SAVR

Automatic Secondary Regulation of Voltage and Usage of Reactive Power

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Within the scope of company’s activities 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"

**Legend:**

- tap number was not changed
- tap number was changed

**TOL400 = -0.5kV**

- No regulator reaction
- Regulator reacts
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
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
First step: Evaluation of variants of possible ways of regulation:

- regulation U
- regulation Q
- regulation cos phi

Selected Variant: \textbf{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 /

\textbf{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 \textbf{SAVR}.
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

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

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

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

Set value
Regulated value
Reactive power
When controlling the voltage the $\cos \Phi$ is not necessary to be kept

Regulation Range Enlargement for Voltage 400 kV

$\cos \Phi$  |  VAR controlled
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.
Principles of automatization of voltage regulation and usage of reactive power

Regulation hierarchy

- Terciary (TRV)
- Secondary (SAVR)
- Primary (AVR)

on the level

- Dispatching
- Production / Generation
- 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
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!

Integration of different primary systems

Integration of different primary systems

Modbus RTU

Modbus TCP

IEC870-5-104

DI, DO

DI, DO

Pilot node e.g. bus – bar 400kV

SAVR

BRUSH

Thermal Power Plant

FCU Enercon

Wind Park_1_

PPC Vestas

Wind Park_\text{n}_

Hydro-power Plant
Principles of automation of voltage and reactive power regulation
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 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

Dispatching, substation

Control system

Power plant

Technology

n

**ČEZ Nord**

**Industrial power plants Chemopetrol**

- Power plant **Prunéřov 1**
- Heat plant **Trmice**
- Power plant **Ledvice**
- Heat plant **Komořany**
WITH THE INCREASE OF GRID COMPLEXITY, THE NEED FOR ITS AUTOMATIZATION IS GROWING

The conceptual solutions

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

- Substation, power plant
  - Control system
  - Technology
  - ARN
  - SRU

Substation
- Rahman
- Wind park
  - Alpha
- Topolog
  - CAS
  - Ventus
REALIZATION OF SINGLE REGULATED PRODUCTION SITES SHOULD BE JUST A QUESTION OF MONTHS

**Key technical steps of implementation:**

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

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

**RES**

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

**SAVR**

SAVR Hradec u Kadaně

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

Fossil power plants

RES

Industrial areas

SAVR ČEZ Morava

SAVR Horní Životice

SAVR ArcelorMittal
Realization of SAVR Ostrava

/Commissioning: Year 2002/

**ARN** – dispatch center
- Ostrava

**SRU** - Power plant
- Třebovice
- Dětmarovice

**Dispatching Ostrava**

**Control system**

Power plant
- Dětmarovice

Technology

**Power plant Třebovice**

Technology

**SRU**

EGÚ Praha Engineering, a.s.
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
• 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
• 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
PŘENOSY A ŘAZENÍ NH

Vratimov R110kV

Kunčice 110kV

Zav.10-23kV

Slev.2 - 23kV

Slev.2 - 6kV

Minihut R110kV

šířk. 1

úd. 1
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)
Transelectrica
Reteaua Electrică de Transport din România
The Action Quantity for Control of Voltage 400 kV is the Reactive Power
• 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)
Test 35: Test of the automatic voltage regulation at the pilot node 400 kV - changes of setpoint with WP Cogeeac, WP Fantanelle West, WP Fantanelle East (with the automatic regulation of transformers 400/110 kV)
27.5.2013
Test 9: Tests of automatic reactive power regulation at the 400 kV pilot node with automatic regulation of transformers 400/110 kV
28.5.2013

- regime U400
- regime Q400
- setpoint U400 kV
- setpoint Q400 MVar

Legend:
- U400SP_CEZ set point ČEZ
- Q400SP_CEZ set point ČEZ
- Q_POI_FE reactive power WP Fantanele East
- Q_POI_CO reactive power WP Cogevalc
- UACT400_PN1 actual voltage 400 kV
- QACT400_PN1 actual reactive power
- Q_POI_FW reactive power WP Fantanele West
SAVR Rahman

400 kV 110 kV 33 kV 0,4 kV 0,4 kV

DSO TSO Local

IEC870-5-104 IEC870-5-104 IEC870-5-104 IEC870-5-104 IEC870-5-104

Diagnostic workplace

SAV EGU SAS ABB

IEC870-5-104 MODBUS TCP

FCU Enercon FCU Enercon FCU Enercon PPC Vestas

Local DSO TSO

SAV EGU

IEC870-5-104
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: Classic Power Plants
Country: CZECH REPUBLIC
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
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 etc.

• 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 ...)
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