SAVR

Automatic Secondary Regulation of Voltage and Usage of Reactive Power

EGÚ Praha Engineering,a.s.

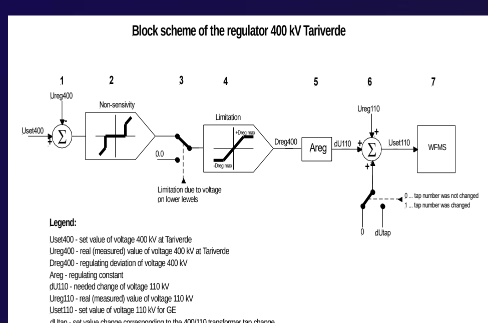
Podnikatelská Str. 539, 190 11 Praha 9 – Běchovice
Phone: + 420 603 247 976, e-mail: egu@egu-prg.cz

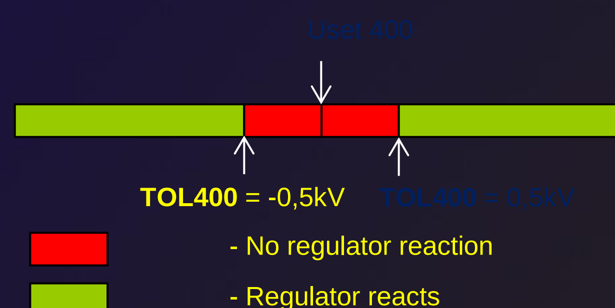
www.egu-prg.cz

Within the scope of company´s activites in the field of **System and Ancillary Services** in the Power Sector there is a dominant know-how and technical ability in the field of **Renewable Energy Sources – RES**. This covers the development and application of methodologies and algorithms, SW and HW systems and technical tools for the regulation of the power network parameters - **voltage and reactive power of the systems** - **at all nominal voltage levels**.

Characteristic products:

- **SAVR** - Automatic System of Voltage and Reactive Power Control
- **ARN** - Automatic Voltage Controller
- **SRU** - Group Voltage Controller
- Dynamic models of Transients in Power Networks
- Verification model for sensitivity analyses
- Analyses and Dynamic Models of "Island"





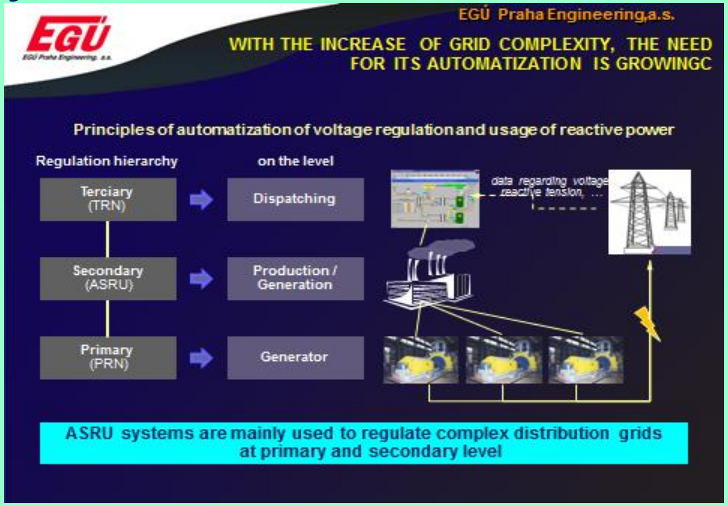
REGULATION OF VOLTAGE AND REACTIVE POWER

Automatic voltage regulation and reactive power system SAVR

The SAVR system is a set of hardware and software tools that make it possible to achieve the desired benefits in the controlled power system. The regulatory activity itself can be provided by means of these following devices (called action members):

- **Generators of all types of power plants**
- **Compensation devices - static and rotary compensators, power reactors**
- **Transformers**

It can be generally said the systems of U and Q control are mainly designed in a three-level hierarchy



REGULATION OF VOLTAGE AND REACTIVE POWER

WHY AN AUTOMATIC SYSTEM OF U AND Q REGULATION – SEE THE ACCENT ON THE EXPECTED BENEFITS OF U AND Q CONTROL

- Increased safety of the operation of the regulated power system
- Increasing the efficiency of operation of the regulated power system /reducing technical losses/
- Improving the quality of electricity supply to the end customer
- Compliance with the tolerance values of reactive power flow agreed with the neighboring power system
- Elimination of the negative reverse effect of the wind and photovoltaic power plants on the regulated power system
- Elimination of the reverse effect of industrial wholesale customers on the regulated power system
- Reduction of the claims on the dispatcher of the regulated power system
- Elimination of reactive power dragging of the electrically close generators

THE MORE COMPLEX THE CONTROLLED GRID IS, THE GREATER ARE REQUIREMENTS FOR ITS REGULATION

Regulation of voltage and reactive power

Project for the ČEZ Distribution a. s.

First step: Evaluation of variants of possible ways of regulation:

regulation U

regulation Q

regulation cos phi

Selected Variant : **REGULATION U**

/ ** The cos phi control can cause a problem with network stability. Voltage and reactive power are affected by active power (Overvoltage occurrence in the system). ** Regulation Q does not help the system and regardless of system requirements, Q is constant /

Regulation of U - Coordinated cooperation of generators and transformers. Properly adjusting the tap position of the superior transformer results in reduction of overflows Q, while maintaining the operating point of the generator in the middle of the P Q diagram. There is therefore a regulatory reserve in the generator excitation system being used by the **SAVR**.

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THE MORE COMPLEX THE CONTROLLED GRID IS,
THE GREATER ARE REQUIREMENTS FOR ITS REGULATION

Regulation of voltage and reactive power

Project for the ČEZ Distribution a. s.

- **Project beginning in the year 2000 - nowadays still under continuation**
- **3 areas:**

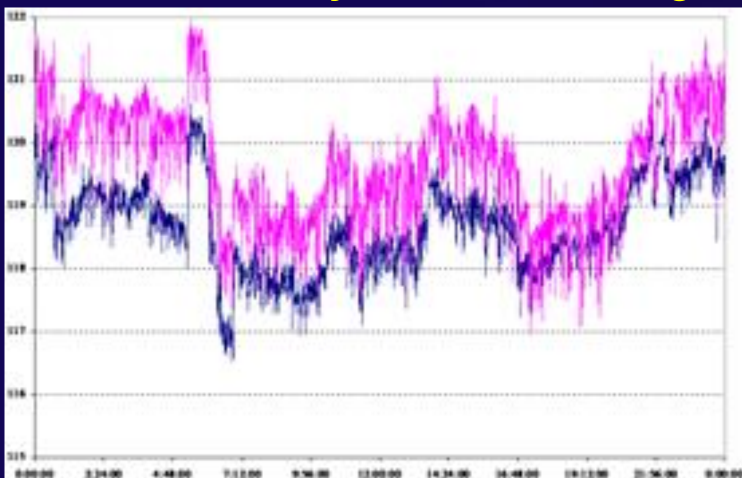
  ČEZ Střed (Central),

  ČEZ Sever (North),

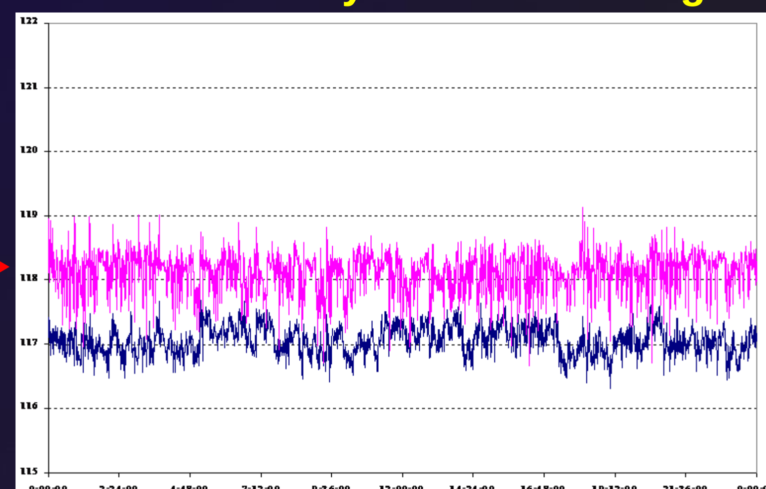
  ČEZ Morava
- **Power plants, industrial companies, renewable resources**

Voltage regulation example

Unregulated power system of 110 kV:
Record of the day course of voltage



Regulated power system of 110 kV:
Record of the day course of voltage



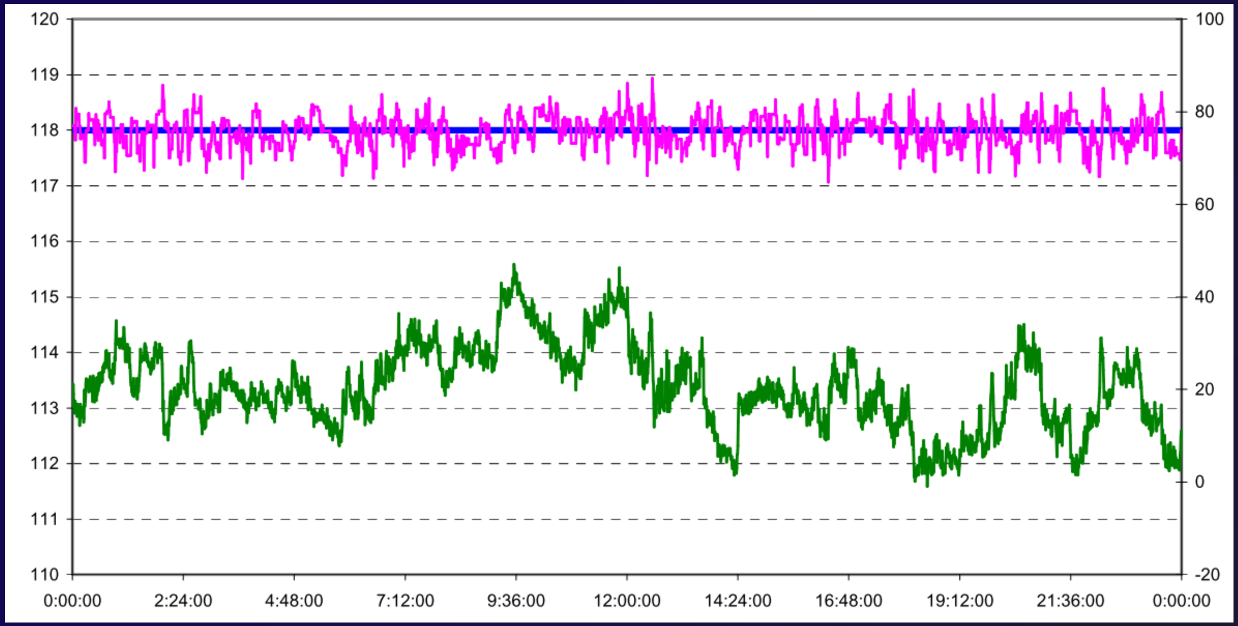
Regulatory process

Voltage regulation

Automatic maintenance of voltage

Active proposing the Q changes in order to keep the voltage within the required limits.

Record of the day course of voltage and reactive power



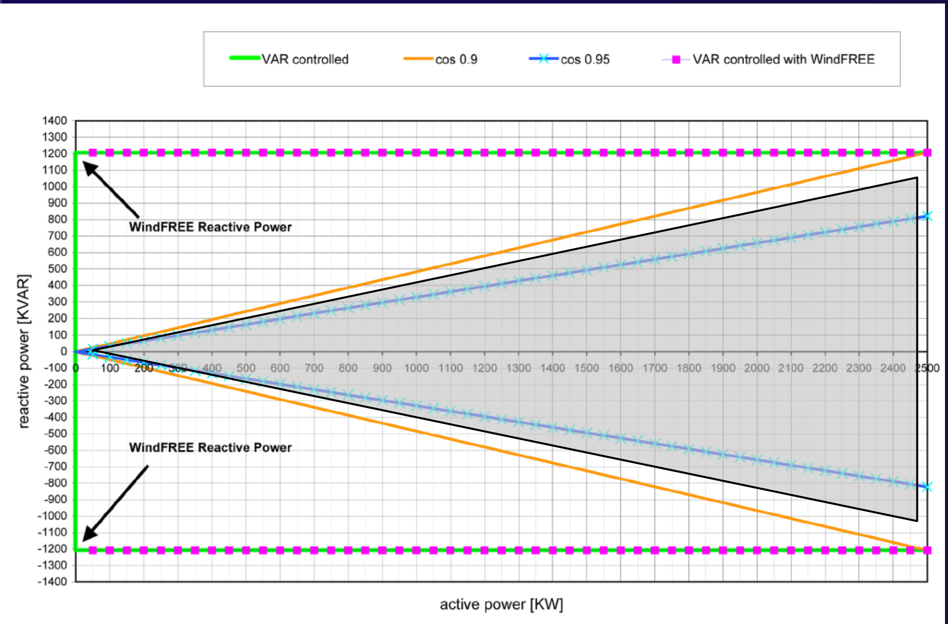
Voltage and reactive power in the system have a local character. Voltage in the individual points of the system may be different.

WITH THE INCREASE OF GRID COMPLEXITY, THE NEED FOR ITS AUTOMATIZATION IS GROWING

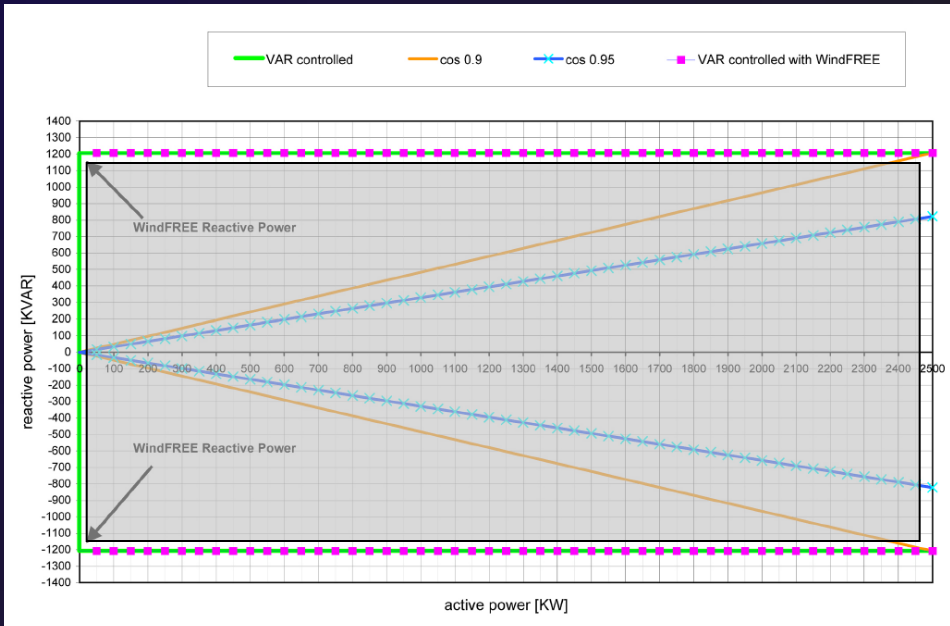
When controlling the voltage the cos Φ is not necessary to be kept

Regulation Range Enlargement for Voltage 400 kV

cos Φ



VAR controlled

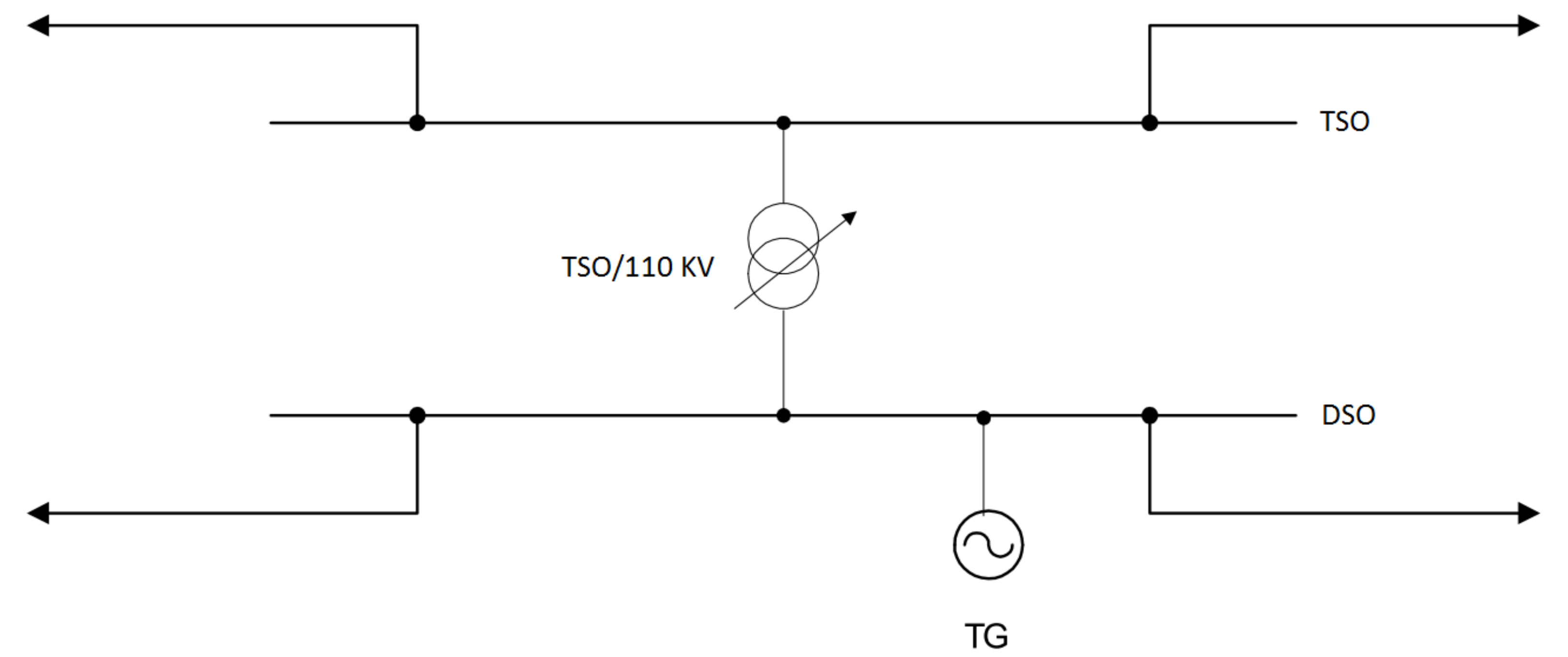


WITH THE INCREASE OF GRID COMPLEXITY, THE NEED FOR ITS AUTOMATIZATION IS GROWING

Reduction of number of switches

Decrease of number of tap changes on TS/110 kV and 110 kV/VN transformers (this saves transformers - lifetime extension, and eliminates large sudden voltage variations)

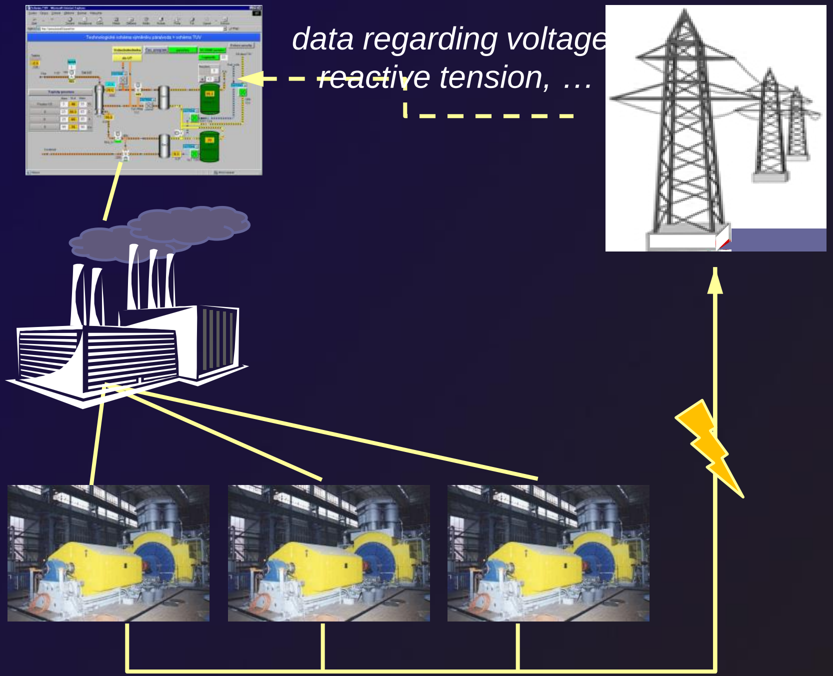
Number of regulatory steps on the transformers is with SAVR reduced. The transformer may no longer regulate the fluctuation of 110 kV voltage, but only its own voltage changes.



WITH THE INCREASE OF GRID COMPLEXITY, THE NEED FOR ITS AUTOMATIZATION IS GROWINGC

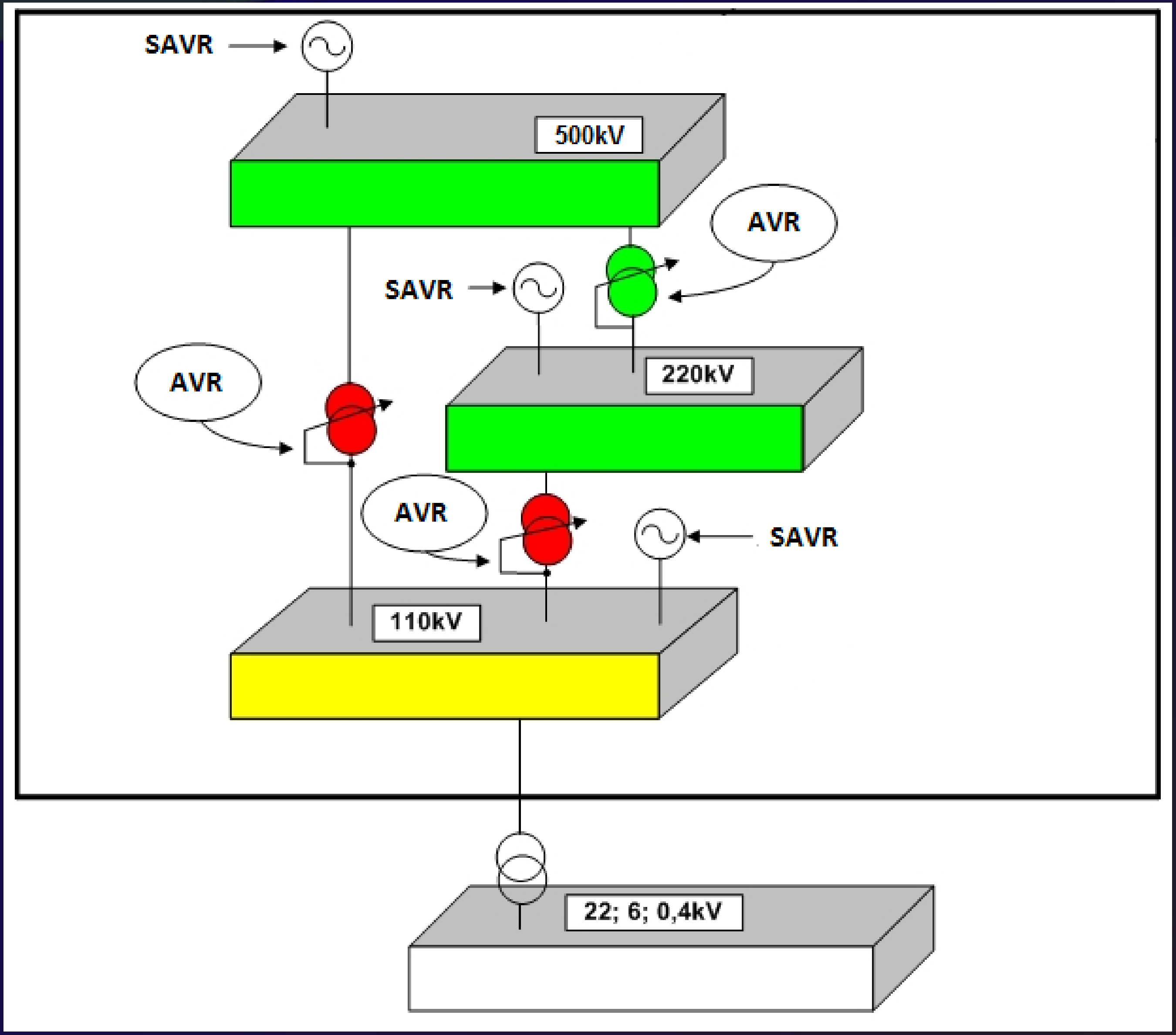
Principles of automatization of voltage regulation and usage of reactive power

Regulation hierarchy		on the level
Terciary (TRV)	⇨	**Dispatching**
Secondary (SAVR)	⇨	**Production / Generation**
Primary (AVR)	⇨	**Generator**



SAVR systems are mainly used to regulate complex distribution grids at primary and secondary level

THE MORE COMPLEX THE CONTROLLED GRID IS, THE GREATER ARE REQUIREMENTS FOR ITS REGULATION



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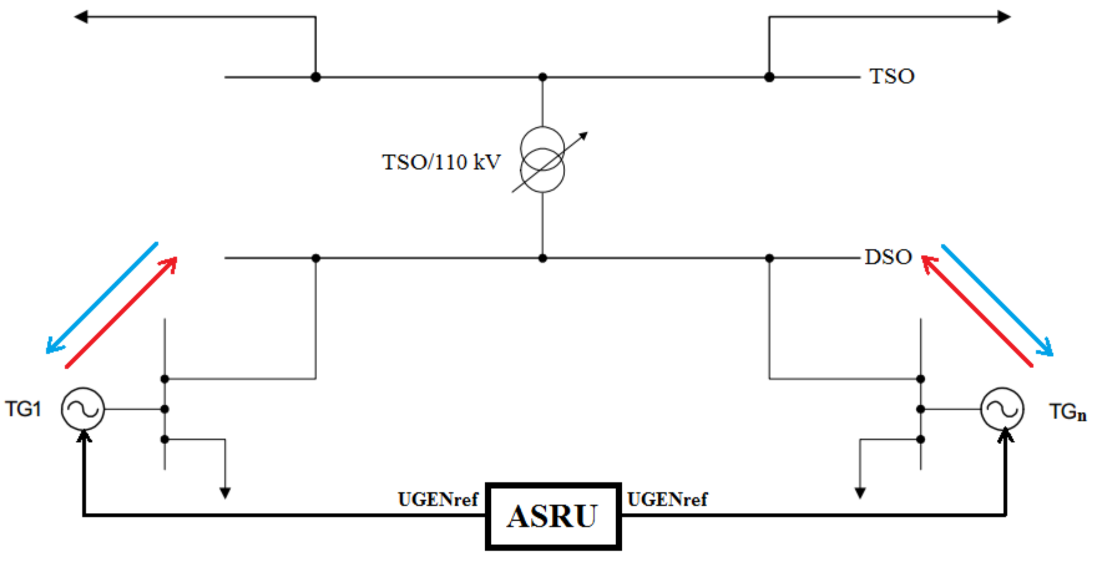
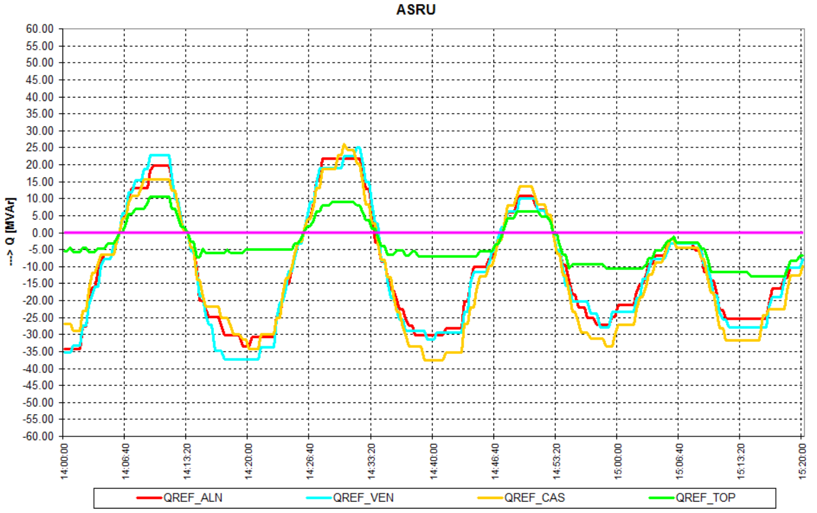
THE AUTOMATIC SECONDARY REGULATION OF VOLTAGE WILL, HOWEVER, BRING MAINLY THE TECHNICAL BENEFITS

Overview of additional benefits from implementation of SAVR

Elimination of overflows of reactive power

SAVR eliminates the overflows of reactive power



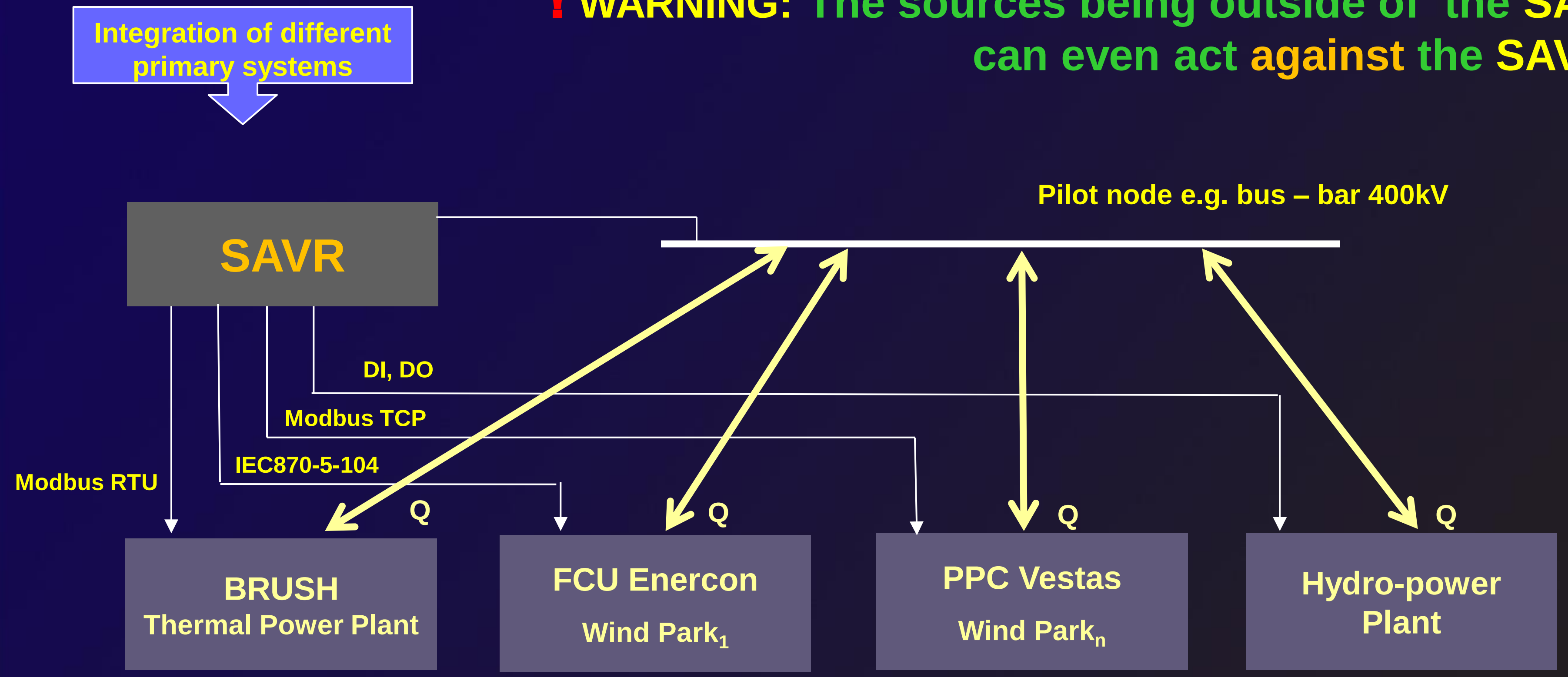


WITH THE INCREASE OF GRID COMPLEXITY, THE NEED FOR ITS AUTOMATIZATION IS GROWING

This is why: SAVR - Automatic Secondary Regulation of Voltage and Reactive Power

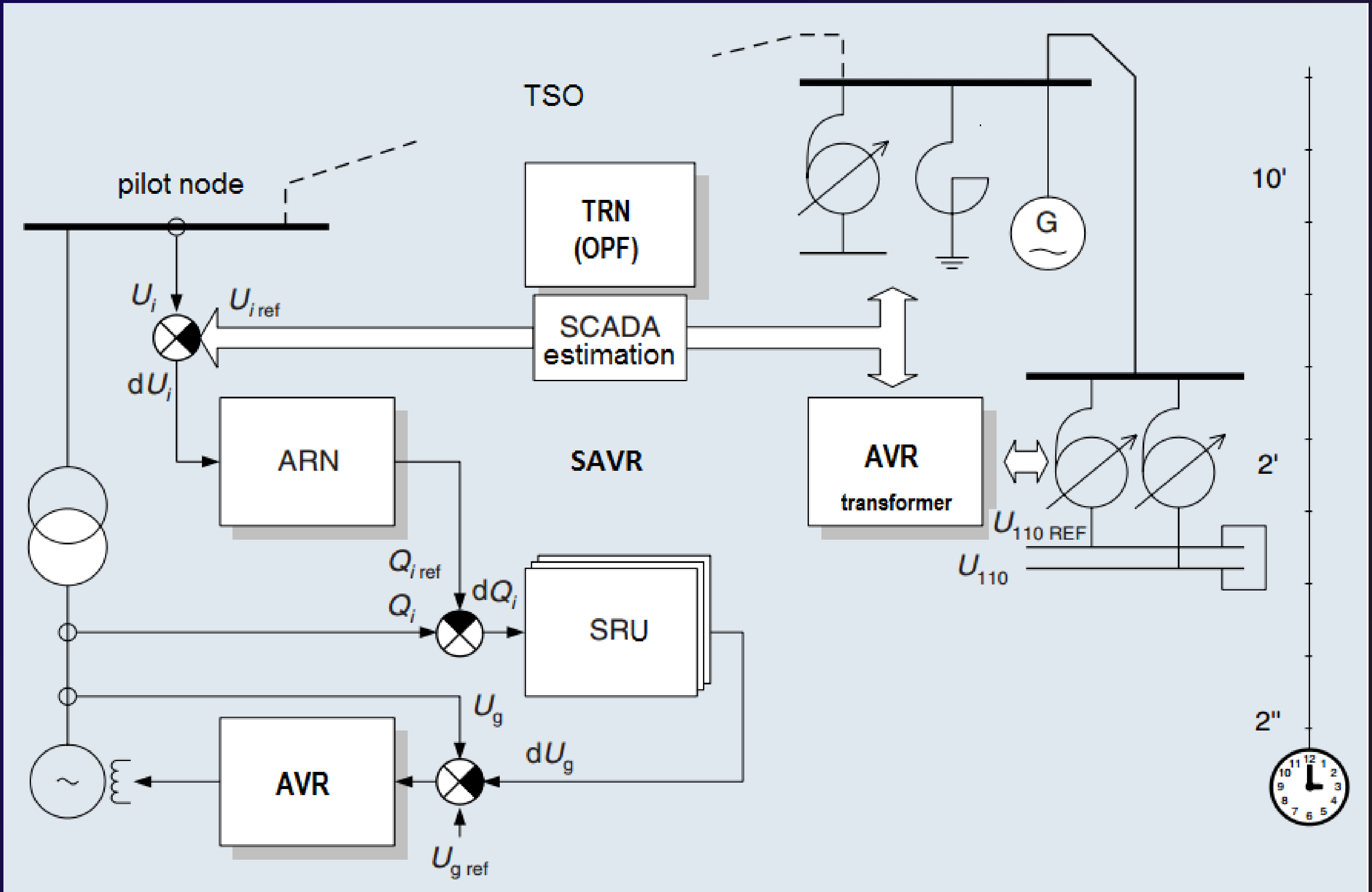
Voltage is being influenced by all the generators, transformers and reactors connected to the pilot node. **SAVR capability** makes it possible in the pilot node to connect different primary systems (different manufacturers, different technologies, different way of connection to the primary system).

! WARNING: The sources being outside of the SAVR can even act against the SAVR !



WITH THE INCREASE OF GRID COMPLEXITY, THE NEED FOR ITS AUTOMATIZATION IS GROWINGC

Principles of automation of voltage and reactive power regulation

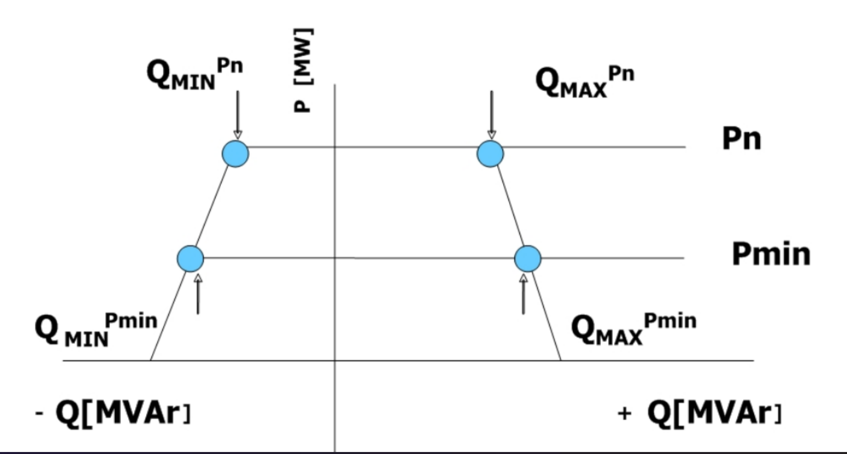


WITH THE INCREASE OF GRID COMPLEXITY, THE NEED FOR ITS AUTOMATIZATION IS GROWINGC

CERTIFICATION

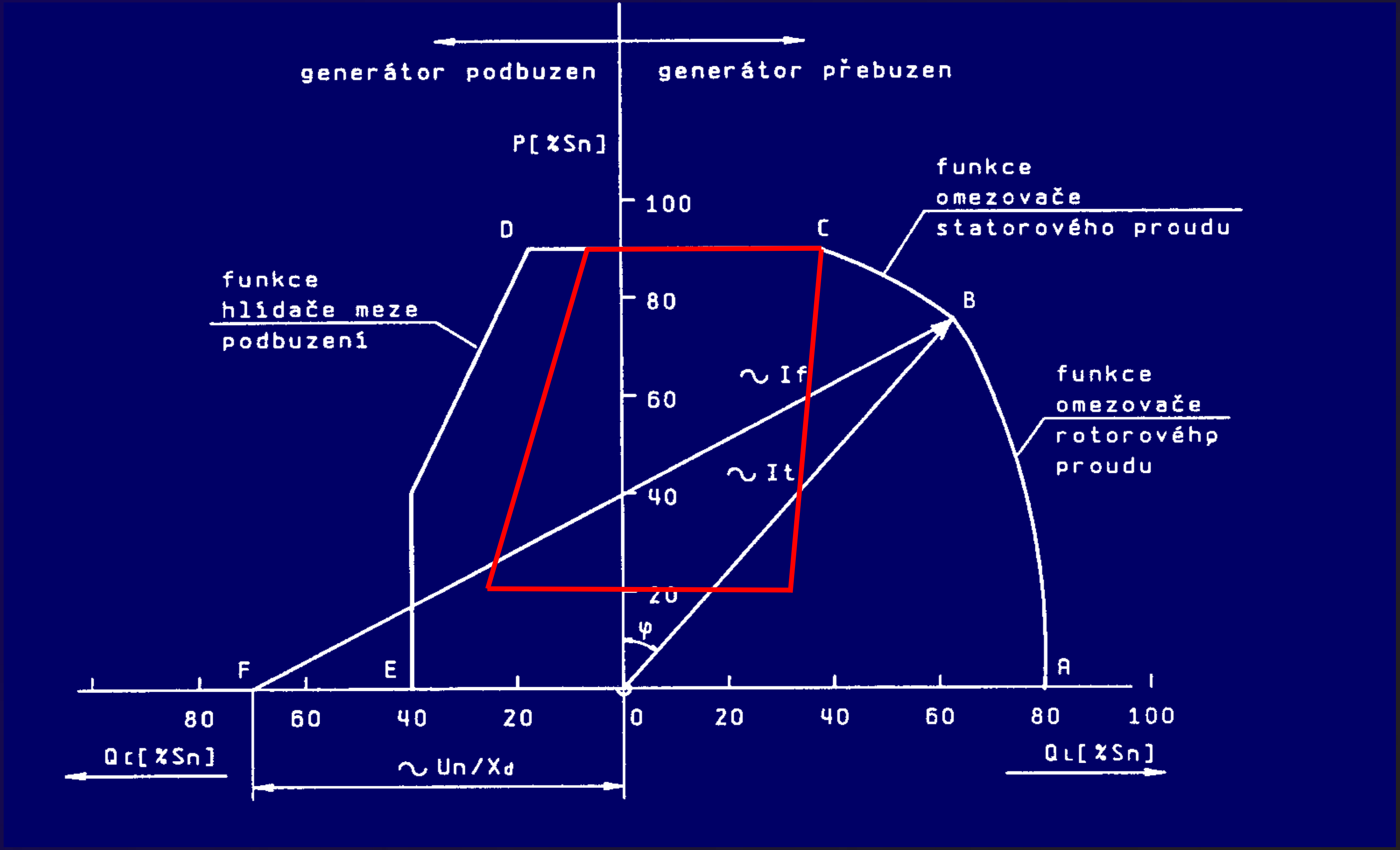
- Test the limits at Pmin Umin and Umax
- Test the limits at Pmax Umin and Umax

Reachable PQ diagram



WITH THE INCREASE OF GRID COMPLEXITY, THE NEED FOR ITS AUTOMATIZATION IS GROWINGC

After the certification



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WITH THE INCREASE OF GRID COMPLEXITY, THE NEED FOR ITS AUTOMATIZATION IS GROWING

The conceptual solutions

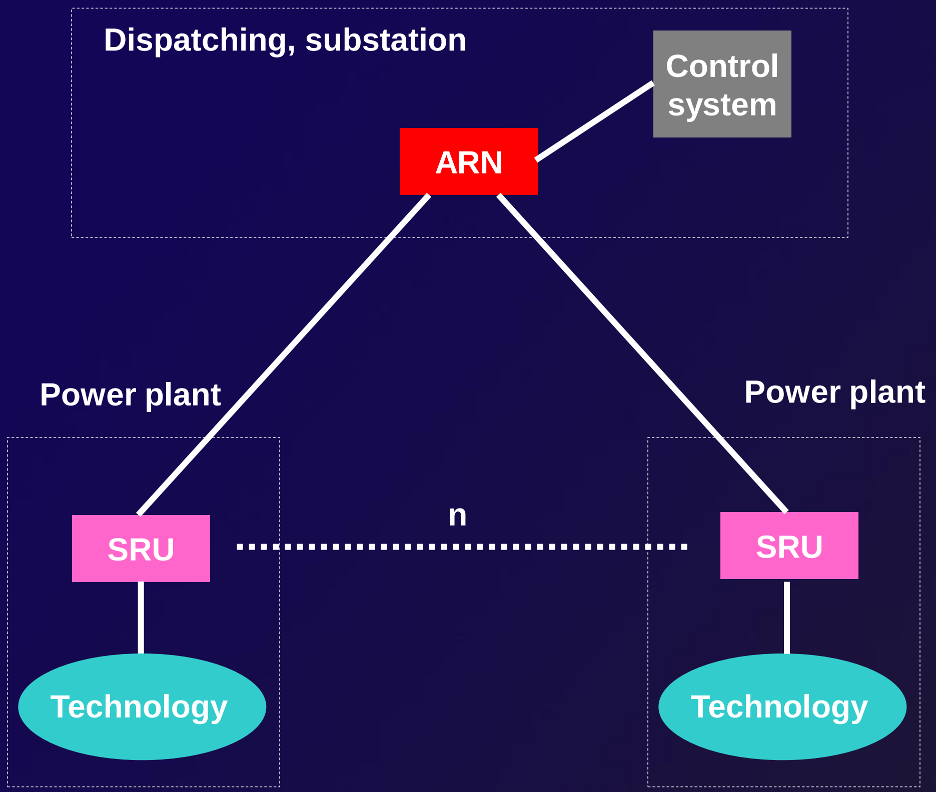
1. **ARN** - substation or dispatch center
   SRU - Power plant

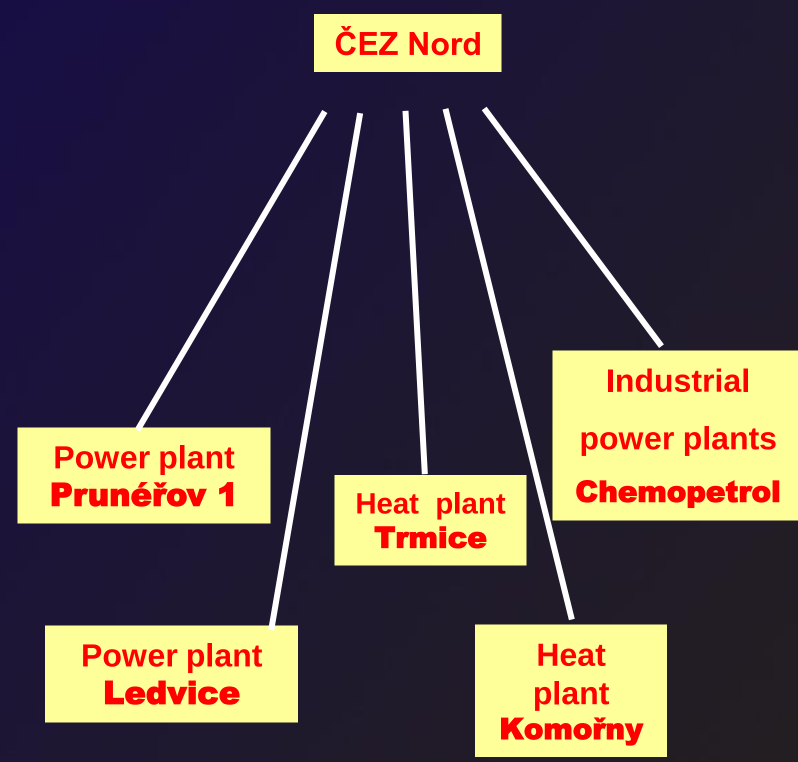
2. **ARN and SRU** – substation or Power plant

WITH THE INCREASE OF GRID COMPLEXITY, THE NEED FOR ITS AUTOMATIZATION IS GROWING

The conceptual solutions

ARN - **substation or dispatch center**
SRU - **Power plant**

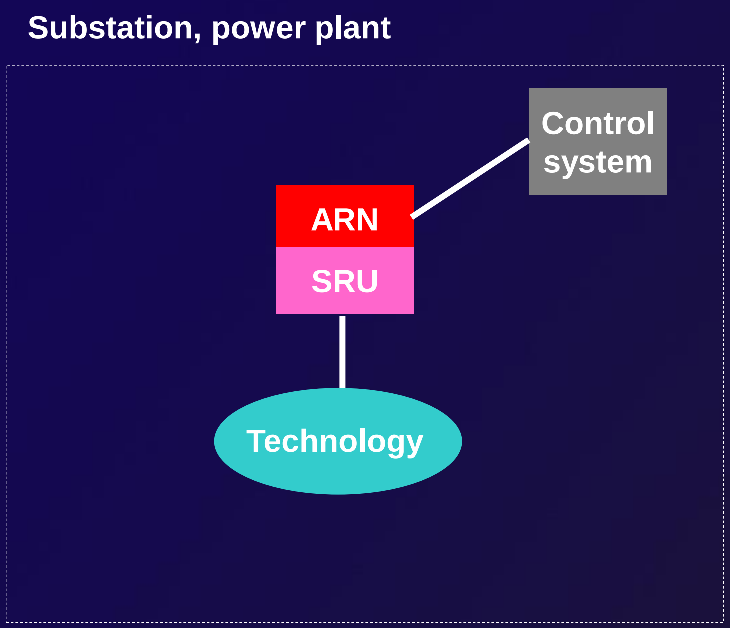


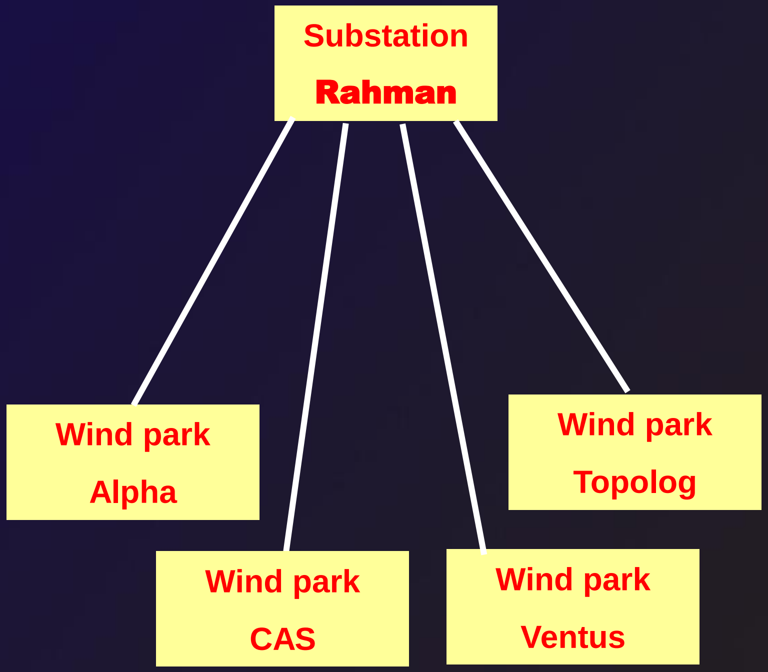


WITH THE INCREASE OF GRID COMPLEXITY, THE NEED FOR ITS AUTOMATIZATION IS GROWING

The conceptual solutions

ARN and SRU – substation or Power plant





REALIZATION OF SINGLE REGULATED PRODUCTION SITES SHOULD BE JUST A QUESTION OF MONTHS

Key technical steps of implementation:

1.	**Initial project**	**SAVR supplier**	Developing (for each generator) the initial project providing compatibility of technical devices: dispatching <=> generation
2.	**Regulator's connecting project**	**Local designer**	Developing the project for connecting regulator to the technology of generation
3.	**Regulator's technology delivery**	**SAVR supplier**	Supply of regulating technical and programming devices
4.	**Regulator's connection**	**Assembler or Operator**	Connecting the regulator to the generator's technology
5.	**Regulator's testing**	**SAVR supplier**	Assembly verification , carrying out the pre-complex and complex tests and training the staff
6.	**Service**	**SAVR supplier + Operator**	Set prerequisites and process of prophylactic and irregular maintenance

Realization takes 6 - 12 months, depending on technical conditions and operational potential (shut downs etc.) of the power plants

Important realization of SAVR

TSO

System power plants	R E S
First system SAVR in the Czech Republic was designed and installed by the EGU Praha Engineering, a. s.	First system SAVR in the Romania was designed and installed by the EGU Praha Engineering, a. s.
SAVR Hradec u Kadaně	**SAVR Tariverde**

Important realization of SAVR

DSO

Fossil power plants	R E S	Industrial areas

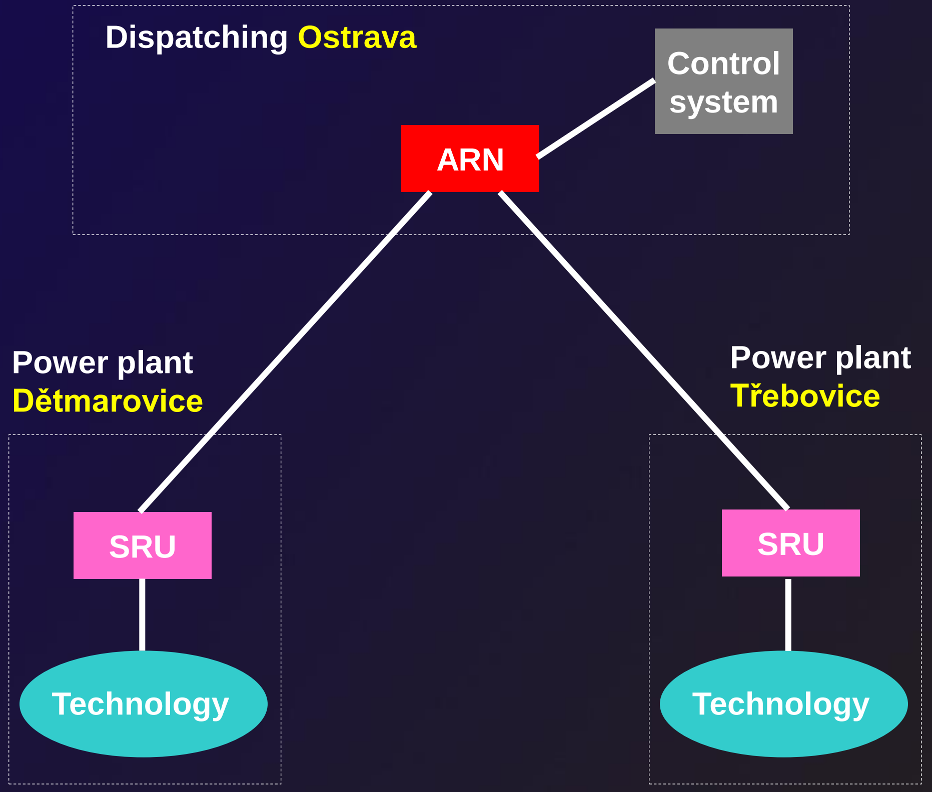
First system SAVR in the Czech Republic was designed and installed by the EGU Praha Engineering, a. s.

SAVR ČEZ Morava	SAVR Horní Životice	SAVR ArcelorMittal

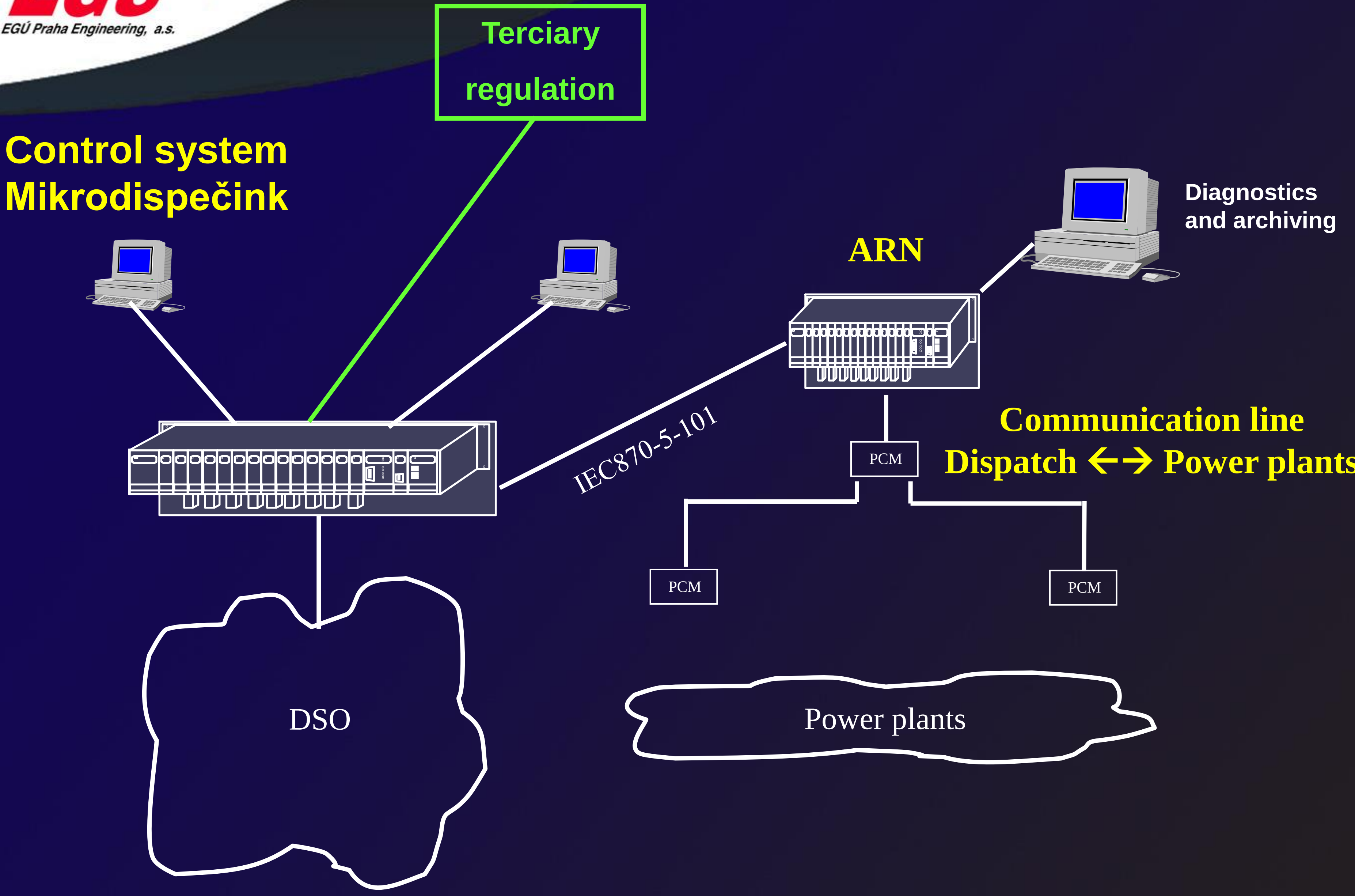
Realization of SAVR Ostrava /Commissioning : Year 2002/

ARN – dispatch center
Ostrava

SRU - Power plant
Třebovice
Dětmarovice



ARN Ostrava


Terciary
regulation
Control system
Mikrodispečink
Diagnostics
and archiving
ARN
IEC870-5-101
PCM
Communication line
Dispatch ←→ Power plants
PCM
PCM
DSO
Power plants

Czech Republic

Realization of secondary voltage control in the industrial enterprises

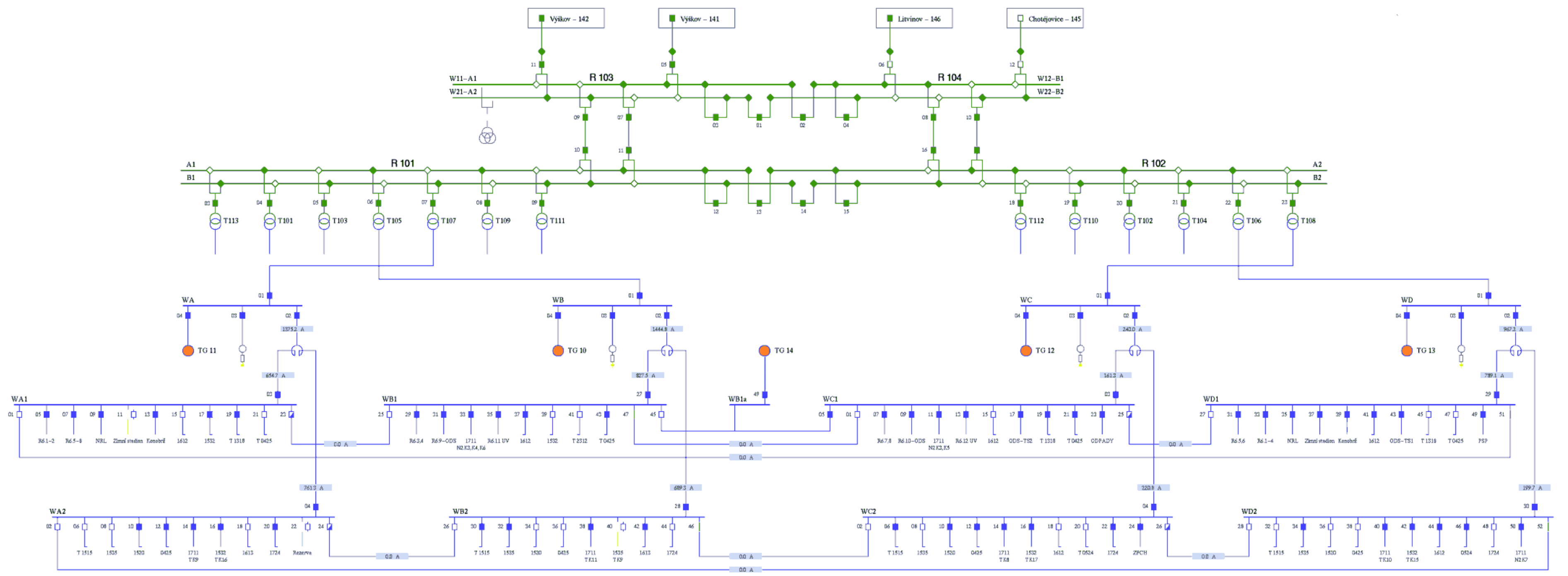
SAVR Unipetrol

SAVR ArcelorMittal

Benefit: The power operators and producers are no longer penalized for not keeping the power factor and for Q overflows

They support and help the power system of 110 kV

SAVR Unipetrol



- Industrial enterprise - production of chemicals (including petrol and diesel)
- Control of the generators TG10, TG11, TG12, TG13 and TG14 (red in the diagram)
- Generators are connected to the network 6 kV
- Voltage of 110 kV control

SAVR Mittal

- Industrial enterprise - iron processing
- Control of the generators TG1-TG8, TG10
- Control of the transformers (number: 28)
- Checking the voltage at 53 substations
- Generators are connected to the network 6 kV
- Voltage of 22 kV control

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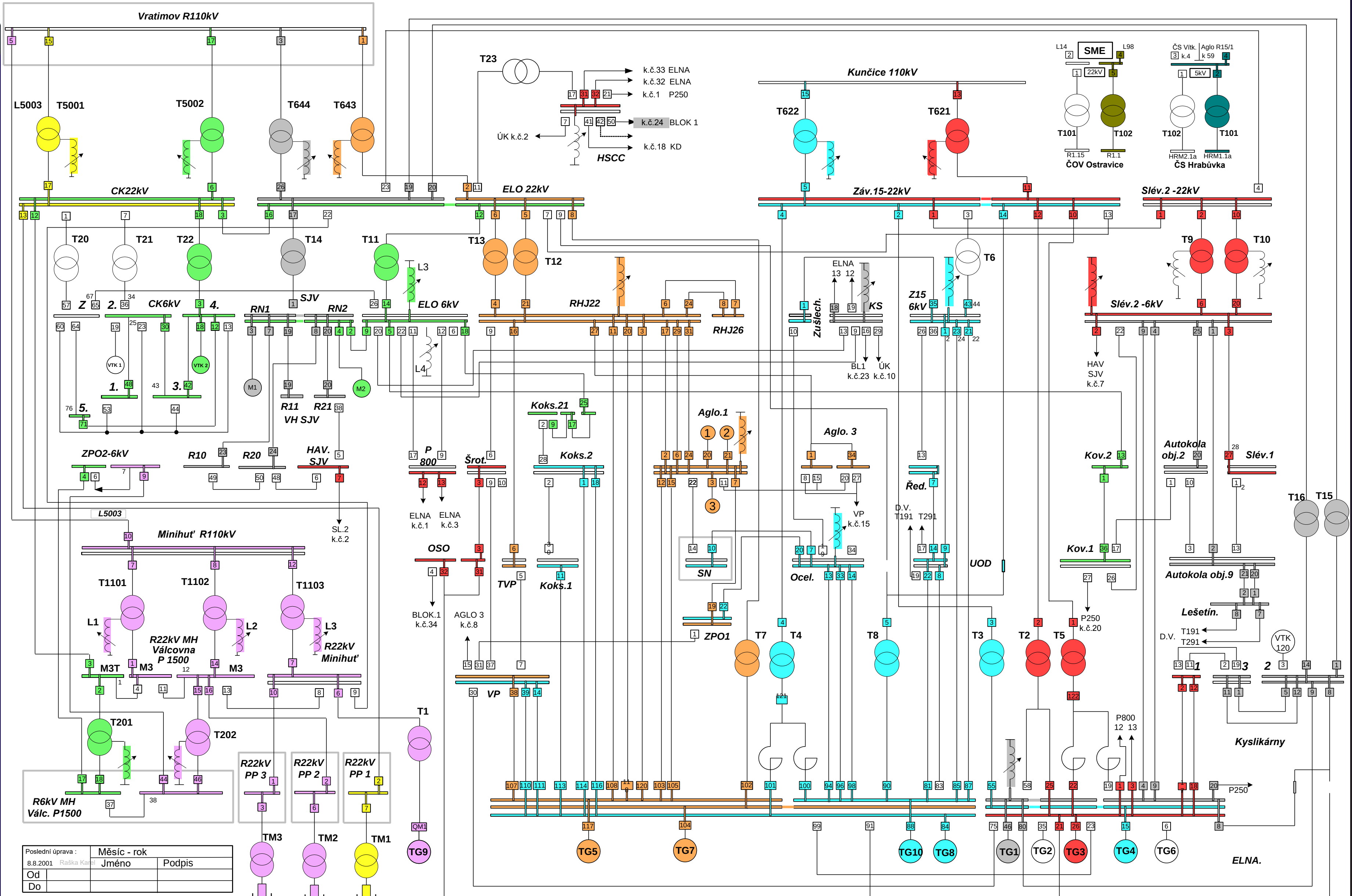
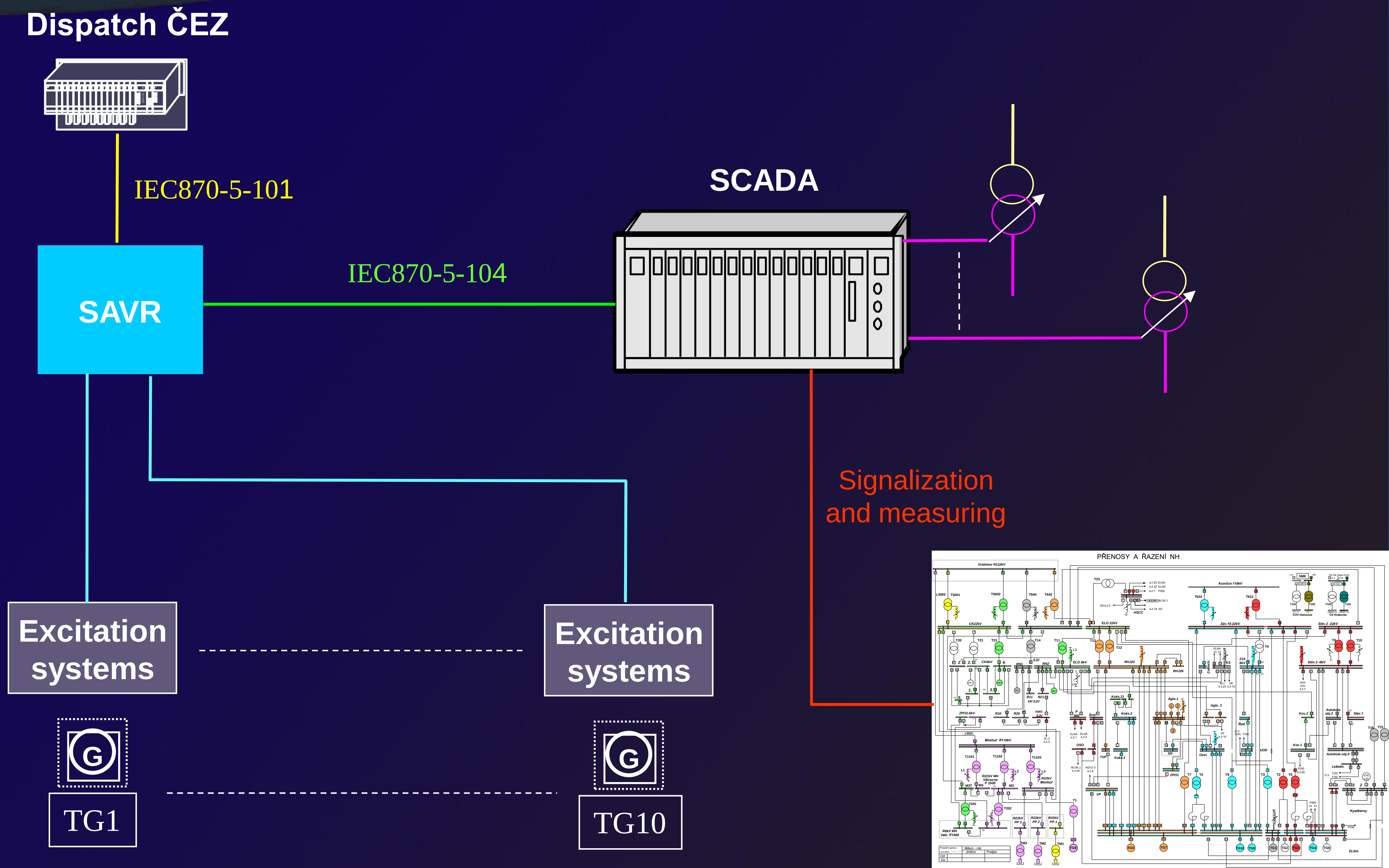
SAVR Mittal

PŘENOSY A ŘAZENÍ NH



SAVR Mittal


Dispatch ČEZ
IEC870-5-101
SCADA
IEC870-5-104
SAVR
Signalization and measuring
Excitation systems
Excitation systems
G
G
TG1
TG10
PŘENOSY A ŘAZENÍ NH

Czech Republic

Realization of secondary regulation of 22 kV voltage

SAVR Kopřivná

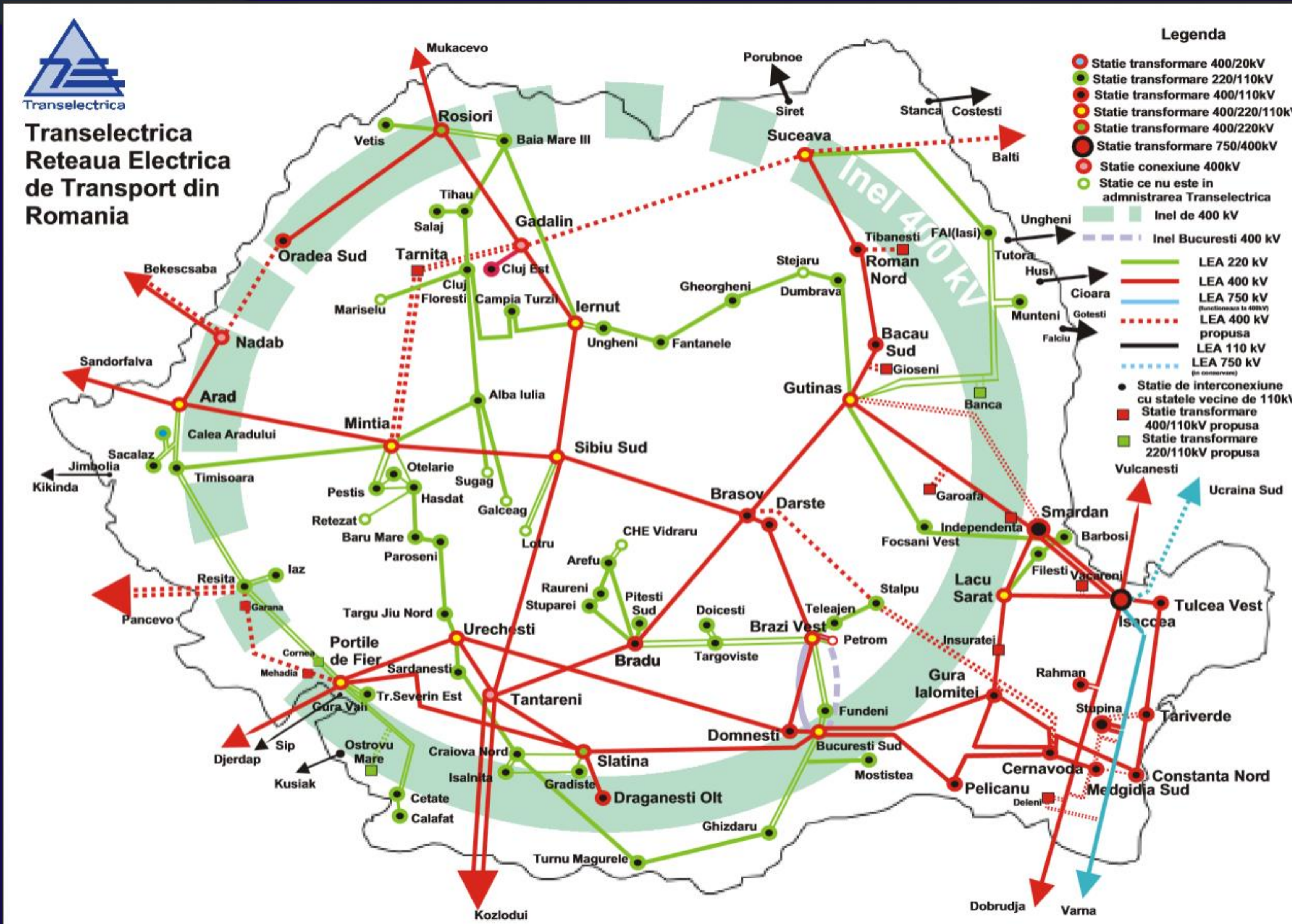
(First controlled small wind source in the 22 kV network in the Czech Republic)

2 x WTGs Enercon (2.3 MW)

Czech Republic

SAVR Kopřivná… 22 kV

ROMANIA

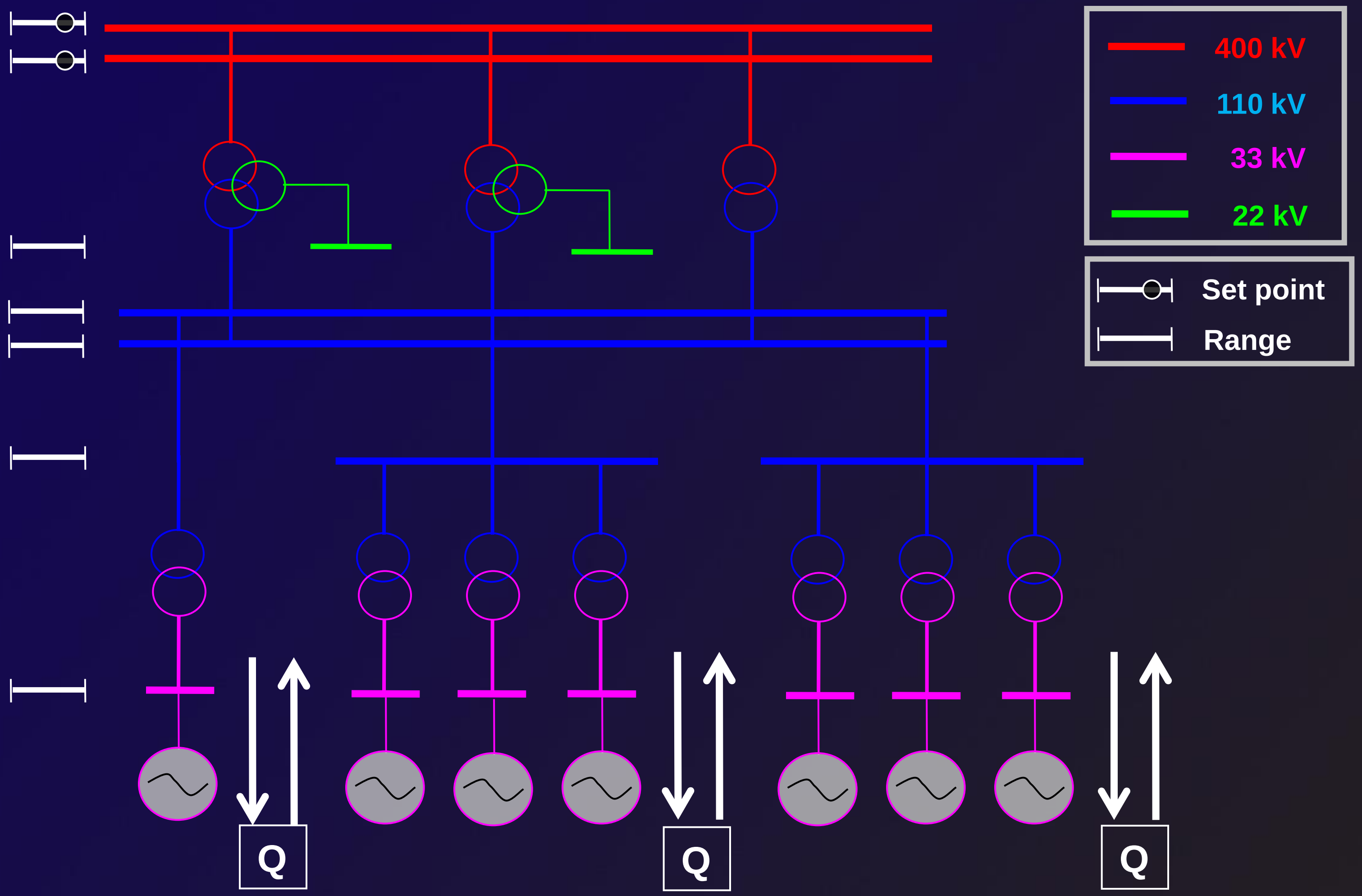


Transelectrica
Transelectrica
Reteaua Electrica
de Transport din
Romania
Legenda
Statie transformare 400/20kV
Statie transformare 220/110kV
Statie transformare 400/110kV
Statie transformare 400/220/110kV
Statie transformare 400/220kV
Statie transformare 750/400kV
Statie conexiune 400kV
Statie ce nu este in admnistrarea Transelectrica
Inel de 400 kV
Inel Bucuresti 400 kV
LEA 220 kV
LEA 400 kV
LEA 750 kV
LEA 400 kV propusa
LEA 110 kV
LEA 750 kV
Statie de interconexiune cu statele vecine de 110kV
Statie transformare 400/110kV propusa
Statie transformare 220/110kV propusa
Inel 400 kV
Mukacevo
Rosiori
Vetis
Baia Mare III
Tihau
Salaj
Gadalin
Oradea Sud
Tarnita
Cluj Est
Cluj Floresti
Mariselu
Campia Turzii
Iernut
Bekescsaba
Nadab
Sandorfalva
Arad
Calea Aradului
Sacalaz
Jimbolia
Kikinda
Timisoara
Mintia
Alba Iulia
Sibiu Sud
Otelarie
Pestis
Hasdat
Sugag
Galceag
Retezat
Baru Mare
Paroseni
Lotru
Resita
Iaz
Garana
Pancevo
Targu Jiu Nord
Urechesti
Portile de Fier
Cornea
Mehadia
Sardanesti
Tr.Severin Est
Gura Vaii
Djerdap
Sip
Kusiak
Ostrovu Mare
Craiova Nord
Isalnita
Slatina
Gradiste
Draganesti Olt
Cetate
Calafat
Tantareni
Turnu Magurele
Kozlodui
Ungheni
Fantanele
Gheorgheni
Stejaru
Dumbrava
Porubnoe
Siret
Suceava
Stanca
Costesti
Balti
Tibanesti
FAI(Iasi)
Roman Nord
Tutora
Ungheni
Husi
Cioara
Munteni
Gotesti
Falciu
Bacau Sud
Gioseni
Gutinas
Banca
Brasov
Darste
CHE Vidraru
Arefu
Raureni
Stuparei
Pitesti Sud
Doicesti
Targoviste
Bradu
Teleajen
Brazi Vest
Petrom
Stalpu
Garoafa
Smardan
Independenta
Focsani Vest
Barbosi
Filesti
Vacareni
Lacu Sarat
Isaccea
Tulcea Vest
Vulcanesti
Ucraina Sud
Insuratei
Gura Ialomitei
Rahman
Stupina
Tariverde
Fundeni
Domnesti
Bucuresti Sud
Mostistea
Ghizdaru
Cernavoda
Pelicanu
Medgidia Sud
Constanta Nord
Deleni
Dobrudja
Varna

SAVR Tariverde

SAVR Tariverde

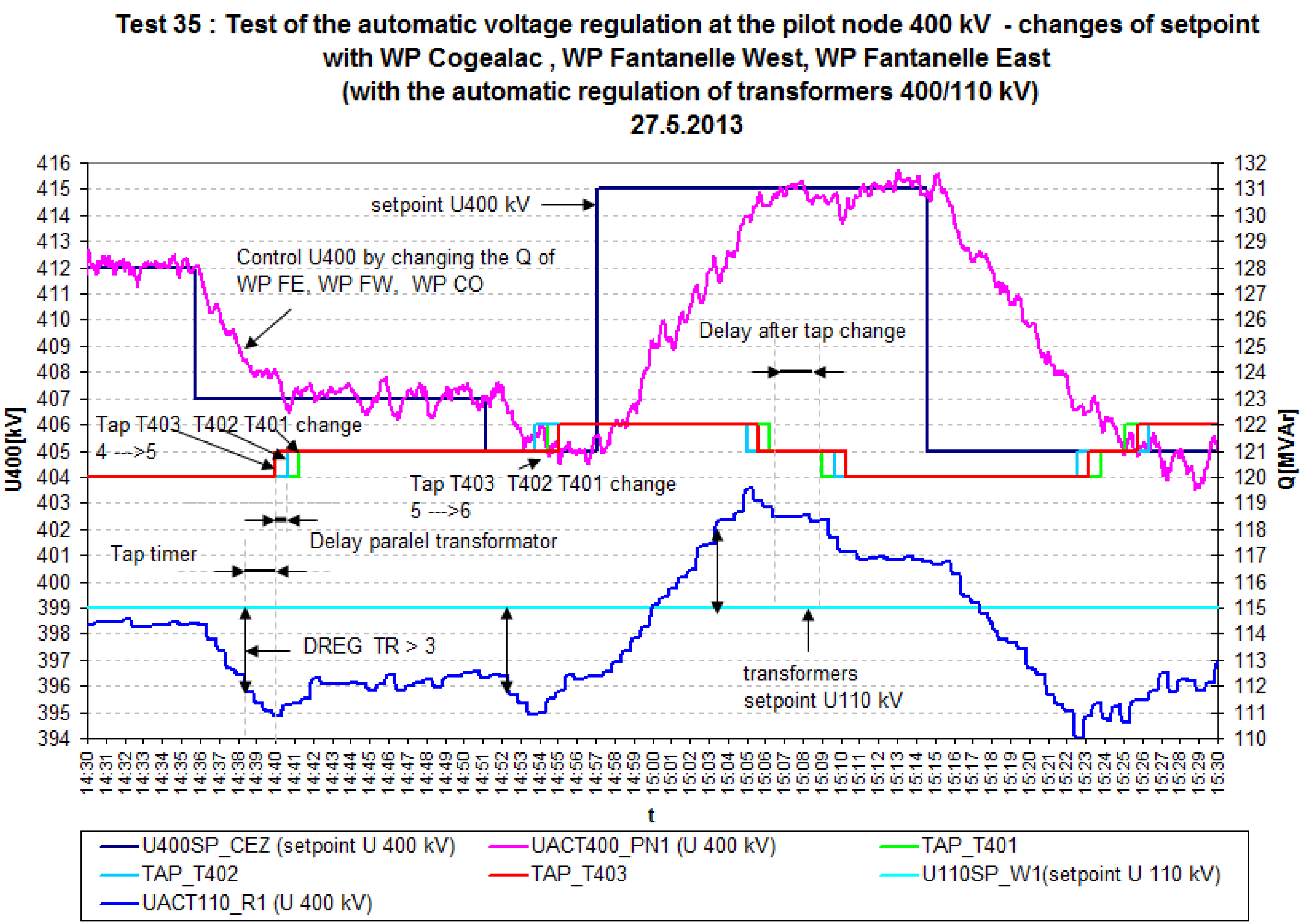
The Action Quantity for Control of Voltage 400 kV is the Reactive Power



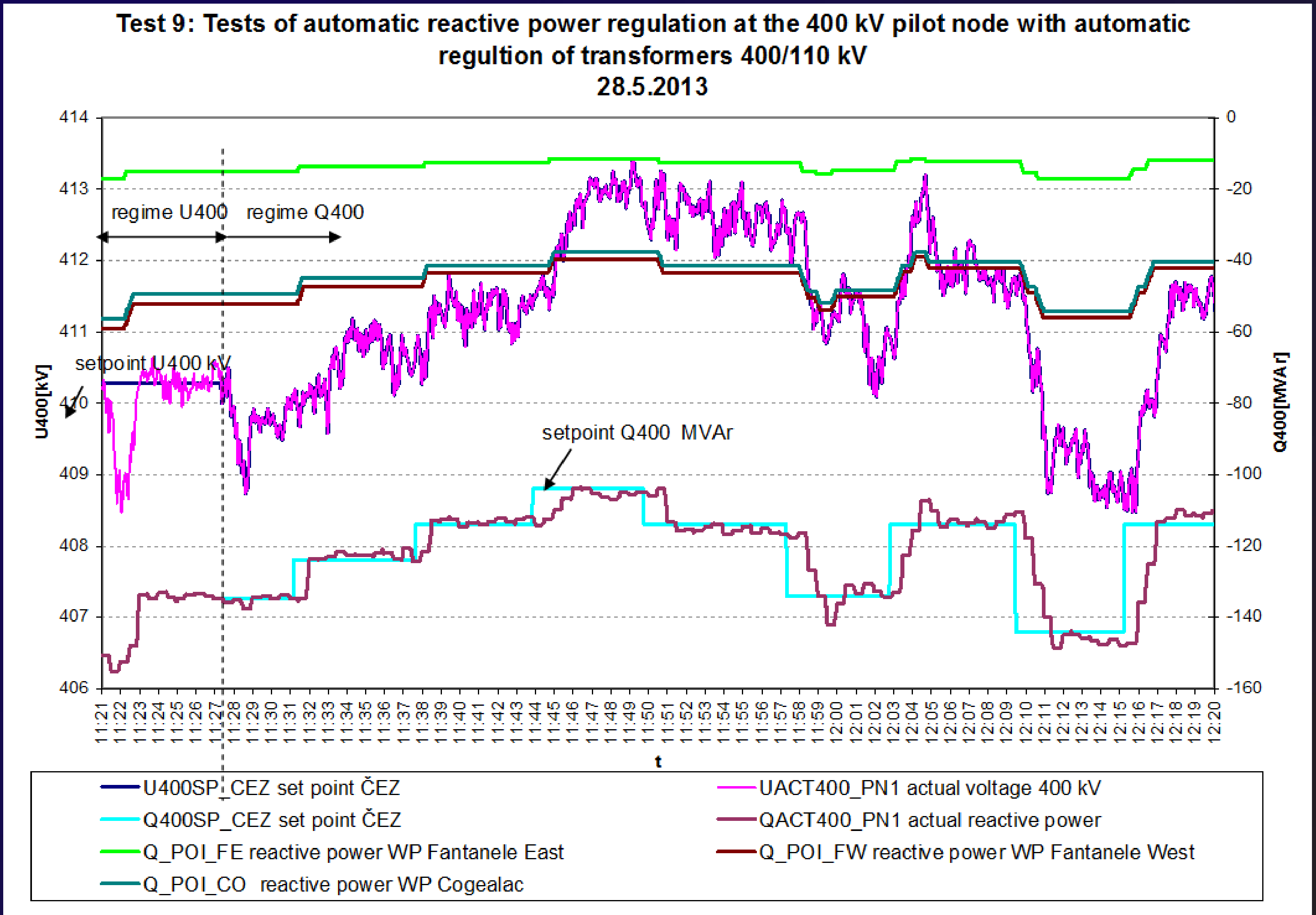
SAVR Tariverde

- Control of voltage 400 kV, Control of active power
- New: Control of reactive power on 400 kV
- New: Priority Control - Authority allocation (Local Dispatching center vs TSO Dispatching center)

SAVR Tariverde



SAVR Tariverde



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SAVR Rahman

Verbund

ERG

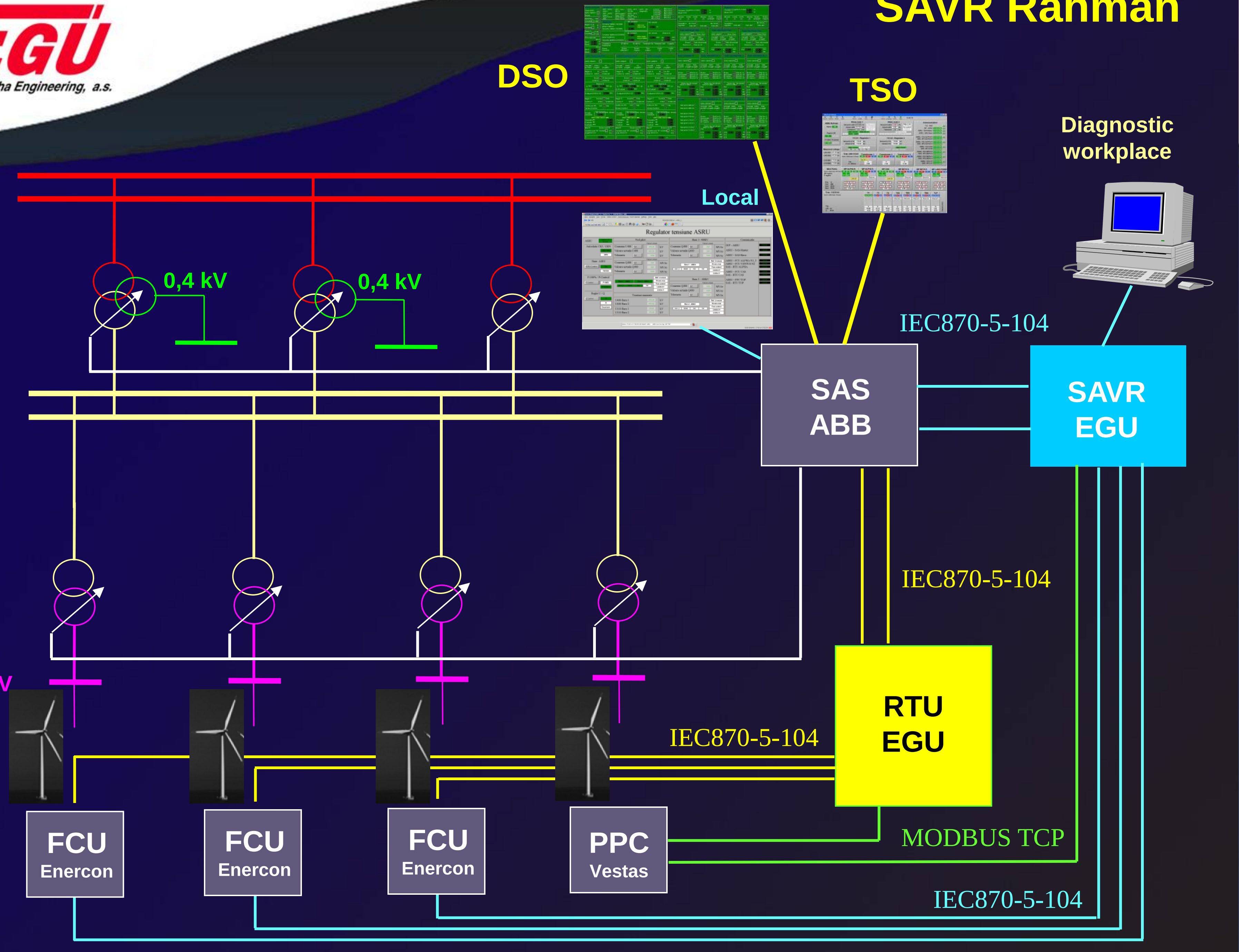
ABB

ENERCON
ENERGIE FÜR DIE WELT

Vestas

EGÚ
EGÚ Praha Engineering, a.s.

SAVR Rahman


DSO
TSO
Diagnostic workplace
Local
Regulator tensiune ASRU
400 kV
0,4 kV
0,4 kV
110 kV
IEC870-5-104
SAS ABB
SAVR EGU
IEC870-5-104
33 kV
RTU EGU
IEC870-5-104
FCU Enercon
FCU Enercon
FCU Enercon
PPC Vestas
MODBUS TCP
IEC870-5-104

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Reference: **Classic Power Plants**

Country: **CZECH REPUBLIC**

- **SAVR ČEZ Sever** - voltage control of 110 kV grid with:
  Power plants: **Prunéřov 1, Ledvice, Trmice, Unipetrol and Komorany**

- **SAVR ČEZ Morava** - voltage control of 110 kV grid with:
  Power plants: **Detmarovice**, **Trebovice**, **Arcelor Mittal Ostrava**, Biocel Paskov, Horní Loděnice, Red Hill

- **SAVR ČEZ Střed** - voltage control of 110 kV grid with:
  Power plants: **Mělník 1, Mělník 2, AGCZ, Plzeňská teplárenská**

Reference: **WIND PARKS**

Country: **ROMANIA**

- **SAVR Tariverde** - voltage control of 400 kV grid with:(660 MW … installed capacity)

1. WP Fantanele East
2. WP Fantanele West
3. WP Cogealac

Investor: **ČEZ Romania**

- **SAVR Rahman** - voltage control of 400 kV grid with: (325 MW … installed capacity … so far)

1. WP Alpha N1,2,3
2. WP Ventus
3. WP Cas
4. WP Topolog
5. ……………..

Investor: **VERBUND Austria**

SAVR

FEW COMMENTS:

- The need for regulation of U and Q is and will be obvious. The emerging development of electricity system decentralization is in this respect of particular and determining importance
- The implementation of the SAVR system itself is conditional on the technical level of the relevant part of the electrical system - availability of controllable action members, communication tools, profiles and processes atc.
- Next steps to developing the particular projects should and will be the reflection of developing trends in energy sector: decentralization ..., digitization ..., robotics ..., IoT applications ..., CS ..., island operations, including the virtual power plants, accumulation ...
- Important question is also the motivation of the energy producers i.e. not only legislative requirements (Grid Codes) but also a financial consideration (ancillary services ...)

COMPANY – CONTACT DATA:

Jaromír Beran … Director of the Company

Phone: + 420 267 193 436

Mobil: + 420 603 229 161

e-mail: beran@egu-prg.cz

www.egu-prg.cz

Petr Čech … Head of the Department:

Control of Power Network Parameters and Control Systems

Phone: + 420 267 193 574

Mobil: + 420 603 247 976

e-mail: cech@egu-prg.cz

www.egu-prg.cz