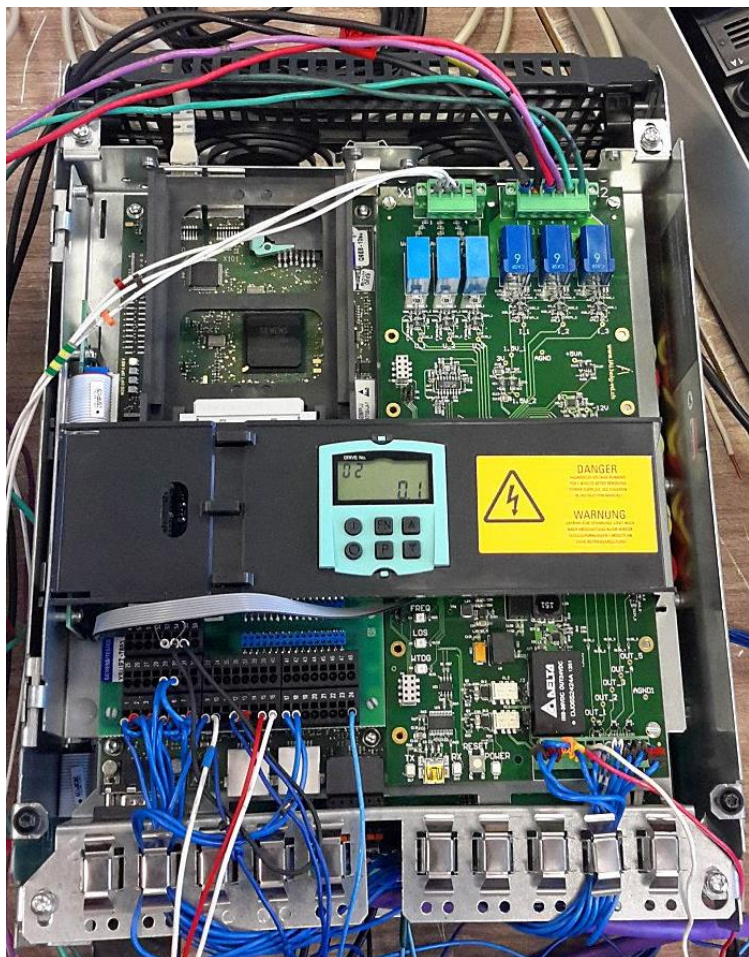


AVR and PSS digital models verification experience using frequency responses obtained by RTDS

Zelenin A.S., Gurikov O.V.,
Kabanov D.A., Eliseev A.A.,
Sulchakova A.Y., Gerasimov D.A.

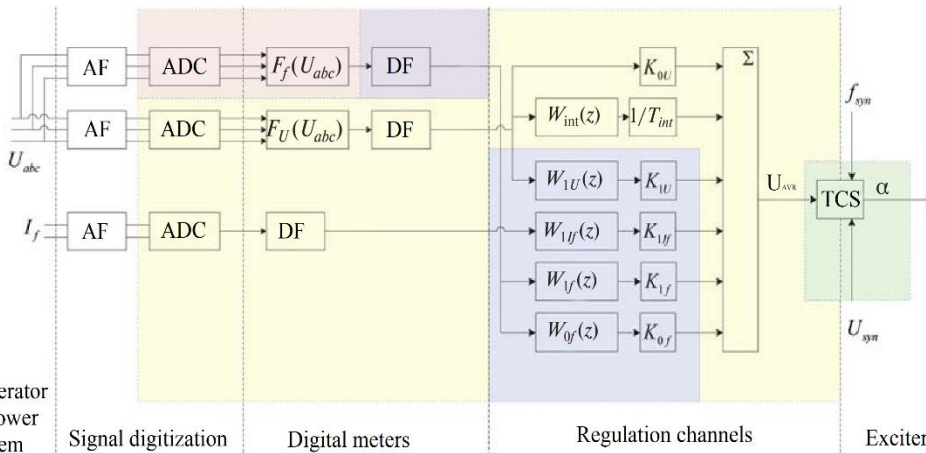
St. Petersburg, 2020





Automatic voltage regulators in JSC "STC UES"

Problem statement



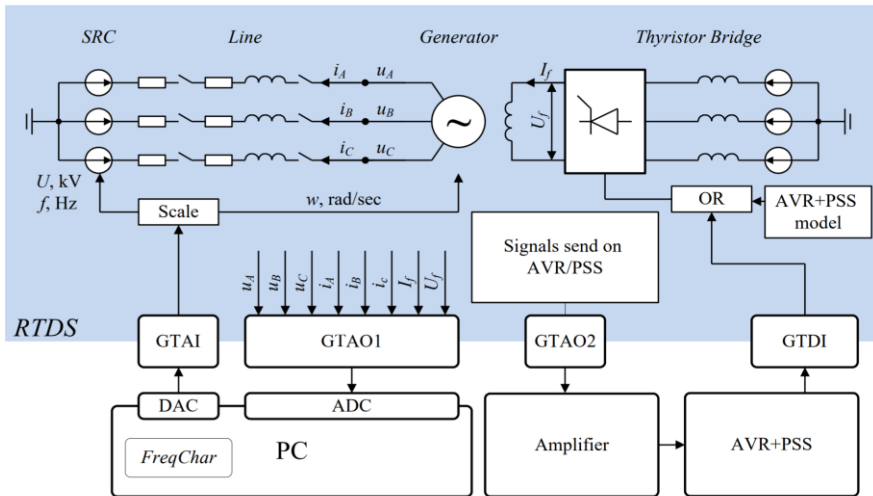
Schematic diagram of AVR

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

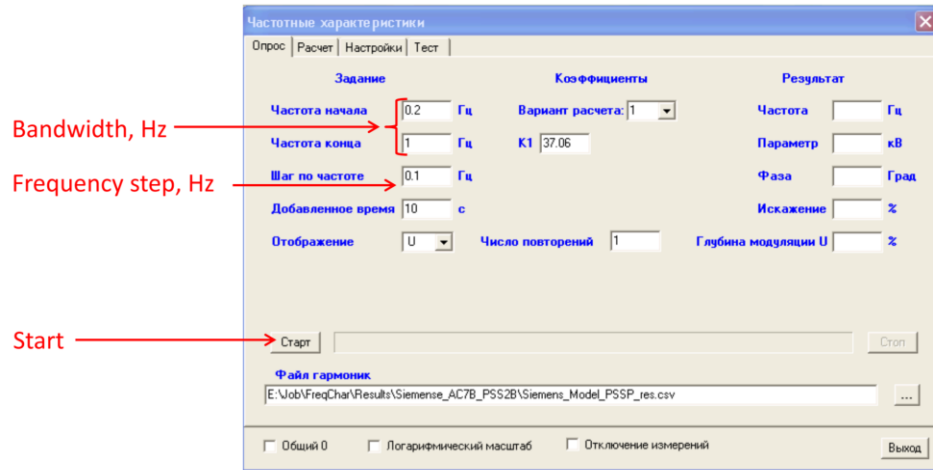
- At the moment, the verification of mathematical models of automatic voltage regulators is carried out on the basis of data provided by the developers of ARV;
- Provided data requires verification;
- The assessment of the correctness of the mathematical model of AVR is performed according to the results 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»;
- The described method allows correction the mathematical models of a regulator.

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

Method description



Stand layout for obtaining experimental frequency characteristics



Bandwidth, Hz
 Frequency step, Hz
 Start

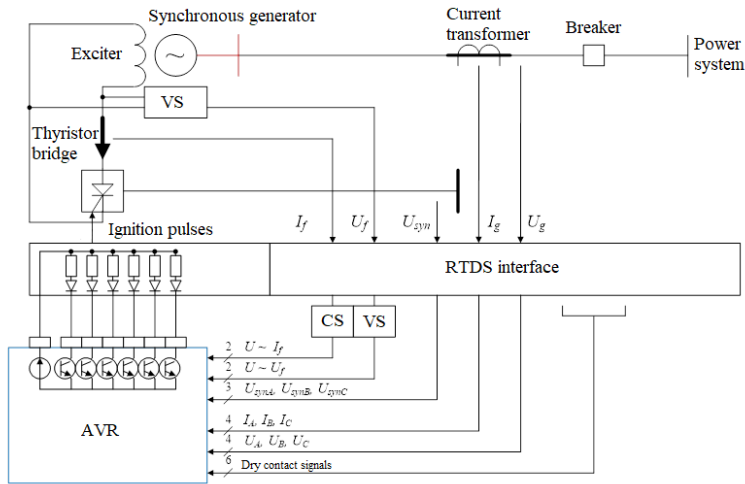
FreqChar software interface

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

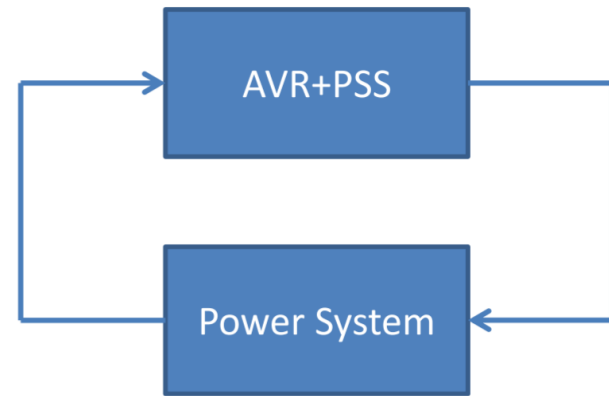


Method description

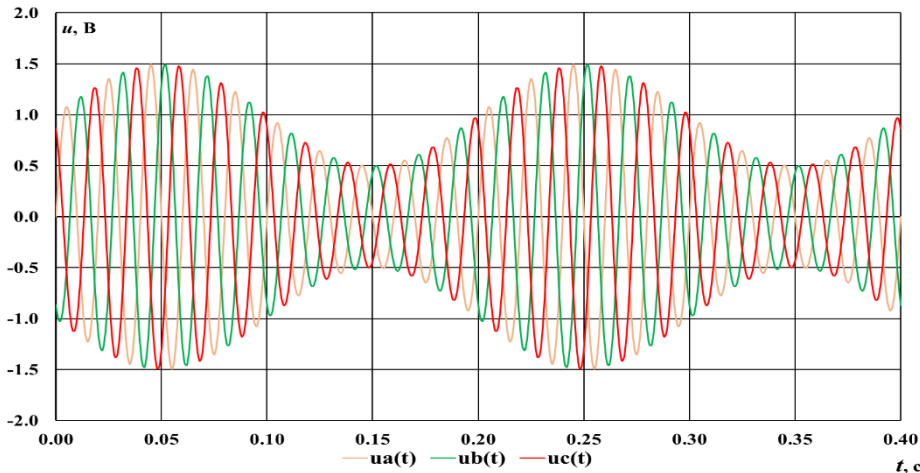
Example of automatic regulator connection scheme



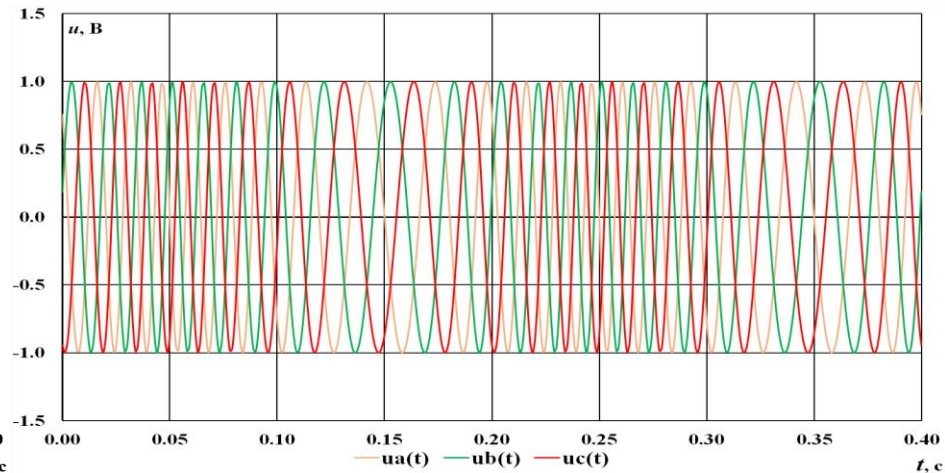
Close-loop system



Voltage amplitude modulation

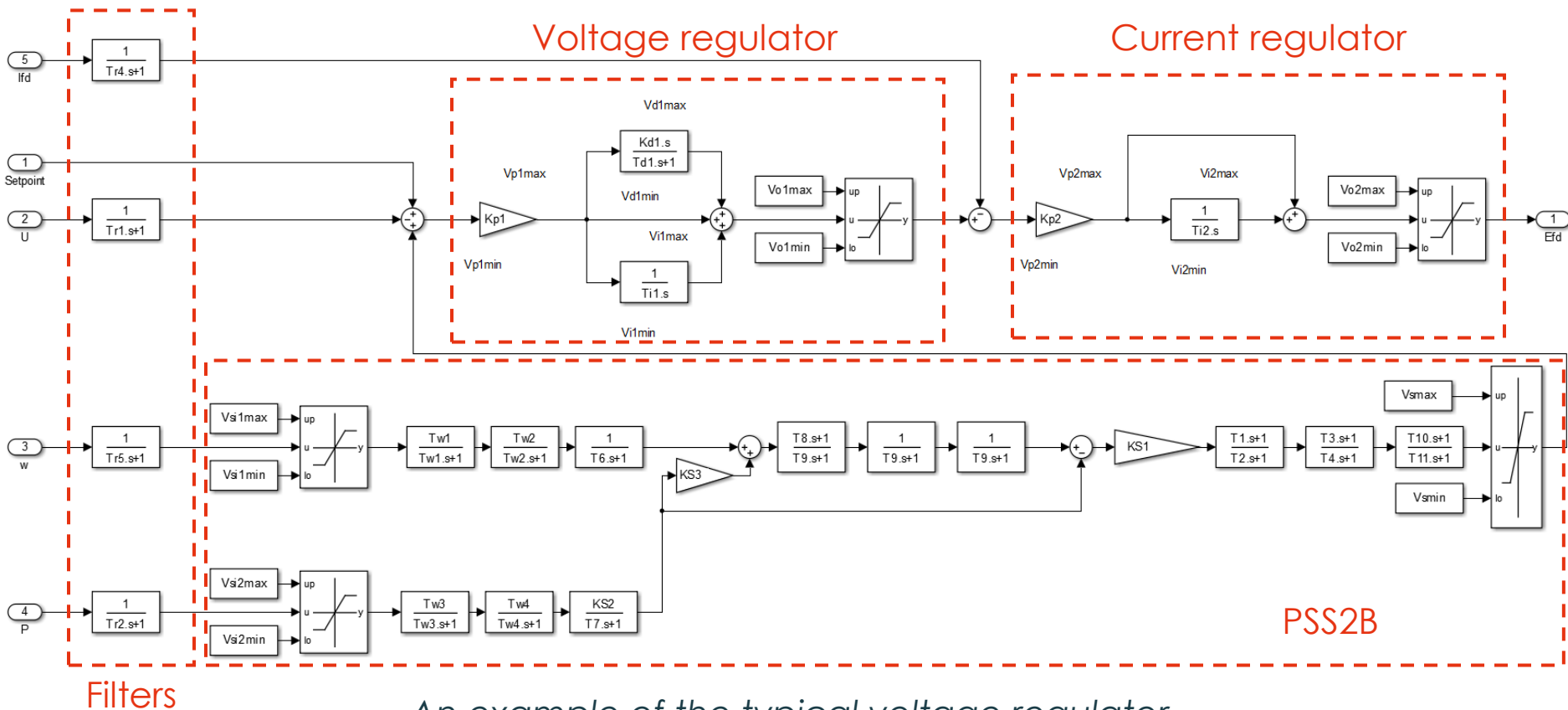


AVR input signal during voltage amplitude modulation



AVR input signal during frequency amplitude modulation

Method description



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.

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.

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:

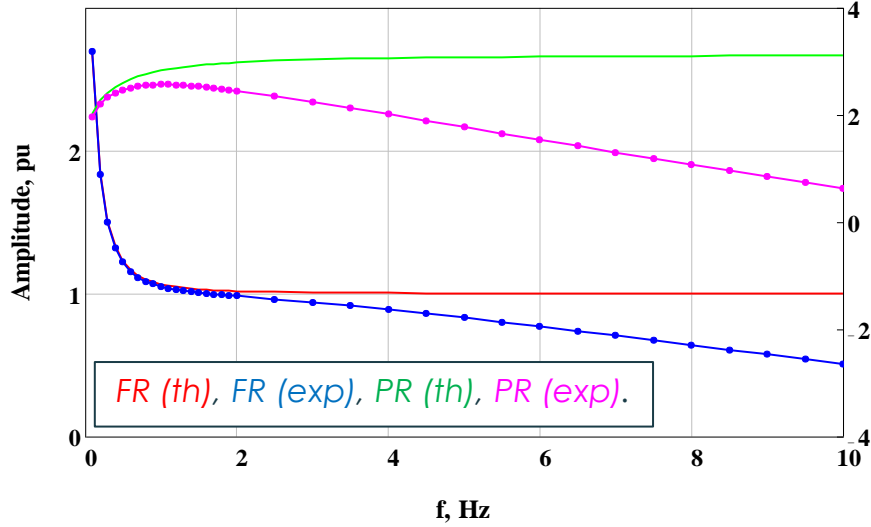
$$\varepsilon_i = \frac{|\Delta r_i| + |r_i \cdot \Delta \varphi_i|}{r_{max}} \cdot 100\%$$

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

Some practical results

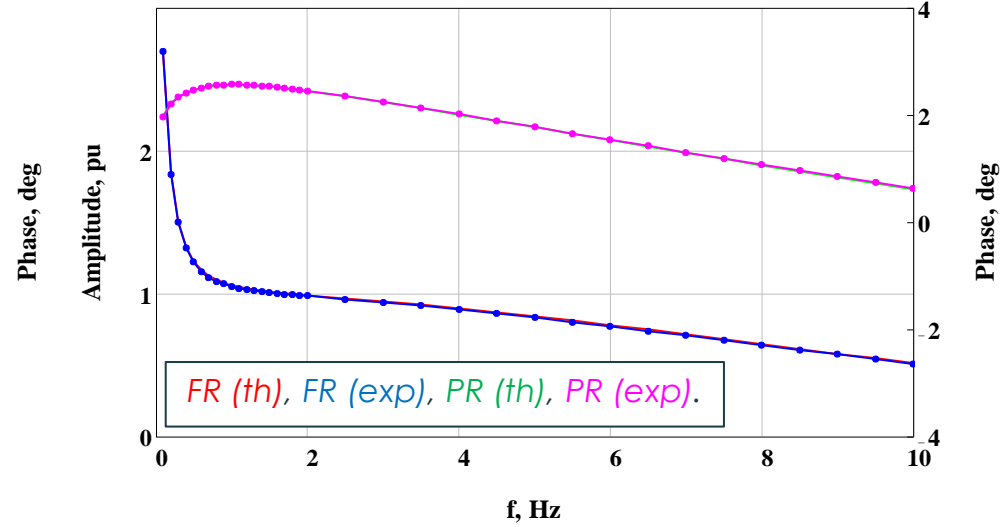
Before the correction

Signal U

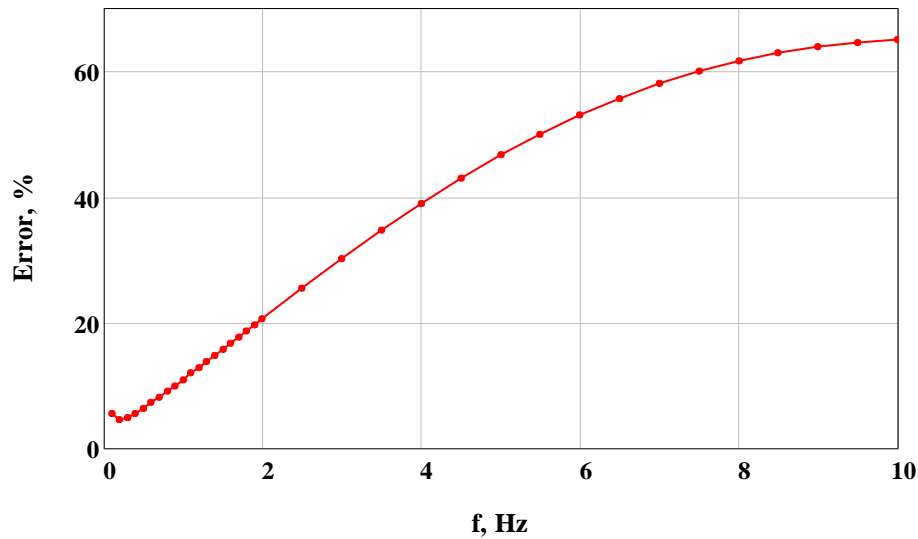


After the correction

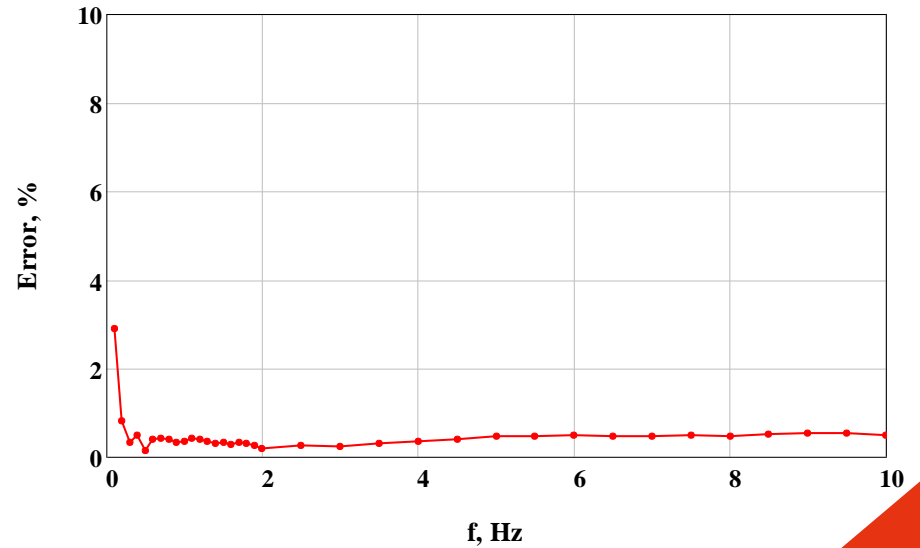
Signal U



Voltage Error



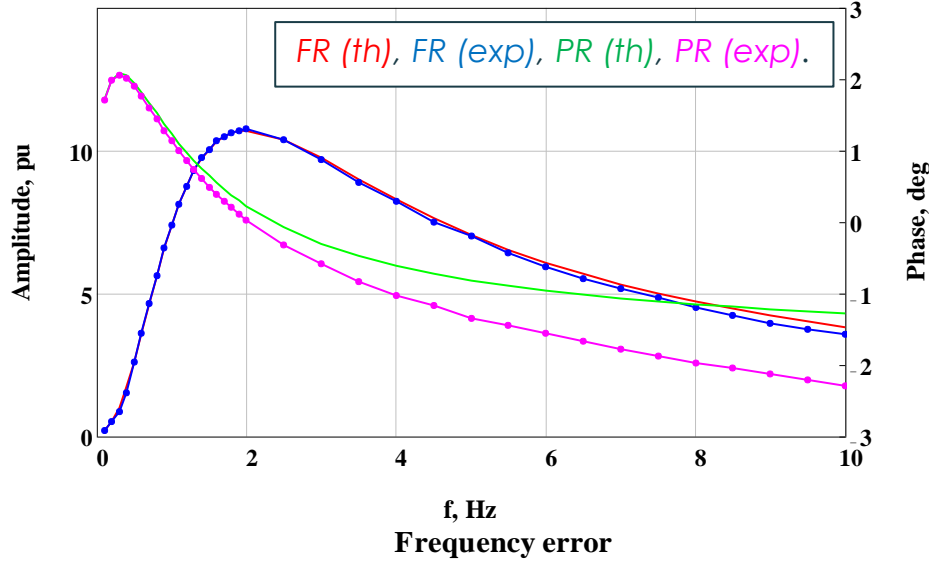
Voltage Error



Some practical results

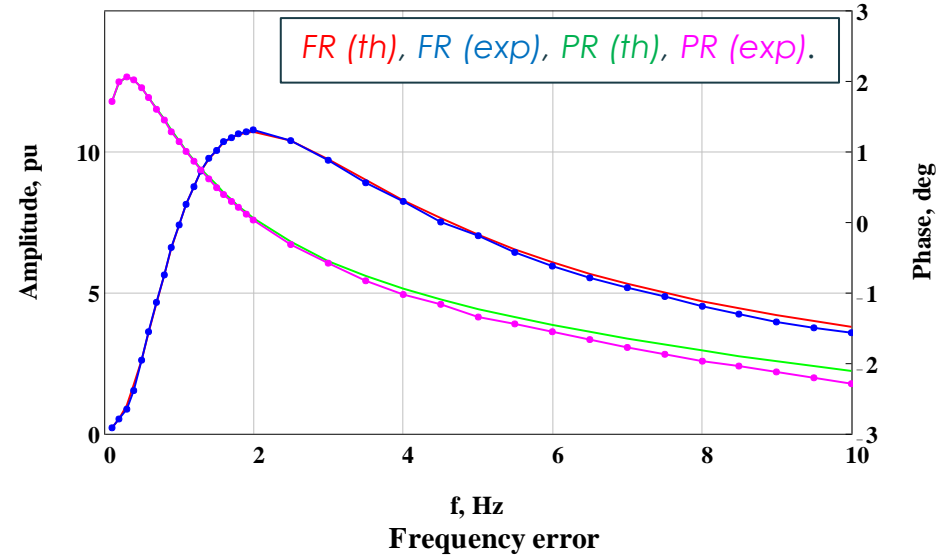
Before the correction

Signal F

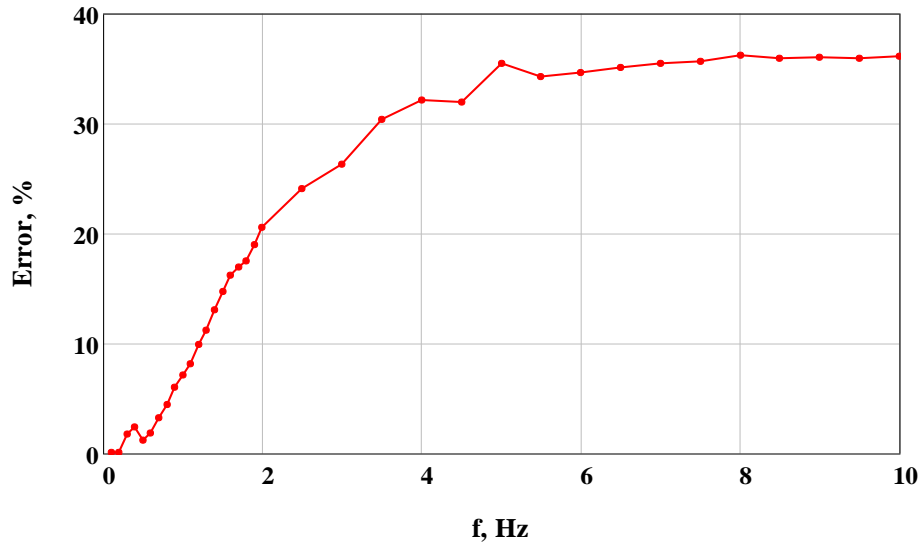


After the correction

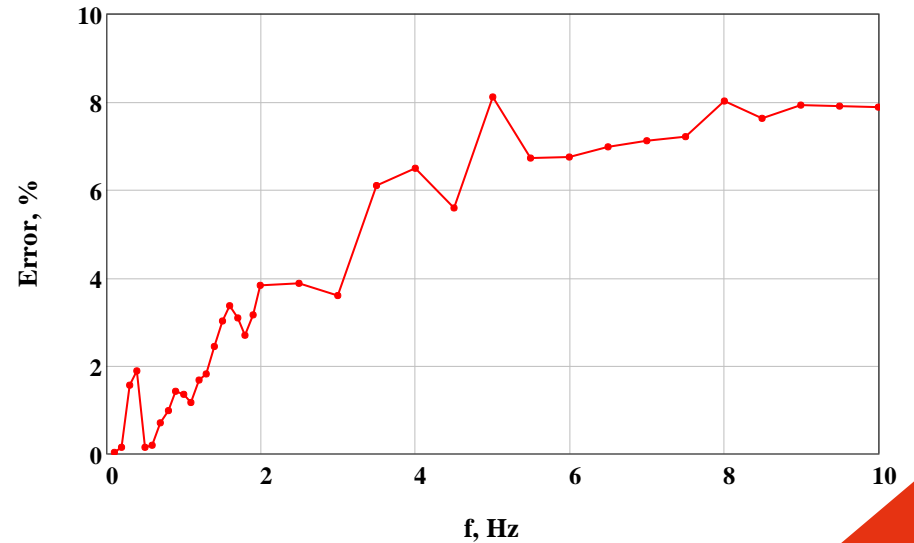
Signal F



f, Hz
Frequency error



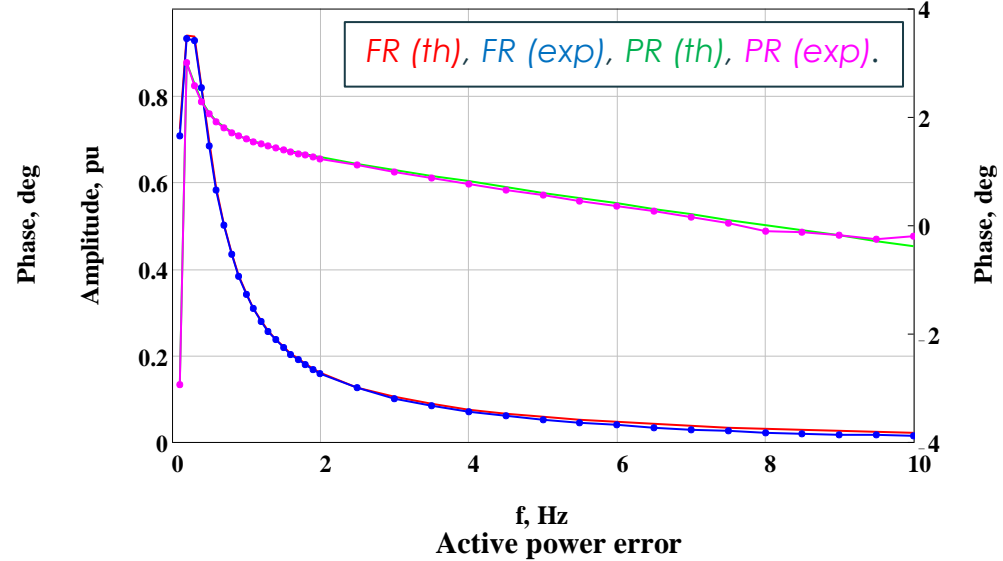
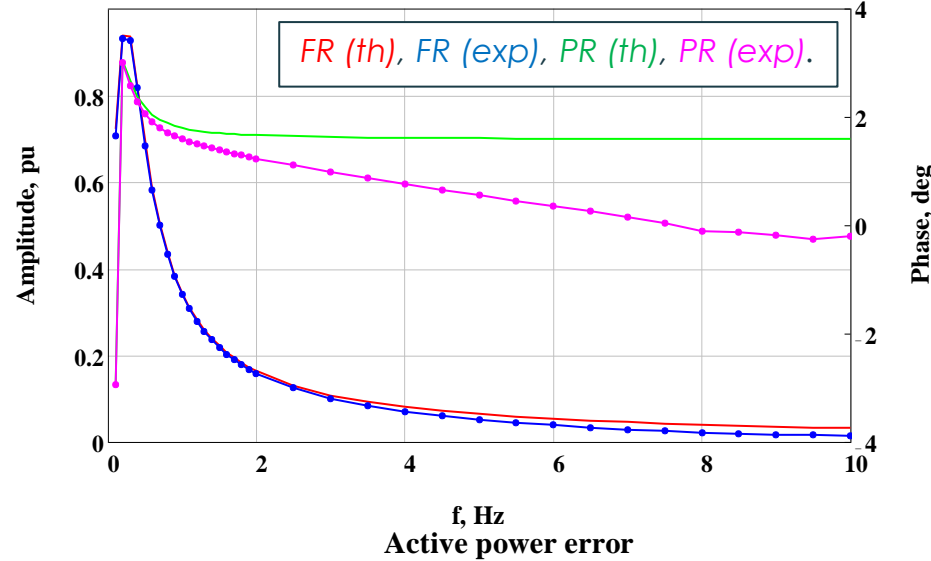
f, Hz
Frequency error



Some practical results

Before the correction
Signal P

After the correction
Signal P



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 $\pm 5\%$ from rated frequency and oscillation frequencies up to about 3 Hz.**

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**.



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



Full name of organization:

Joint Stock Company

«Scientific and Technical Center of Unified Power System»

(JSC «STC UPS»)

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Thank you for your attention!

