Connection of power production

Stig Fretheim

The project overarching objectives

- Reduce cost of grid connection of DG through facilitating use of new technologies and methods.
- (WP1) Describe background and best practices
- (WP2) Make new technology and new products relevant to the network companies
- (WP3) Make sure voltage optimization is optimally utilized
- (WP4) Increased knowledge of socioeconomic consequences of allowing production limitation
- (WP5) Increase knowledge about DGS stability properties FRT
- (WP6) The results of the project's activities will be gathered in a handbook for the network companies

DGnett – Partisipants in the project

- REN (Responsible for the project)
- REN have 60 Grid companies as owners.
- REN makes guidelines and specifications
- SINTEF (Energy Research Institute)

- BKK Nett
- Agder Energi Nett
- Sunnfjord Energi
- NTE Nett
- Troms Kraft Nett
- Eidsiva Nett
- Lyse Elnett
- Voss Energi
- Norlandsnett
- Helgelandskraft
- Eidefoss
- SFE Nett
- Vang Energiverk

History

- The challenge started 15 years ago when it became profitable to build smaller hydro-powerplants, typically from 1 til 10 MW.

- The regulator NVE found 25 TWh with investment cost below 0,3 Euro / kWh.

- In addition, approx. assumes that up to about 5 TWh of this potential can be realized over a ten-year period.

History WP1

- The high potential for building small power plants lead to challenges with connection these power plants to the grid.
- The power plants had both:
  - Synchronous generators
  - Asynchronous generators

- This led to unwanted island operation in 15 to 20 cases where the voltage for the customers raised from 230 V to 500 V and more. Destroying a lot of equipment. Giving the responsible grid companies a high replacement cost especially for the grid customers within the electrical island.

- One grid company Agder Energi started the work with setting the right restrictions and conditions for the generators.

- REN worked with Agder and presented 150 pages of;
  - Guidelines for connection
  - Private law agreement

History WP1

- The agreement is from medium high voltage 1 -24 kV and was later extended to:
  - A contract set of 24 to 420 kV with reference to TSO and grid codes on some aspects
  - A contract set (simplified) of 230 to 1 kV with reference (European PV norms EN 50438)

The comment from one of the larger power produces in Norway was that it places the Grid company next to God, and we replied that it was the best feedback so far.

From the low voltage contract:

Compensation and liability in general 10.1.

Introduction A party is liable for damage and loss which is negligently imposed on the other party within the applicable of the law. The feed incustomer is, however, liable for damages without regard to guilt for any financial loss suffered by the Network Company against other customers and which is a direct or indirect consequence of the Customer's breach of the obligations under the Agreement.

REN Agreement 0300
CONNECTION AGREEMENT FOR DG UNITS
(Framework Agreement)

Appendix 1:

Definitions

Appendix 2:

Connection and grid agreement for DG- customers

Appendix 3:

Technical requirements

- U1: Overall requirements
- U2: Design and design requirements
- U3: Commissioning of the DG
- U4: Operation and Maintenance of the DG Unit
- U5: Requirements for voltage and power flow
- U6: Requirements for generator and generator equipment
- U7: Requirements for protection
- U8: Generator transformer and grounding system requirements
- U9: Requirements for connection
- U10: Requirements for lockable Connection Point
- U11: Procedure for the acquisition and assembly of RTU
- U12: Procedure for procuring and installing high voltage measuring equipment
- U13: Requirements for Measuring Transformers

Appendix 4:

Adjustments and special conditions

- U1: Description of installation
- U2: Connection Point

Appendix 5:

Documentation

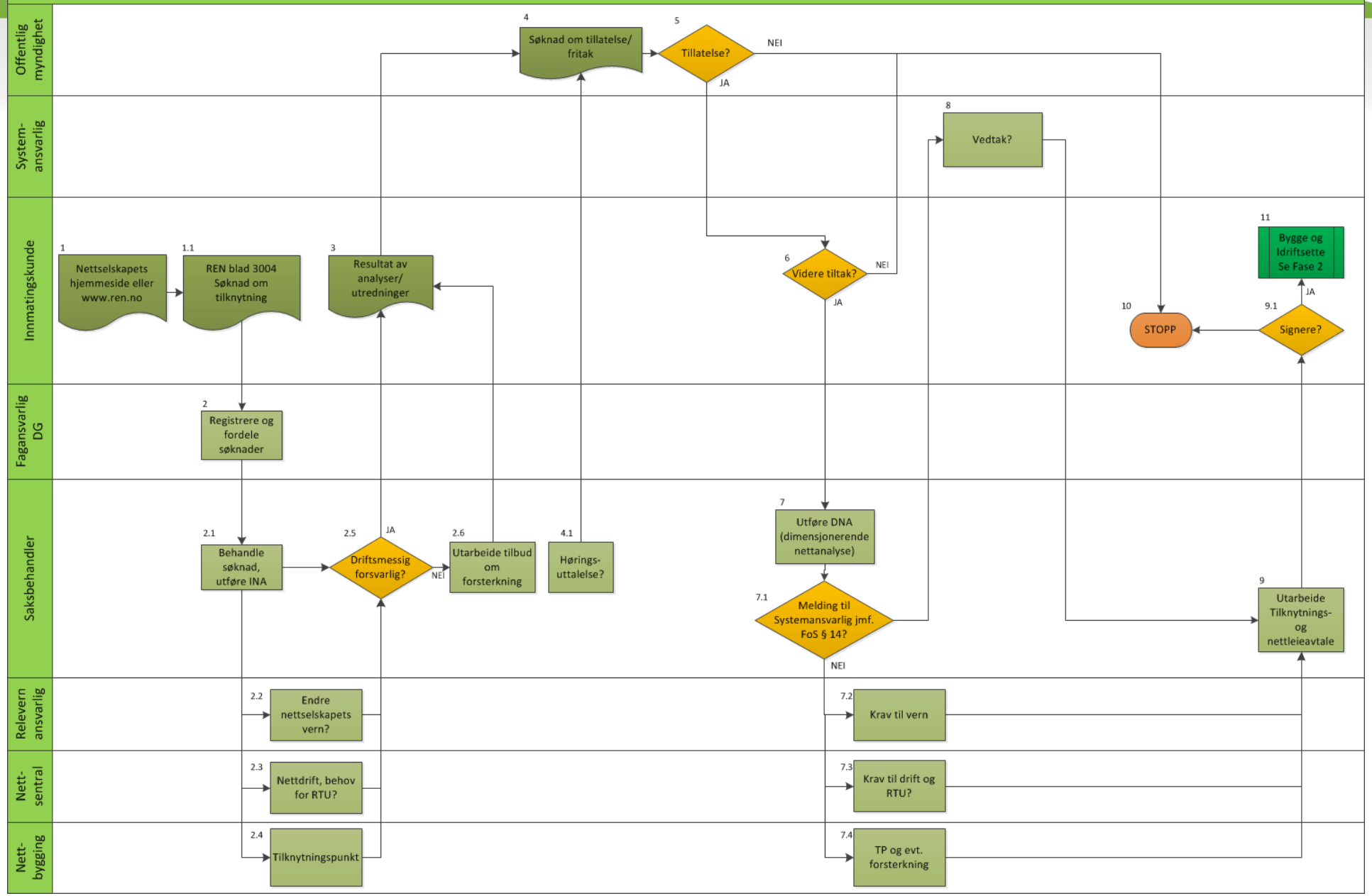
- U1: Self-declaration
- U2: General documentation
- U3A: Documentation of DG device with synchronous generator
- U3B: Documentation of DG unit with asynchronous generator

Appendix 6:

Site Acceptance Test (SAT)

REN blad 3002 vedlegg 1. Planlegge og beslutte

Fase 1



DGnett – Alternatives for increased hosting capacity

Reduce cost of grid connection of DG through facilitating use of new technologies and methods.

- **Duration: 2014 – 2017**
- **Budget: 9 533 kNOK**
- **Supported by grid companies and the Norwegian Research Council**

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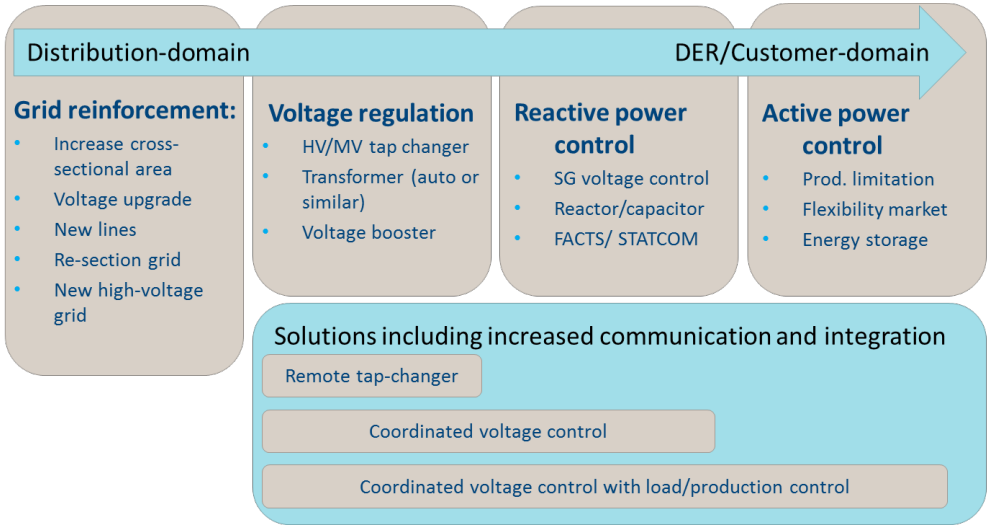

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(WP2) Make new technology and new products relevant to the network companies

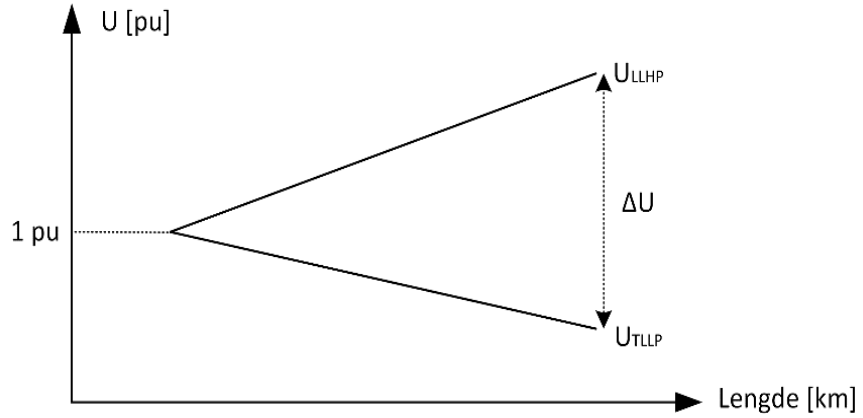
Tiltak	Limitation in connection capacity	Advantages	Disadvantages
Grid Upgrade / New Network	• Voltage Variations • High voltage • Current carrying capacity • Voltage leap	• Reduced loss costs • Assumed higher reliability • Reduced complexity in the network, compared with alternative measures	• Other measures often have lower investment costs • Existing networks have a high residual life • Areas with construction work that are particularly expensive or demanding for nature conservation etc.
Shunt reactor (coil)	• Voltage Variations • High voltage	• The generator does not have sufficient capacity to pull reactive power. • The connection of a power plant leads to voltage problems further on the radial due to existing power plants. • Reduce network losses (low power price or low service life).	• Use of synchronous generator to draw reactive power is often less expensive. • High net loss costs (high current price or high usage time).
Series voltage regulator	• Voltage Variations • High voltage	• DG causes too high voltage in many network drives. • Reduced loss costs in relation to voltage regulation with reactive power	• Often lower cost to build a new grid.
Distribution transformer with automatic step switch	• Voltage Variations	• The connection of the DG causes too high voltage in only some network drives. • Reduced loss costs in relation to voltage regulation with reactive power.	• The connection of the DG causes too high voltage in many distribution sub stations.
High temperature lines	• Transmission capacity	• Advantage of high temperature lines in cases where increased conductor cross section would lead to replacement of poles.	• Often, no power capacity limiting the connection of the DG to the powerline. • Often not allowed with blank lines in the distribution network. • Increased loss costs compared to building lines with increased cross-section

Tabell 1 – Oversikt over tiltak for å øke tilknytningskapasitet

(WP3) Make sure voltage optimization is optimally utilized

- Recommendations for setting voltage regulator in small power plants and step switches in power and distribution transformer.
- These recommendations shall first and foremost ensure that the operation and the connection of existing and new small power stations in high-voltage distribution networks are operated optimal.
- In addition, they will help reduce costs for power producers and grid companies.

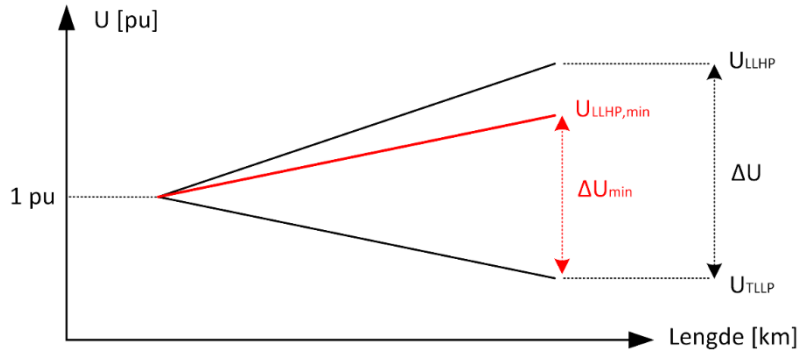
(WP3) Make sure voltage optimization is optimally utilized



- Heavy load - Low production (TLLP)
- Light load - High production (LLHP)

If the voltage variation ΔU from the load-analysis without regulation is less than 5% at all points in the network, no voltage regulation in the DG unit (s) will be required.
In such cases cosφ control with cosφ = 1 is a good choice of control mode.
This applies irrespective of whether there is one or more DG units attached to the radial.

(WP3) Make sure voltage optimization is optimally utilized



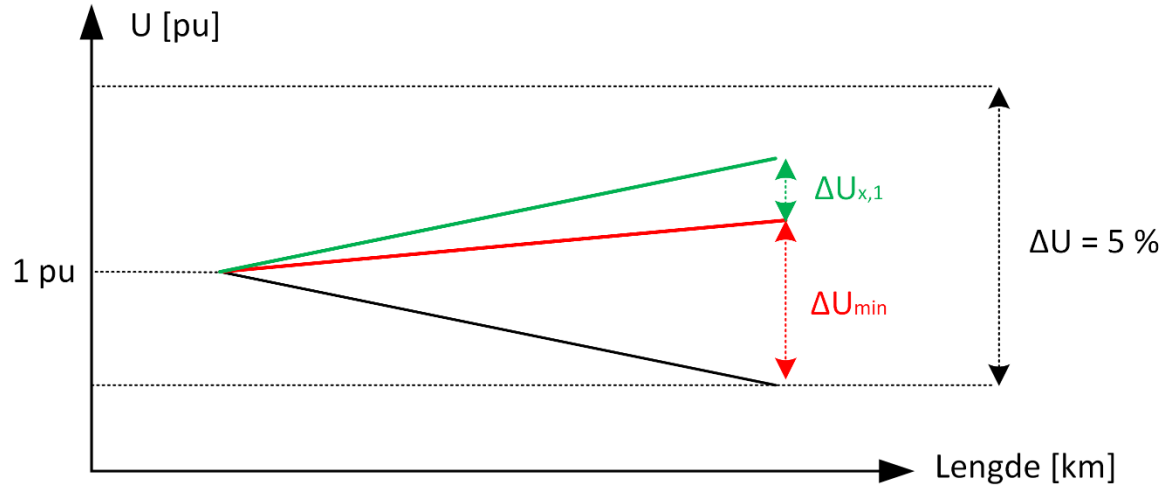
- Heavy load - Low production (TLLP)
- Light load - High production (LLHP)

In cases where the voltage variation ΔU from the initial load flow analysis exceeds 5%, it will be necessary to examine the regulatory capacity of the DG unit (s). This will be crucial for selecting the control mode, set point and any alternative measures..

By doing a load flow analysis with max output of active power (P = P_max) and maximum consumption of reactive power (Q = -Q_max) in DG unit (s), it is possible to investigate whether the DG unit (s) has sufficient regulatory capability at LLHP to reduce the voltage ΔU to below 5%.

(WP3) Make sure voltage optimization is optimally utilized

- One DG unit connected to the radial: Use voltage regulation with setpoint U_ (DG, min) + 3.75%
- Multiple DG units connected to the Radial: Determine Control Mode and Setpoint for the DG Devices:
  - The power plant with the highest voltage effect with reactive power, the power plant with the greatest ΔU_x, should be in fixed voltage setpoint regulation.
  - Based on the size of ΔU_x for the power plants, as well as ΔU_min radius, an assessment can be made whether one or more of the plants should be in cosφ regulation with cosφ = 1.



(WP4) Increased knowledge of socioeconomic consequences of allowing production limitation

- Production limitation can be economically profitable in some case.
  - Technically possible in today's power plant
  - Multiple analyzes are required to investigate losses as a result of lost production

Production limitation

NVE the regulator clarifications

- Not allowed to enter into restrictions on production as a lasting alternative to network investments.
- Temporary production limitation can be agreed
- While waiting for the network to be ready (granted a license and investment decision has been made)

(WP5) Increase knowledge about DGS stability properties FRT

Power plants small

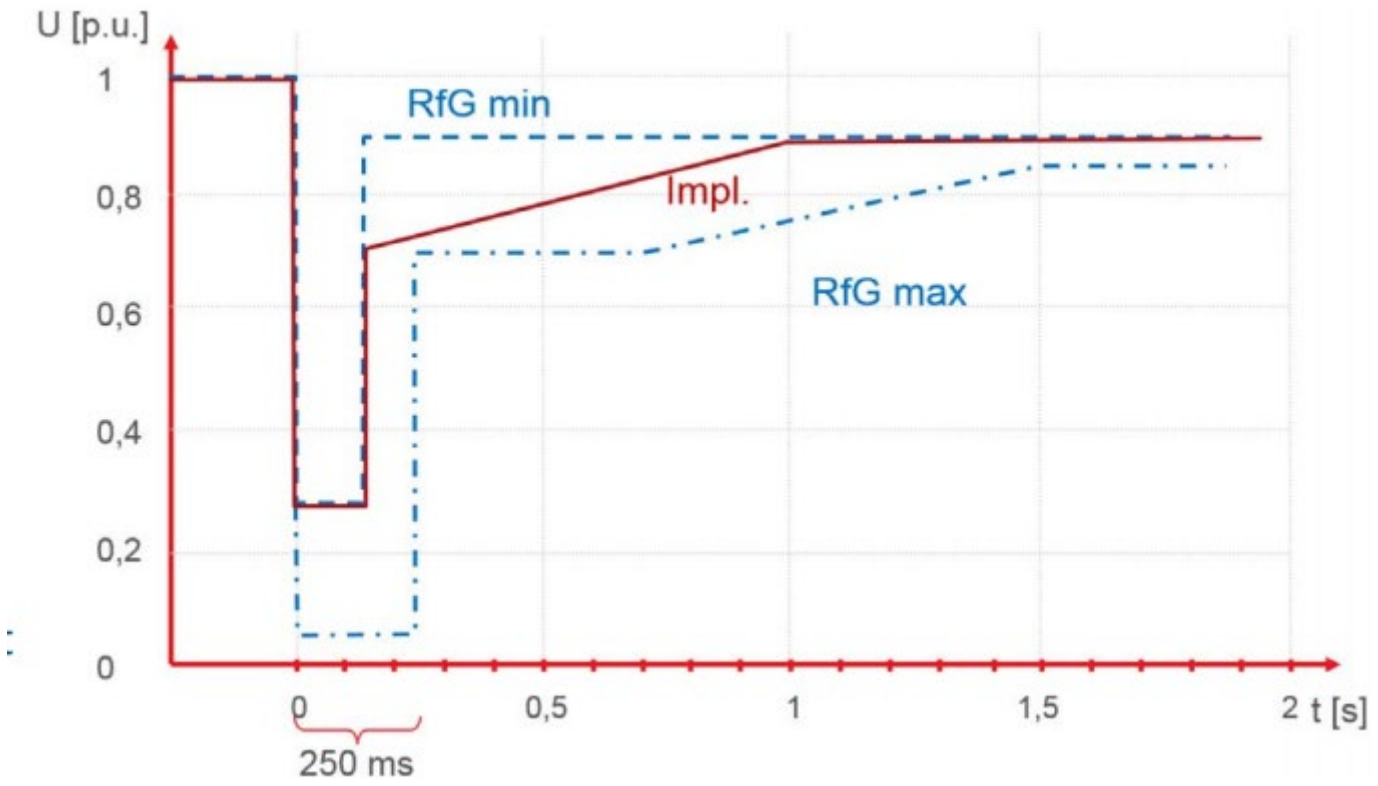
- Inertia constant (high)
- Transient reactance (low)
- Active power output at error (low)
- Reactive power output at error (high)
- Magnetic system and
- voltage regulation - ceiling voltage (high)

Grid

- Fault clearing time (short)
- Voltage at connection point before, below, and after failure (high)
- System impedance (low)
- R / X ratio (high)

Grid codes to be implemented I 2019

Is a blackout during the summer night every 50 years enough to make every power plant increase the investments cost with a significant percentage



Thank you for your time

From Bergen in april