НТЦ ЕЭС Противоаварийное управление

AVR and PSS digital models verification experience using frequency responses obtained by RTDS

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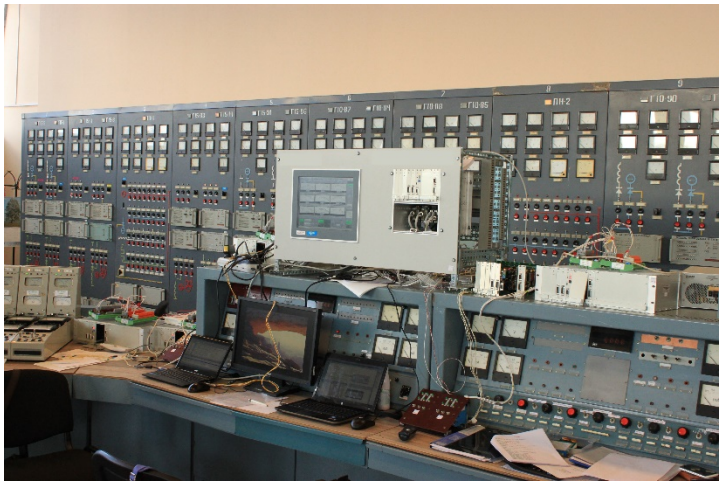
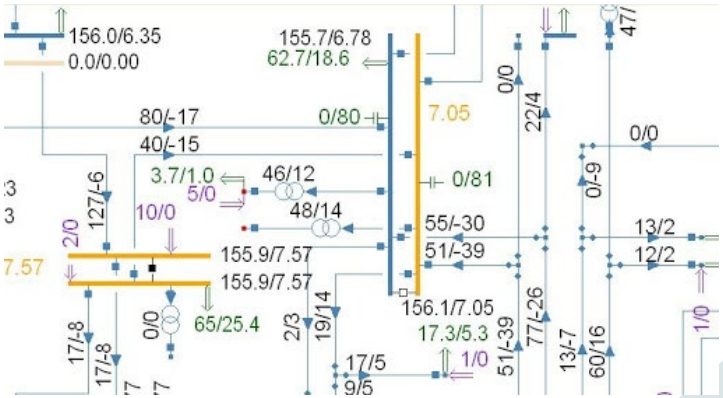
St. Petersburg, 2020

Introduction

JSC «STC UPS»
Tasks overview





FULL NAME:

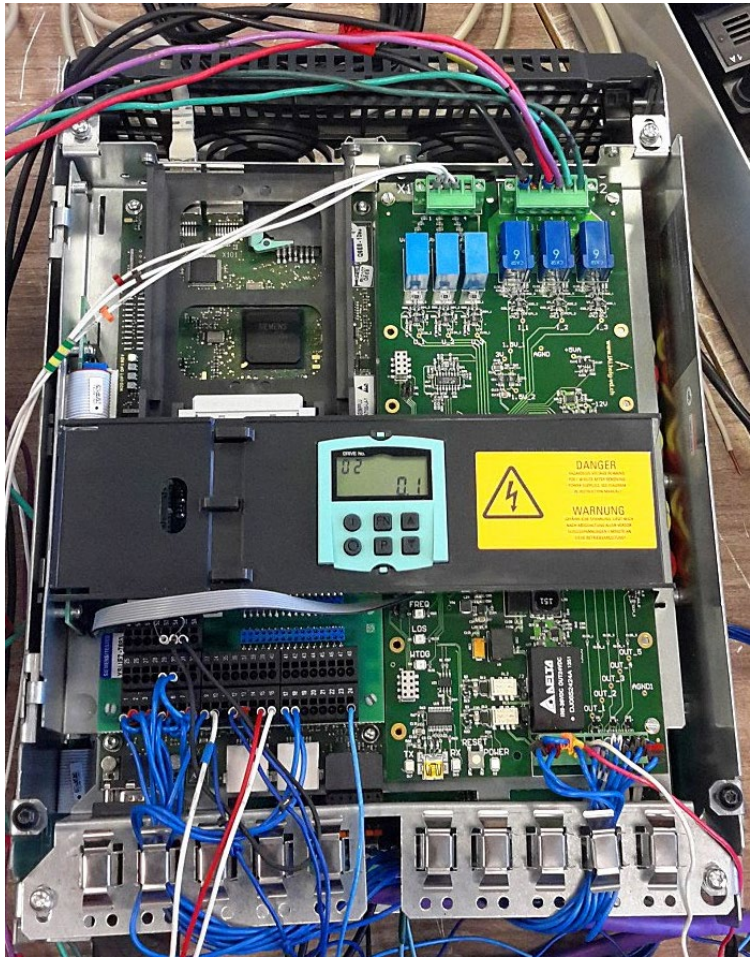
Joint Stock Company «Scientific and Technical Center of Unified Power System».

PRIMARY GOALS:

- Power systems design and development;
- Stability, reliability and survivability of power grids. Operation and emergency modes control;
- Development of computer model for electrical power systems steady-state evaluation;
- Transient stability analysis;
- Development of specialized software;

The work of our department is centered around power system stability research. A lot of tasks are associated with automatic voltage regulators (AVR), power system stabilizers (PSS) and analysis of their performance.

Introduction



Automatic voltage regulators in JSC "STC UES"

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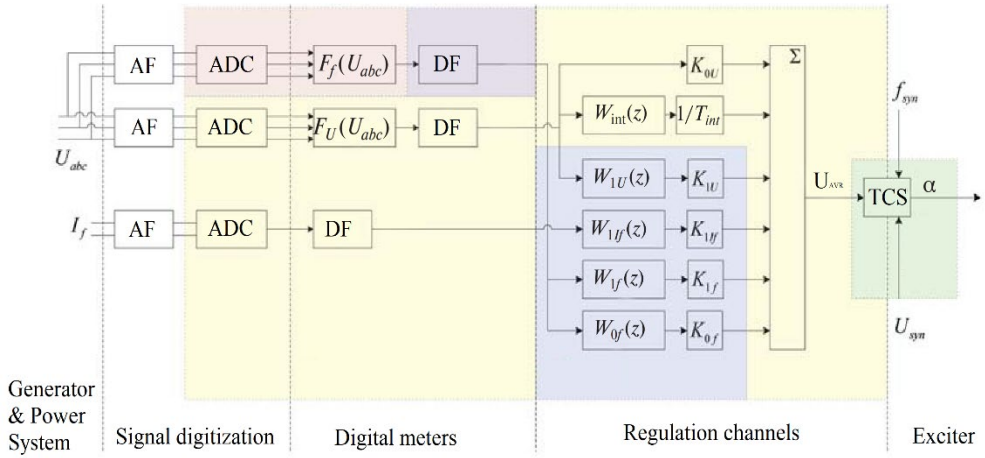
Problem statement



Schematic diagram of AVR

AF – Analog filter
ADC - Analog-to-digital converter
DF – Digital Filter
TCS - Thyristor control system

- The method for obtaining reliable frequency characteristics was developed in JSC «STC UPS»;
- The described method allows correction the mathematical models of a regulator.

- At the moment, the verification of mathematical models of automatic voltage regulators is carried out on the basis of data provided by the developers of ARV;
- Provided data requires verification;
- The assessment of the correctness of the mathematical model of AVR is performed according to the results of comparison of the frequency characteristics of live models of regulators and the corresponding mathematical models;

- The method for obtaining reliable frequency characteristics was developed in JSC «STC UPS»;
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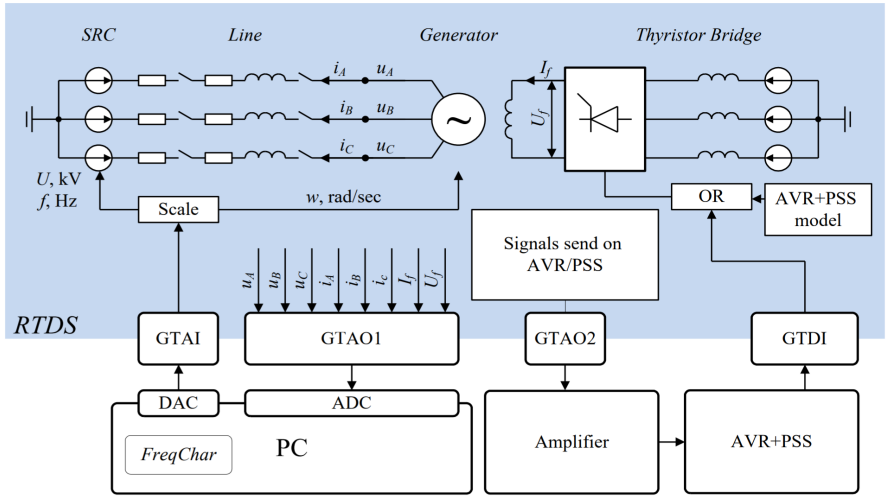
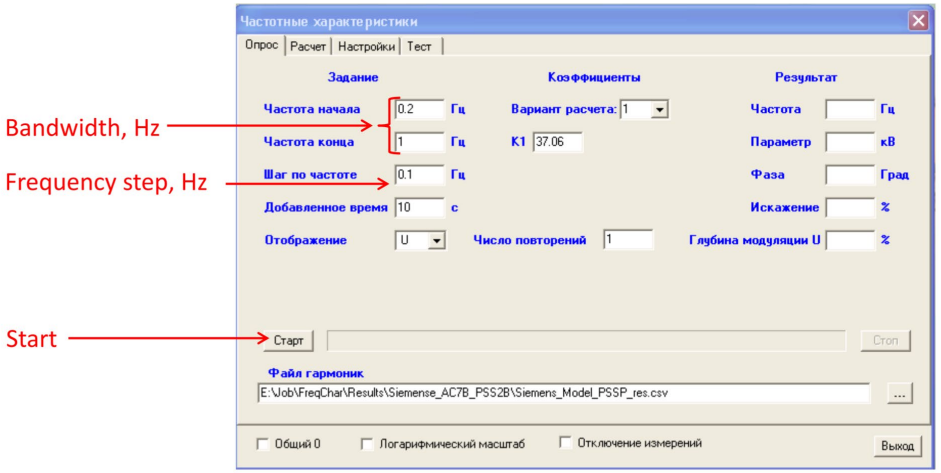
Method description

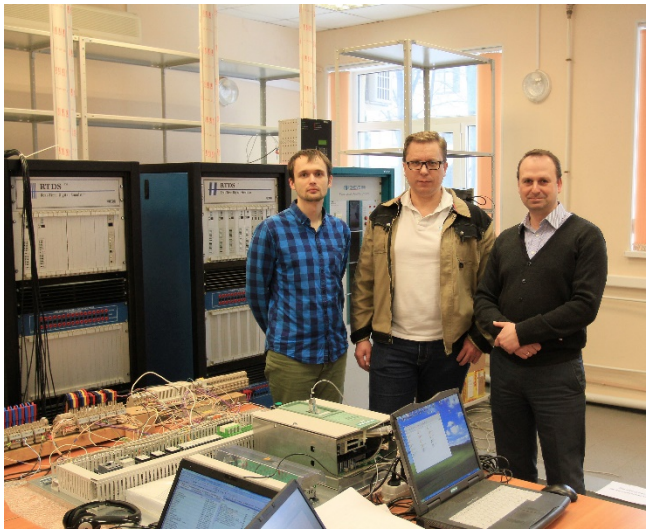


Stand layout for obtaining experimental frequency characteristics



FreqChar software interface

- The method was developed in 2013;
- No special AVR preparation is required;
- Imitation of connection to real equipment;



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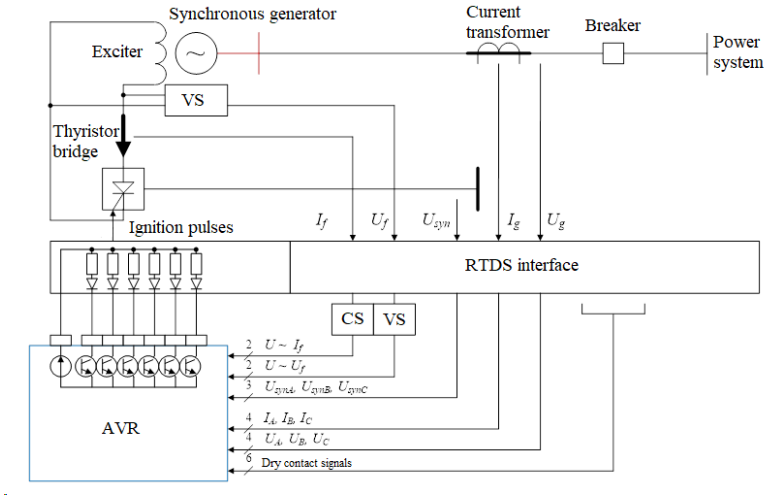
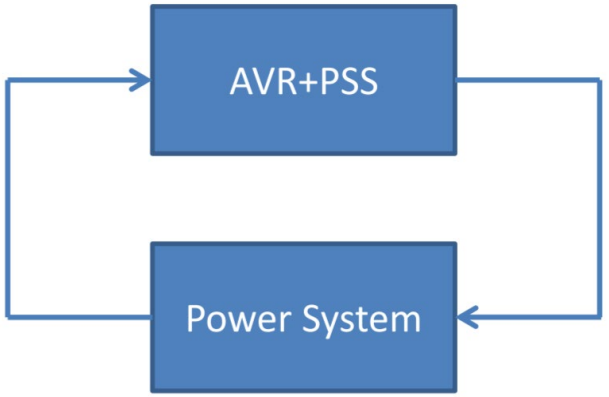
Method description

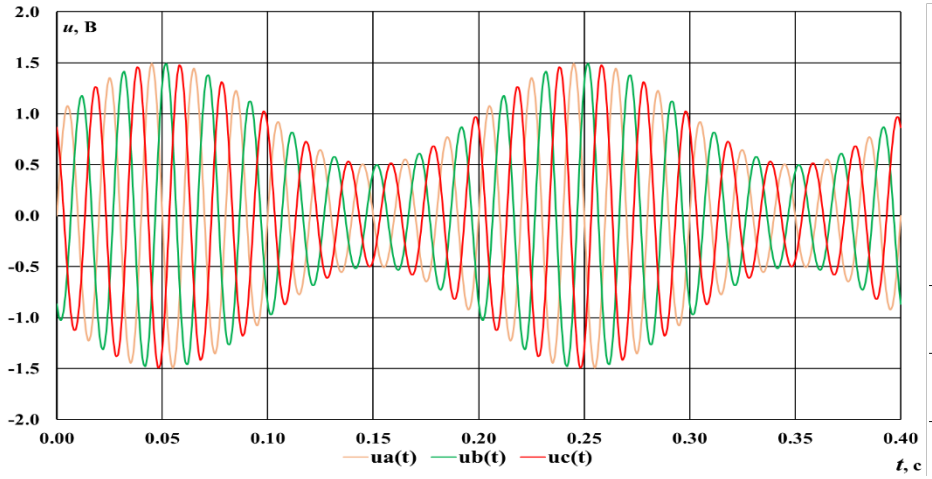
Example of automatic regulator connection scheme



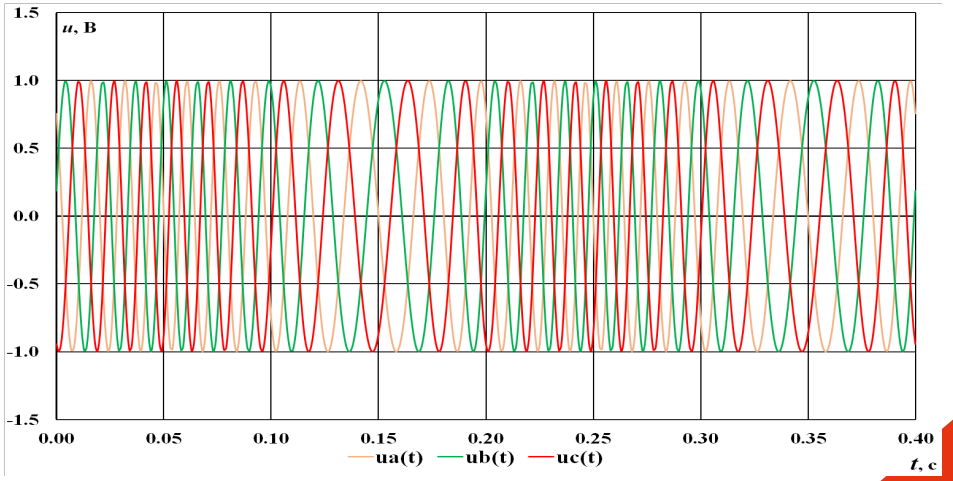
Close-loop system



Voltage amplitude modulation



AVR input signal during voltage amplitude modulation



AVR input signal during frequency amplitude modulation

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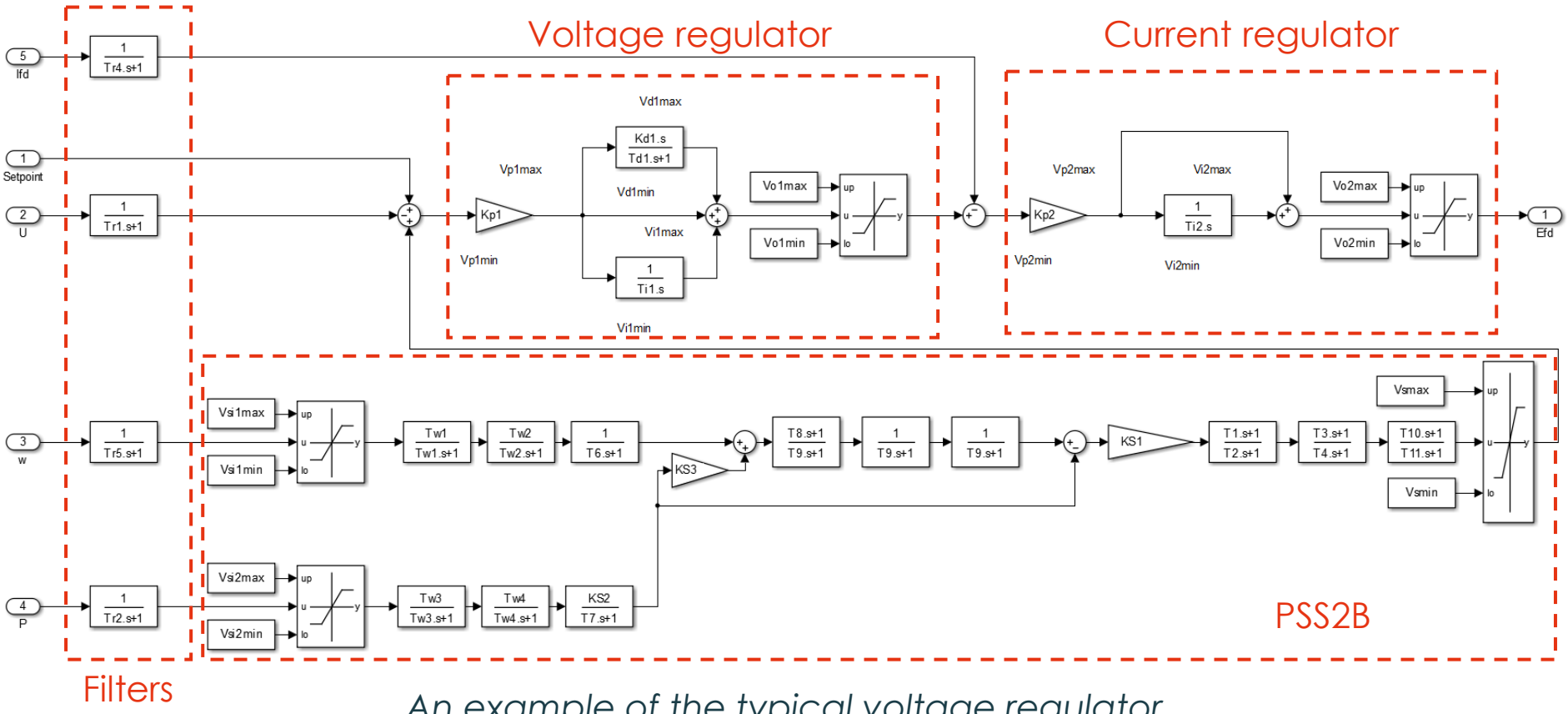

An example of the typical voltage regulator

- In most of voltage regulators PSS can not work without AVR ;
- This method accounts for this fact. Thus, frequency characteristics can be obtained for simultaneously operating channels.

Method description

RTDS model consists of:

- The simplest model of an electrical power system;
- Thyristor independent excitation system for synchronous generator;

Model features :

- Synchronous generator rotor speed and angle are independent variables;
- No saturation of the synchronous generator;
- Ability to change voltage and frequency of a slack bus according to given pattern;
- Lumped transmission line model is used.

Experience of using the method: several years of working with foreign and domestic models of regulators.

Experience

How the technique works :

Comparison of the frequency response (FR) and phase response (PR) of a live AVR model and its mathematical models: the one provided by the manufacturer and the one obtained according to the methodology developed by JSC «STC UPS».

The quality assessment of the mathematical model is performed based on the error evaluation:

$$\varepsilon_i = \frac{|\Delta r_i| + |r_i \cdot \Delta\varphi_i|}{r_{max}} \cdot 100\%$$

A mathematical model is recognized as verified if the error does not exceed 10% for each point of the experimental frequency characteristics.

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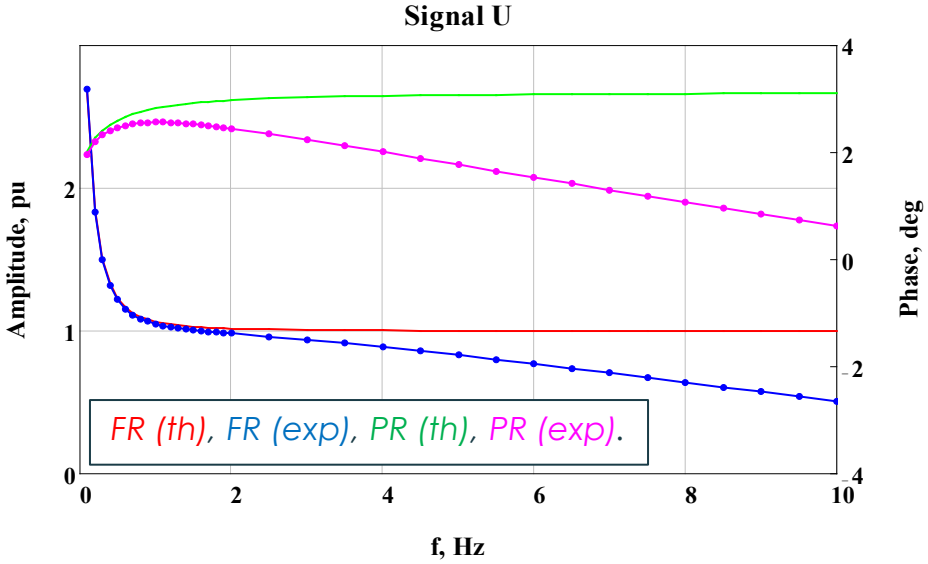
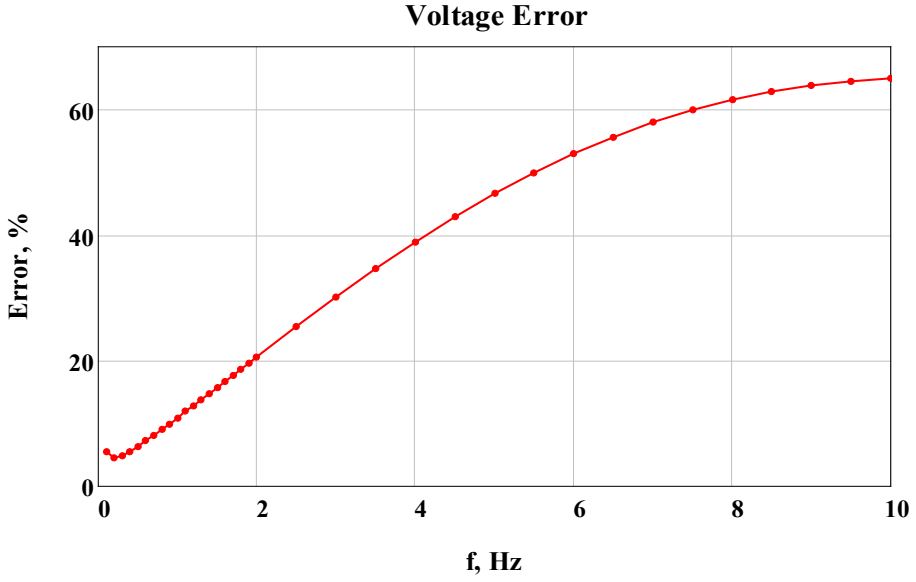
Some practical results

Before *the correction*





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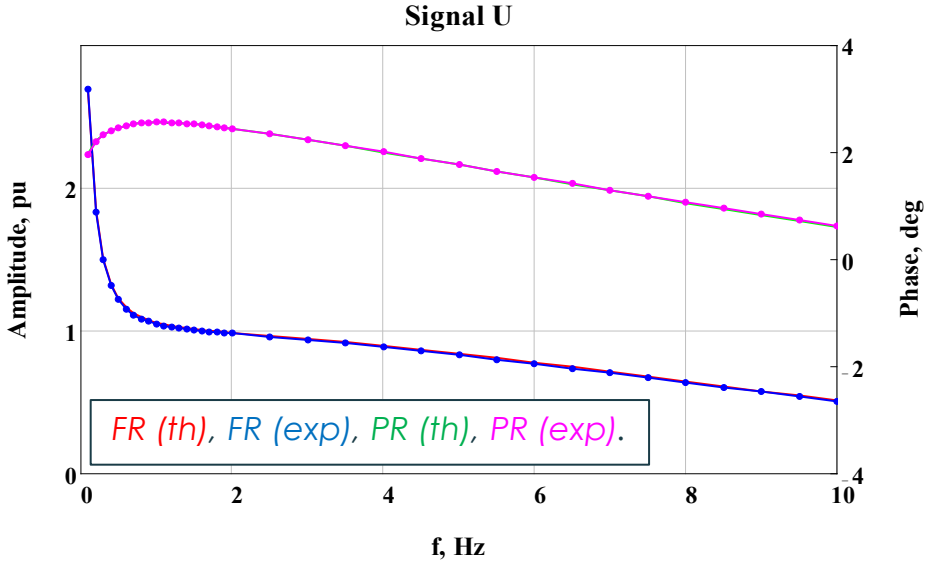

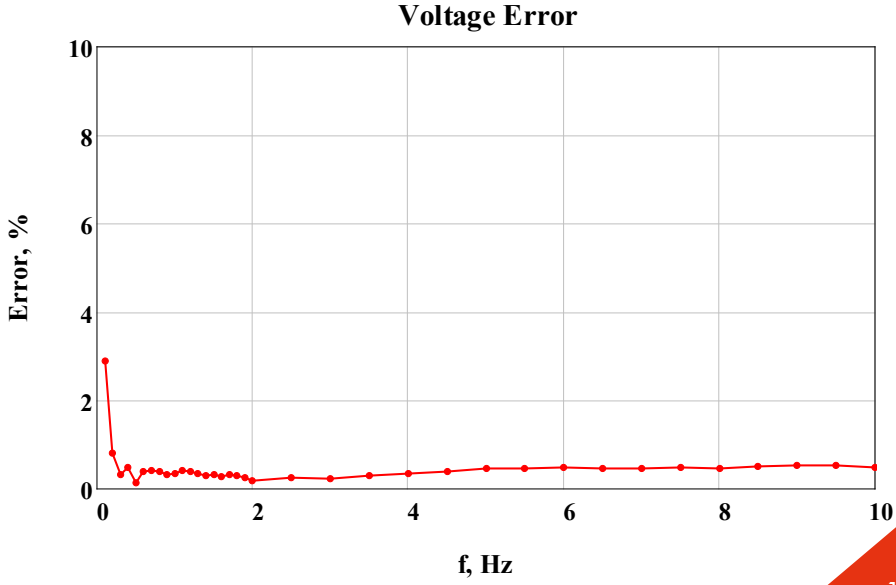

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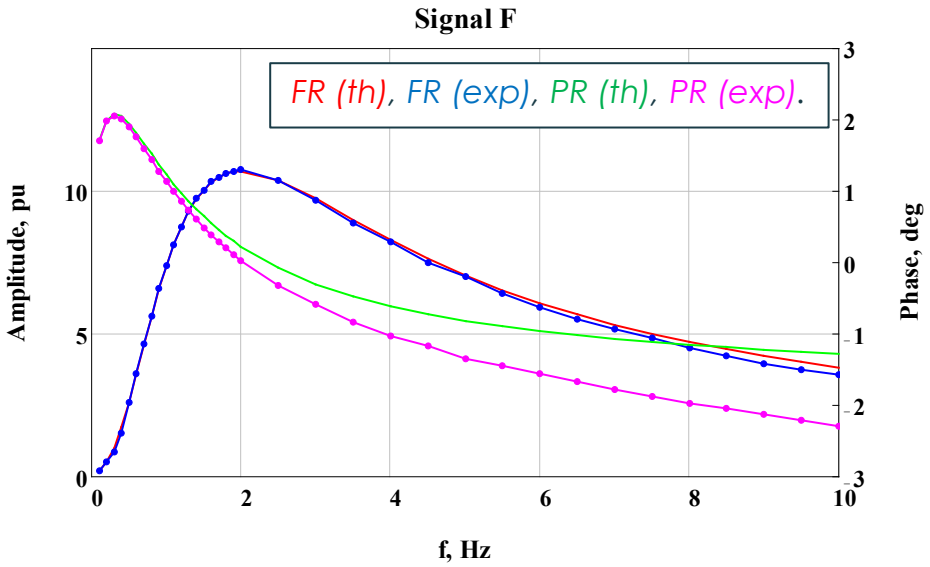

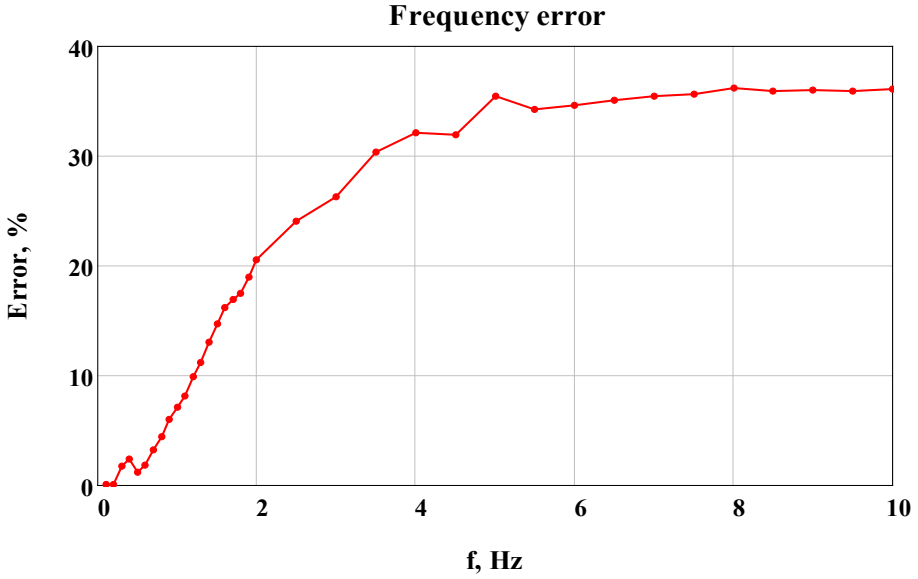

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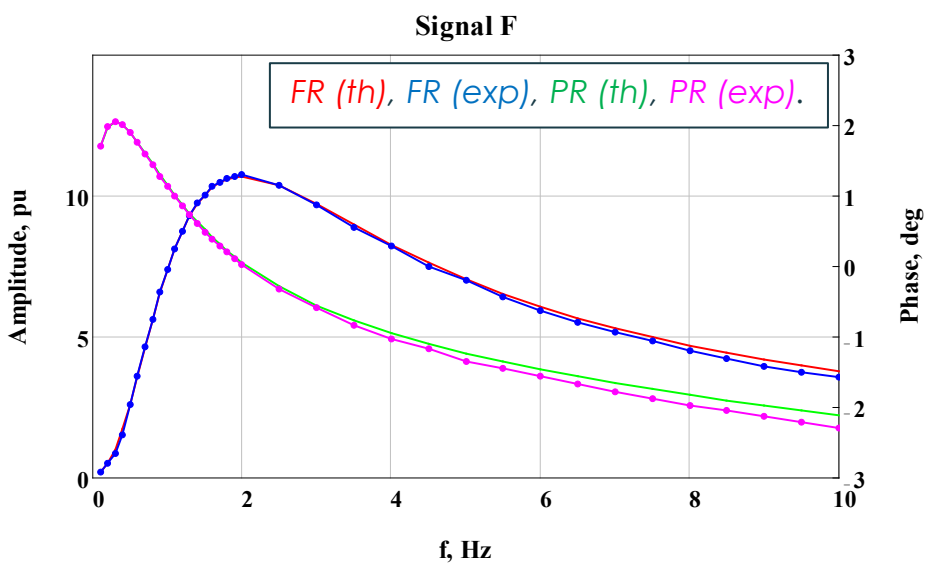

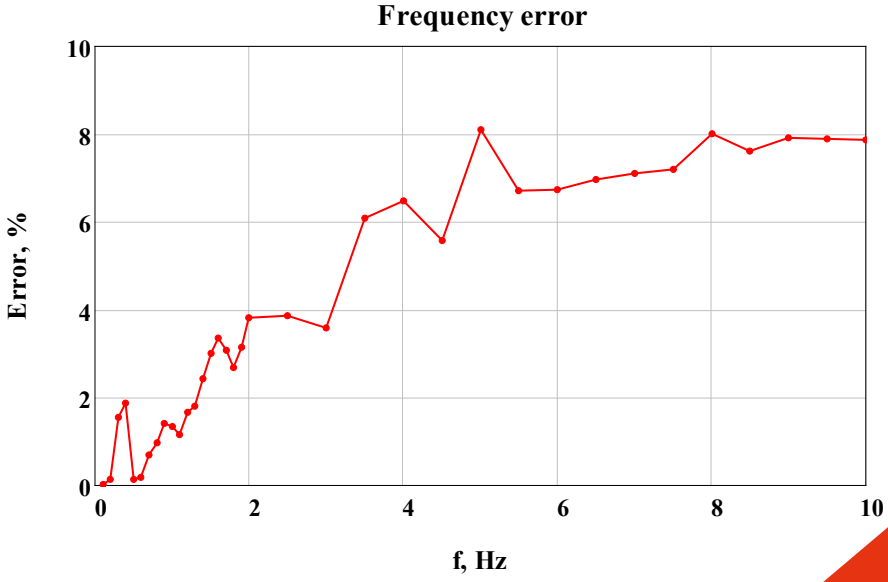

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Some practical results

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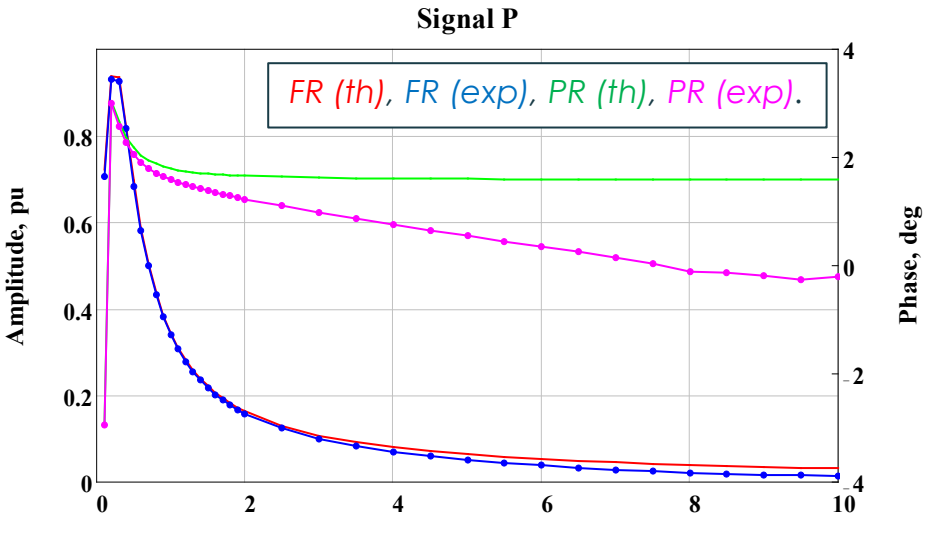

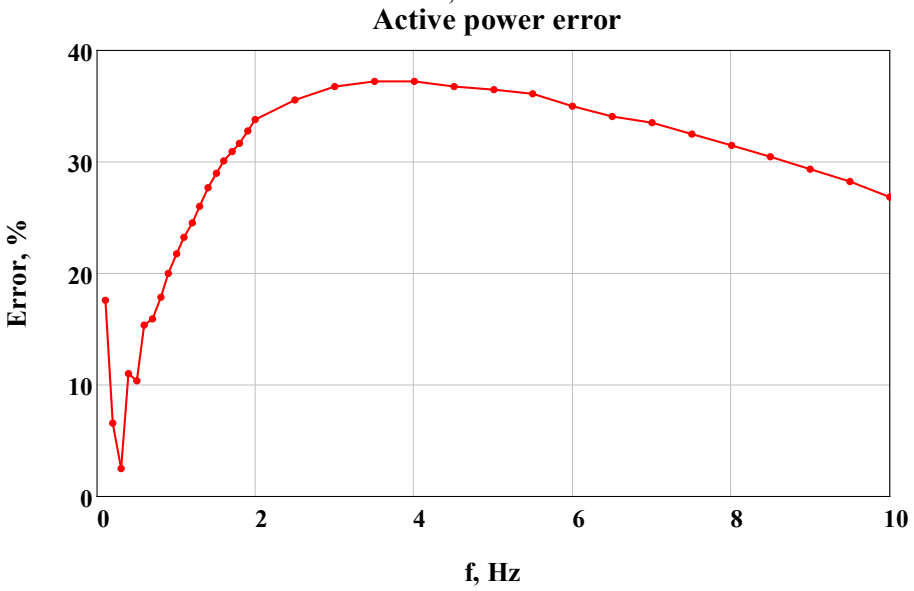

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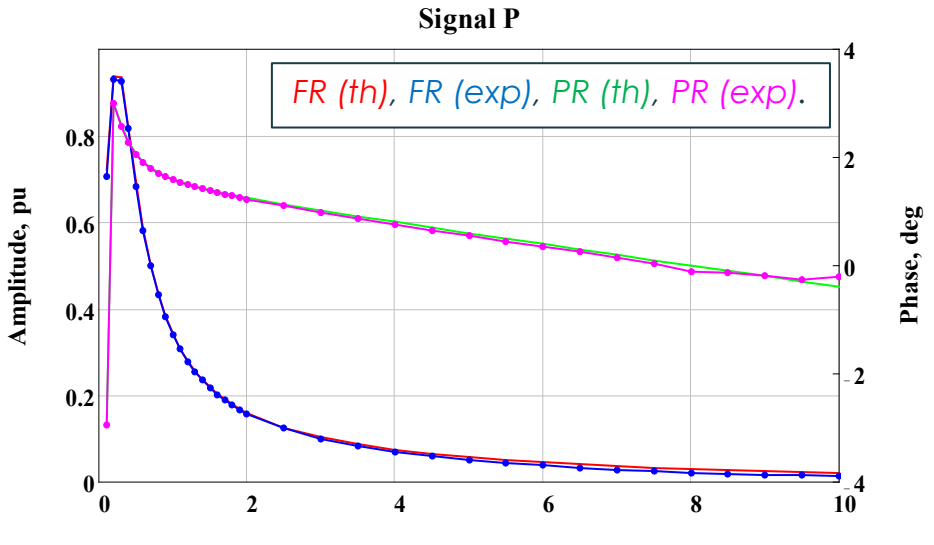
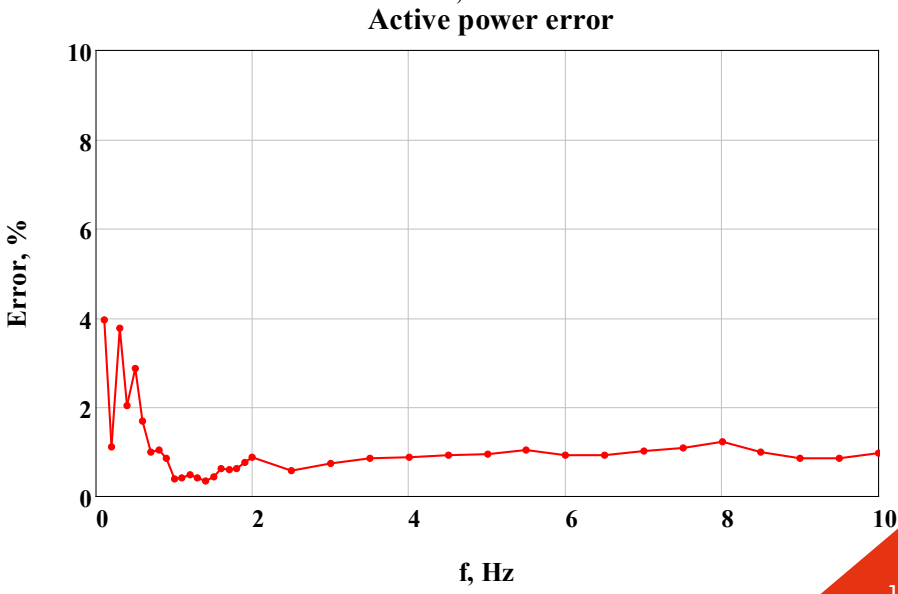




Some practical results

Error assessment

Chanel	Frequency range in which the error does not exceed 10%				
	Initial model				After correction
	Reg. 1	Reg. 2	Reg. 3	Reg. 4	
Voltage	0 – 1 Hz	0 – 2.5 Hz	non	0 – 10 Hz	0 – 10 Hz
Frequency	0 – 1.2 Hz	0 – 0.7 Hz	non	0 – 1.5 Hz	0 – 10 Hz
Active power	0.2 – 0.5 Hz	0 – 0.5 Hz	non	non	0 – 10 Hz
Excitation current	0.2 – 2 Hz	0 – 2 Hz			0 – 10 Hz

The main reason for inaccuracies in the mathematical model – the characteristics of the meter models are not considered.

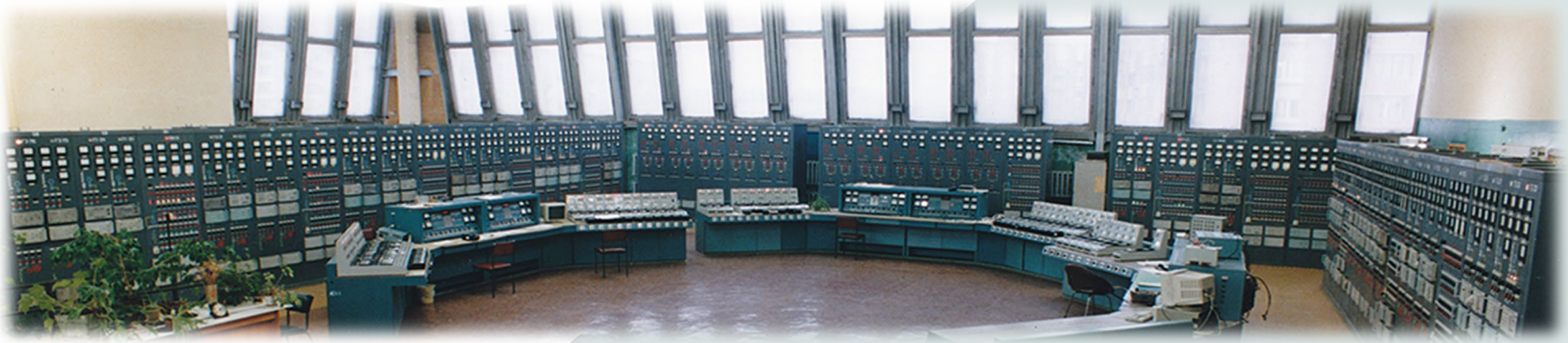
IEEE Std 421.5-2016
IEEE Recommended Practice for Excitation System Models for Power System Stability Studies

The models themselves do not allow for regulator modulation as a function of system frequency, an inherent characteristic of some older excitation systems. The models are valid for frequency deviations of ±5% from rated frequency and oscillation frequencies up to about 3 Hz.

Conclusion

Main results:

- Initial mathematical models can not be used;
- The use of the described methodology developed by JSC «STC UPS» with the help of RTDS technologies allows obtaining reliable frequency characteristics for further use;
- The use of RTDS provides many advantages, namely, it allows you to completely get rid of a wide variety of nonlinear physical properties;
- Many years of experience in using the method for adjusting mathematical models of domestic and foreign equipment indicate its efficiency.



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Conclusion

Certification and device testings in JSC «STC UPS» with the help of RTDS

Automatic load shedding	**Power swing protection**	**Overfrequency protection systems**
Automatic voltage regulator	**Phasor measurement units**	**Overload protection systems**
Automatic Transfer Switch	**Automatics of power station unloading**	**Group controller of active power**

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Thank you for your attention!