMI development[3]. HMI plays an important role in micro-grid EMS[4]. Effort for EMS visualization have made[5] .

Nowadays SCADA/EMS generates alarm using indications and measurement, and operators utilize alarm list to grab the urgent information. As power networks becoming bigger and bigger, the devices to be monitored becoming more and more, and a single fault in the gird can trigger dozens of events

and alarms, the operators can easily miss or misconceive the signals. After receiving the signal correctly, the operators have urgent time to follow the events. As SCADA/EMS has a large data set(millions of data point), and the grid situation is in constant change, it is vital to present the information in a clear and proper way.

So it is very important to properly present the information in HMI to make the operators comprehend the information in a quick and easy way, and to grab the overall situation easily. By doing so, the safety and economic of power gird and the efficiency of operator can improved.

"A picture is worth a thousand words", and a videos is worth a thousand pictures. As computer graphic technology progress a lot, some graphic ideas which very difficult to accomplished can be achieved nowadays. The goal of a good HMI is to present more useful information in the smallest area of screen. In one word, HMI should present more information in a way of clear and easily understood.

2. New Presentation Methods

2.1. Indication Alarm Presentation

A brief and clear alarm and event list can speed and smooth the process of fault restoration. Normally the alarm and event list lists the alarm or event according to their incoming time. Usually a single fault can trigger dozen of alarm or event, if several fault happen at the same time, these alarm and event will jam with each other, and make operators hard to understand the situations.

By clicking an alarm or event list to show all the incoming alarm or event of the same bay within a specific period (30 seconds) in Sequence-Of-Event(SOE) time order, operators can focus on that device(bay) and speed the fault restoration process.

Using simple Artificial-Intelligent(AI) can analyze the related alarm and event and make a single line message the cause of fault, for example "xxx line tripped and re-closing failed". For the line fault it is easy to implemented by simple logic calculation.

Modern power systems are very complex, each operator in charge of a large area. When fault happens, information floods in, operators may feel nerves and helplessness. If a signal missed or misunderstood, the operator is blamed for that, but a poor alarm and event system may be the mail cause. A clear, prompt and correct alarm system can make the chance of error as lower as possible.

2.2. Measurement Presentation

Normally measurements are present in digital number in different color to represent their characteristics, for example green represents in normal condition , red represents over the limit, cyan represents manual input data,etc. But some status of the measurement can not be represented.

Here suggest some method to represent some important status of measurements.

1.Data background flashed when the measurement refreshed.

2.As time go by the brightness of the data dime down, to represent the freshness of the data.

3.The color of the data change in spectrum mode, which means color change according to the load rate of the device, as shown in Fig.1.

4.Special characteristics represent by typeface, underline of the data, prefix or suffix of the data,etc.

5.Data are flicking when it is out of its limit to get operator's attention.

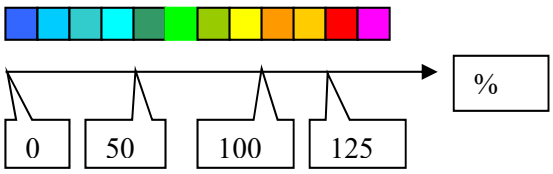

Fig. 1 Analogue measurement data spectrum color presentation.

Symbol of device, for example line,circle,square or complicated icons which represent device (line, station, busbar, transformer, etc) normally in static mode in the diagrams, but should in dynamic mode to vividly represent the status of the device.

Like a map, the size of the icon can represent its voltage level, and let the color free to represent the operating status of the device. For example busbar color represent its voltage. . Color of substation icon can represent the load rate of the transformer in the station, as shown in figure 2. Power flow can be visualized as animated arrow.

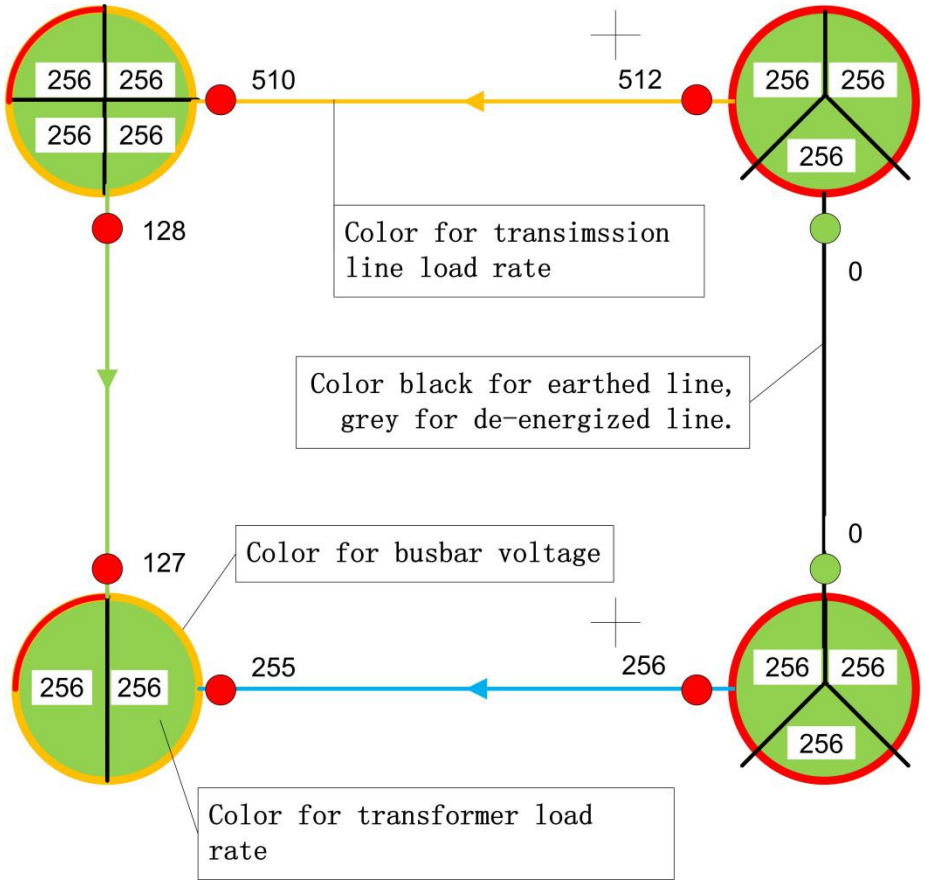

Fig. 2 New presentation for power networks diagram

2.3. Measurement Alarming Process

Some alarming limits of measurements are related to weather, for example the current capacity of a line is function of ambient temperature. Normally these value are fixed, some changed by seasons. If the limits changed according to the ambient condition , the capacity of the device can operate close to its limit, by that means the dead capacity can be freed. For example if a line set it limit from 40℃ to 20℃ ambient temperature, its capacity will be increased 10%-20%, and have a huge economic benefit. So some limit have a relation with other measurement is a practical way to increase the capacity of the device.

For device like line or transformer that have a relation with thermal stability, the operation limit not only relate to the value but also to the time that has passed over the limit. These limits have the property of inverse time limit, that means if over the limit a little bit can last long, but if over the limit a lot can last very short. As the alarm list in SCADA/EMS do not represent inverse time limit, the operators are difficult to reckon the time to expire. Each type or model of device has its limit-time-chart as shown in the figure 3, so according to the tracing plot in the limit-time-chart, the time left to operation can be accessed and shown in the alarm list.

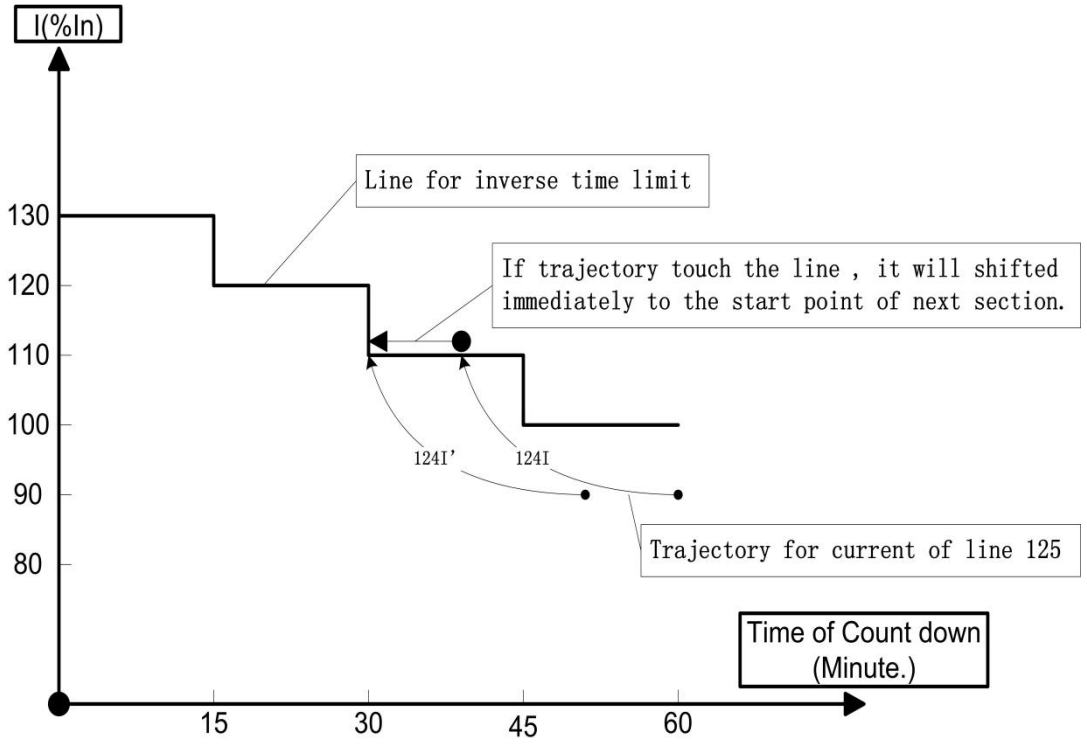

Fig. 3 Presentation of thermal inverse time limit of measurement alarming

2.4. Topology represent in HMI

Electric grid is a topology structure. Switch like device such as circuit breaker and isolator connect or disconnect the power network. Using color to represent the topology status of the network is of helpful to operators. But first of all a topology engine must work and the status of switches must be correct. Then the problem is that color is limited.

Representing live,dead(de-energized) or ground status, the color can be consistent with live status of measurement color, for dead status gray is used and ground status black is used.

2.5. Risk assessment represent in HMI

N-1 scan is a normal practices of grid risk assessment, but normally it only represent in form of table. Comparing to table, presentation in the one-line-diagram is much more intuitive. The device that fail N-1 scan should clearly indicated, the effecting part of the network also, but in different background color. The power effected should be shown beside the device. The N-1 risk assessment presentation is shown as figure 4.

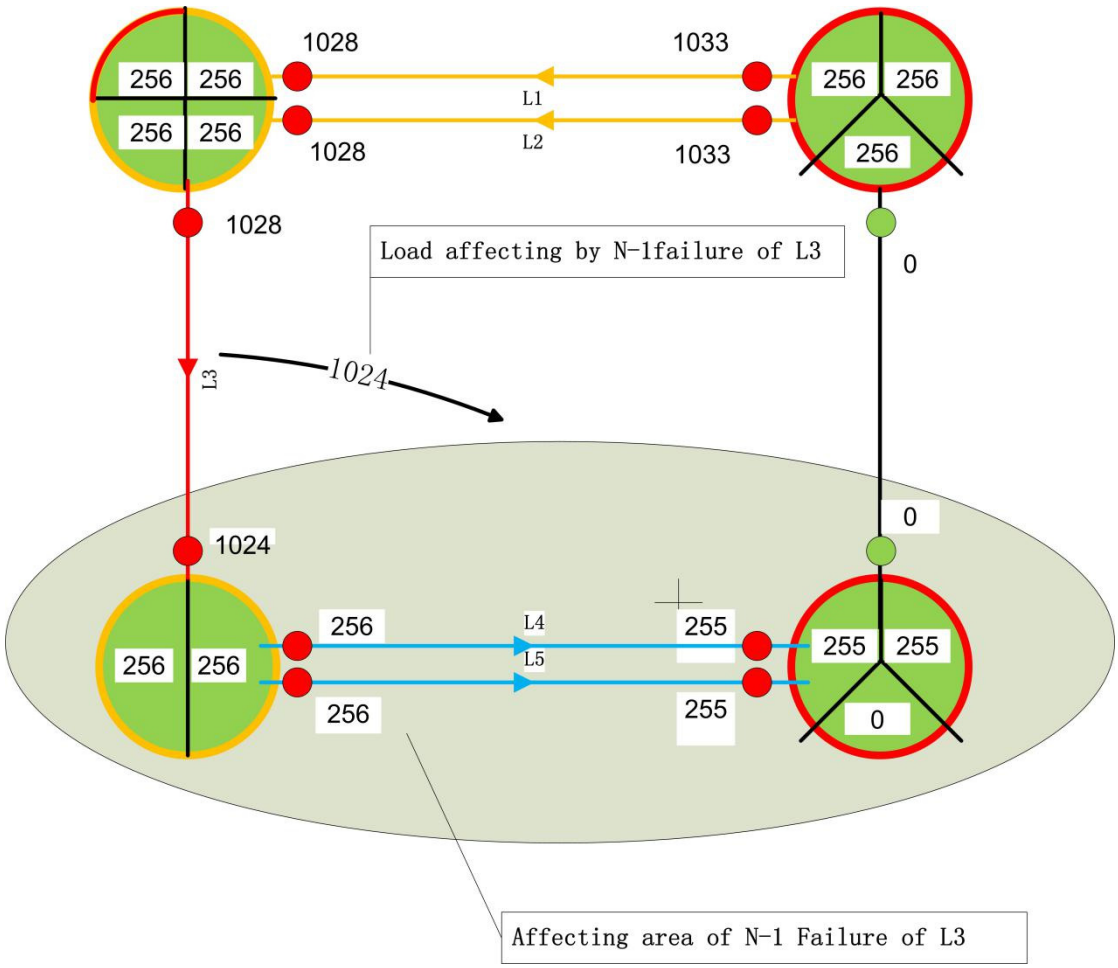

Fig. 4 N-1 risk assessment presentation

2.6. KPI Presentation

Electric grid is a complex system that has vast number and types of devices that their operation status are in constant change. A clear Key-Performance-Index(KPI) system to represent the overall situation is a powerful tool to improve grid operation performance. The KPI system should includes real-time economic and reliability aspect of the power grid.

First of all the most important index are frequency and voltage. Frequency represent the power balancing status, and a series of control action follow to frequency, for example under-frequency load shedding. For an interconnected system only one frequency exists.

Voltages are also very important. But voltage at different points have different value. How to use a single value to represent the overall voltages? Using the key voltage control point or weighted average voltage may represent the overall voltages.

The main goal of a dispatching center is to balance the power, so load and renewable energy prediction is very important. The short term prediction within hours should be updated according to the newly information, especially weather condition that not only include temperature but also humidity ,cloud and win speed. Showing prediction and trend in the same graph can be helpful.

Percent of power lost is one of the most important parameter of power economic. Real-time percent of power lost is a good indicator represent how efficiency the power gird. Real-time percent of power lost should be calculated through power-flow calculation, or through algebra calculation of post state-estimated measurement.

To represent the reliability of the grid, a good indicator is the sum of all the not supplied power after N-1 scan.

All the above KPIs could be shown in trend graph to make operators easily understand the trending.

2.7. Google Earth Map Like Interface

Geographic Information System(GIS) can make the route of one-line diagram shown in a map background. Combining GIS to SCADA/EMS can make operators sense the overall information related to map. Lots of information can be shown on map, for example weather information, route of line, place of substation, fault points, voltage-level contour, black-out area, etc.

Contour as a graphical aid is utilized to indicate regional issues. For example voltage-level contour on the map can be used to identify pockets of low or high voltage of MV or LV networks.

The Interface containing geographic information can be Google Earth like. When zoom in, details emerge. Different layer on the diagram can be chosen to represent different topics. To search a device, a search engine and a search bar should be included in the HMI.

Workforce information such as location of repair car can be shown on the map to assistant the optimal workforce dispatching.

Animation or video can be included in the HMI to represent movement on the map. Time slide can represent the time of the diagram. Dynamic weather information on the map can shown the movement of bad weather.

3. Conclusion

A clear and concise SCADA/EMS HMI can greatly enhance the working efficiency of operators. This HMI can make the operators understand the overall situation but not neglecting any detail, and enhance their control ability of the networks. By doing so, the power networks capability reach is maximum point.

Acknowledgments

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