ECEC

Power Grid Monitoring and Controlling

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Introduction – 1 China Power Industrial

China power industrial has the fastest growth in the world.

By the year 2010, the total installed generating capacity will reach 862GW;

By the year 2020, it will be 1,324GW.

Just took one year, in 2006, China gained 110GW installed capacity.

Took over 100 years, China got it's first 100GW generate capacity.

-- New development

The world first 1,000kV AC and 653km transmission line was operated since Aug, 2006 in China. It includes three substations and a double transmission line with 5 million kVA power capacity.

It connects North China Grid to Central China Grid. The cost was over 6 billion RMB.

First 1,000kV Model Line

AC Model line Opening Ceremony

Introduction – 3 China Power Industrial

-- New development

By the end of 2010, China State Grid will add 1,000kV transmission lines with 4,200 km and 9 substations with total capacity at 39 million kVA.

By the year 2020, China will install interstate, super high voltage power transmission line with load capacity over 200 GW. It will be 15% of the nation's total Installed units.

1,000kV AC Model Pole & Tower Test

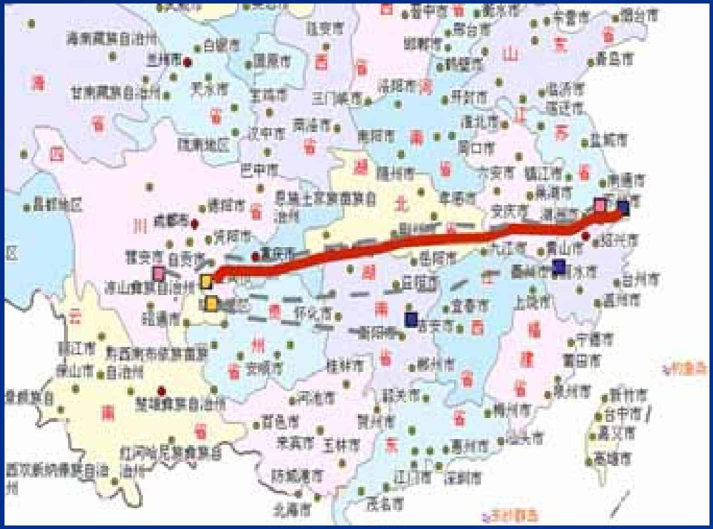
Introduction – 4 China Power Industrial

-- New development

The model ±800kV DC transmission line project was launched by China State Grid in May 2007. It brings the power over 2,000km and cross 8 provinces from Sichuan in south-west of China to Shanghai in east China. It is projected to be done In the year 2012.

The maximum transmission capacity is 7,000MW. It costs over 18 billion RMB.

±800kV Model line Opening Ceremony



±800kv DC Model line Map

Introduction – 5, WAMAP

WAMAP -- Wide Area Monitoring Analysis Protection and controlling system

What WAMAP does:

- To meet today's high standards of power safety requirements
- Total solution for large scale power grid
- 3-state data acquisition platform
- Dynamic database design
- System analysis and online decision-making
- Online fault-simulations

Introduction – 6, WAMAP

How it was built:

A large scale R&D project -- WAMAP

Five years of research and development (2002 – 2007)

Hundreds of engineers were involved in WAMAP

- 9-2002 to 9-2003 System define and Study
- 10-2003 to 9-2004 Initial design and detail design
- 6-2004 to 7-2005 Phase-1 developing and FAT
- 8-2005 to 3-2006 Past RTDS test
- 11-2004 to 12-2005 PMU installation
- 4-2006 to 9-2006 Phase-1 field setup and SAT
- 1-2006 to 10-2006 Phase-2 development and FAT
- 10-2006 to 3-2007 Final phase-2 installation and SAT
- 6-2007 Phase-3 finalizing in Jiangsu, a sub grid of ECG

Introduction – 7, WAMAP

People who was involved in WAMAP Project

East China Gird Company (ECG)

East China Electric Consulting Co., Ltd. (ECEC)

Nanjing Automation Research Institute (NARI)

East China Electric Information Engineering Co., Ltd. → PMU Installer

NARI Technology Development Co., Ltd. (NARI TECH)

China Electric Power Research Institute (EPRI)

Beijing Sifang Automation Co., Ltd

} PMU Supply

East China Electric Power Test & Research Institute

Shanghai Jiao-Tong University

And

ABB, Alston, SEL, WESCON (involved in WAMAP RTDS test)

Background – 1

- The *tremendous growth* of China’s power system requires a high reliable power system which has become a major challenge for the power engineers of China.
- The East China power Grid (ECG) covers four provinces and Shanghai city which are the *most developed regions* in the country. In this region of 471,400km^2, the land is only 4.8% of the nation’s total, it creates over 30% of the GDP of the country.

China Map with circled East-China Region

ECG’s 500kV transmission lines in 2006

Background - 2

- Since 2006, ECG has became the ***world 2nd largest wide area power grid*** with maximum power load of over 100,000 MW after US PJM Company. In this summer ECG's peak load has reached over 120,000 MW.

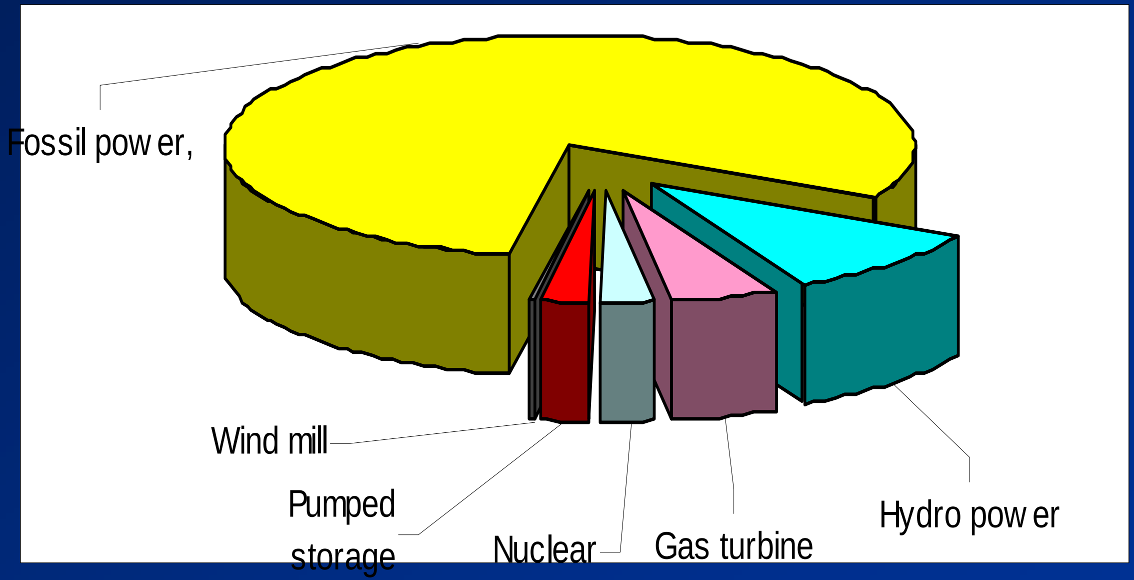
- By the end of 2006, ECG boosted 500kV transmission lines with 15,600km, and 60 substations of 500kV with total capacity of 95 million kVA.

- In an increasingly complex power system as well as the ever greater demands in a market-driven environment in East China, power blackout prevention has become a major concern by the power companies and the government.

Background - 3 ECG Power Sources

By the end of 2006, the total installed the capacity of power generate units in ECG has achieved 152GW.

The power that was supplied by the outside of region through 500kV DC transmission lines was accumulated up to 34.5 billions kWh in 2006.



Fossil power	80.0%
Hydro power	10.1%
Gas turbine	4.8%
Nuclear	2.7%
Pump storage	2.1%
Wind mill	0.3%

1 Introduction – China Power Industrial

2 Why WAMAP

3 WAMAP System Requirements

4 WAMAP System Specifications

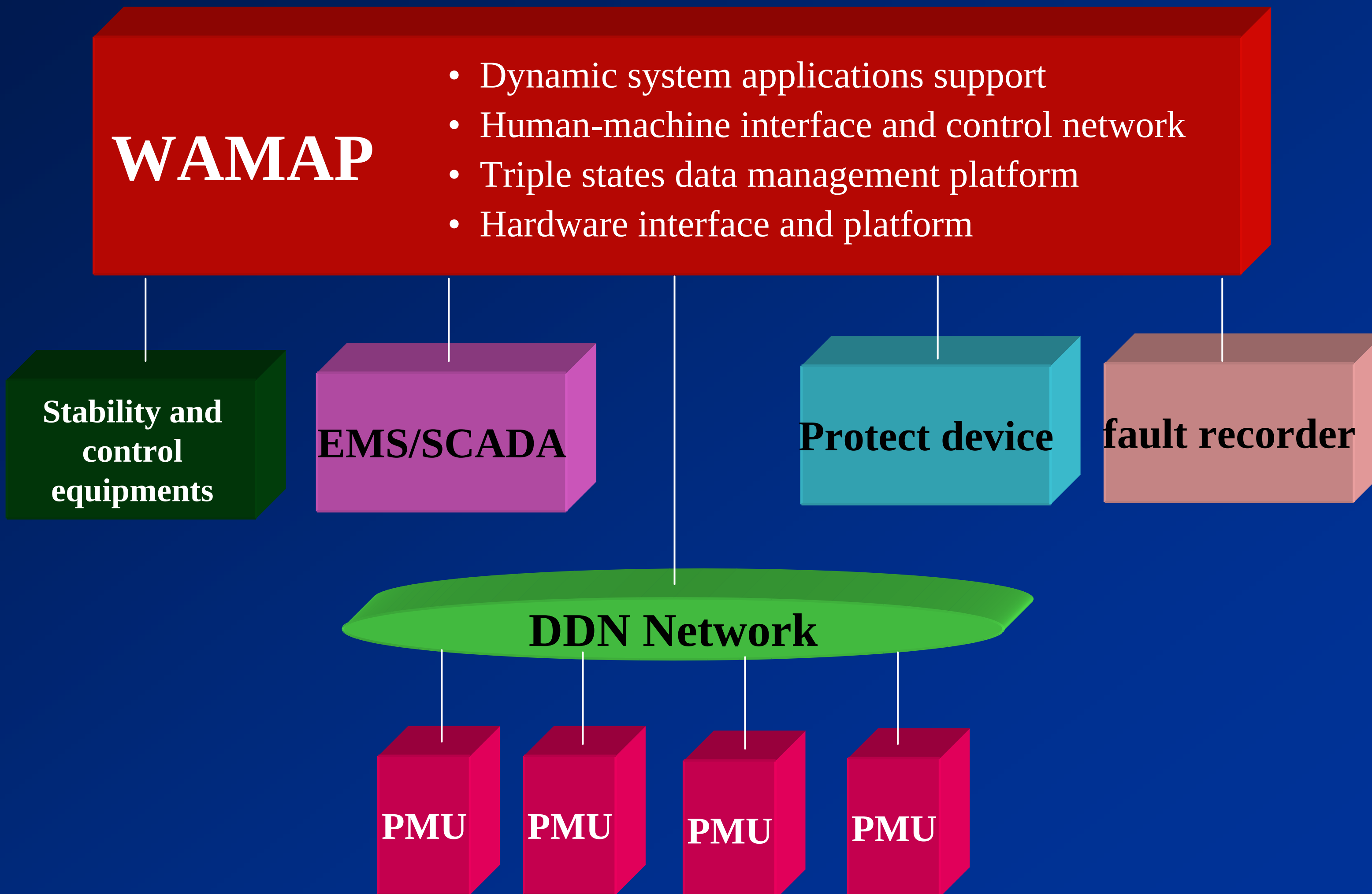
5 WAMAP Features & Comparisons

6 Conclusion

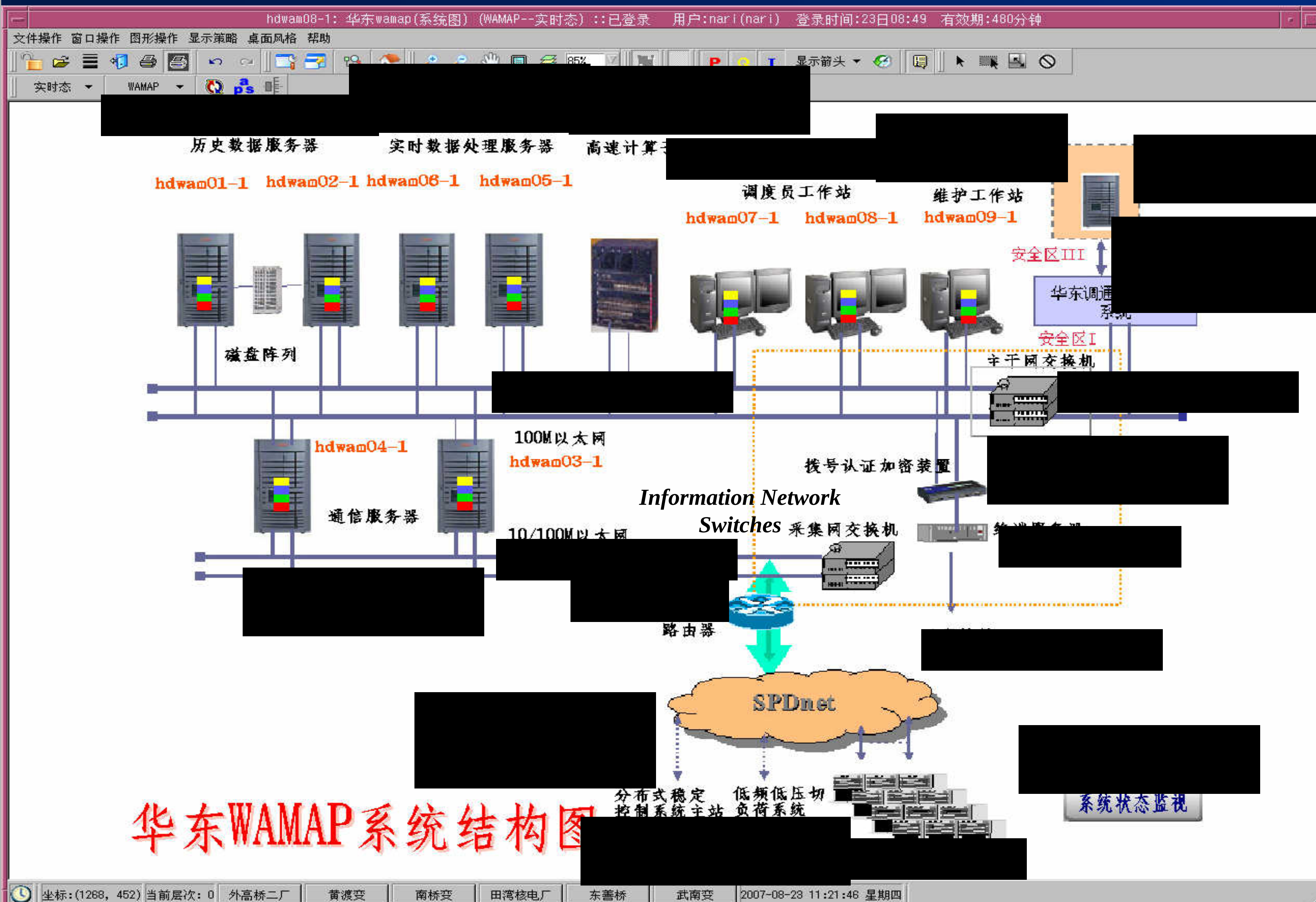
The WAMAP system requirements are:

1. To monitor and acquire steady state data as well as dynamic and transient states data.
2. To analyze the dynamics of a power system so that it can provide a decision-making assistance as well as prevention control assistance.
3. To generate a fast fault-analysis report and support an online decision making assistance.
4. To monitor the quantity and quality of the add-on services of power market.

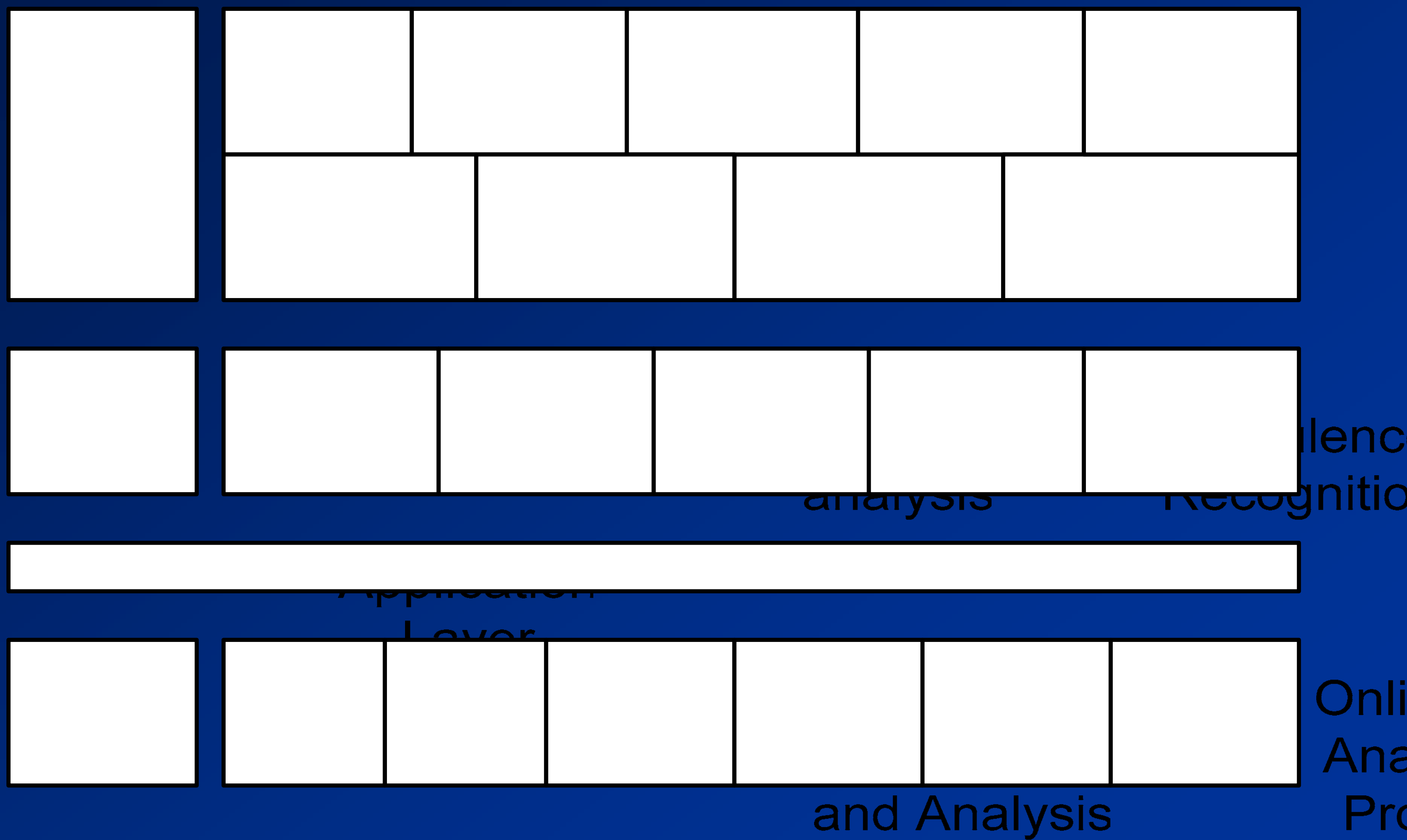
WAMAP System Configuration



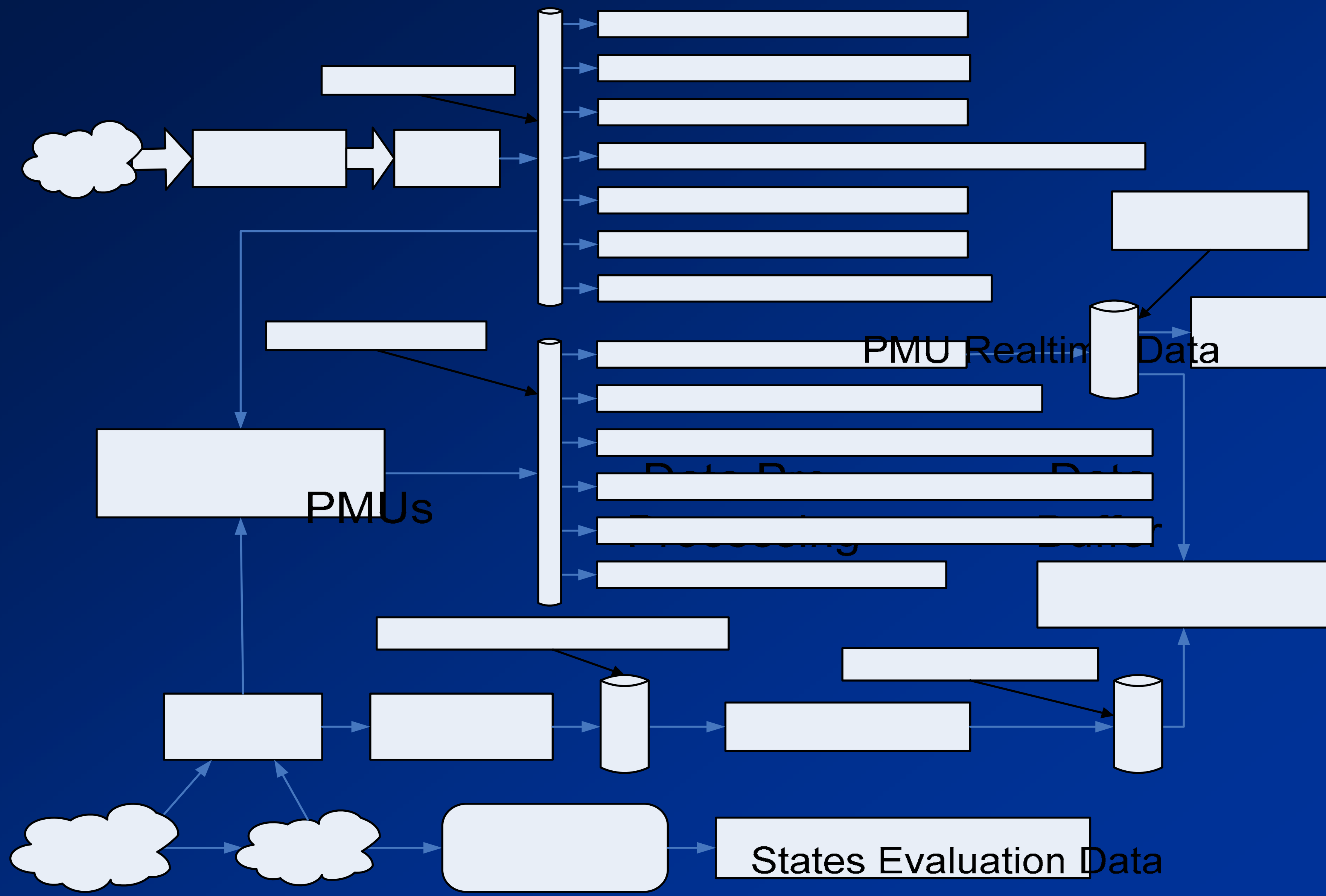
WAMAP System Hardware Configuration



WAMAP System Software Configuration



WAMAP System Data Flow



WAMAP System Key Technical Specification

- System Processing Capacity: 5,000 bus points and 200 cases in 3 minutes per cycle.
- CPU power: Parallel processing method with 32 CPUs.
- SCADA/EMS Sampling Rate: 12,500 points, 2 min per cycle.
- CIM file communication format between ABB-EMS and WAMAP system.
- PMU transmission speed : 25 to 100 frame per second.
- PMU data memory storage capacity: 14 days.
- PMU standards: IEEE 1344-1995 (R2001),IEEE Std C37.118-2006

Three phases in system development

- Phase I, the main focus is on building the system's platform, the distribution of the PMUs, and the acquisition of the dynamic real-time data of the power system.
- Phase II, is based on the acquired dynamic real-time data, an algorithm is designed to analyze rotor angle, voltage, and frequency stability of the power system.
- Phase III, is an online safety evaluation and control are executed.

In Phase I,

The main focus is on the data acquisition, offline analysis and simulation.

1. Power grid dynamic performance monitoring.
2. Fast real-time fault analysis and intelligent alarm system based on the PMU information.
3. Detailed fault analysis based on the integrated power grid information.
4. Add-on service for power quality monitoring.
5. Low Frequency Oscillation (LFO) online monitoring.
6. Simulation modeling and parameter validation.

In Phase II,

1. Integration of the State Estimation method (SE) with the PMU data
2. LFO analysis.
3. Online analysis and projections for rotor-angle, voltage, frequency, safety, and stability.
4. Online monitoring for power transmission.
5. Modeling and parameter checking.

- *In addition to the monitoring of the dynamics, the safety, and the stability of a power system, the WAMAP system provides prevention and alarm controls for a power system.*

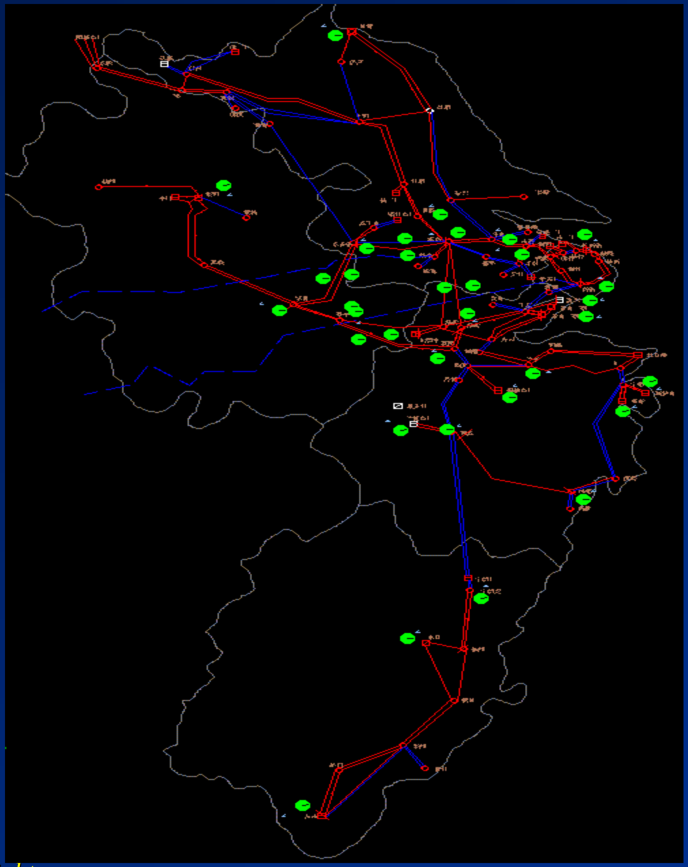
In Phase III,

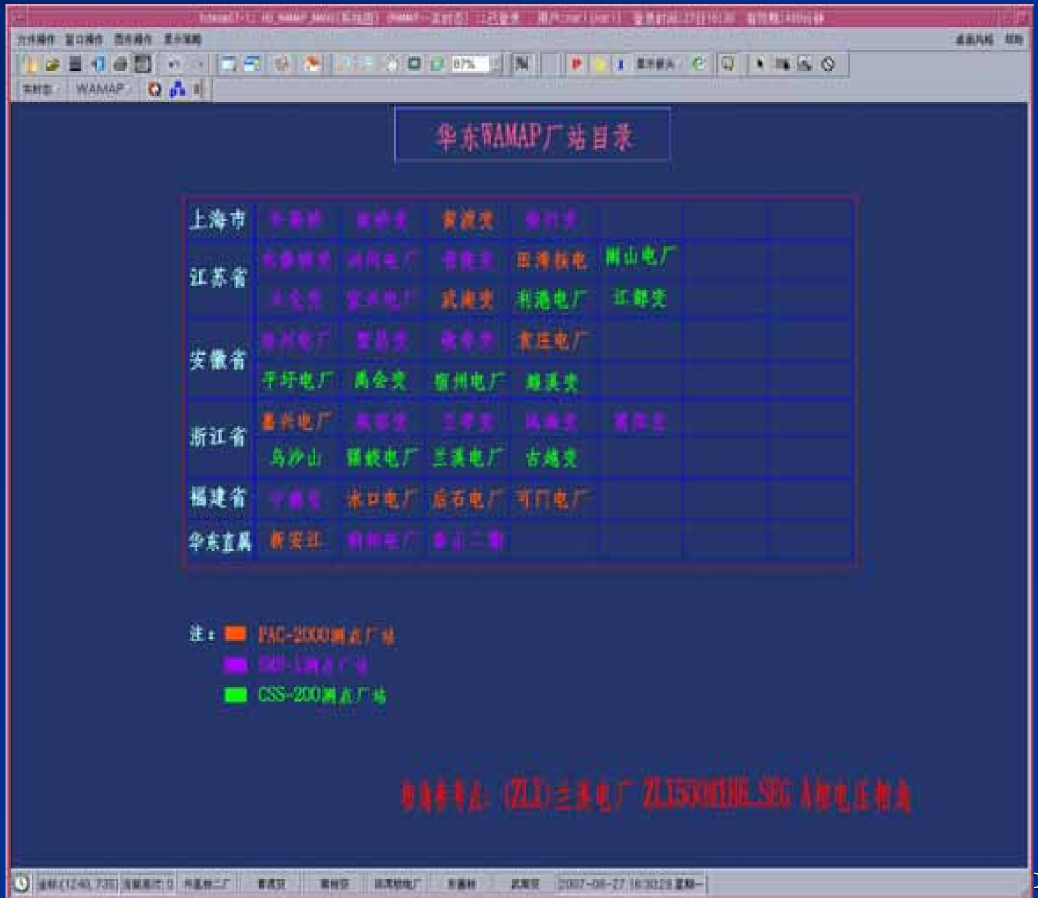
The main focus is on the implementation of the control functions.

1. To make an online dispatching adjustment by using the "Real-Time Prevention and Control Strategy Table". The order is sent to the related generators via the AGC system and to the security control equipment.
2. To control the rotor angle of the local Power System Stabilizer's (PSS) in order to eliminate LFO.
3. To provide a wide area protection control.
4. To provide some assistance for post-contingency decision-making.

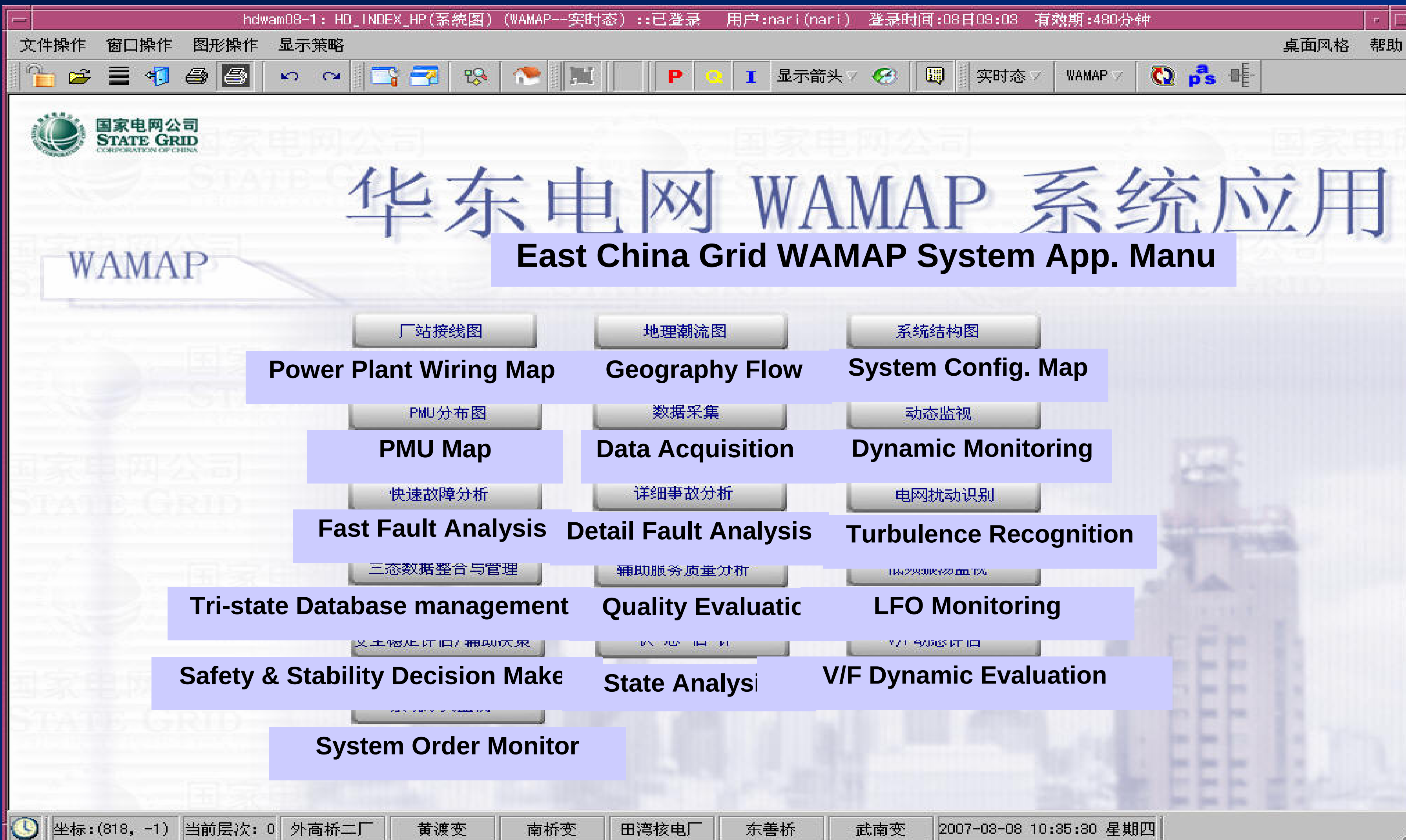
ECG PMU Installation Status

- 40 sets PMU have been installed in power plants & substations of ECG.
- The information over 150 PMU's from four provinces will be integrated into ECG's WAMAP system in the near future.

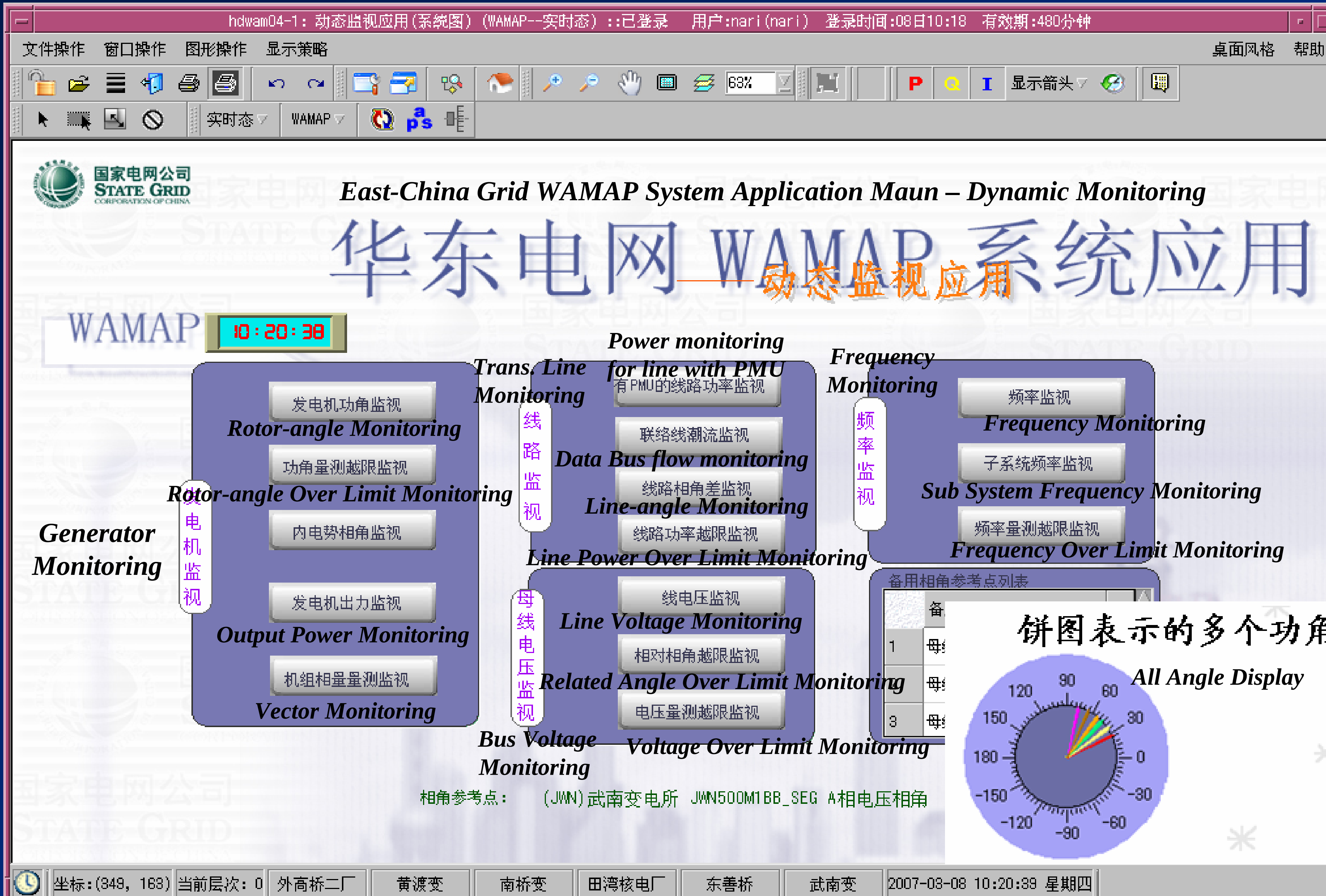




GUI-1, WAMAP User Interface (App. Layer)



GUI-2, Power Grid Dynamic Performance Monitoring



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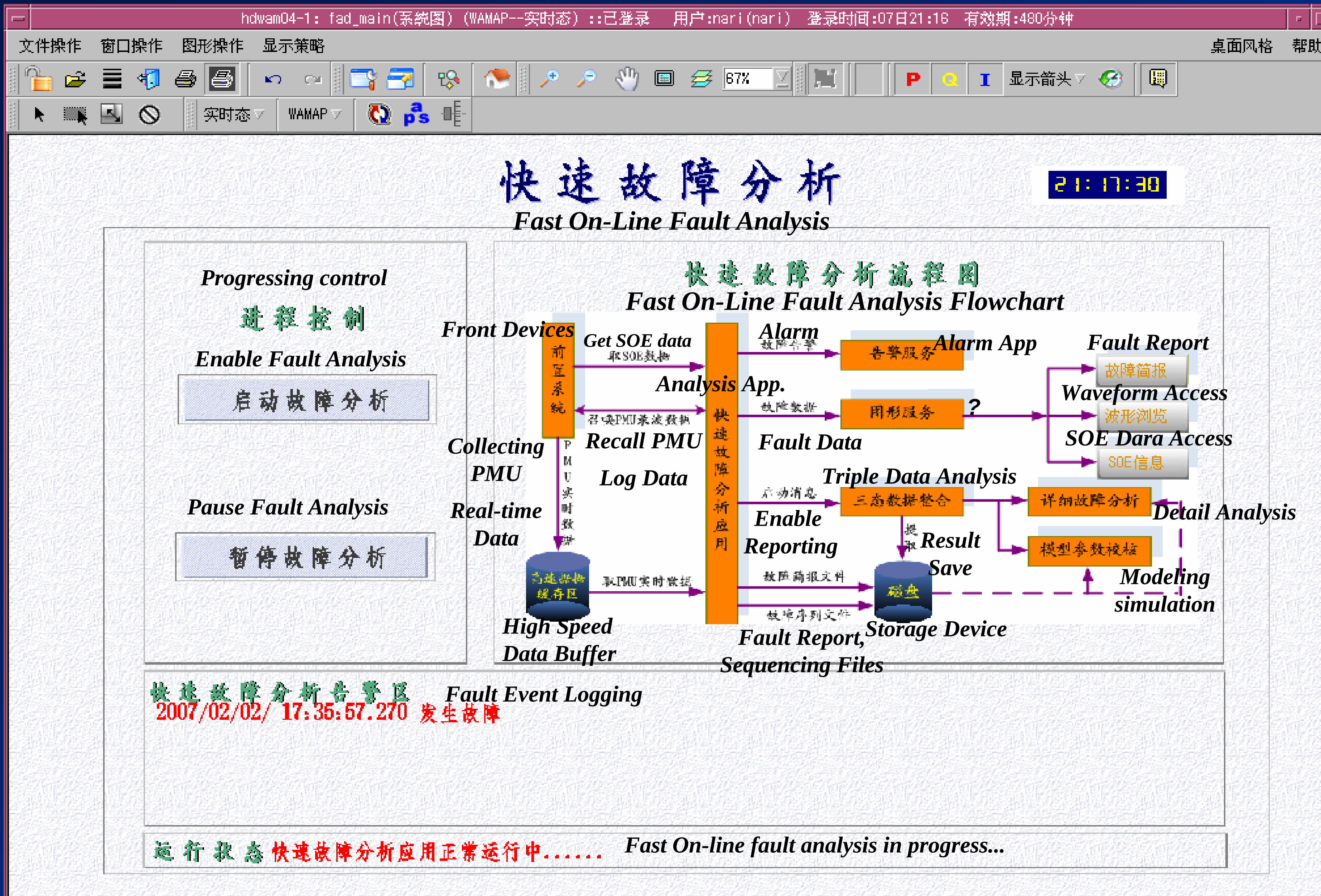
GUI–3, Fast On-Line Fault Analysis



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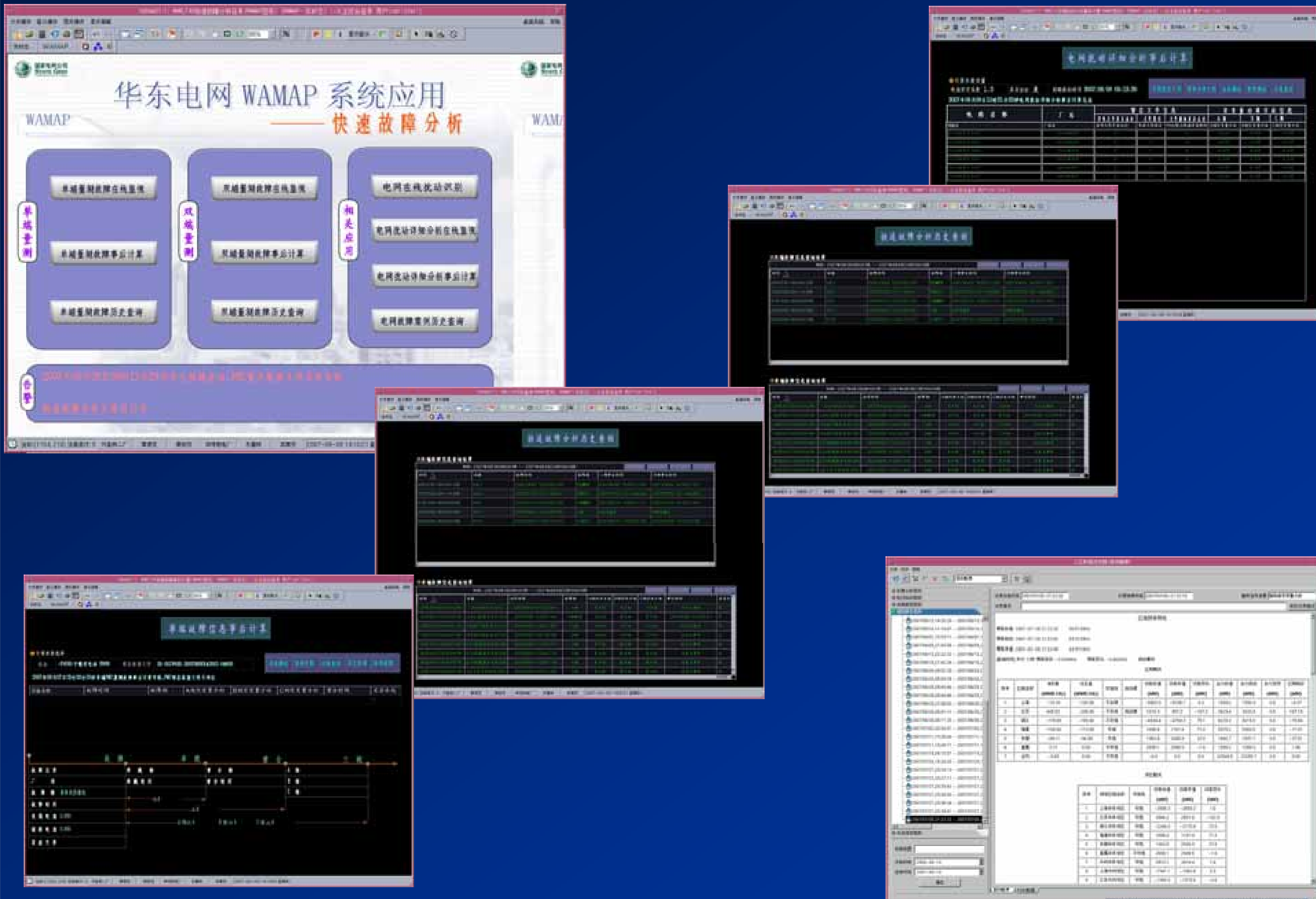
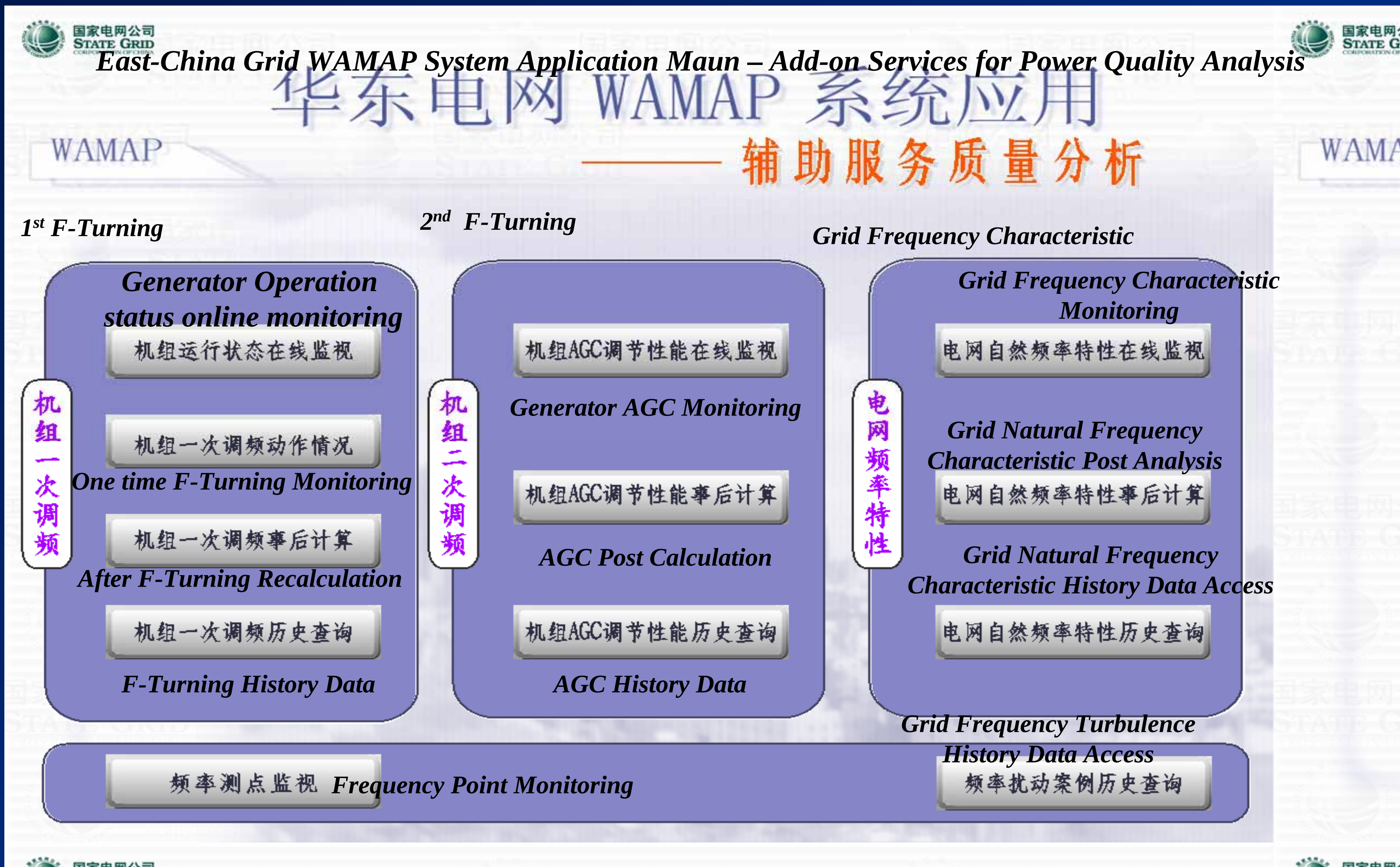
GUI – 4A, Example of Fault Analysis

500KV Line Fault due to “SONWEI” Typhoon in FuJian, June 2006

GUI – 4B, Example of Grid Turbulence Identification



GUI -5, Add-on Services for Power Quality Monitoring



GUI – 6A, Example of Frequency Monitoring of a Power Plant

hdwam08-1: WAM_AS_PFR机组一次调频事后计算(参数模板图) (WAMAP--实时态) ::已登录 用户:nari(nari) 登录时间:21日08:07 有效期:480

Name of Power Plant -> (ZQNGJ)强蛟电厂 ZQNGJ2002FGEN *<- ID # of generator*

2007/08/19 10:14:25 至 2007/08/19 10:15:15

共计 50.0 s 点数 100 间距 0.50 s 状态 正常

调差系数	6.9 %	延迟时间	0.0 s	调频死区	0.049 Hz
15.1 %	6.0 %	0.0 %	0.0 s	49.5 %	0.033 Hz

最近一次计算信息

18	32	37	44
起始点	频率极值点	出力极值点	结束点

机组类型 火电
额定出力 600 MW

机组频率(Hz)	频率初值	49.992	频率极值	49.944	对应频率	49.947	频率末值	49.955	频率变化	-0.037
机组出力(MW)	出力初值	502.5	对应出力	508.5	出力极值	509.7	出力末值	509.0	调频贡献	6.51

统计性能

统计次数

1

Tolerance

调差系数

平均值 6.9 %
偏差率 15.1 %

延迟时间

平均值 0.0 s
偏差率 0.0 %

调频死区

平均值 0.049 Hz
偏差率 49.5 %

GUI – 6B, Frequency Monitoring of a Power Plant *(Example)*

Event Time: 2007.8.26 19:20:53,

Location: Luo-He power plant in Anhui

Event Log: 600MW 4# generator was shut down.

WAMAP Monitors the responses of the regulation of excitation system of generators.

Qianjiao plant in Zhejiang

Houshi plant in Fujian

Wushashan plant in Zhejiang

Kemen plant in Fujian

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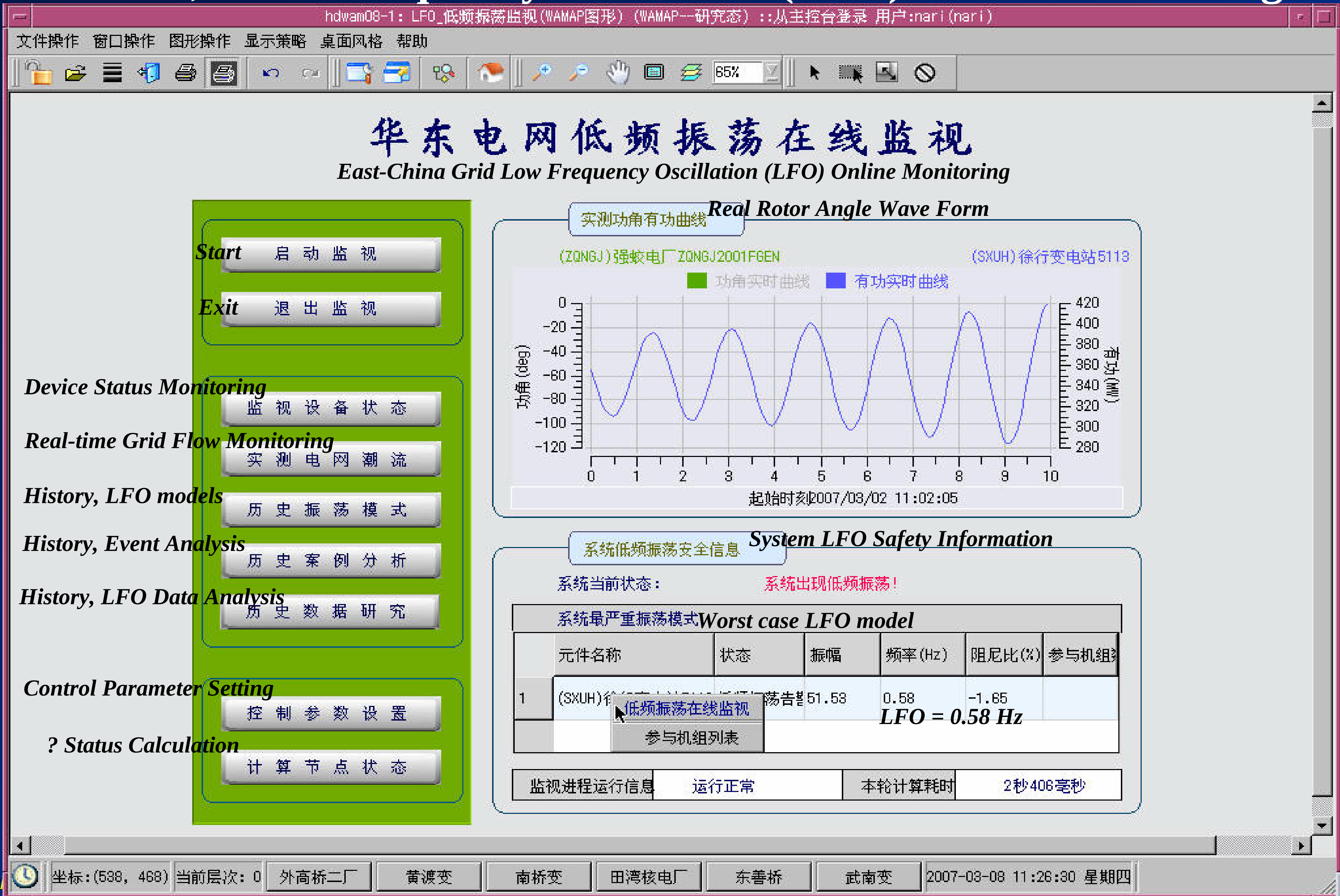
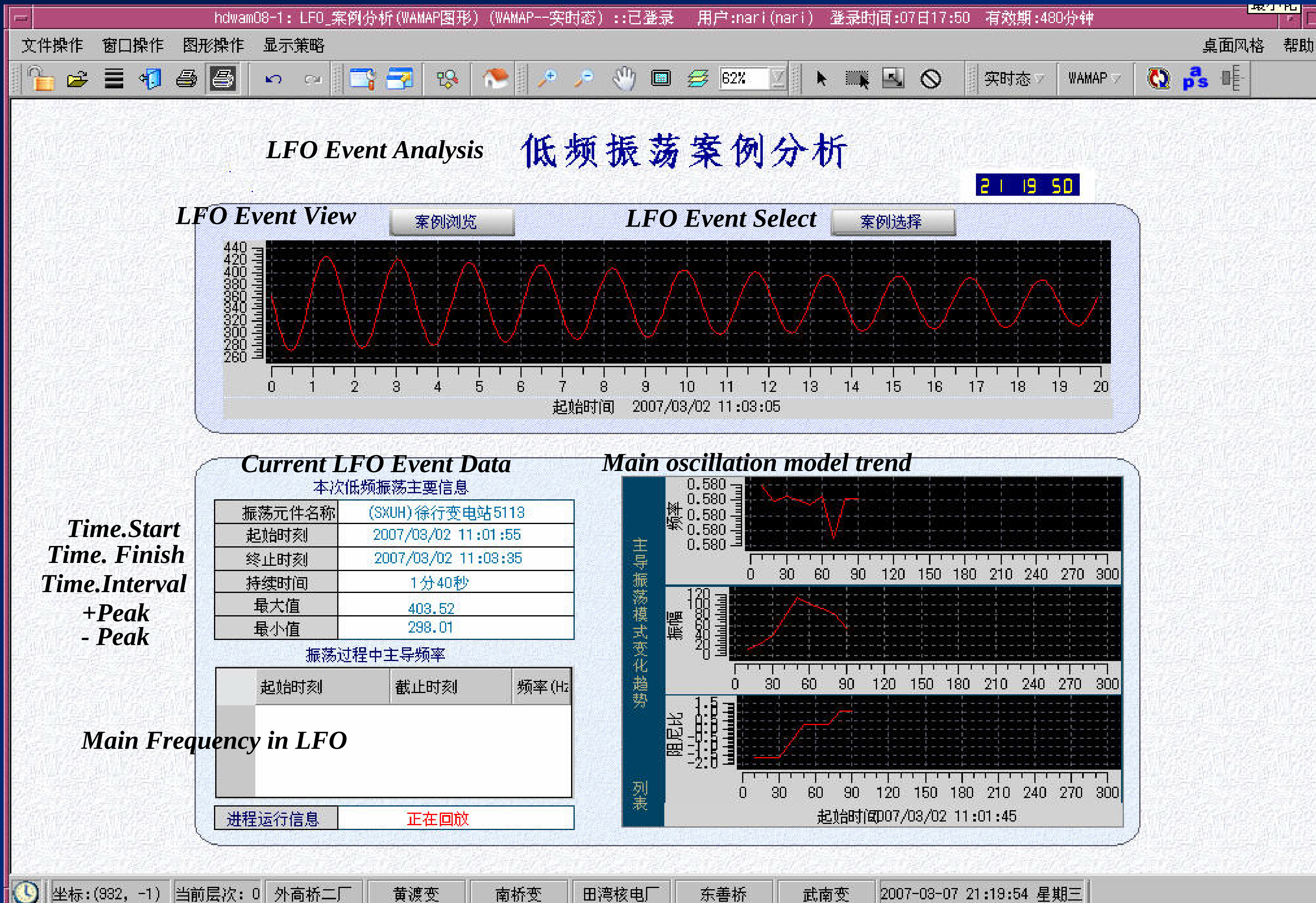
GUI–7, Frequency Quality Monitoring

GUI–8, Low Frequency Oscillation (LFO) Online Monitoring



GUI–9, Low Frequency Oscillation (LFO) Analysis

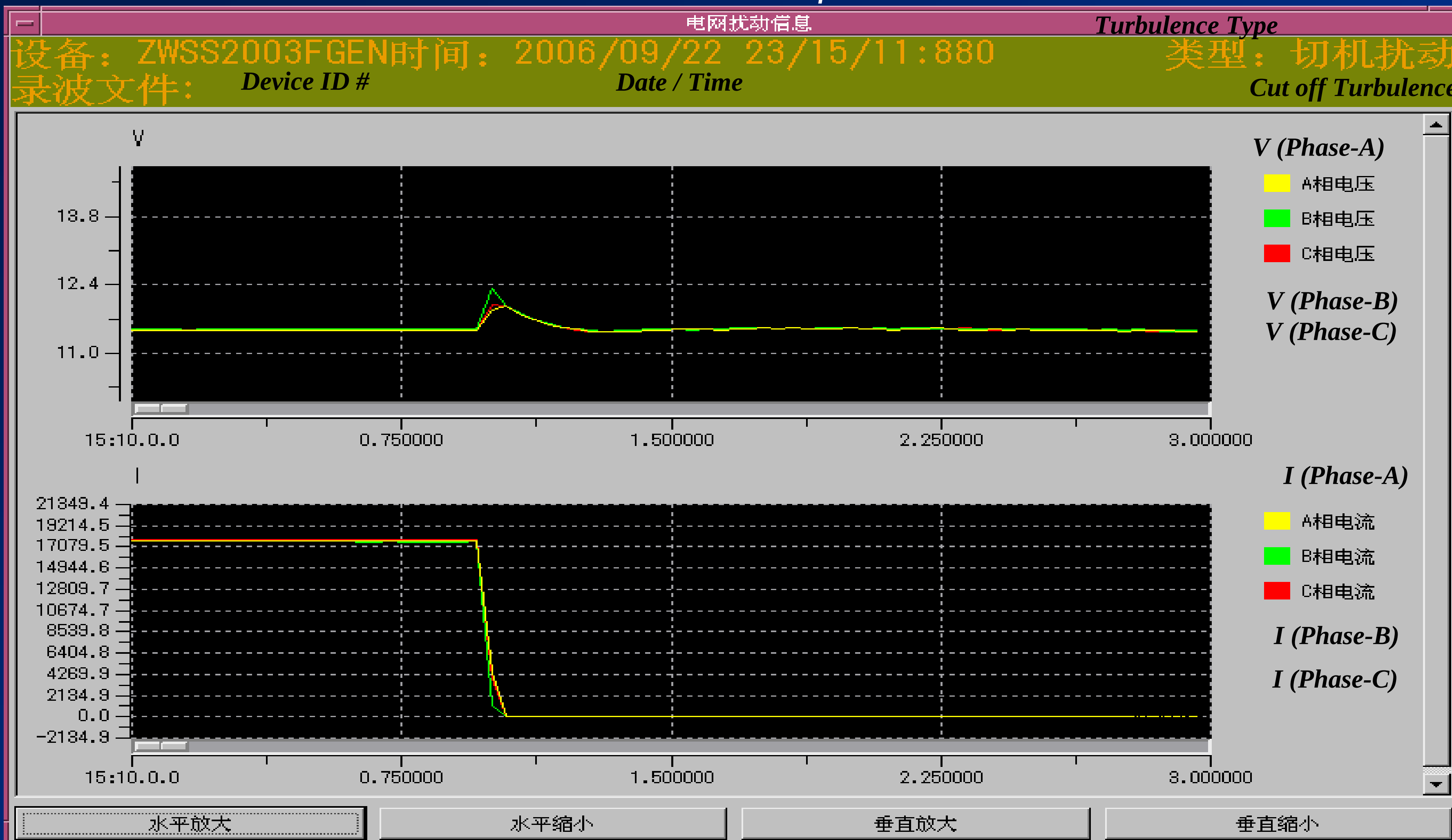


Ex. Report : Integration of the State Estimation (SE) with PMU data

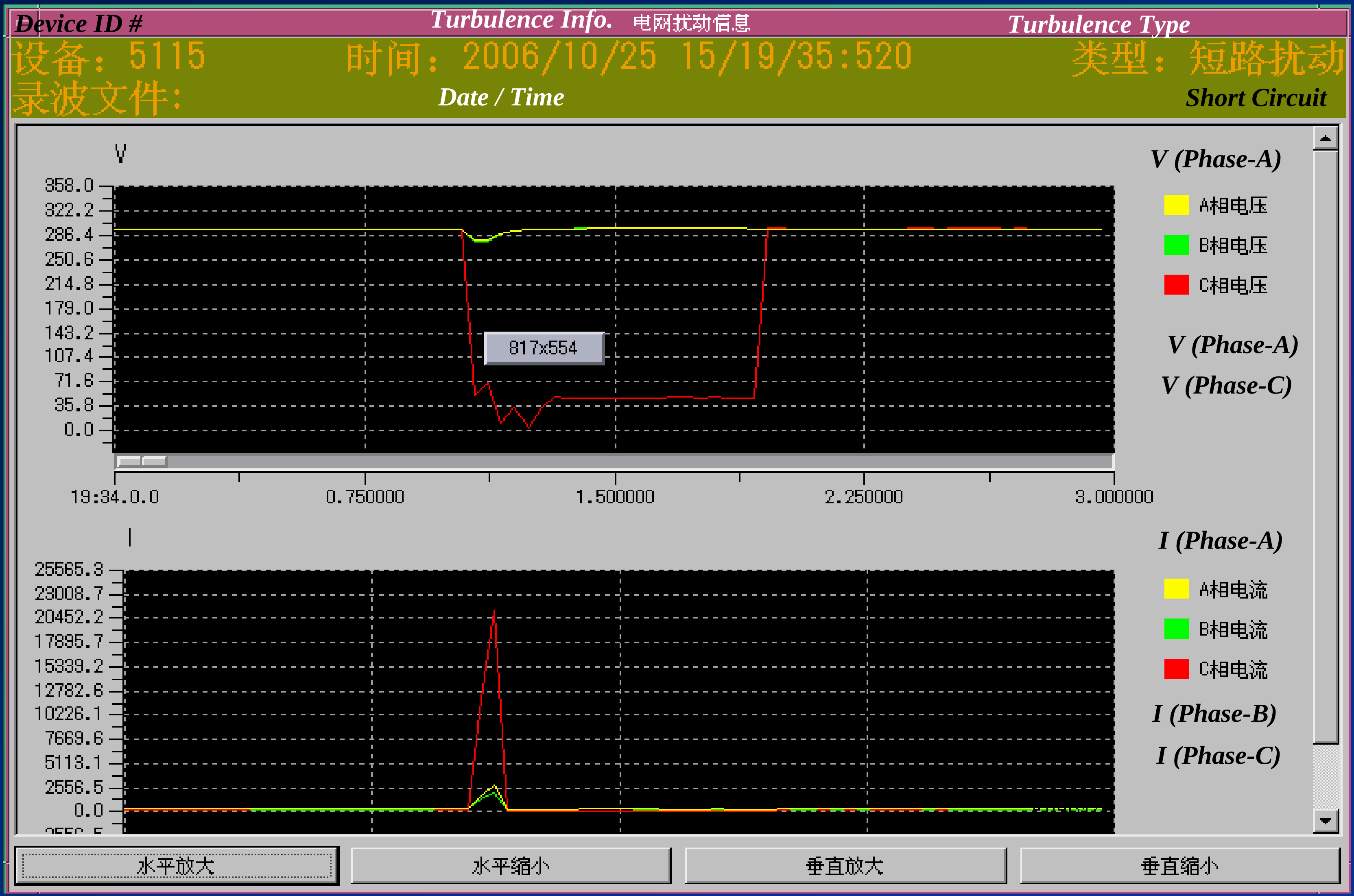
Load flow	5905 line active power	5905 line reactive power	5915 line active power	5915 line reactive power
SCADA (Normal)	-143.2	-84.1	-241.6	-53.0
SE (Normal)	-136.3	-90.0	-239.0	-43.0
SCADA (Err. Introduce)	-200	-120	-320	-80
SE (Err. Introduce)	-169.2	-95.0	-268.5	-47.0
SE with PMU (weight factor = 0.01)	-157.0	-93.0	-260.2	-44.2
SE with PMU (weight factor = 1.00)	-138.7	-93.2	-241.0	-47.0

GUI–10, Turbulence Online Identify – Cut off test on 600MW Generator

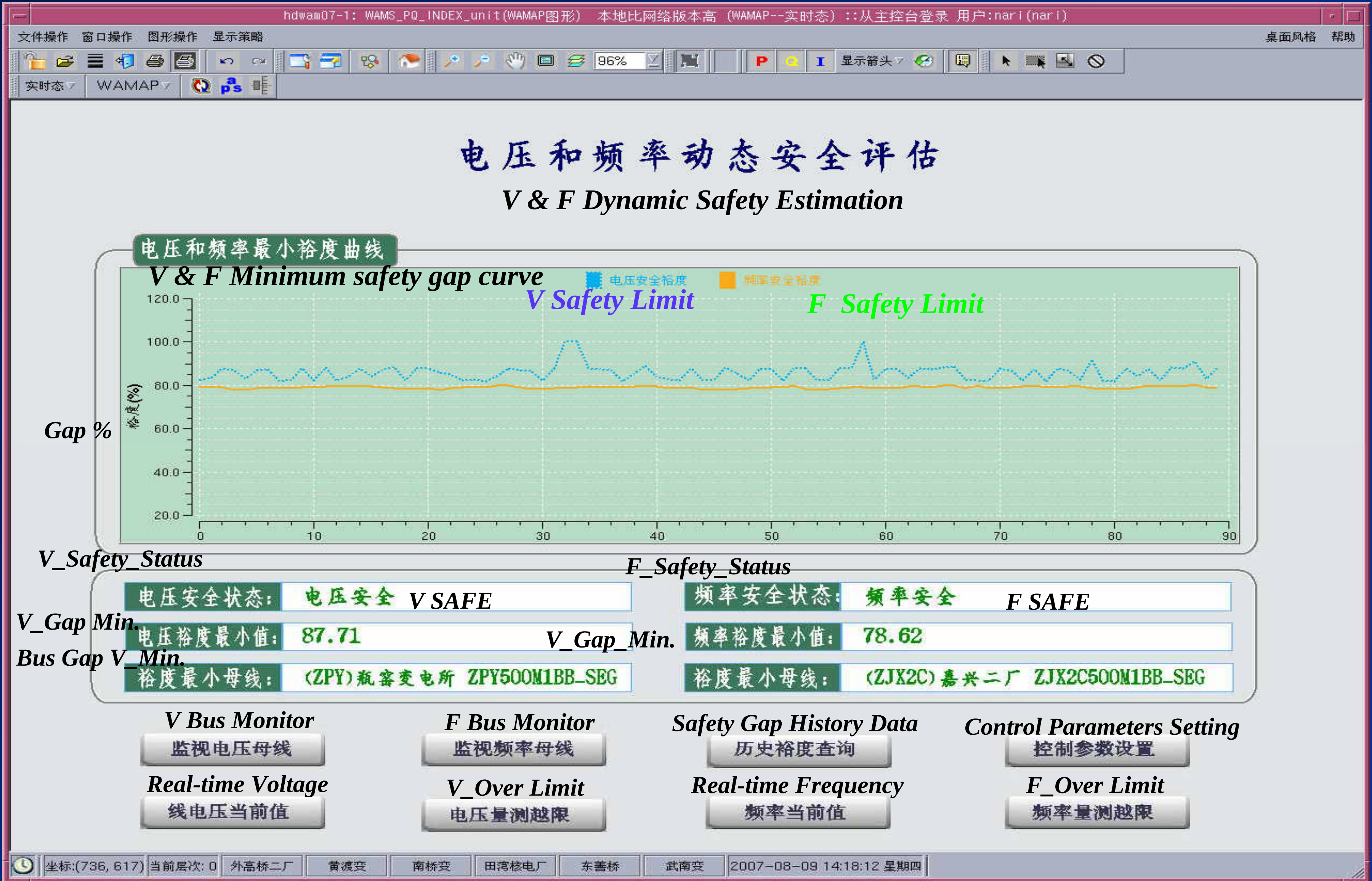
Turbulence Info.



GUI–11, Turbulence Online Identify -- Short Circuit in a 500kV Line



GUI–12, Online Safety Analysis Based On V & F



GUI-13, Online Safety Margin Analysis for Bus Voltage

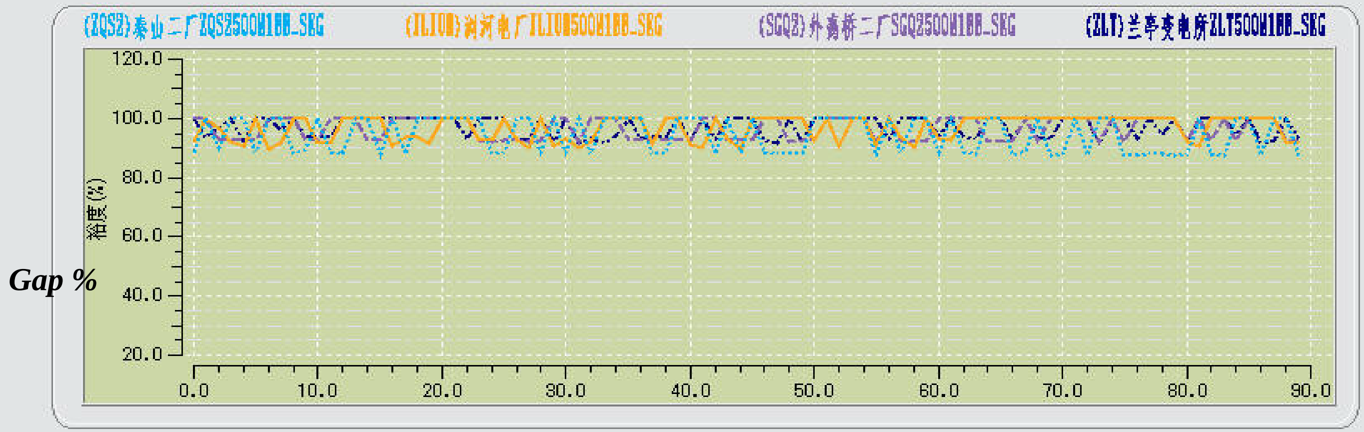
hdwam08-1: WAMS_PQ_电压监视母线(WAMAP图形) (WAMAP--实时态) ::已登录 用户:nari(nari) 登录时间:07日17:50 有效期:480分钟

文件操作 窗口操作 图形操作 显示策略 桌面风格 帮助

实时态 WAMAP 69%

母线电压安全裕度

BUS Voltage Safety Estimation



	母线 Bus name	区域 Area	安全状态 Safety Status	安全裕度(%) Safety gap%	门槛值(p.u) Threshold	持续时间 Time Interval
1	(ZQS2)秦山二厂 ZQS2500M1BB_SEG	华东直属	电压安全	87.70	0.75	1.00
2	(JLIUH)浏河电厂 JLIUH500M1BB_SEG	江苏	电压安全	91.79	0.75	1.00
3	(SGQ2)外高桥二厂 SGQ2500M1BB_SEG	上海	电压安全	92.22	0.75	1.00
4	(ZLT)兰亭变电所 ZLT500M1BB_SEG	浙江	电压安全	93.42	0.75	1.00
5	(JLG)利港 JLG500M1BB_SEG	江苏	电压安全	94.01	0.75	1.00
6	(AXC)敬亭变电所 AXC500M1BB_SEG	安徽	电压安全	94.88	0.75	1.00

坐标:(945, -13) 当前层次: 0 外高桥二厂 黄渡变 南桥变 田湾核电厂 东善桥 武南变 2007-03-07 21:14:40 星期三

GUI-14, Online Safety Margin Analysis for Bus Frequency

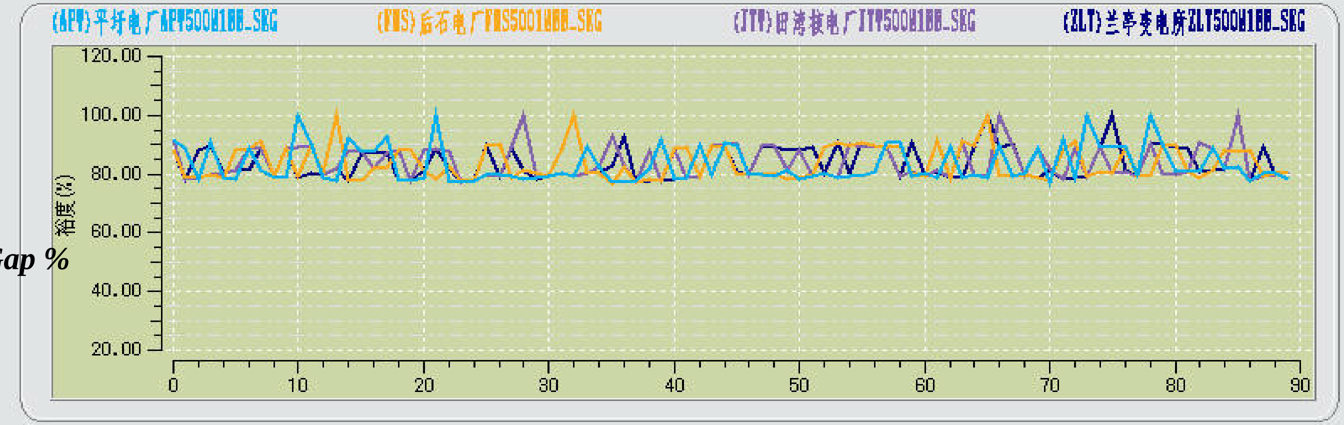
hdwam08-1: WAMS_PQ_频率监视母线(WAMAP图形) (WAMAP--实时态) ::已登录 用户:nari(nari) 登录时间:07日17:50 有效期:480分钟

文件操作 窗口操作 图形操作 显示策略 桌面风格 帮助

实时态 WAMAP 69%

母线频率安全裕度

BUS Frequency Safety Estimation



	母线 Bus name	区域 Area	安全状态 Safety Status	安全裕度(%) Safety gap%	门槛值(Hz) Threshold	持续时间 Time Interval
1	(ALH)洛河电厂 ALH500ZM1BB_SEG	安徽	频率安全 Safe	77.91	49.00	0.50
2	(JJINL)晋陵变电所 JJINL500M1BB_SE(	江苏	频率安全	77.99	49.00	0.50
3	(JLIUH)浏河电厂 JLIUH500M1BB_SEG	江苏	频率安全	78.02	49.00	0.50
4	(FNDB)宁德变电站 FNDB500M1BB_SEG	福建	频率安全	78.06	49.00	0.50
5	(ZQS2)秦山二厂 ZQS2500M1BB_SEG	华东直属	频率安全	78.07	49.00	0.50
6	(JTW)田湾核电厂 JTW500M1BB_SEG	江苏	频率安全	78.11	49.00	0.50

坐标:(530, -3) 当前层次: 0 外高桥二厂 黄渡变 南桥变 田湾核电厂 东善桥 武南变 2007-03-07 21:16:26 星期三

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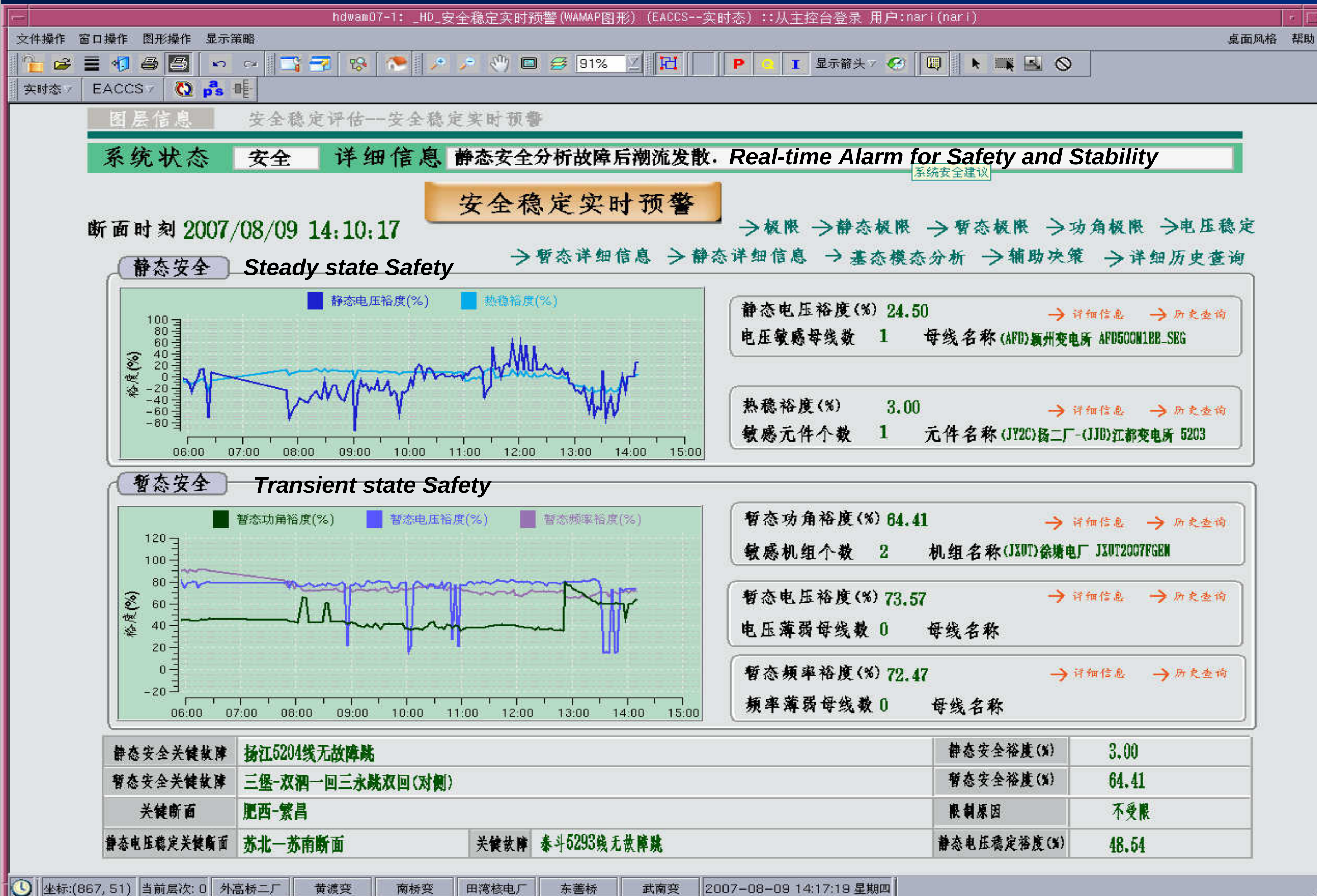
GUI – 15, Real-time Alarm for Safety and Stability



GUI – 16, Online Evaluation of Active Power Limitation on Steady State Voltage Stability

	断面名称	当前潮流	在线极限	离线极限	离线极限说明	在线极限说明
1	上盐线	897	1260	1200	上盐线正常[illegible]	[illegible]受热稳限制,设置为离线的1.05倍
2	任庄—上河5237线	547	1024	975	任庄—上河5237线正常方式 阳城和苏北安控投	不受热稳限制,设置为离线的1.05倍
3	任庄—上河5238线	538	1024	975	任庄—上河5238线正常方式 阳城和苏北安控投	不受热稳限制,设置为离线的1.05倍
4	肥西—繁昌	1104	1995	1900	肥西—繁昌正常方式	不受热稳限制,设置为离线的1.05倍
5	任庄—上河	1085	2048	1950	任庄—上河正常方式 阳城和苏北安控投	不受热稳限制,设置为离线的1.05倍
6	三堡—双泗	1524	2520	2400	三堡—双泗正常方式 阳城和苏北安控投	不受热稳限制,设置为离线的1.05倍
7	上江双线	895	2100	2000	上江双线正常方式	不受热稳限制,设置为离线的1.05倍
8	上江—上盐	1792	3150	3000	上江—上盐正常方式	不受热稳限制,设置为离线的1.05倍
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

From the user perspective,

The WAMAP system provides:

- A Multi-States Data Management Platform which consists of dynamic data from PMUs, steady data from EMS, and transient state data from the reaction of protection devices.
- An online prevention strategy and an emergency control strategy by using a rapid data processing and analysis.
- An add-on system service tool package for the power market such as the monitoring of frequency, voltage, and the evaluation of power plant contract execution.
- A rapid safety margin analysis of a power system.
- An efficient utilization of the transmission capacity and the generation capacity of a power system in order to meet economic interest of power companies.

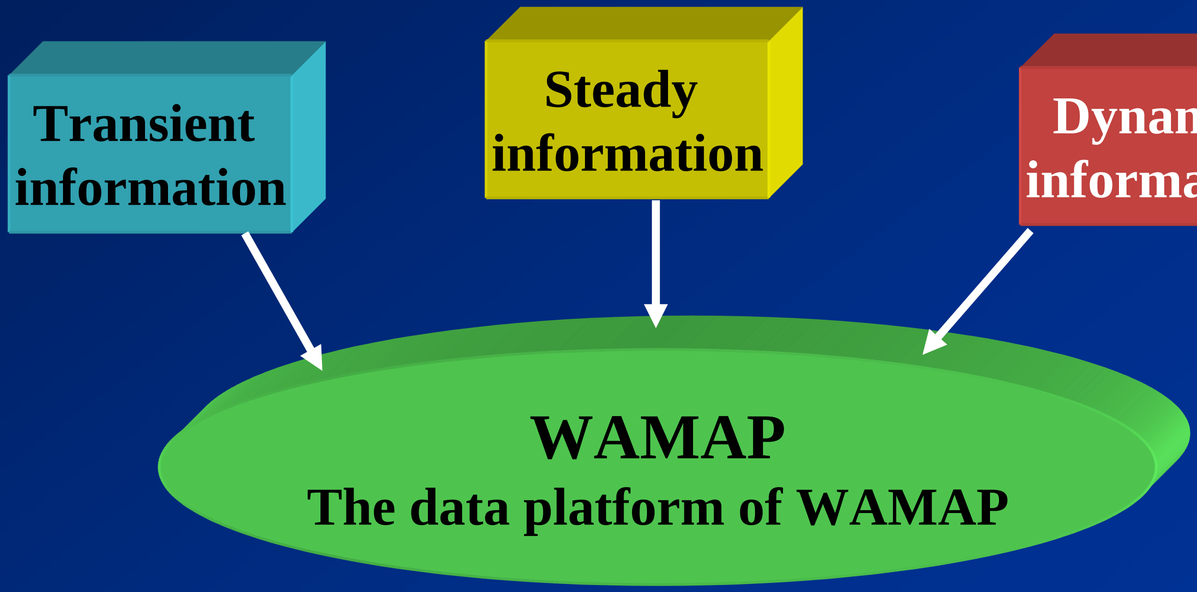
Overall, *WAMAP vs. WAMS*

- WAMS monitors system dynamics and logs data. In contrast to the SCADA system (in which only the steady state is monitored), WAMS made some improvement by the inclusion of system dynamics monitoring.
- WAMS analyzes only the transient states data provided by the independent protection device. As a result, the simulation of a power system is based only on a real local operation environment.
- The WAMAP system, however, advances its capability significantly over WAMS. Its goal is to achieve a power grid protection over a wide area. This is achieved by including all condition simulation of the power system, with its human-machine interface.
- WAMAP is a next generation system for power grid monitoring and controlling after WAMS.

Function	WAMAP	WAMS
Data Acquisition	3 States	Dynamic state only
Multiple States Data Management	Uniform timestamp and Management	NO
Characteristics of Online Analysis (Angle, frequency, voltage)	YES	NO
Assistance for post-contingency decision-making	YES	NO
On-line fault prevention and emergency control strategy	YES	NO
Fault finding and locating	YES	NO
Offline power system simulation model and parameter checking	YES	NO
Damping control and other process control	YES	NO
Online check of power system modeling parameters	YES	NO

WAMAP's Foundation: Triple state Data Platform

WAMAP uses all 3 kinds of information



The Triple-State Data Type

Device	Type of Data Output
PMU	Vector, state and wave records
SCADA/EMS System	Remote data, tele-signalization data, network and component modeling parameters.
Integrated Protection Relay Management System	Protection configuration, On/Off status, operation data, operation current and voltage, wave records.
Stability Control Devices	Configuration and operation information.
Fault Waveform Recording Devices	Recording fault current and voltage waveform.

Data sharing issue is resolved by WAMAP data management platform

When a problem occurs, the PMU real-time data acquisition unit shall be invoked to collect data such as frequency, voltage, current, active power, reactive power and switch status. At the same time, all of the action information from fault protection device, recording devices, auto-protect switches, and other stable control devices will be recorded and transmitted to the analysis center.

To power system researchers, the sharing of information from different time, different devices, states and areas is always an important topic. An additional benefit of a WAMAP system is that it is built to resolve this “critical” data sharing issue by using a unique data management platform.

The main functionality of the WAMAP's data management platform includes:

- Collecting,
- Logging,
- Sorting,
- Categorizing
- Real-time data Processing for all three states

Using these data, the WAMAP system will be able to perform system protection estimation, Sequence of Event (SOE), Post Disturbance Record (PDR), analysis of fault process, modeling and parameter checking as well as stability margin calculation

Conclusion - 1

How to do? what to do?

---- the most difficulties in five years of WAMAP development.

1, No idea, Thinking hard In the WAMAP beginning stage.

--- After 1 year WAMAP system study, we divided project to phase-1,2,3

2, Difficult to finalize WAMAP system requirements

--- After 2003 North America blackout, our goal is confirmed.

3, Big challenge in testing

--- Spent great effort to complete dynamic simulations, functional test, as well as the system level test. The same tests were repeated for multiple times.

4, The Interface issue was often a problem during integration

--- Issues are in the data sharing, communication within EMS, protection device, data acquisition and data logging devices.

5, Management challenges

--- “wide area grid” project needs “wide area” management method. A lot push, a lot patience and proper orders as well as rewards.

Conclusion - 2

ECG Control Center

ECG Headquarter in Shanghai

Dynamic data from field

Master station computer Room

Conclusion - 3

Design begin meeting >

< System Planning meeting

< Phase-1 Detail Design Meeting V

Final stage WAMAP Design Meeting V

< Problem Solving and Discussion

Conclusion - 4

Meeting for finalizing of system design phase

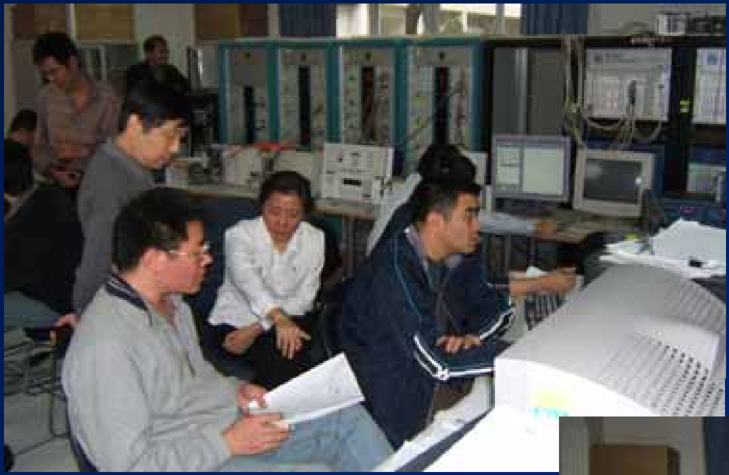
WAMAP Feasibility Discussion Meeting

Project Contract Meeting with suppliers

Conclusion - 5

Engineers in WAMAP Project Development

Conclusion - 6



WAMAP System
Application Function
RTDS Test

2005.7.15--7.29
Ist RTDS test

2005,10.8--10.22
2nd RTDS test

2006.3.8—3.28
3rd RTDS test

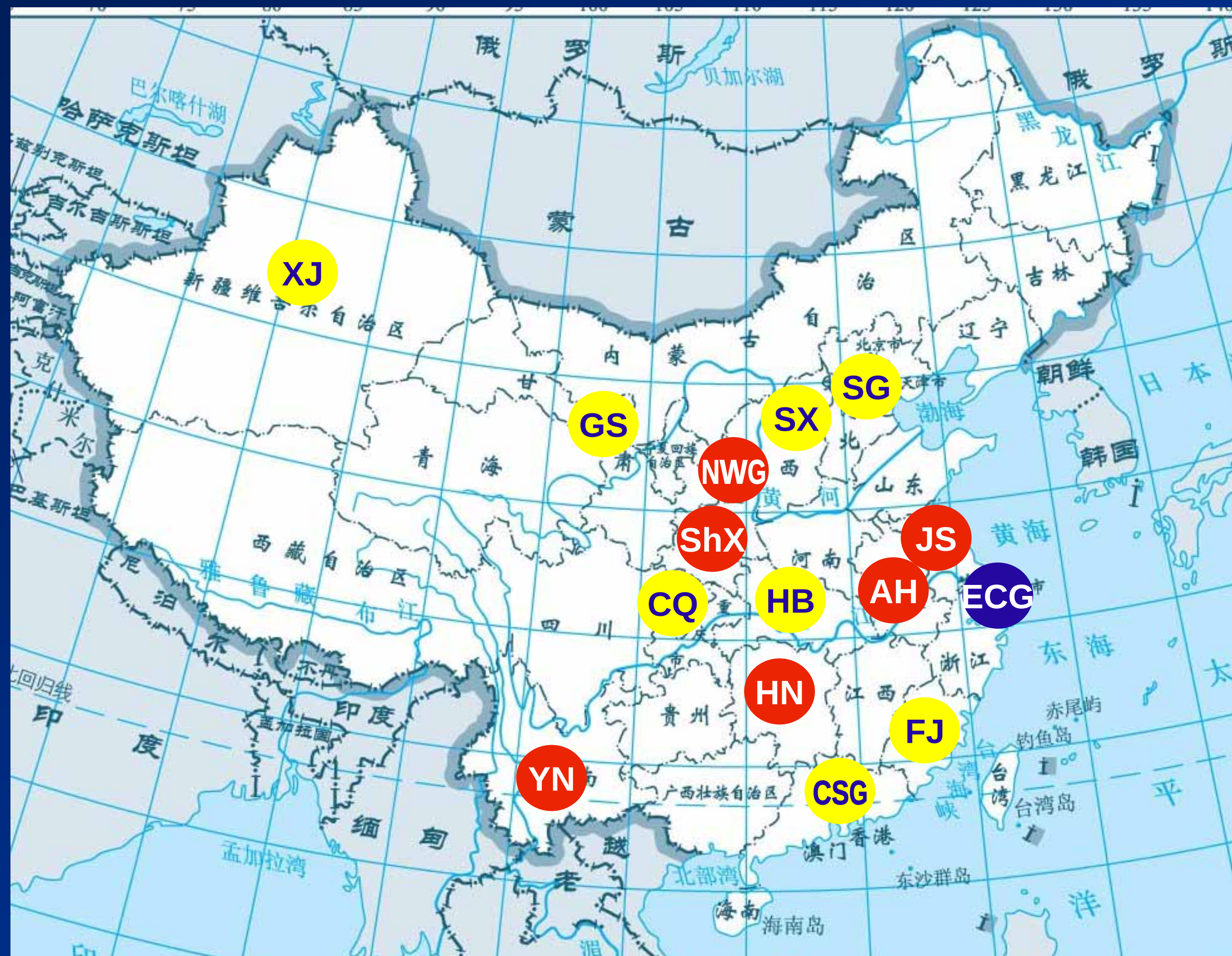
Conclusion - 7

WAMAP System Developments in China Power Grid

ECG The WAMAP system of East-China is operating and stepping ahead in the China

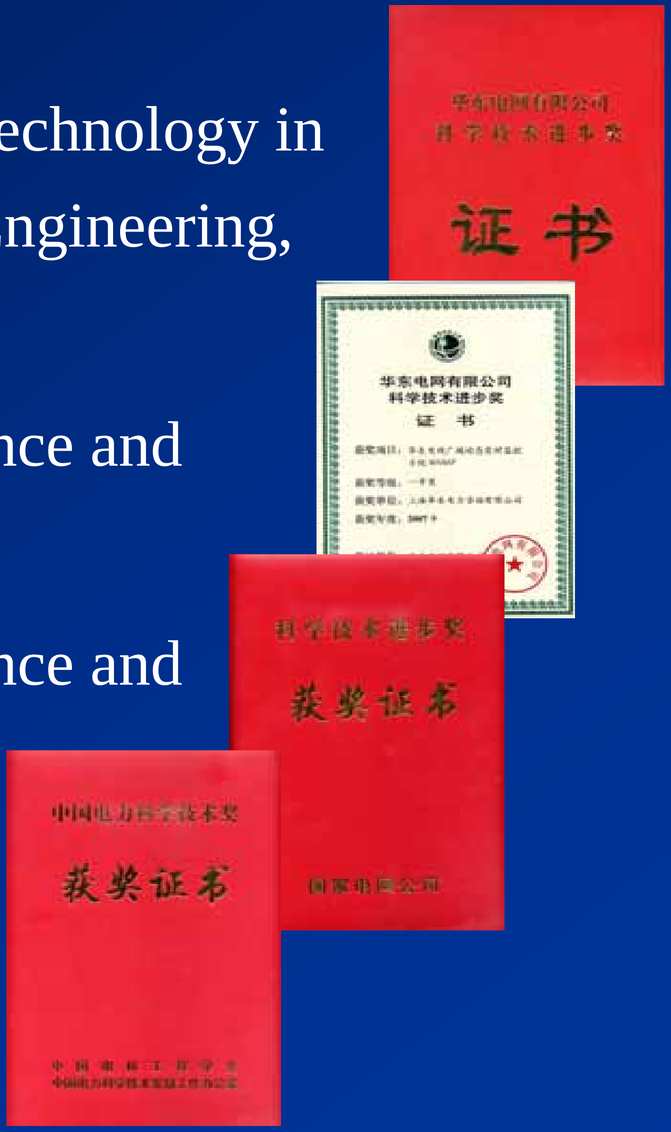
6 systems in progress

8 systems In beginning stage



WAMAP, National wide Recognition

- Prize Award, Advanced Science and Technology in Electric Power , Society of Electrical Engineering, China (CSEE)
- 1st Place Prize Award, Advanced Science and Technology, China State Grid (CSG)
- 1st Place Prize Award, Advanced Science and Technology, East China Grid (ECG)



Conclusion

- Without a system-level data platform and the capability to analyze the triple-state data, our power system is not a robust system.
- Based on its unique "Triple-State Data Management Platform", the WAMAP system is capable of a wide area power grid monitoring and control. It uses today's the most advanced technologies to gather steady-state, dynamic-state, and transient- state data in order to provide a complete protection of a power system.
- The WAMAP system is currently being developed by the power engineers of East China Power Grid Co. The first two phases have been completed and it is now in its third phase. The system was able to detect LFOs in its early stage. In many cases, its online fault-simulators have prevented wide area power outages with satisfactory preliminary results.

Ms. Xianping Hong

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- CEO, East China Electric Consulting Co.,Ltd
- Member of IEEE
- Member of the standing council of Shanghai Society of Electrical Engineering (SSEE)
- Member of the standing council of Shanghai Electro _technical Society (SES)
- The council Member of Shanghai Women Engineers Association (SWEA)
- Graduated from the Electrical Engineering Department of Shanghai Jiao-tong University in 1982.

Welcome to ECG & Welcome to Shanghai, China

Thank You !

If any questions, please contact me at

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Xianping HONG, CEO

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