5.6.2025

Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026

KJV2026
New requirements for demand connections

What, why and when?

Presentation to stakeholders on 5th of June 2025

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Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026

Agenda

1. Introduction - Development of Grid Code requirements

- Setting the scene: what's going on in Finnish power system?
- Framework of TSO's technical requirements
- Timeline for KJV2026 update

2. Why do we need to update the Grid Code for Demand connections now?

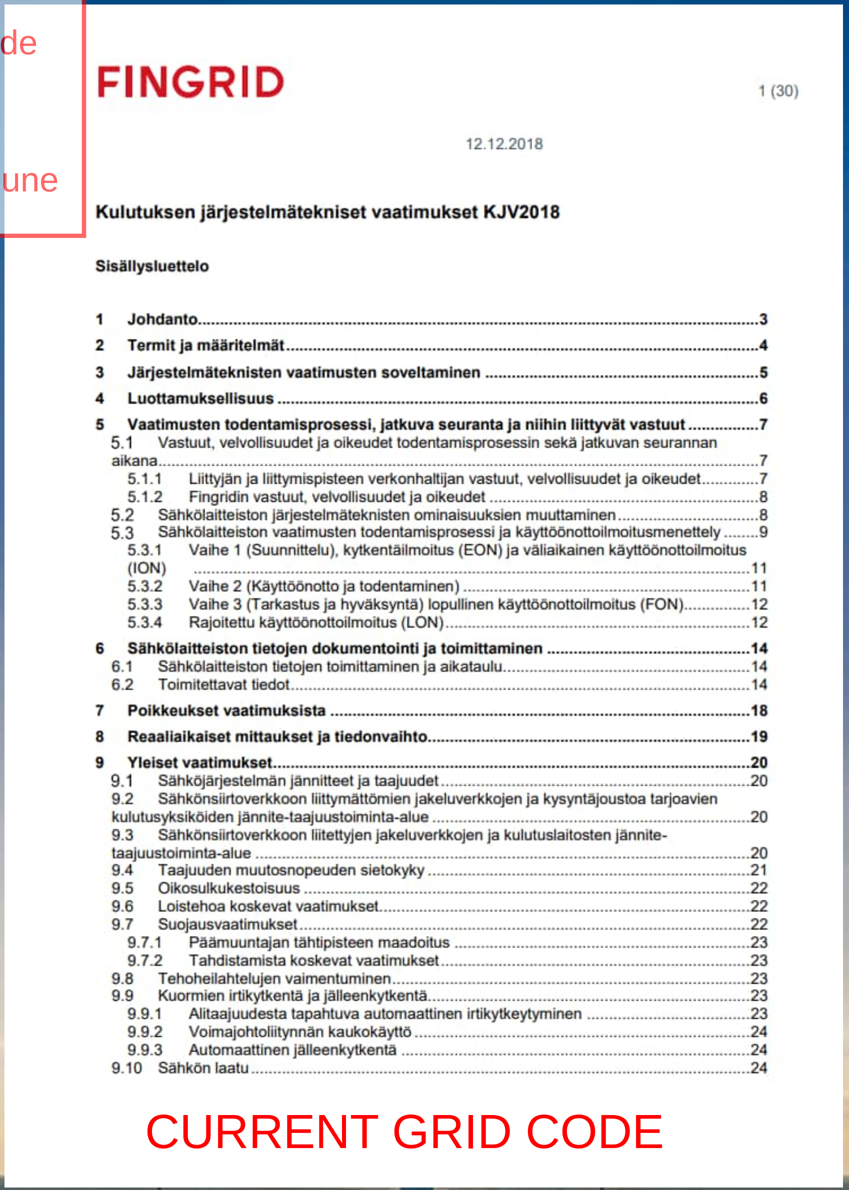
- Results from Fingrid's internal studies
- Identified risks in different technologies

3. New Main requirements for Large loads

- LVRT / PFAPR
- Reactive Power Compensation
- Signals and emergency control

4. Compliance Process

- How to demonstrate grid compliance?



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1 (30)

12.12.2018

Kulutuksen järjestelmätekniset vaatimukset KJV2018

Sisällysluettelo

CURRENT GRID CODE

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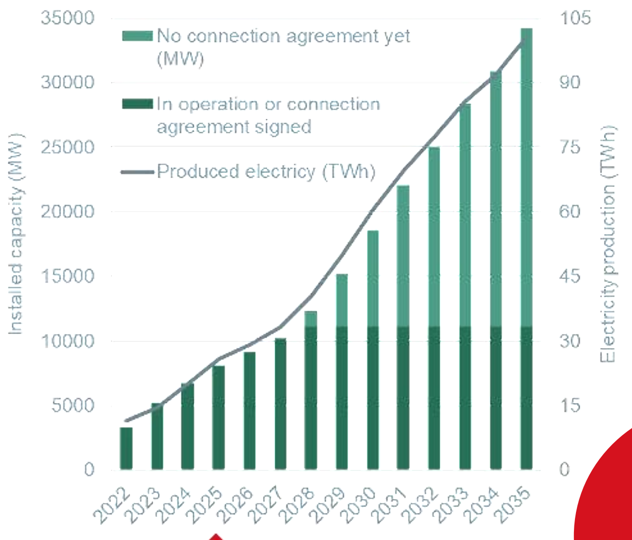
Outdated
see: KJV2026 Grid code specifications for Demand Connections
Presentation for stakeholders 12th of June 2026

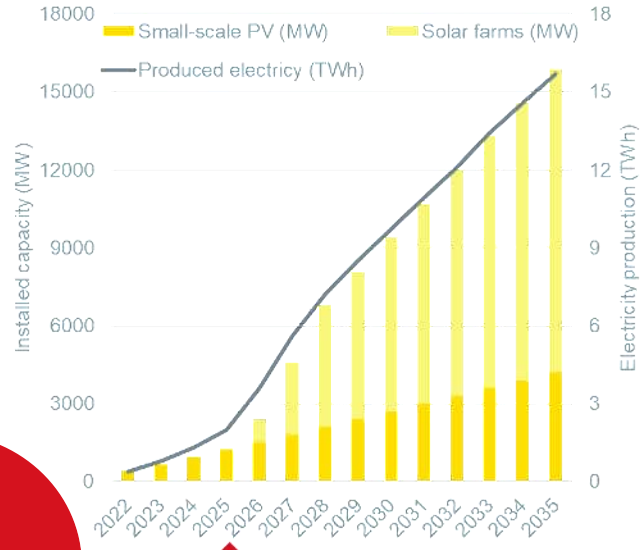
Setting the scene: What’s going on in Finnish power system?

Production vs. demand?

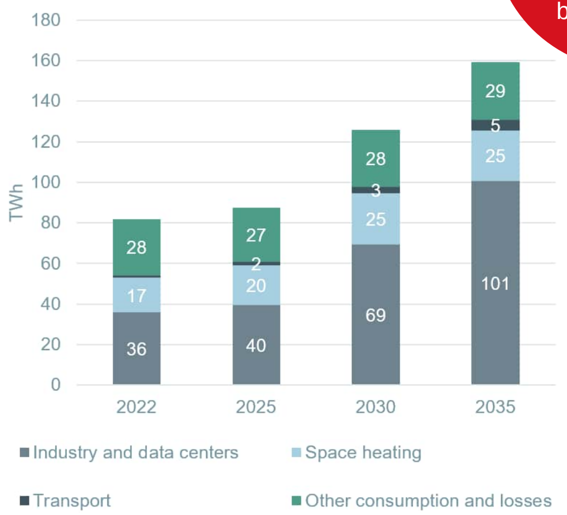
Amount of connection inquiries:

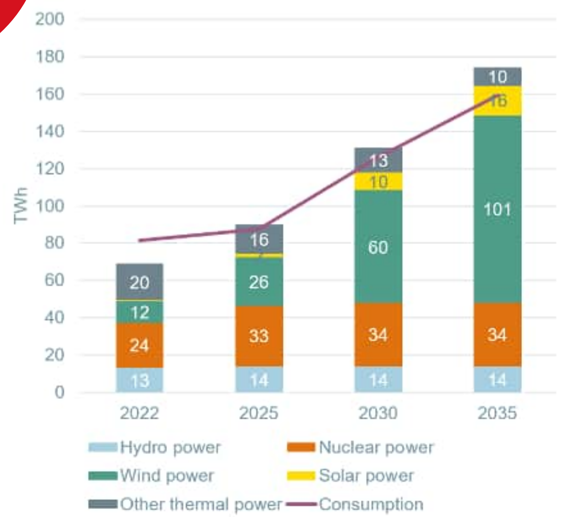
Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026

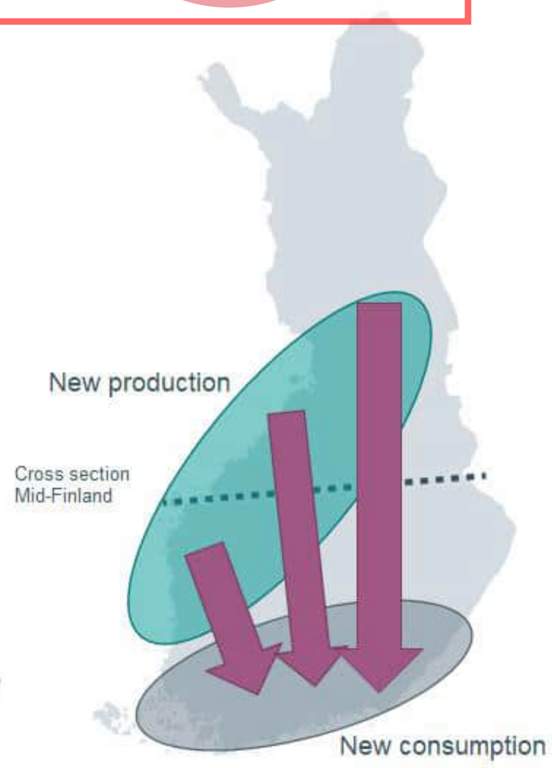




Energy storages: 27 GW requested, realistically several GW to be built in next 5 years







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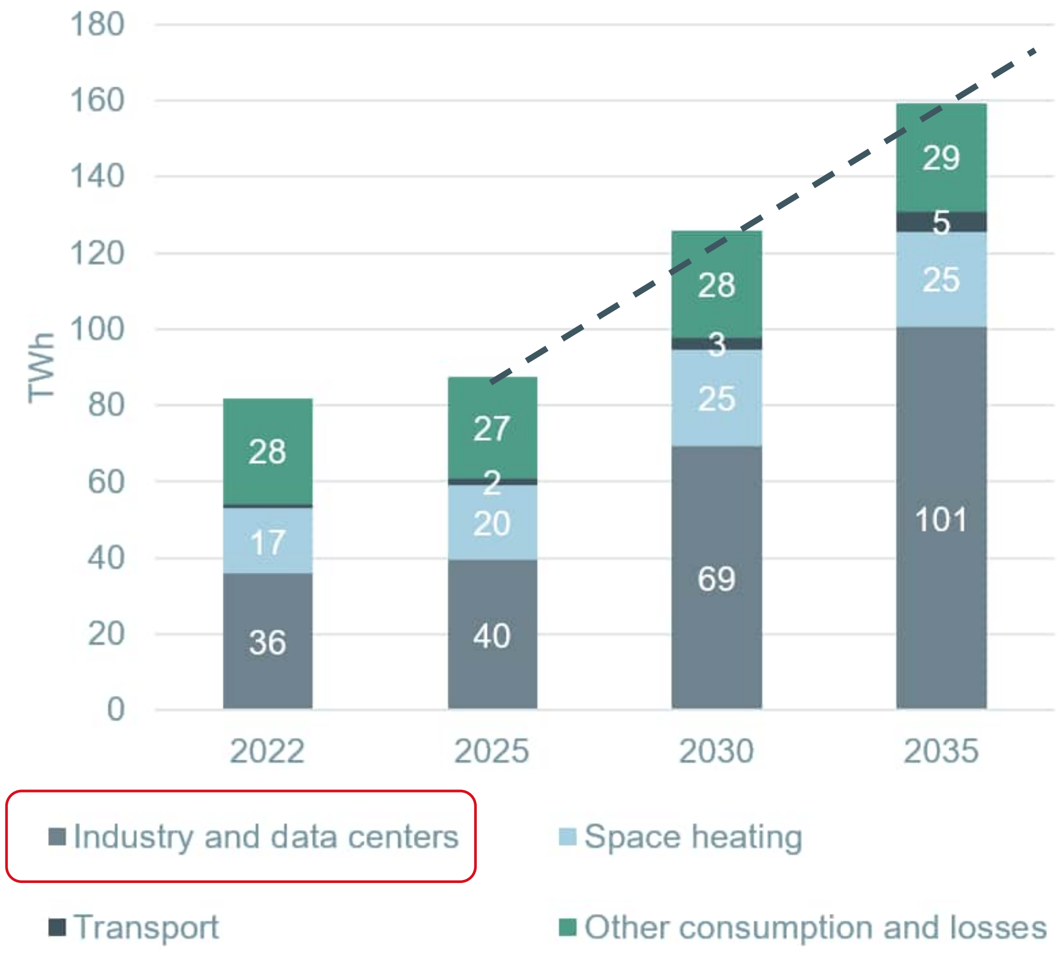
+ 40 TWh / 5 a + 40 TWh / 5 a = + 80 TWh / 10 a?

Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026



Liityntäkyselyitä
5.6.2025:
~71 GW

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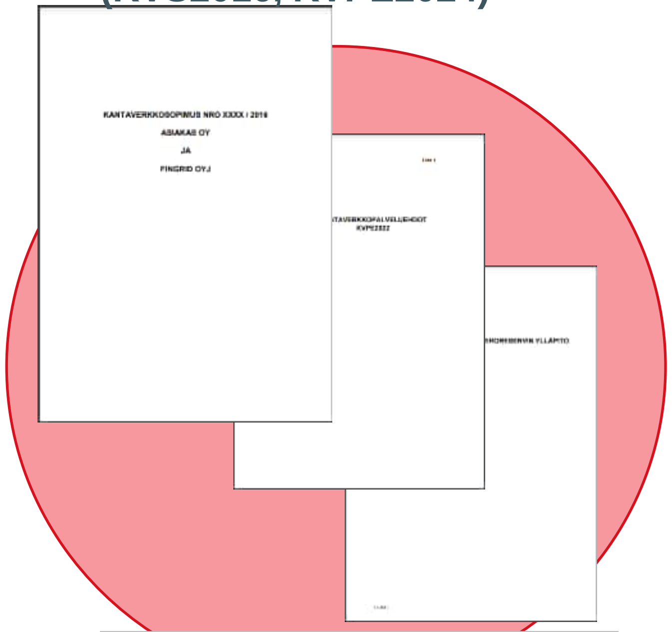
The Rules

Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026

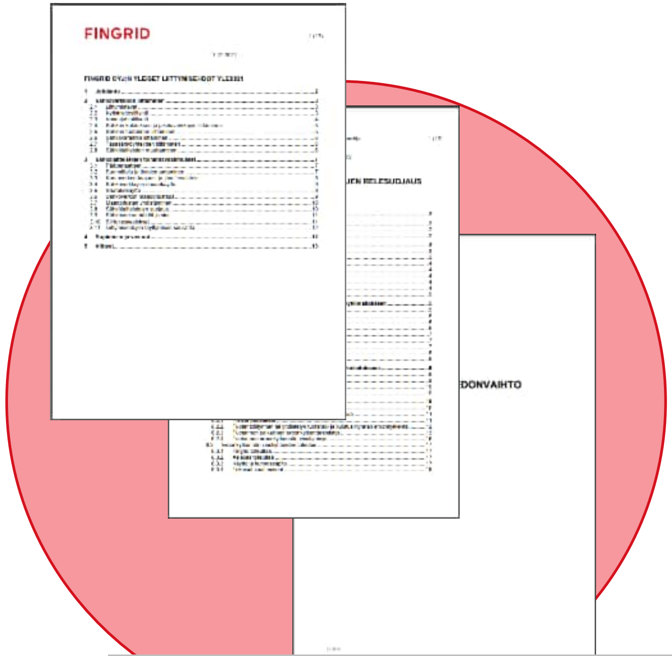
Connection agreement

Grid agreement and grid connection fees
(KVS2016, KVPE2024)



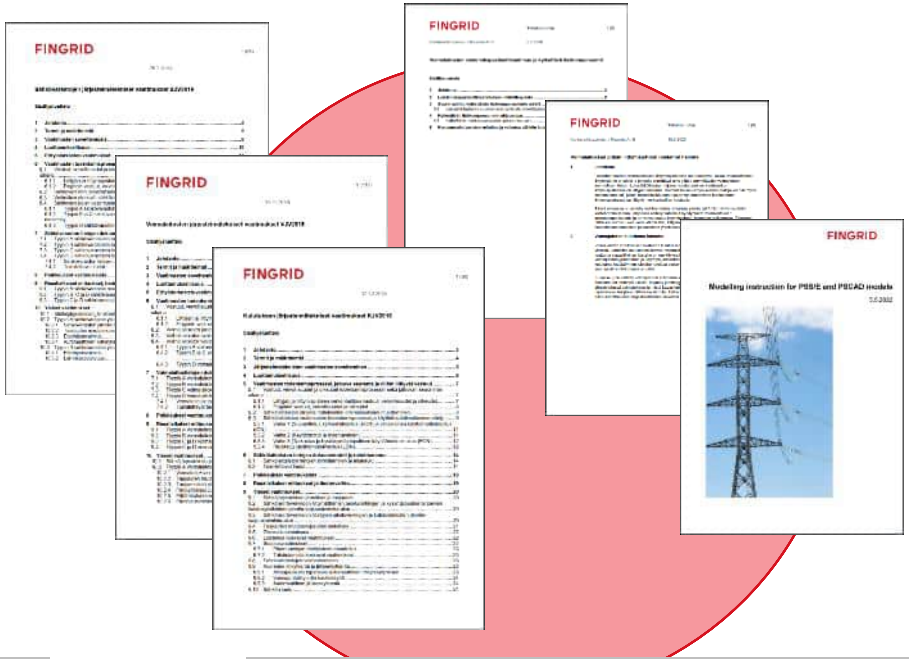
- Main grid service terms,
- Reactive power fees, etc.

General connection terms
(YLE2021)



- Connection types
- Technical principles (connection only)

Grid Code specifications
(VJV2024, SJV2024, KJV2018 → KJV2026)

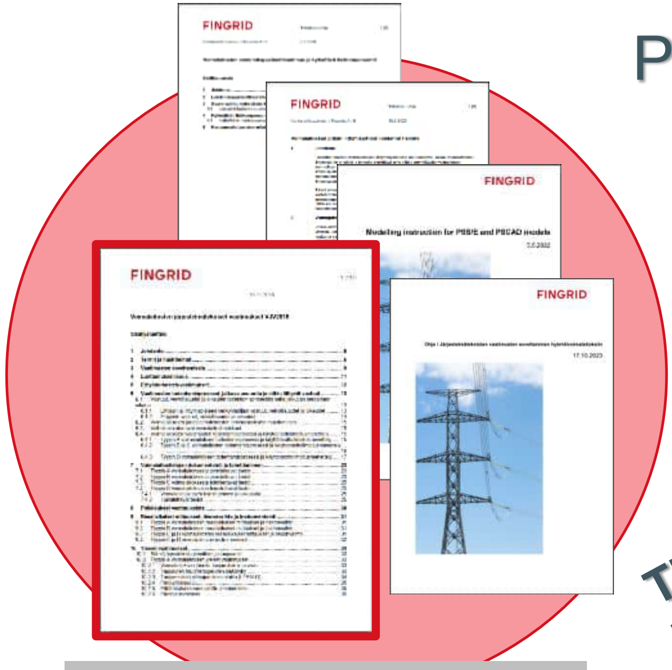


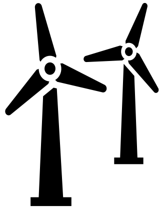
Technical requirements for the equipment to be connected: production or demand

Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026

Are technical requirements in balance?

Production



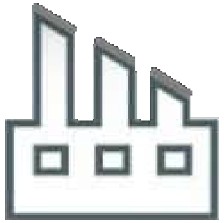


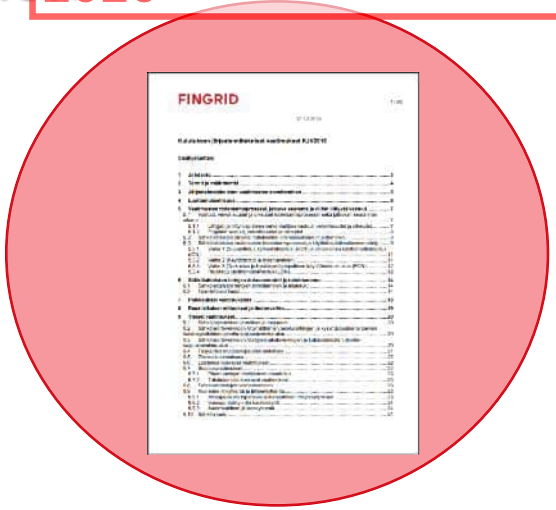
+ technical requirements and modelling instructions

The Grid code is in force from year 2024!

- Voltage oscillations caused by windfarms
- Sub synchronous oscillations in series compensated grid
- Modelling requirements
- Hybrid power plants
- BESS systems and Grid Forming

Consumption





The Grid code is in force from year 2018!

- Inquiries: 71 GW?
  - Largest sites are over 1000+ MW
  - Converter connected load;
    - P2G, Data centers, steel/aluminium,
  - Electric boilers

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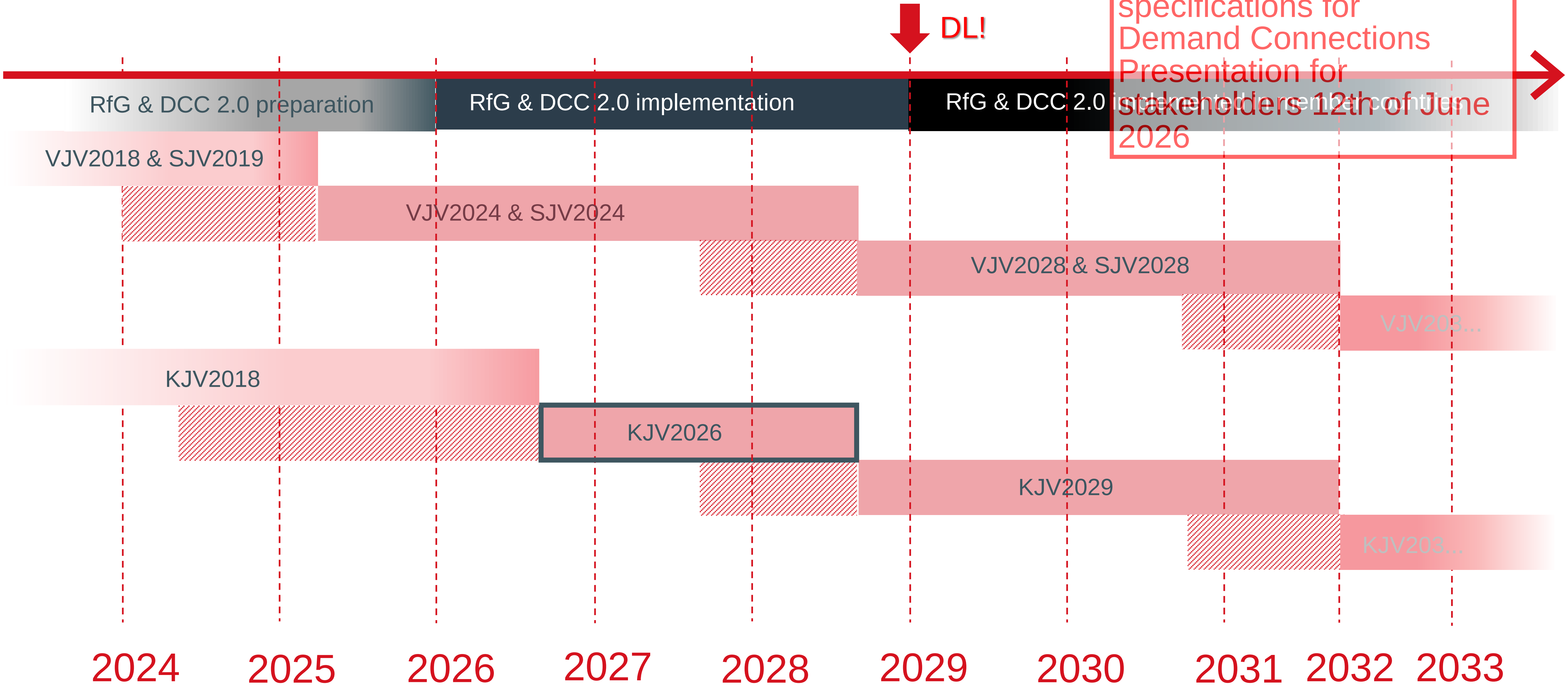
Timeline of the Grid Code development – Finland vs. EU

Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026



RfG = European Grid code for power plants, ”Requirements for Generators”
DCC = European Grid code for Demand Connections

VJV = Grid code for power plants
SJV = Grid code for energy storages

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What is KJV2026 made of?

Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026

Demand Connection Code "1.0":

KOMISSION ASETUS (EU) 2016/1388,

annettu 17 päivänä elokuuta 2016,

kulutuksen verkkoon liittämistä koskevasta verkkosäännöstä

National Energy Market Law:

Sähkömarkkinalain 45 §:n 1 momentin mukaan **järjestelmävastaava kantaverkonhaltija** vastaa Suomen sähköjärjestelmän teknisestä toimivuudesta ja käyttövarmuudesta siten, että sähköjärjestelmä toimii luotettavasti ja varmasti sekä huolehtii valtakunnalliseen tasehallintavastuuseen kuuluvista tehtävistä ja valtakunnallisesta taseselvityksestä tarkoituksenmukaisella ja sähkömarkkinoiden osapuolten kannalta tasapuolisella ja syrjimättömällä tavalla (järjestelmävastuu).

Sähkömarkkinalain 45 §:n 2 momentin mukaan **järjestelmävastaava kantaverkonhaltija** voi asettaa järjestelmävastuun toteuttamiseksi tarpeellisia ehtoja voimalaitosten, energiavarastojen ja kuormien sekä sähköverkkojen liittämiselle sähköjärjestelmään sekä sähköjärjestelmän ja siihen liitettyjen voimalaitosten, energiavarastojen, kuormien ja sähköverkkojen käyttämiselle. Ehtoja voidaan soveltaa yksittäistapauksissa sen jälkeen, kun Energiavirasto on ne vahvistanut sähkö- ja maakaasumarkkinoiden valvonnasta annetun lain 10 §:n mukaisesti. Vahvistettuja ehtoja voidaan soveltaa muutoksenhausta huolimatta, jollei valitusviranomainen toisin määrää.

KJV2026

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KJV2026 timeline (1/2)

Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026

DRAFT!

DRAFT!

Fingrid

1st Public presentation 06/2025
Presentation of main requirements

9/25-10/25

2nd Public presentation + Releasing KJV2026 document for comments
10/2025

11/25-12/25

Changes after 2nd comment round 11/2025

KJV2026 delivery to Energy Authority 12/2025 for confirmation

June | July | August | September | October | November | December

Stakeholders

6/25 – 8/25

Commenting period

10/25-11/25

Commenting period

Your feedback is highly appreciated!

- **Impact on your technology to be connected?**
- **What it means to meet the requirement?**
- **Alternative solutions?**

Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026

KJV2026 timeline (2/2)

Energy Authority

Public hearing by energy authority 1-3/2026

1/26-3/26

Fingrid

Changes to KJV2026 according to public hearing and delivery to Energy Authority 6/2026

4/26-5/26

Energy Authority

Energy Authority's review & final public hearing

6/26-8/26

Energy Authority to confirm KJV2026?

January | February | March | April | May | June | July

Stakeholders

Commenting period

Stakeholders

Commenting period

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Outdated
see: KJV2026 Grid code specifications for Demand Connections
Presentation for stakeholders 12th of June 2026

Background and objectives of the network regulation reform

Fingrid's system studies

EU regulation DCC 2.0

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EU regulation: DCC 2.0

Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026

ACER
European Union Agency for the Cooperation of Energy Regulators

COMMISSION REGULATION (EU) …/…

of …

establishing a Network Code on Demand Connection

(Text with EEA relevance)

THE EUROPEAN COMMISSION,

Having regard to the Treaty on the Functioning of the European Union,

Having regard to Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity (recast) (¹), and in particular Article 59 (13) thereof,

Whereas:

(1) The swift completion of a fully functioning and interconnected internal energy market is crucial to maintaining security of energy supply, increasing competitiveness and ensuring that all consumers can purchase energy at affordable prices.

(2) Regulation (EU) 2019/943sets out non-discriminatory rules governing access to the network for cross-border exchanges in electricity with a view to ensuring the proper functioning of the internal market in electricity. In addition Article 3 of Directive (EU) 2019/944 of the European Parliament and of the Council (²) requires that Member States should ensure, inter alia, , a level playing field where electricity undertakings are subject to transparent, proportionate and non-discriminatory rules, fees and treatment. Where requirements constitute terms and conditions for connection to national networks, Article 59(7) of the same Directive requires regulatory authorities to be responsible for fixing or approving at least the national methodologies used to calculate or establish them. In order to provide system security within the interconnected transmission system, it is essential to establish a common understanding of the requirements for grid connection applicable to demand facilities and distribution systems, including closed distribution systems. Those requirements that contribute to maintaining, preserving and restoring system security in order to facilitate proper functioning of the internal electricity market within and between synchronous areas, and to achieve cost efficiencies, should be regarded as cross-border network issues and market integration issues.

(3) Harmonised rules for grid connection for demand facilities and distribution systems should be set out in order to provide a clear legal framework for grid connections, facilitate Union-wide trade in electricity, ensure system security, facilitate the integration of renewable electricity sources, increase competition, and allow more efficient use of the network and resources, for the benefit of consumers.

2

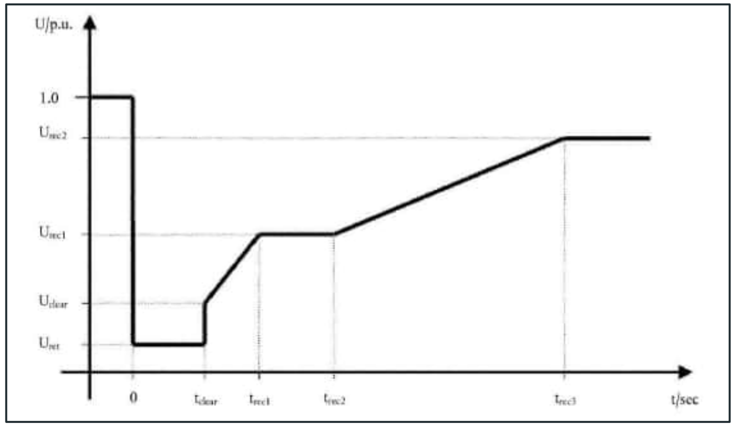


Table (3)X.1.3

Voltage parameters for Figure (4)XX.d of a power-to-gas demand unit.

Voltage parameters (pu)	
U_{ret}:	0
U_{clear}:	0
U_{rec1}:	0
U_{rec2}:	0,85

1. This Regulation establishes a network code which lays down the requirements for grid connection of:

(a) transmission-connected demand facilities;

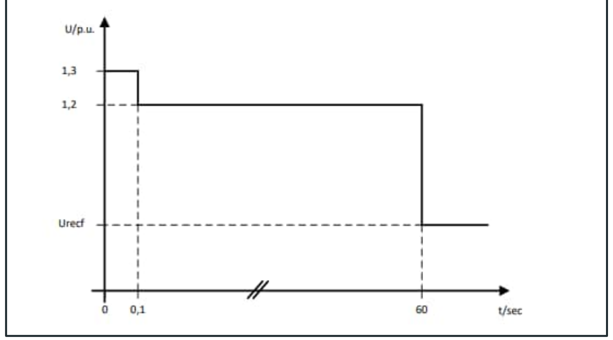
(b) transmission-connected distribution facilities;

(c) distribution systems, including closed distribution systems;

(d) demand units, used by a demand facility or a closed distribution system to provide demand response services to relevant system operators and relevant TSOs;

(e) V1G electric vehicles and associated V1G electric vehicle supply equipment, heat-pumps and power-to-gas demand units.

High voltage-ride-through profile of a power-to-gas demand unit



Nordic	47,5 Hz-48,5 Hz	30 minutes
	48,5 Hz-49,0 Hz	To be specified by each TSO, but not less than 30 minutes
	49,0 Hz-51,0 Hz	Unlimited
	51,0 Hz-51,5 Hz	30 minutes
	51,5 Hz-52,5 Hz	10 seconds

When the network voltage resumes, after the fault has been cleared, to a value within the voltage range of 0,85 pu – 1,1 pu, a power-to-gas demand unit shall recover its active power ~~output~~consumption~~s~~ level at the connection point. The relevant TSO shall specify the magnitude and time for active power recovery. ~~to:~~

→ Datacenters?
Electric Boilers?

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ENTSO-E raises a concern of large scale P2G units

Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026

Hint: These are relating to system frequency!

entsoe

ENTSO-E Position on Urgent Connection Requirements for Power-to-Gas Demand Facilities

Approved | 17 September 2024

From: System Development Committee

RECOMMENDATIONS

Therefore, to ensure secure operation during the planned rapid expansion of Power-to-Gas capacities, ENTSO-E recommends the introduction of technical requirements at national level for all Power-to-Gas demand facilities with a connection point of 110 kV and above in Europe as soon as possible. These requirements should at a minimum address the following:

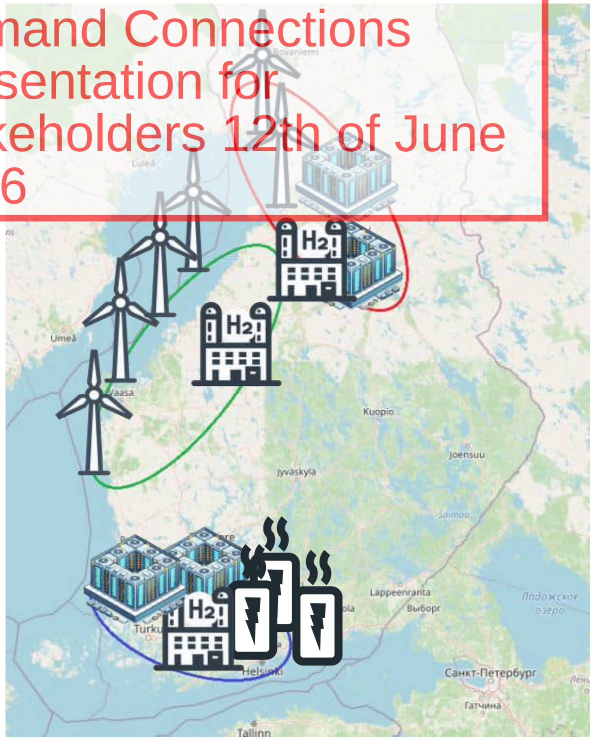
- Rate of Change of Frequency robustness;
- Fault-Ride-Through capability; and
- Active power recovery after faults.

To ensure security of supply and a level playing field, all Member States, competent entities, and system operators are encouraged to take the appropriate steps at national level to implement these requirements considering the national legal frame.

Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026

Fingrid’s system studies

- *As the transmission system operator (TSO) with system responsibility, Fingrid is in responsible for ensuring the technical functionality and security of Finland’s power system.*
- *Study questions;*
    - *How should demand facilities respond during various grid events?*
    - *How should demand facilities operate in converter dominated power system?*
    - *To what extent can a single grid event impact a large number of loads? (Voltage dip propagation)*
- Three areas inclued;
    - *Production dominant area*
    - *Neutral area*
    - *Consumption dominated area*
- **Impacts on;**
    - ***Frequency stability***
    - ***Voltage stability***
    - ***Power transmission***



In addition to this

- Stakeholder/OEM interviews
- TSO co-operation

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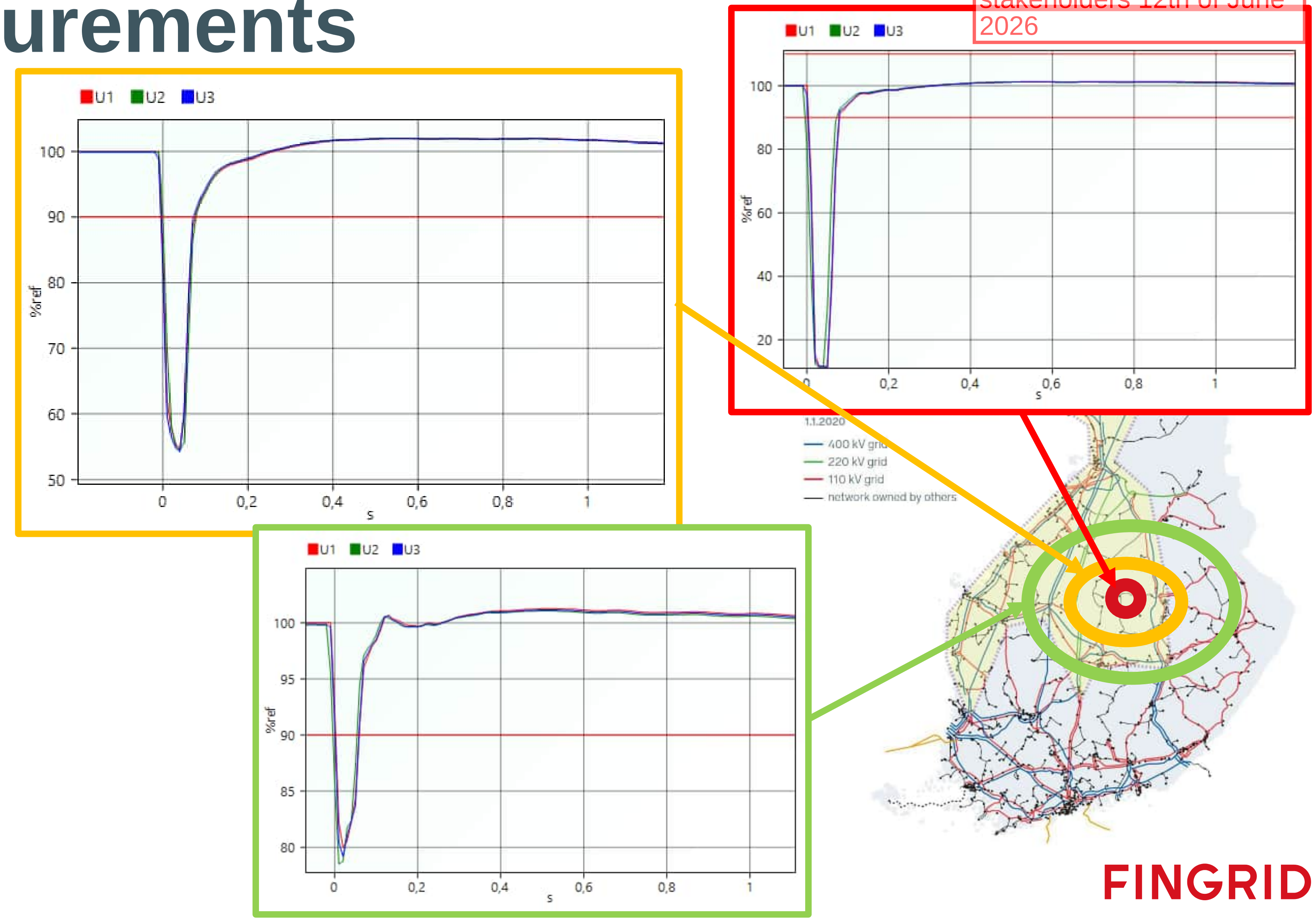
Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026

Propagation of voltage dip during fault in 400 kV Grid: Measurements

Future view of ”voltage dip propagation”;

- As we strenghten our grid we actually make the voltage dips to propagate over larger areas due to smaller impedances between the nodes
- Less synchronous generators
- Situation gets worser



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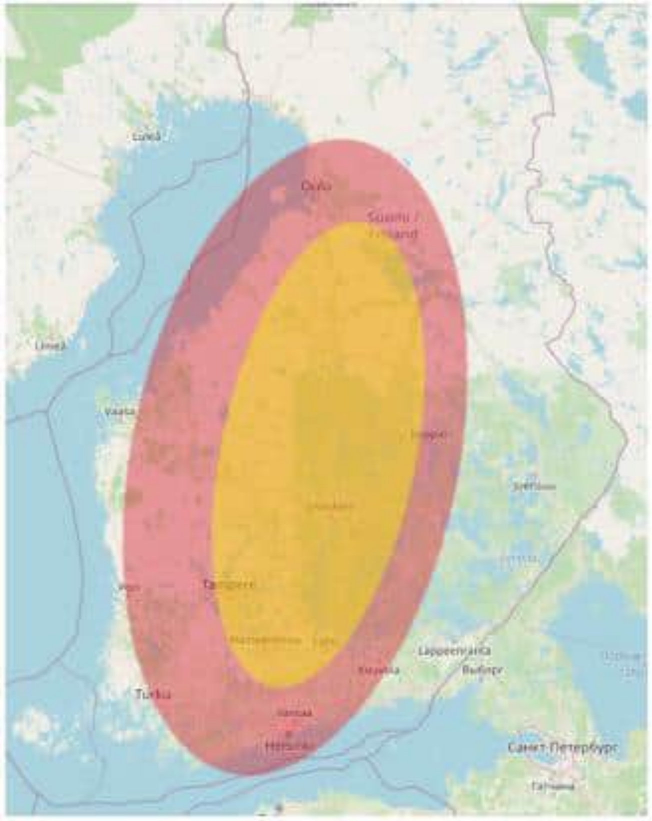
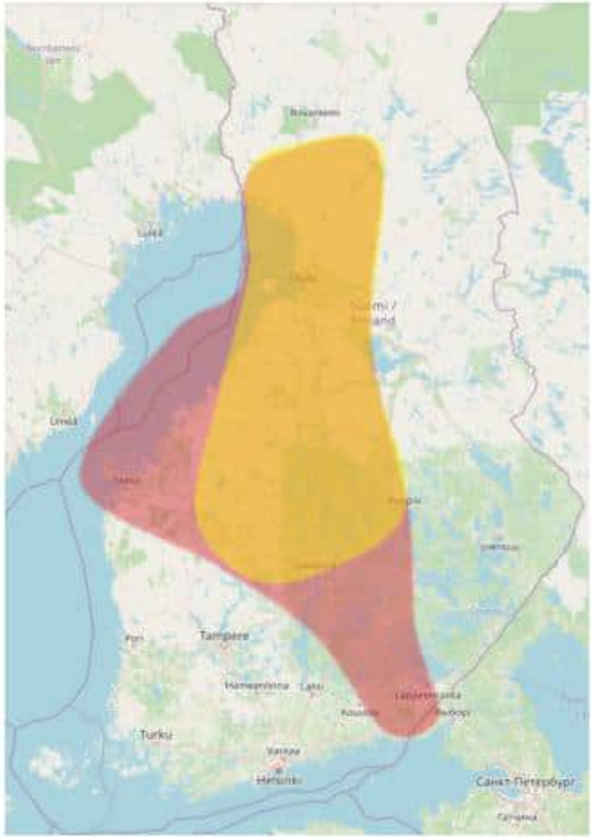
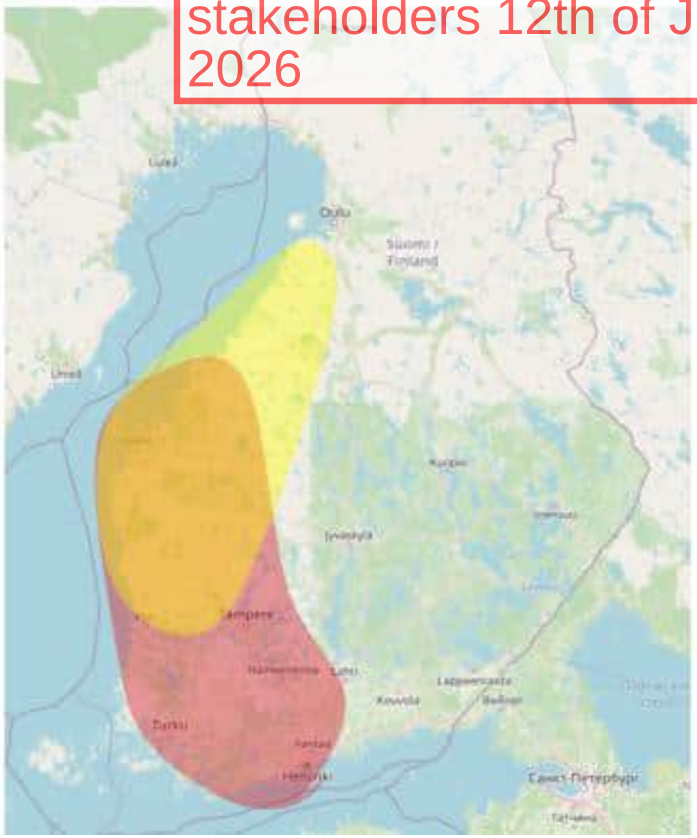
Propagation of Voltage dip by simulations 2025 vs 2030

Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026

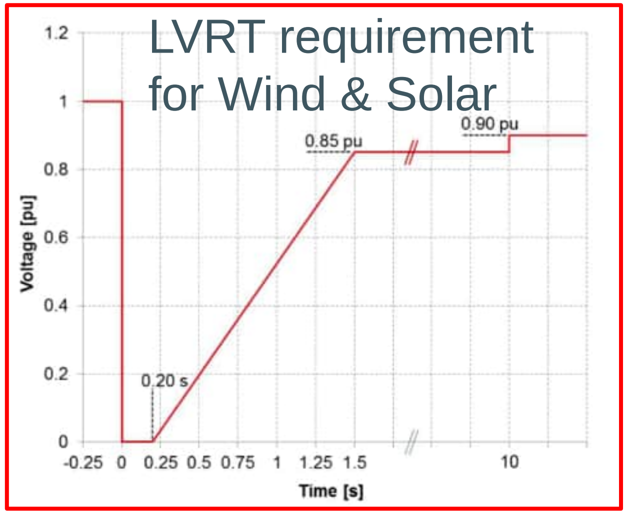


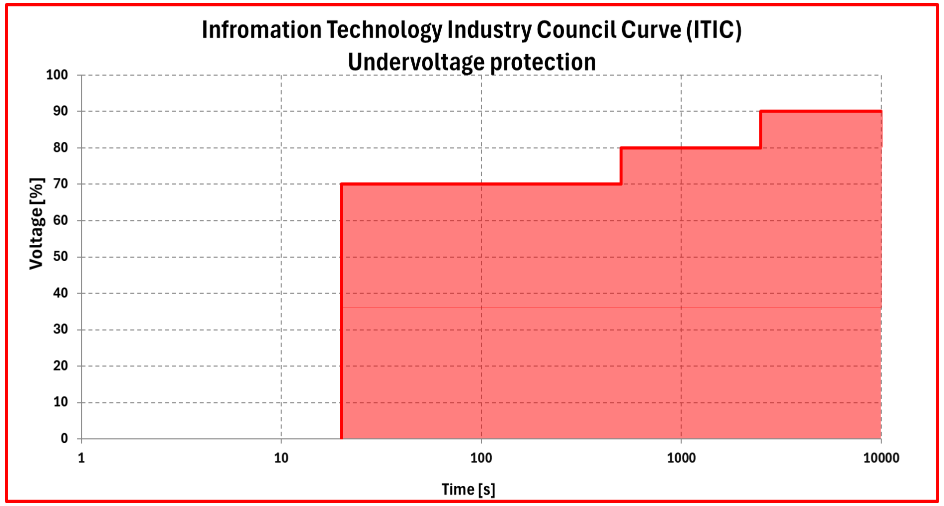




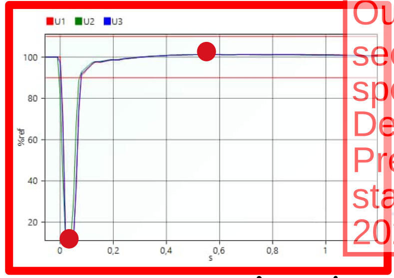
Why this is important?

- Power plants has **Low Voltage Ride Through LVRT** requirement (below picture) and **Post-Fault Active Power Recovery PFAPR** determined (< 3 seconds)

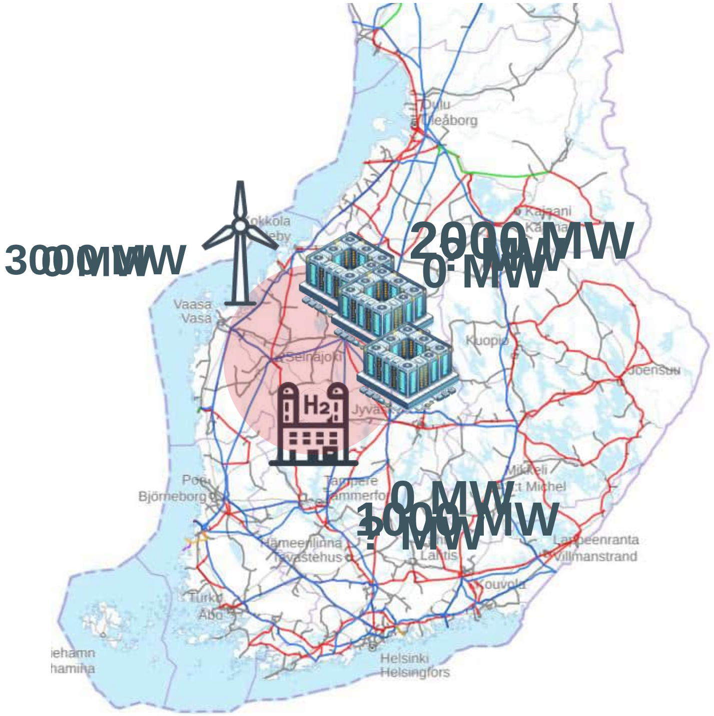




- Demand facilities doesn't have this clearly determined (KJV2018)
  - Several risks has been identified that large load facilities WILL disconnect during voltage dip
    - P2G = process trip
    - Datacenters = Strict undervoltage protections (ITIC/CBEMA curves)



Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026



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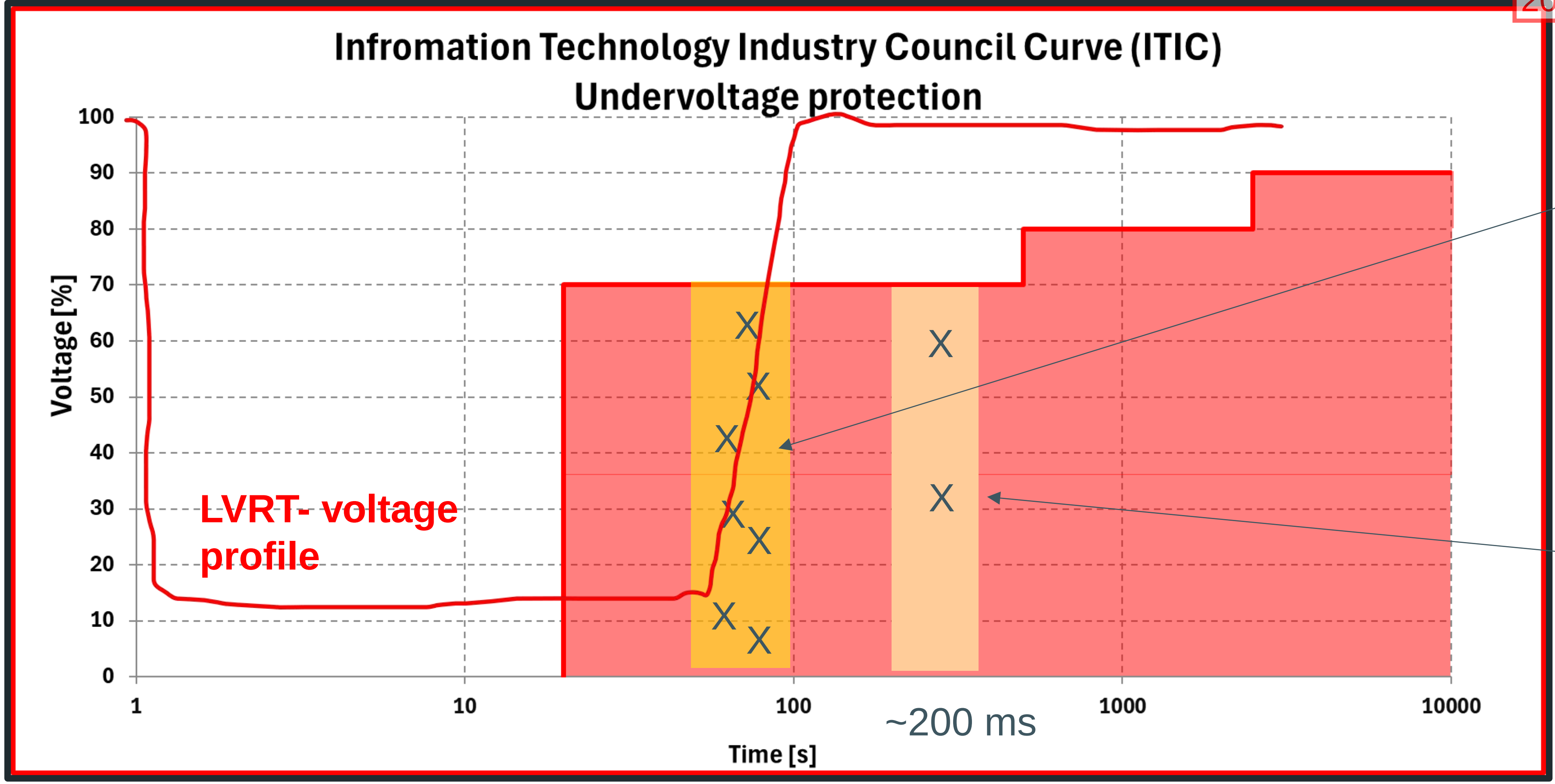
ITIC /CBEMA curve

Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026

TSO **can not** fix this!



Typical protection time of 400 kV system

~70 ms

Back-up protection time of 400 kV system

~200 ms

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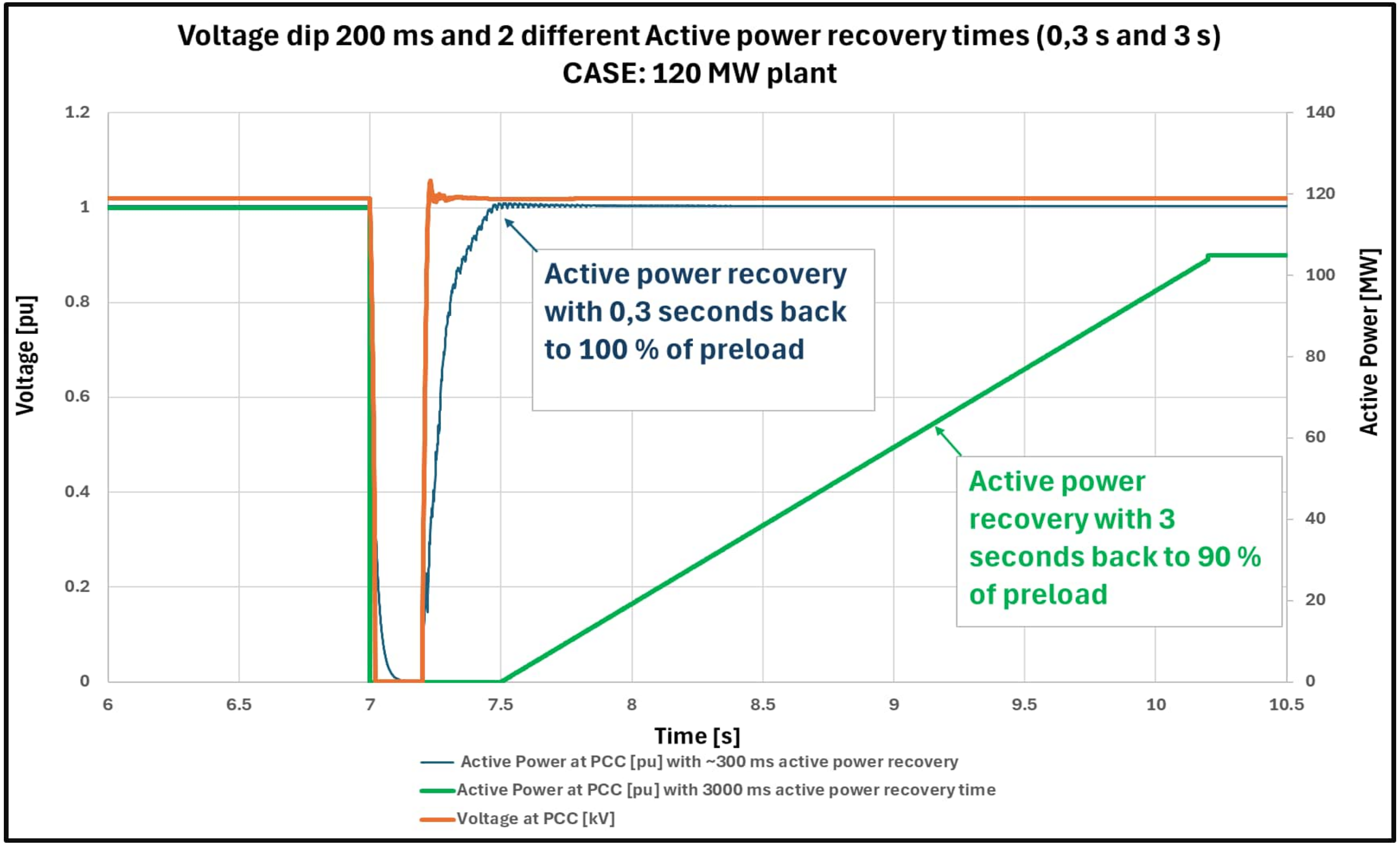
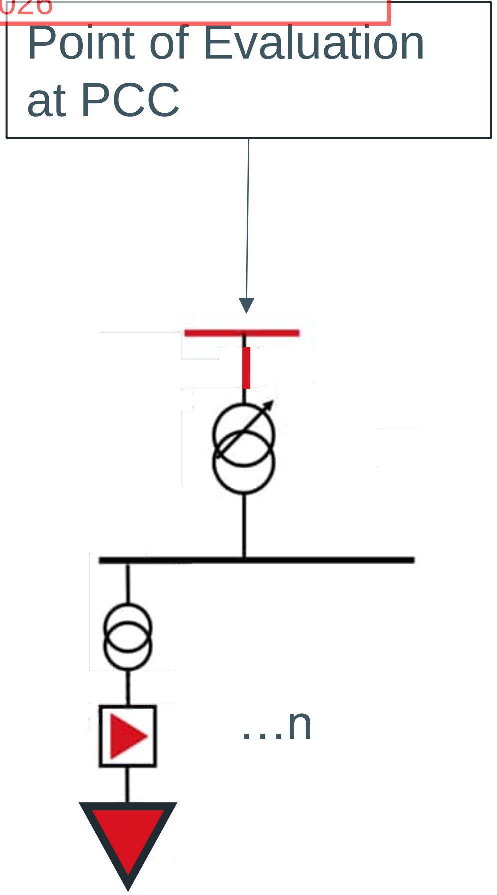
What is active power recovery (PFAPR)?





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Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026

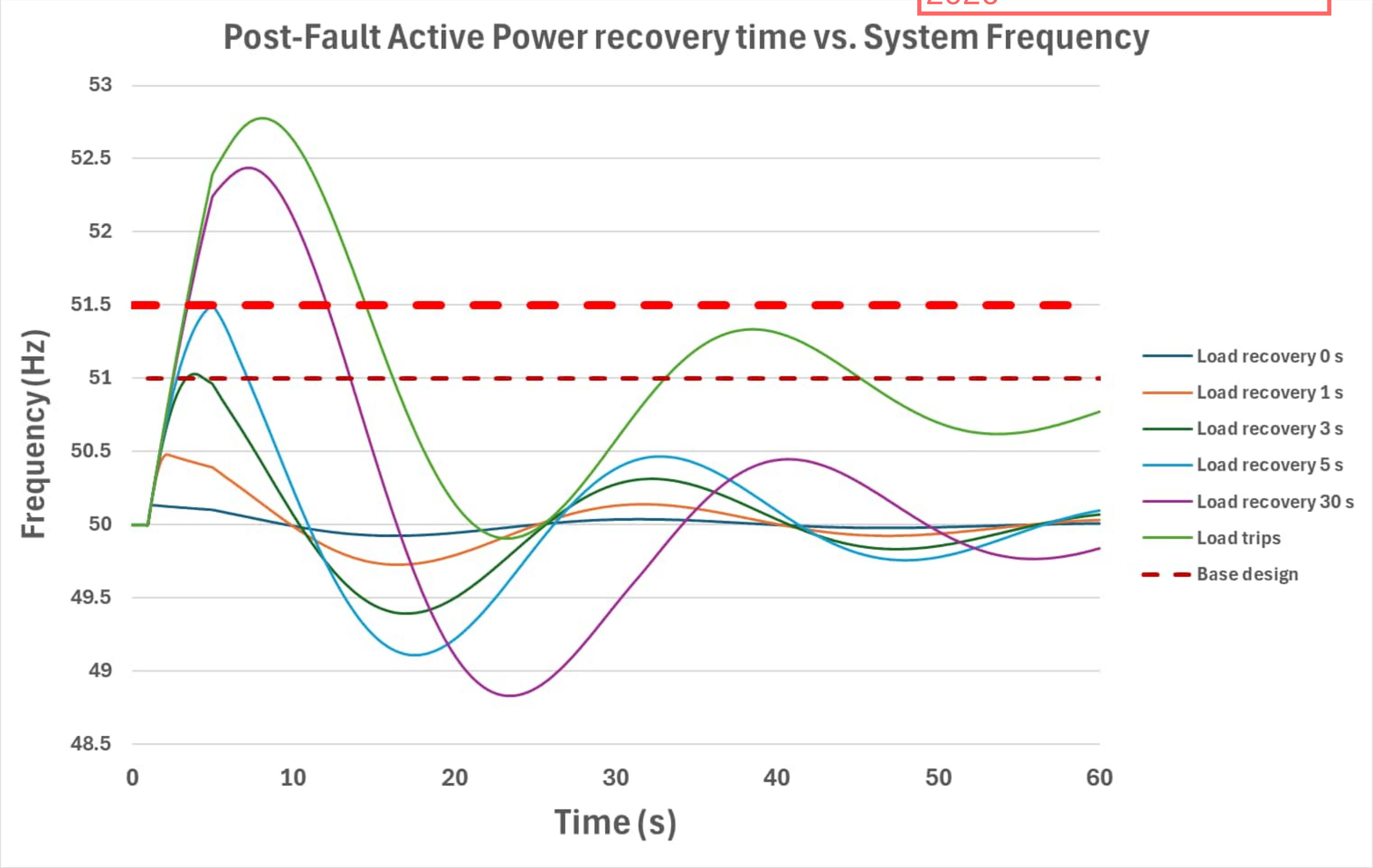
What if PFAPR is left out of specification?

And..

+ Future loads are large
+ Voltage dip propagation
+ Several loads are affected by same dip
-> Significant risk of over frequency!

FREQUENCY INSTABILITY

Studies also show local overvoltages on a transmission system level, power transmission swings etc. all require fast recovery time



Low Voltage Ride Through requirement and Post-Fault Active power requirement are needed in KJV2026

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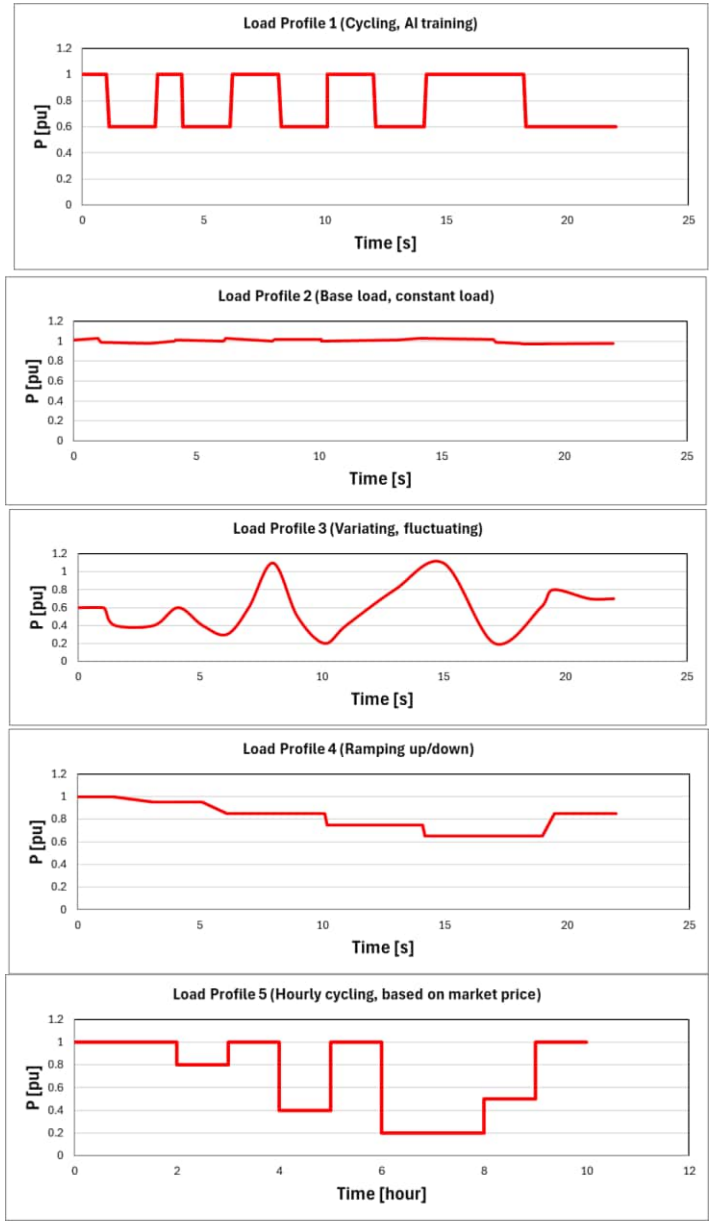
Interactions?

Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026

- Demand profile might vary;
  - Because of the cost per MW
  - Because of the temperature / climate
  - Because of the cycling power needed by the process
  - Or might be constant

- Most of the new loads are converter connected loads;
  - Non-linear
  - Includes PLL's



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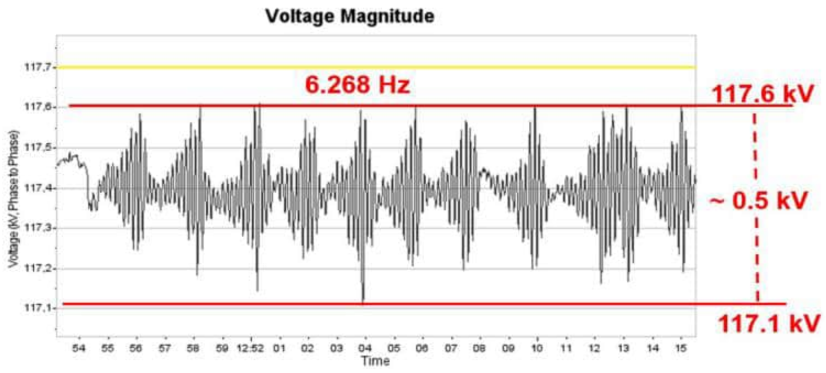
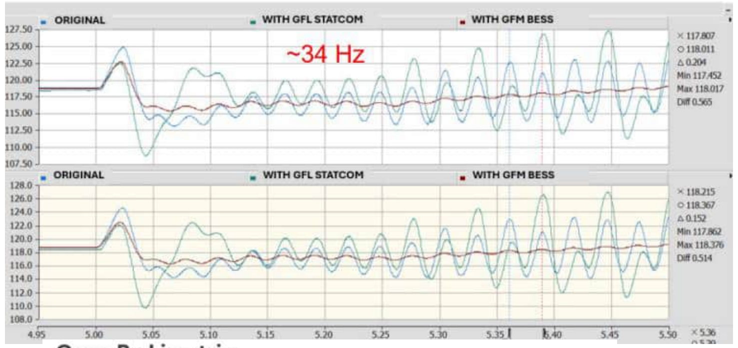
Interactions in practice?
- experiences from generation

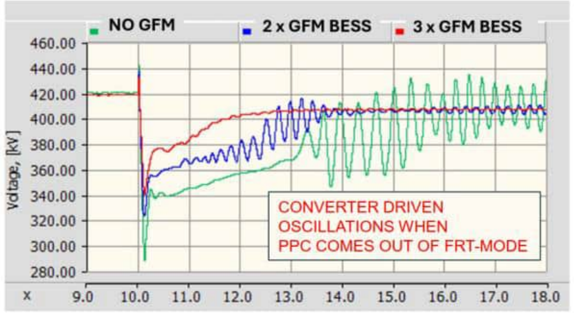
Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026



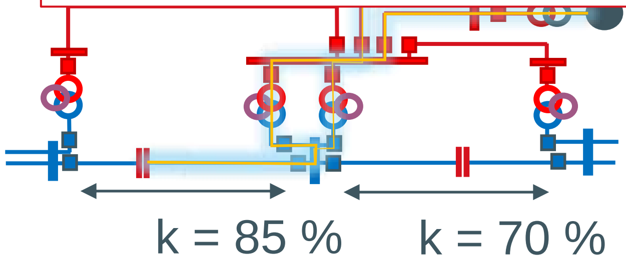
Instability of Wind Farm voltage controllers



Case B : Line trip
400 kV bus voltage

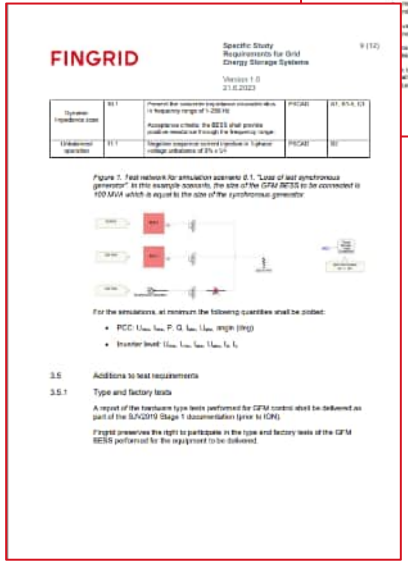


DFIG Wind Farms and serial compensated transmission grid



Converter dominated power system – recovering from fault

SSO damping requirement (DFIG's)



Grid Forming requirement – "Virtual synchronous machines"

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Three different cases which has system level impacts

Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026

NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Incident Review
Considering Simultaneous Voltage-Sensitive Load Reductions

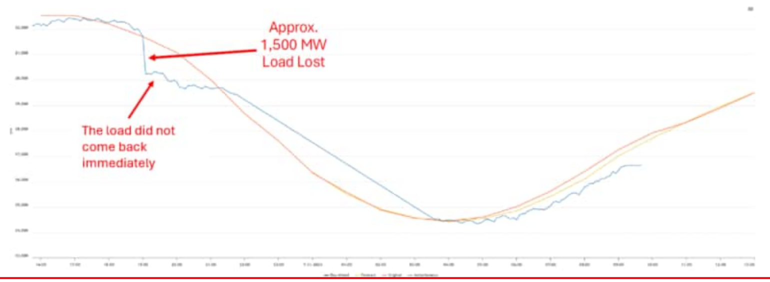
Primary Takeaways
Operators and planners of the Bulk Electric System (BES) should be aware of the risks and challenges associated with voltage-sensitive large loads that are rapidly being connected to the power system. Specifically, when considering data centers and cryptocurrency mining facilities, entities should be aware of the potential for large amounts of voltage-sensitive load loss during normally cleared faults on the BES. Voltage-sensitive data center-type loads have increased on the system and are predicted to continue growing rapidly. The 2024 NERC *Long-Term Reliability Assessment* (LTRA) documents and discusses this potential growth of data center-type loads. This vignette highlights this load-loss potential based on analysis of a recent event in the Eastern Interconnection and offers some considerations for BES operators, planners, and regulators concerning identifying and mitigating the potential reliability effects and risks presented by these large voltage-sensitive load losses for future operations.

Summary of Incident
A 230 kV transmission line fault led to customer-initiated simultaneous loss of approximately 1,500 MW of voltage-sensitive load that was not anticipated by the BES operators. The electric grid has not historically experienced simultaneous load losses of this magnitude in response to a fault on the system, which has historically been planned for large generation losses but not for such significant simultaneous load losses. Simultaneous large load losses have two effects on the electric system: First, frequency rises on the system as a result of the imbalance between load and generation; second, voltage rises rapidly because less power is flowing through the system. In this incident, the frequency did not rise to a level high enough to cause concern. The voltage also did not rise to levels that posed a reliability risk, but operators did have to take action to reduce the voltage to within normal operating levels. However, as the potential for this type of load loss increases, the risk for frequency and voltage issues also increases. Operators and planners should be aware of this reliability risk and ensure that these load losses do not reach intolerable levels.

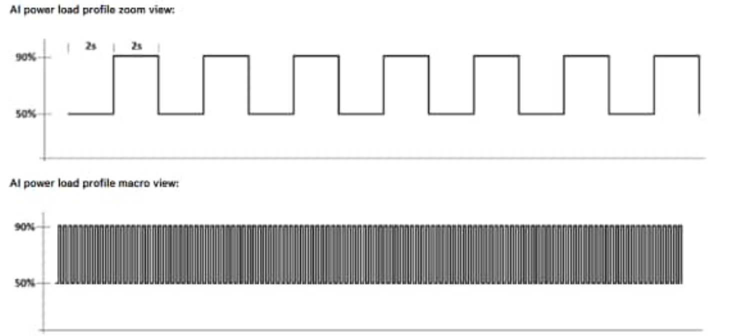
Incident Details
At approximately 7:00 p.m. Eastern on July 10, 2024, a lightning arrestor failed on a 230 kV transmission line in the Eastern Interconnection, resulting in a permanent fault that eventually "locked out" the transmission line. The auto-reclosing control on the transmission line was configured for three auto-reclose attempts staggered at each end of the line. This configuration resulted in 6 successive system faults in an 82-second period. The protection system detected these faults and cleared them properly. The shortest fault duration was the initial fault at 42 milliseconds, and the longest fault duration was 66 milliseconds. The voltage magnitudes during the fault ranged from .25 to .40 per unit in the load-loss area.

1500 MW lost due to UPS parametrization; approx. 60 datacenters

MW of load reduction was exclusively data center-type load. The area where the disturbance occurred has a high concentration of data center loads.



Discussions with the data center owners also identified another protection/control scheme that impacts the response of data center load to voltage disturbances on the grid. The scheme detects and counts voltage disturbances on the grid. If a certain number of voltage disturbances are seen within a certain time, the data center will transfer its load to the backup system, and it will remain there until it is manually reconnected to the grid. The typical number of voltage disturbances that trigger this scheme is three, and a typical time is one minute. As such, three voltage disturbances within one minute will result in data centers using this protection/control scheme transferring their load off the grid and staying off until they manually transfer back. This scheme can be deployed on both centralized and decentralized UPS designs. A load characteristic for this type of data center control scheme can be seen in Figure 10.



AI training: in this example the load cycling is 0,25 Hz when **Interarea oscillations between Finland and Sweden are 0,30-0,40 Hz!**

Must be locally damped, since grid cannot damp this!

VERTIV:
evaluating-performance-large-ups-ai-white-paper-sl-71956.pdf

Data Center Power System Stability – Part I: Power Supply Impedance Modeling

Jian Sun, *Fellow, IEEE*, Mingchun Xu, Mauricio Cespedes, and Mike Kauffman

***Abstract*—This two-part paper presents methods to predict, characterize and ensure the stability of data center power systems based on impedance analysis. The work was motivated by recent power system resonance incidents in new data centers. Part I presents new input impedance models for single-phase power sup-**

confronted the renewable energy and HVDC industry in recent years [2], [3].

In 2017, an almost identical resonance phenomenon was observed in multiple Meta data centers. Fig. 1(a) shows a set

SSO ?

frequency due to control delays. Negative damping near the fundamental frequency can cause low-frequency resonance when the grid impedance is high. This is a common problem for large-scale wind and PV systems [8], [10], and is identified as the root cause for the low frequency resonance described in Part I. On the other hand, delay-induced negative damping is responsible for high-frequency resonances [11], [13]. (Refer

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Target of the new requirements

- Improve the Demand Facilities ***grid fault/event resilience - secure frequency stability***

- Prevent harming ***interactions***

- Add more ***visibility and operability*** of new Demand Facilities

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DRAFT!

KJV2026
Main requirements

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Point of evaluation of requirements

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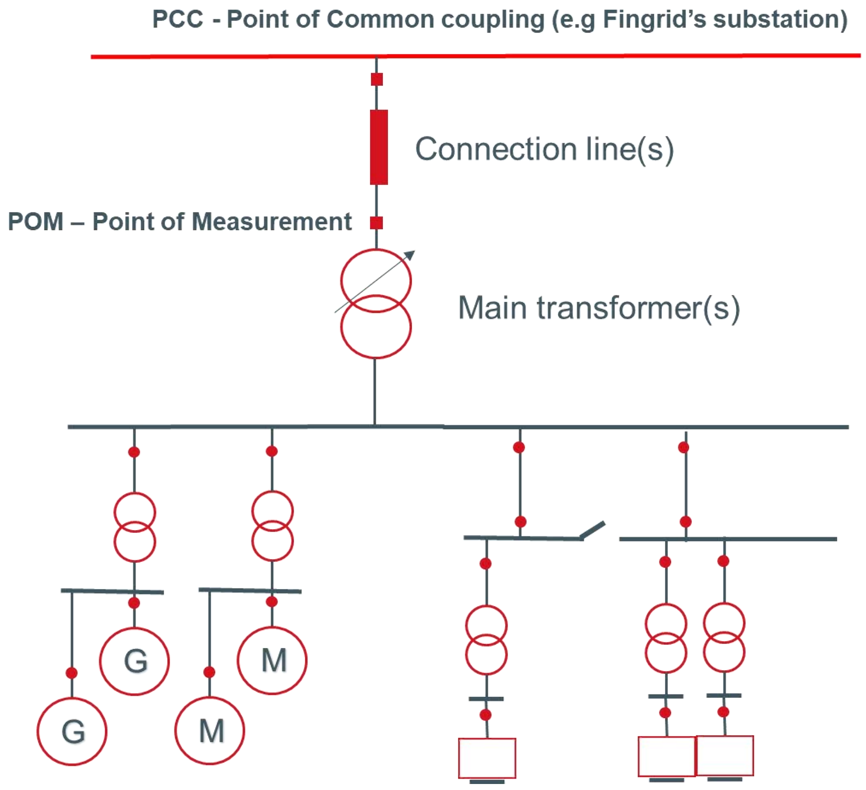
- PCC = Point of Common Coupling, point where connection agreement is done.
  - LVRT, PFAPR, Reactive power window
- POM = Point of Measurement
  - Requirements for instruments; disturbance recorders, power quality
  - Dynamic Voltage control reference point



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1. Scope and classification

Details of the requirements might vary because of voltage class or type class or power class

- **KJV2026 requirements are applied to new electrical equipment “Demand facilities”** which are to be connected to the power system
- KJV2026 shall also apply to **existing demand facilities when their system characteristics are changed**.
  - *This is standard clause in grid codes – If demand facility build at the time of KJV2018 is partially modernized at the time of KJV2026, this clause does not mean that demand facility must fully meet KJV2026 if the parts which are no modernized are limiting factor to meet KJV2026 requirements. Changes and modernizations and impact from current grid code is always assessed separately! Fingrid evaluates this as per case.*
- KJV2026 will apply for Demand Facilities which are classified by type classes and power classes. Also for those ones which are connected to Distribution Networks.

3 **Scope**

The Grid Code Specifications for Demand Connections apply to the following electrical equipment connected to Finland’s power system:

- demand facilities connected to the transmission grid,
- distribution networks connected to the transmission grid,
- distribution networks, when connection point voltage is at least 110 kV, including closed distribution systems,
- demand facilities used to offer demand-side management services to relevant network operators or the transmission system operator.
- Addition to KJV2018: demand facilities connected or to be connected to the Finnish power system shall follow the requirements as per table classifications

Power class	Demand facility Pmax
Type E	(10 MW ≤ P_{max} < 30 MW)
Type F	(30 MW ≤ P_{max} < 250 MW)
Type G	(250 MW ≤ P_{max})

Type class	Demand facility type
H	Electric boilers and heat pumps
S	EAF and LF
D	Datacenters, server halls
G	Power to Gas
P	Other industry

EAF = Electric Arc Furnace
LF = Ladle Furnace

P = Other industry =e.g process industry

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2. Phase 0 – Preliminary design phase

Requirement for Demand facilities over 30 MW (Power class: F and G and Type class H, S, D, G, P)

Stage 0 Preliminary planning will be held for:

- At the earliest possible stage before signing the connection agreement.
- Overall view: What kind of Demand facility? What is the load profile and technology to be used?
  - AI training, Active power cycling, etc. IGBTs, Thyristors, Centralized UPS, SVCs, STATCOMs etc.
- First technical discussions about interconnection process and grid interactions
- Specific Study Requirements
- Compliance monitoring process, including monitoring methods and follow-ups
  - Datacenter vs. P2G plant vs. Steel factory vs. Electric boiler plant – technical differences!
- Preliminary timelines for compliance process

Same requirement is for power plants/ energy storages VJV2024/SJV2024

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3. Specific study requirements

Requirement for Demand facilities over 30 MW (Power class: F and G and Type class H, S, D, C, P)

Fingrid assesses the need for a specific study in at least the following areas:

- Subsynchronous interaction
- Geomagnetically induced currents
- Dampening of power oscillations
- Low minimum short-circuit power at the connection point
- Converter interaction phenomena
- Power quality – New requirements under work! (target to have them published at same time as KJV2026)
- Dynamic voltage control

Similar requirement as for power plants/ energy storages VJV2024/SJV2024

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4. Voltage and Frequency window at PCC

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Requirement for Demand facilities over 30 MW (Power class F and G) and Datacenters and Electric boilers over 10 MW

and Demand facilities offering demand-side management services (reserve market participation)

- No change in Figure 9.1
- No change in RoCoF (2 Hz / s)

Note: ACER's proposals for frequency/voltage in DCC 2.0 are not introduced yet in KJV2026.

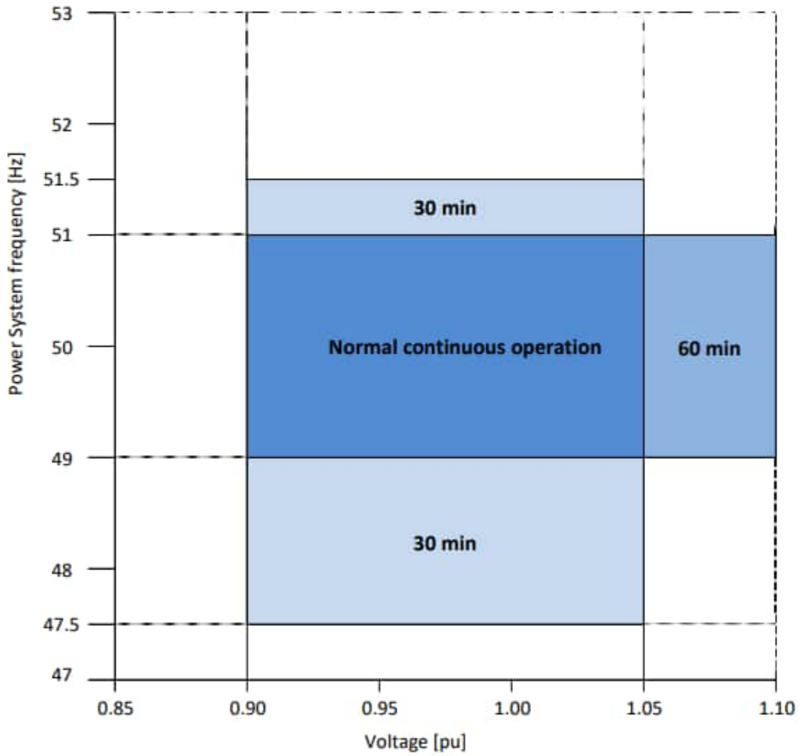

Figure 9.1. The electrical equipment must remain connected to the network at various frequencies and voltages at the connection point set out in the figure. The 1.00 pu voltage base of the continuous operating range in the 400 kV grid is always 400 kV. At other voltage levels, the voltage corresponding to the 1.00 pu value shall be inquired from the relevant network operator.

5. Robustness against phase jumps

Requirement for Demand facilities over 30 MW (Power class: F and G and Type class H, S, D, G, P) and

Datacenters and Electric boilers over 10 MW (Power class E)

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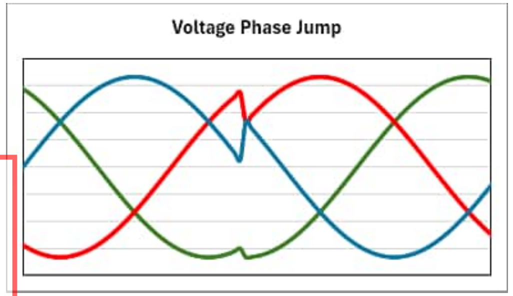
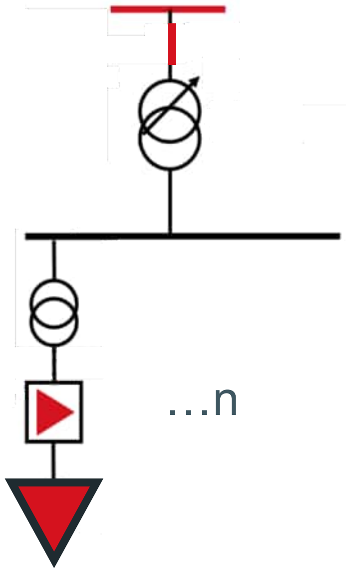
- Demand facility shall not disconnect from the grid in case of PCC voltage phase jump of +/- 30 degrees.
- This affects
  - Main converters: IGBT's, thyristor bridges, UPS systems etc.
  - Auxiliary loads: drives, frequency converters, pumps, fans etc. which might cause cascade trip

Voltage Phase jump at PCC





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6. Interactions

Requirement for Demand facilities over 30 MW (Power class: F and G and Type class H, S, D, C, P) and Datacenters and Electric boilers over 10 MW (Power class E)

The facility must not cause amplification (negative damping) of power oscillations, or cyclic power fluctuations in the Nordic power system.

In the Nordic synchronous system, inter-area power oscillations occur at the following frequencies:

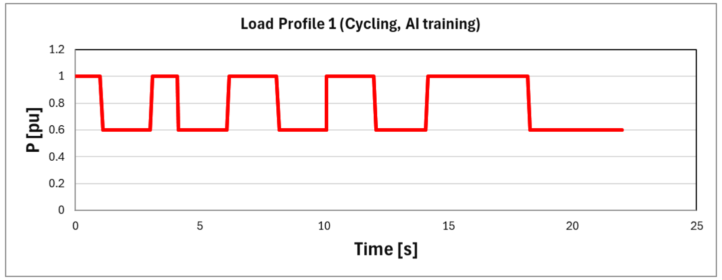
- 0.2–1.0 Hz, with the dominant oscillation mode around 0.3–0.5 Hz.

Voltage fluctuations caused by converter-connected power plants occur at:

- 1–15 Hz.

Resonance frequencies of series-compensated networks occur at:

- 5–45 Hz.



- The consumption facility must not cause cyclic power variations that amplify power oscillations in the 0.2–45 Hz frequency range in the power system. The connecting party and Fingrid will assess the facility’s impact on the damping or amplification of power oscillations.
- If the consumption facility causes forced power oscillations or amplifies existing oscillations, it must be equipped with compensation devices and/or additional control functionalities. For example: STATCOMs, E-STACOMs, BESS, Super Capacitors, Active Power Compensation, POD etc.
- If necessary, the consumption facility must be equipped with a protection device capable of disconnecting the load that causes power oscillations to the Grid.
- If the connecting party detects that its equipment is interacting with the power system or another consumption facility in a way that causes power or voltage oscillations, the connecting party must immediately contact the grid operator and Fingrid.

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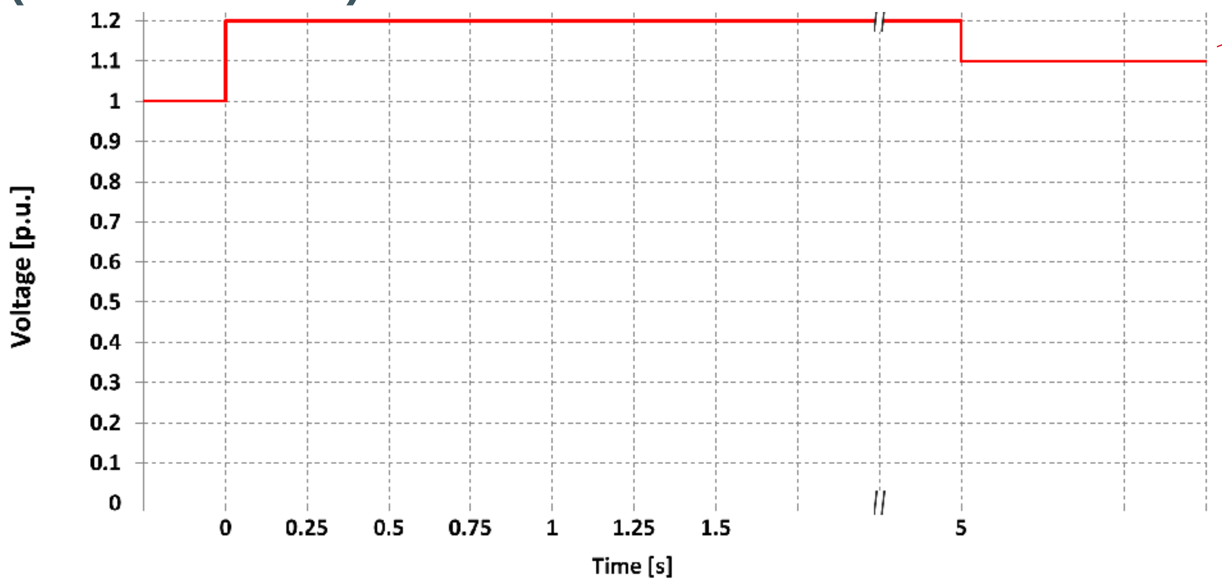
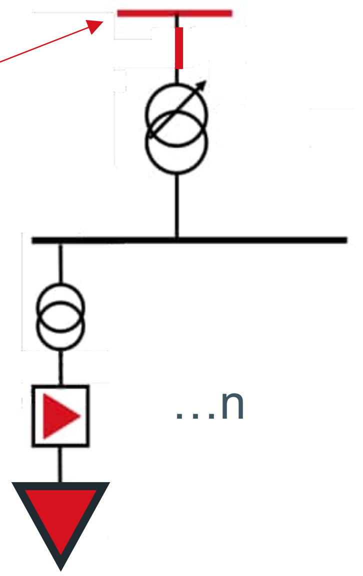
7. Over Voltage Ride Through

Requirement for Demand facilities over 30 MW (Power class: F and G and Type class H, S, D, G, P) and Datacenters and Electric boilers over 10 MW (Power class E)



Voltage magnitude at PCC



For 110 kV system
1.00 pu = 118 kV

For 400 kV system
1.00 pu = 400 kV

The requirement for overvoltage withstand capability applies to both symmetric faults (three-phase short circuits) and asymmetric faults (two-phase short circuits and ground faults, single-phase ground faults).

Note! E.g load which are acting as constant impedance;
- P = (U)^2/ R => 44 % overload if voltage reduction will not take place fast
- extra fast OLTC's might have possibility to reduce 1-2 steps within 5 seconds?

$$P = \frac{U^2}{R} = G_e U^2$$

*At 1.20 pu voltage, disconnecting of cap banks might be preferable

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Voltage magnitude at PCC

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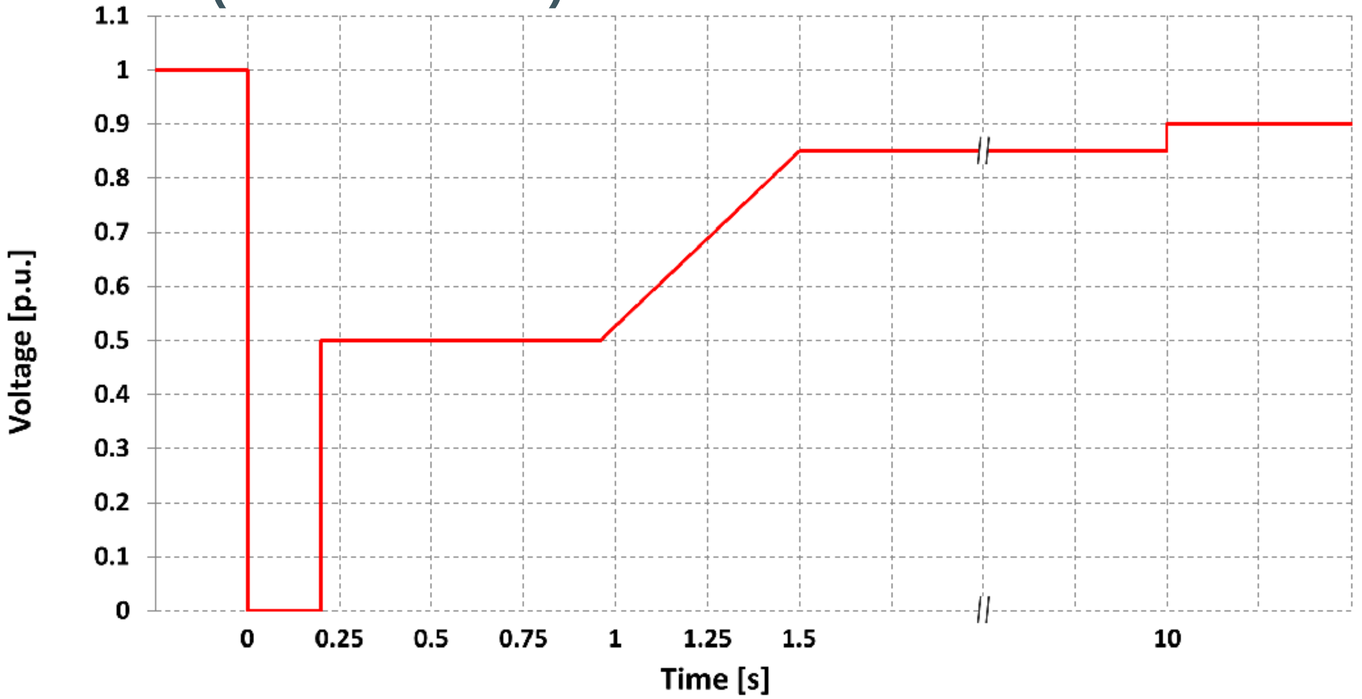
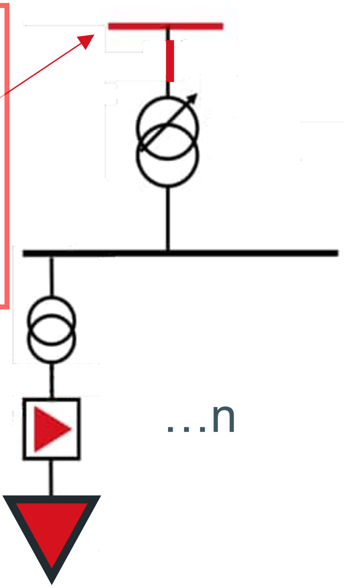
8. Low Voltage Ride Through

Requirement for Demand facilities over 30 MW (Power class: F and G and Type class H, S, D, G*(1, P*(1) and Datacenters and Electric boilers over 10 MW (Power class E)



Voltage = 0 p.u. for 200 ms (bolted fault)



- Following operations/functionalities are allowed during LVRT (typical in converters)
  - Active current limitation when supply voltage is below 90 %
  - Current blocking when supply voltage is below 50 %

Hint: Disconnection of Mechanical compensation units might be preferable during LVRT – depending on PFAPR performance (see requirements 9 and 10)!

The requirement for Low voltage withstand capability applies to both symmetric faults (three-phase short circuits) and asymmetric faults (two-phase short circuits and ground faults, single-phase ground faults).

*(1 see exceptions in requirement 9.

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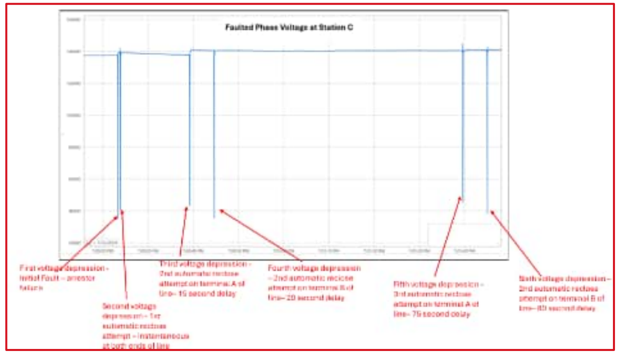
8.1 Multiple Low Voltage Ride Through

- Demand facility shall ride through ten (10) 100 ms bolted faults during 90 second period.

Permanent fault in the grid and/or storms + fast auto reclose + slow autoreclose

- On request Fingrid can deliver more detailed times for auto reclose times used in 110 kV or 400 kV system to help evaluation



Background: NERC report: (see earlier pages)

Question for developers:

- *Are undervoltage ”event counter” functions crucial for Demand Facility?*
- *What is the background to use such protection functions?*
- *Measurement of “event counter” from ph-ph or ph-g measurements? Three or single phase measurements to trigger counter? Why?*

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see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026

9. Post-Fault Active Power Recovery

- **Requirement for Demand facilities over 30 MW (Power class: F and G and Type class H, S, D, G*(1, P*(2) and Datacenters and Electric boilers over 10 MW (Power class E)**
- The consumption facility must restore the active power level that existed prior to the fault (LVRT) with a predetermined accuracy and within a specified time after the voltage at the point of common coupling has returned to the level of 0.90 pu.
- The specified levels and times for active power recovery (recovery time / recovery level) for different consumption categories are as follows:

Type Class	Active power	Active power recovery level	Active power recovery time
Datacenters	10 MW ≤ Pmax	90 %	< 0,5 s
Electric Boiler/Heat pumps	10 MW ≤ Pmax	90 %	< 1,0 s
Power to Gas	30 MW ≤ Pmax	90 %	< 1,0 s (1
EAF/LF	30 MW ≤ Pmax	90 %	< 1,0 s
Other industry	30 MW ≤ Pmax	70 %	< 1,0 s (2

(1 Exceptions can be agreed

(2 Exceptions can be agreed

(next pages)

9. 1) Exception of Post-Fault Active power Recovery of Electrolyzer plants

Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026

What is the performance and with what technology?

Voltage dips in area A:

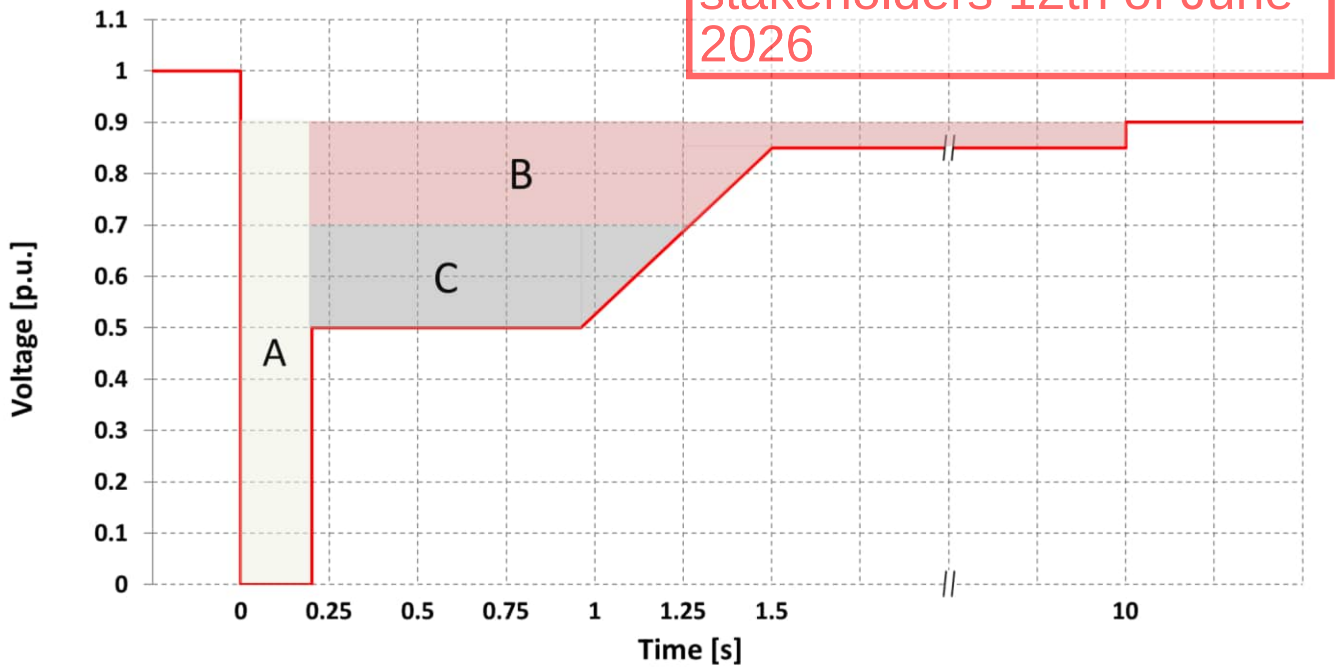
- PFAPR = < 1 s

Voltage dips in area B:

- PFAPR = max 6 s *

Voltage dips in area C:

- PFAPR = as technically justified by the technology provider *



This is agreed upon during the Stage 0 preliminary design meeting. An exception for electrolyzer plants may be considered if the slower recovery time does not pose a system-level risk. Fingrid will assess the total volume of electrolyzers in the system and evaluate the associated risk due to delayed recovery. <u>If a system-level risk is identified, the requirement of PFAPR < 1 second will apply.</u>

9. 2) Exception of Post-Fault Active power Recovery Other/Process industry

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What is the performance and with what technology?

Voltage dips in area A:

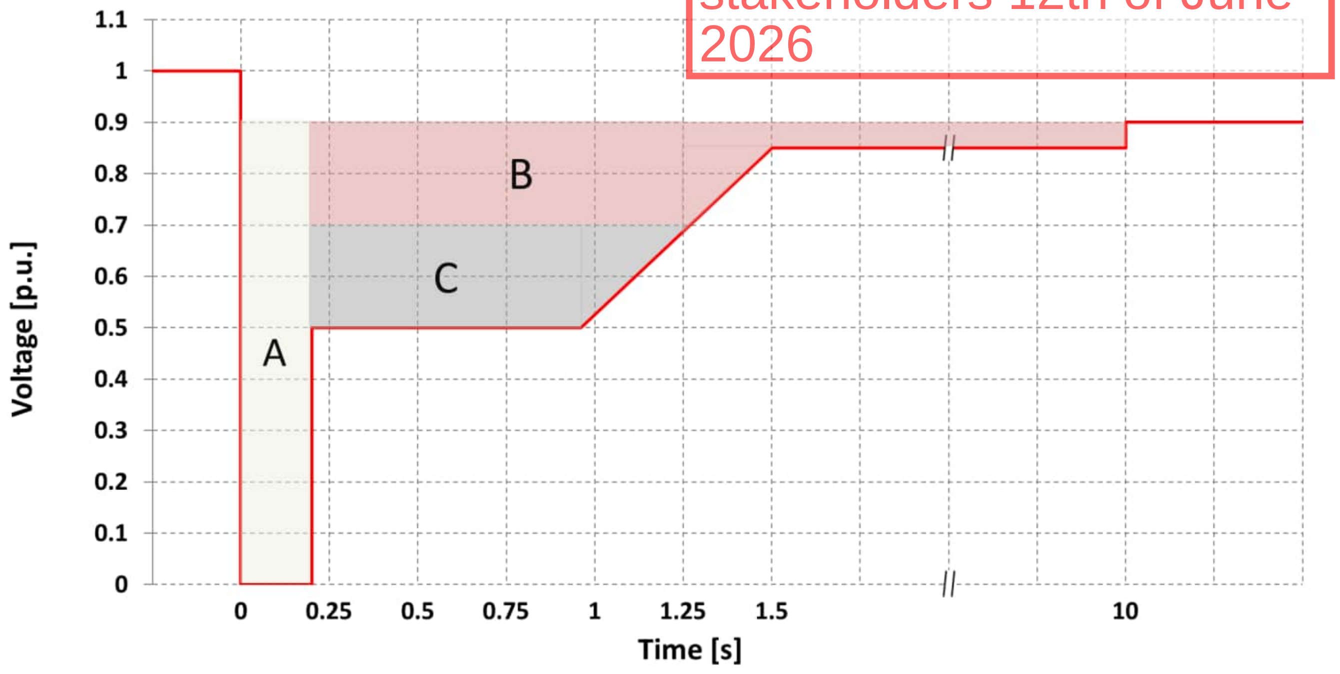
- PFAPR = < 1 s *

Voltage dips in area B:

- PFAPR = max 6 s *

Voltage dips in area C:

- PFAPR = as technically justified by the technology provider *



*This is agreed upon during the Stage 0 preliminary design meeting. An exception for process industry may be considered if the slower recovery time does not pose a system-level risk. Fingrid will assess the total volume of this kind demand facilities in the system and evaluate the associated risk due to delayed recovery. <u>If a system-level risk is identified, the requirement of PFAPR < 1 second will apply.</u>

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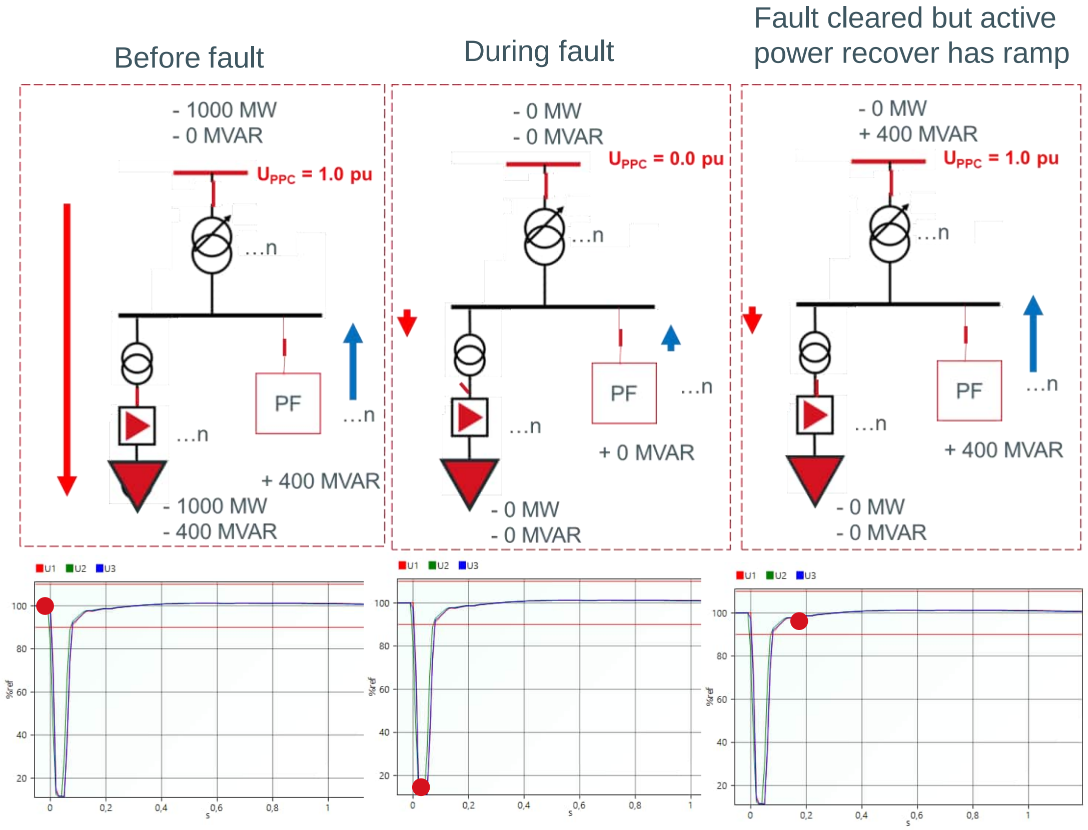
10. Reactive power compensation during voltage disturbances



Requirement for all Demand Facilities connected at 110 kV or higher and with > 50 MVar compensation units

(Type class H, S, D, G, P)

- The consumption facility must manage reactive power at the connection point during active power recovery following a voltage disturbance to prevent overvoltage or undervoltage conditions.
- If the facility includes mechanically switched reactive power compensation equipment exceeding 50 MVAr, the connecting party must provide analysis and calculations demonstrating how the facility controls reactive power during:
  - Voltage disturbance (LVRT), and the recovery of active power (PFAPR)
    - If the active power recovery (PFAPR) is immediate (e.g constant impedance load) -> no issue
  - Otherwise, specific logic shall be implemented to control the compensation units

Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026

11. Study report on Voltage Disturbance Tolerance

Requirement for all Demand Facilities with Pmax > 30 MW
(Power class: F and G and Type class H, S, D, G, P)

- A separate report must be prepared for the consumption facility regarding its voltage disturbance tolerance. The report must describe how the Demand facility together with auxiliary systems is designed to withstand voltage disturbances and how it meets the requirements of sections LVRT and PFAPR. Focus must be put on identifying cascade trips.
- The report must comprehensively address the facility’s design principles, including component dimensioning, protection, process, and automation design:
  - Voltage disturbance tolerance of the power distribution system, including HV, MV, LV and DC systems.
  - Protection, control, and automation systems of electrical drives and electrical actuators
  - Critical processes and/or electrical systems that affect compliance with the requirement (risk of cascade trip)
  - Fingrid reserves the right to request a separate risk assessment during the connection process, which shall be arranged and covered by the connecting party.

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see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026

12. Voltage and Reactive Power Control of the Consumption Facility

Requirement for all Demand Facilities connected at 110 kV or higher (Type class H, S, D, G, P)

The consumption facility must be capable of maintaining a power factor above 0.99 or, at most, **within the reactive power window** [MVAR] relative to active power as specified in Fingrid’s separate guideline on reactive power delivery at the connection point.

- This requirement must be met if the grid voltage varies within the range of -5% to +5%, without changing the active power consumption.
- The requirement must also be fulfilled at partial load, if partial load is one operation point of the Demand Facility
- The requirement does not apply during the startup and shutdown of the facility. Note: power quality considerations do apply.

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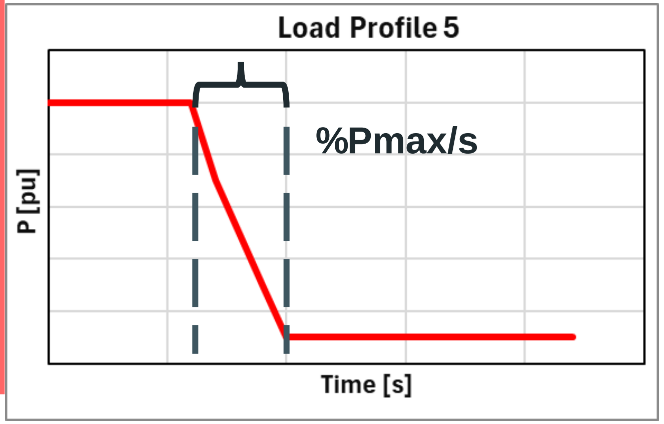
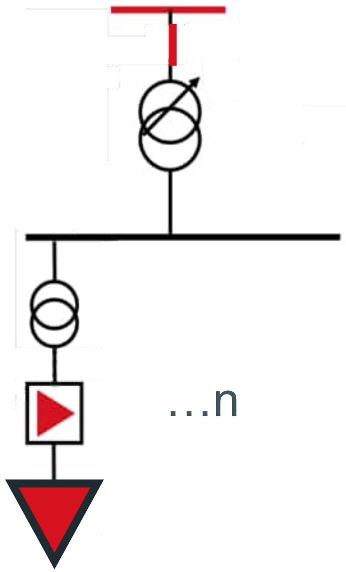
13. Active power control

Requirement for Demand facilities over 30 MW

(Power class: F and G and Type class H, S, D, G, P)



- Fluctuations in active power caused by market controls or third parties must be limitable when necessary. In such cases, the maximum rate of change in active power must be limitable;
  - 5–100% of Pmax / min but max 50 MW / minute.
  - Fingrid must have the capability to activate a request to limit the rate of change in active power.



- *Higher rates of change are permitted if the consumption facility provides demand response, if an active power limitation level is activated, or if the facility is recovering from a voltage disturbance.*

Q: How to control this in practice?

14. Signals from TSO to the Demand Facility

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Requirement for Demand facilities over 30 MW

(Power class: F and G and Type class H, S, D, G, P)

Note! These signals are not direct control signals from Fingrid (TSO). They are *requests of changes to plant operation* sent from Fingrid to the responsible operator (RO) of the plant (instead of e.g. phone call).

Active power restrictions (emergency control)

- Activation of active power limitation – on/off
- Active power limitation set points – 0-100%
- Active power rate of change limitation 0-100 % Pmax/min

Others

- Reactive power compensation units – statuses and open/close request
- Special controllers – statuses and on/off request (e.g POD)
- Normal state/alert state/emergency state state/blackout state/restoration state.
  - The status information is informative and can be used to implement controls agreed upon separately with the Demand facility owner or relevant network operator.

Taulukko 11.1. Kulutuslaitoksen käytöstä vastaavan toimijan Fingridiltä vastaanottamat ohjauspyynnöt. Yksittäisen ohjauspyynnön toteutus voi vaatia useita erillisiä signaaleja.

n:o	Ohjauspyyntö	Vastaanotettava tieto
1.1	Pätötehon rajoitussäädön aktivointi	Päälle/pois
1.2	Pätötehon rajoitussäädön asetus	0-100 %
1.3	Pätötehon rajoitussäätö toteutunut	kyllä/ei
2.1	Alijännitesuojan aktivointi	Päälle/pois
2.2	Alijännitesuoja toiminut	Kyllä/ei
3.1	Pätötehon muutosnopeuden rajoitus aktivointi	Päälle/pois
3.2	Pätötehon muutosnopeuden rajoitus	0-100 % / min
4	Kompensointilaitteiston kytkentä	Päälle/pois
5	Erikoissäädön ohjaus (esim. POD)	Päälle/pois
6	Käytönpalautuksen tila	Normaalitila / hälytystila / häiriötila / suurhäiriötila / palautustila. Tilatieto on informatiivinen ja sitä voidaan käyttää Liittyjän tai Liittymispisteen verkonhaltijan kanssa erikseen sovittavien ohjausten toteuttamisessa.

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15. Active power limitation in emergency case

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Requirement for Demand facilities over 30 MW
(Power class: F and G and Type class H, S, D, G, P)

Fingrid reserves the right to define the operational readiness requirements of active power limitation. (DCC)

The consumption facility must be equipped with an active power limitation control system, which Fingrid must be able to remotely control in emergency situations. The consumption facility must be capable of reducing its active power consumption to four (4) different power levels when Fingrid activates the power limitation either automatically or manually.

The active power limitation control must be implemented at the facility using a active power limitation function, which must take into account at least the following:

a) The limitation function must be switchable on/off via separate signal.

b) Predefined active power levels must be configurable in advance: four levels, for example: minimum power, 30%, 50%, and 70%. If deviations from these levels are necessary, they must be defined together with Fingrid, considering the facility's dynamic and operational capabilities.

c) The facility must have a downward regulation capability of at least 30%.

d) The limitation control must activate within 1 second and be executed within a time agreed upon with Fingrid. (The speed of the power adjustment depends on the technical characteristics of the consumption facility.)

e) Active power limitation shall be priority set point for the demand facility. Demand facility must implement the most recently activated power setting, regardless of whether the previous level was reached or not.

f) If the activated active power setting cannot be achieved, the facility must reduce its power to the current minimum level at which operation can continue.

g) When the power limitation is deactivated, the facility may restore its active power within the normal power adjustment rate (Pmax/min).

The connecting party must prepare a description of the implementation of the limitation function and submit it to Fingrid.

16. Under voltage load shedding and active power reduction in emergency case

Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026

Requirement for Demand facilities over 30 MW
(Power class: F and G and Type class H, S, D, G, P)

Fingrid reserves the right to define the operational readiness requirements for load disconnection due to undervoltage. (DCC)

The consumption facility must be equipped with an active power reduction based on voltage measurement. Load disconnection and active power limitation due to undervoltage must be based on three-phase voltage measurement at the connection point or another point agreed upon with Fingrid.

Operational readiness for load disconnection means that active power can be controlled downwards using a limitation function either linearly or in step(s) through load disconnection. The following features are required at a minimum for the undervoltage-based active power limitation and disconnection function:

a) The limitation function must be switchable on/off via a separate signal that Fingrid can request activation. By default, the function is off.

b) The limitation function must measure voltage from all three phases. The voltage is measured at the connection point or another point agreed upon with Fingrid.

c) The limitation function must be able of locking the main transformer(s) tap changers in undervoltage conditions.

d) The limitation function must activate within 1 second. The settings are defined together with Fingrid, taking into account the facility's capabilities and location.

e) The limitation function must be capable of immediately disconnecting predefined loads. The disconnection thresholds and times are agreed upon with Fingrid. At least 30% of the loads must be connected to the protection scheme.

The connecting party must prepare a description of the implementation of the active power limitation and disconnection due to undervoltage and submit it to Fingrid.

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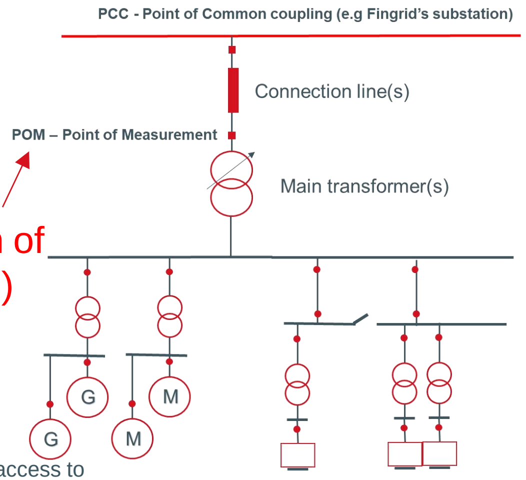
17. Instrumentation of Demand Facility



Location of device(s)

Requirement for all Demand Facilities with over 30 MW (Power class: F and G and Type class H, S, D, G, P)

Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026

Power Quality

The connecting party must continuously and reliably monitor the power quality of the consumption facility while it is connected to the power grid throughout its entire lifecycle. One or more continuous power quality recording systems and the necessary measurement transformers must be installed at the consumption site. The following conditions must be met in the measurement setup:

- The continuous recording system must measure according to standard IEC 61000-4-30, Class A.
- The measurement transformers (VT's) must be suitable for reliable power quality measurement (Harmonics up to 2,5 kHz).
- The power quality of the consumption facility must be measured comprehensively enough to enable localization of any potential disturbance source based on the measurements.

Can be the same device

Disturbance and Swing recorders

A continuous recording system must be installed in consumption facilities, with rapid access to its measurements granted to the operator responsible for the site. The recording system must enable continuous logging of the consumption site's and its controllers' operations whenever the site is connected to the grid. The equipment must accurately record disturbances and changes in the power system.

The recording system must meet the following requirements:

- The recorder must measure and record the voltages and currents at the connection point—or another measurement point agreed upon with Fingrid—as instantaneous values, phase by phase.
- The recorder must measure and record active and reactive power as well as frequency at the connection point or another agreed measurement point. The recording frequency for power and frequency measurements must be at least 50 Hz.
- In addition to the quantities listed in points 1 and 2, it is recommended to record the operating points of controllers and SCADA system log data.
- The sampling and recording frequency for current and voltage measurements must be high during transient events (4 kHz or higher).
- The recorder's time must be synchronized with an external time server (e.g., the facility's automation system or a GNSS system).
- The recording system must be implemented so that the operator responsible for the consumption facility has access to the recorder's measurements within one hour, and the grid operator at the connection point and Fingrid receive the recordings within eight hours of request.
- The recording system must have a memory capacity covering at least 30 days. The recording can be implemented using an application-based solution where measurement data is transferred to an external data repository, provided that continuous recording is ensured (e.g., during communication disruptions).

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18. Simulation models

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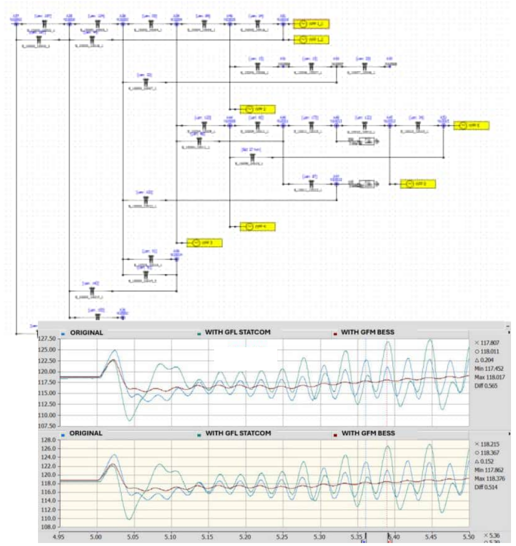
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026



Requirement for all Demand Facilities over 30 MW

(Power class: F and G and Type class H, S, D, G, P)

Three purposes of use;

1) Validating the compliance of invidual Demand Facilities as a part of connection process
2) Validating the compliance in a system context
3) To enable Fingrid to ensure the technical performance and security of Finland's power system

Two different softwares used;

- PSS/E for RMS simulations
- PSCAD for EMT simulations
- Similar requirements as for power plants and energy storages. Aggregation methods etc presented here;
  - https://www.fingrid.fi/en/grid/grid-connection-agreement-phases/grid-code-specifications/modelling-instructions/

Separate instruction is being prepared – estimated release in Q1-Q2/ 2026

Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026

Compliance process

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19. Compliance process of Demand facility

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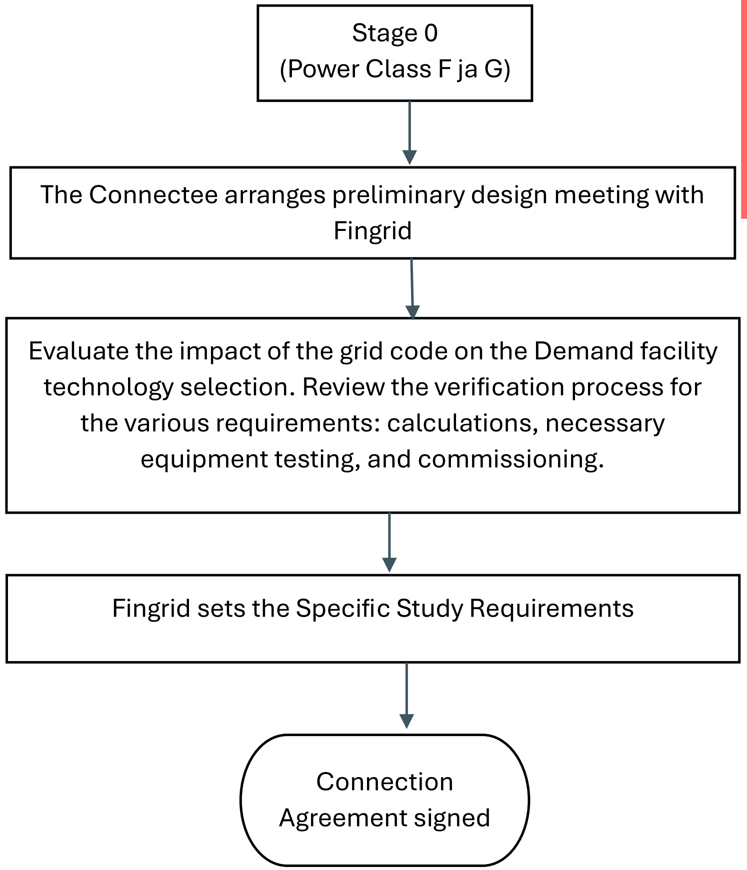

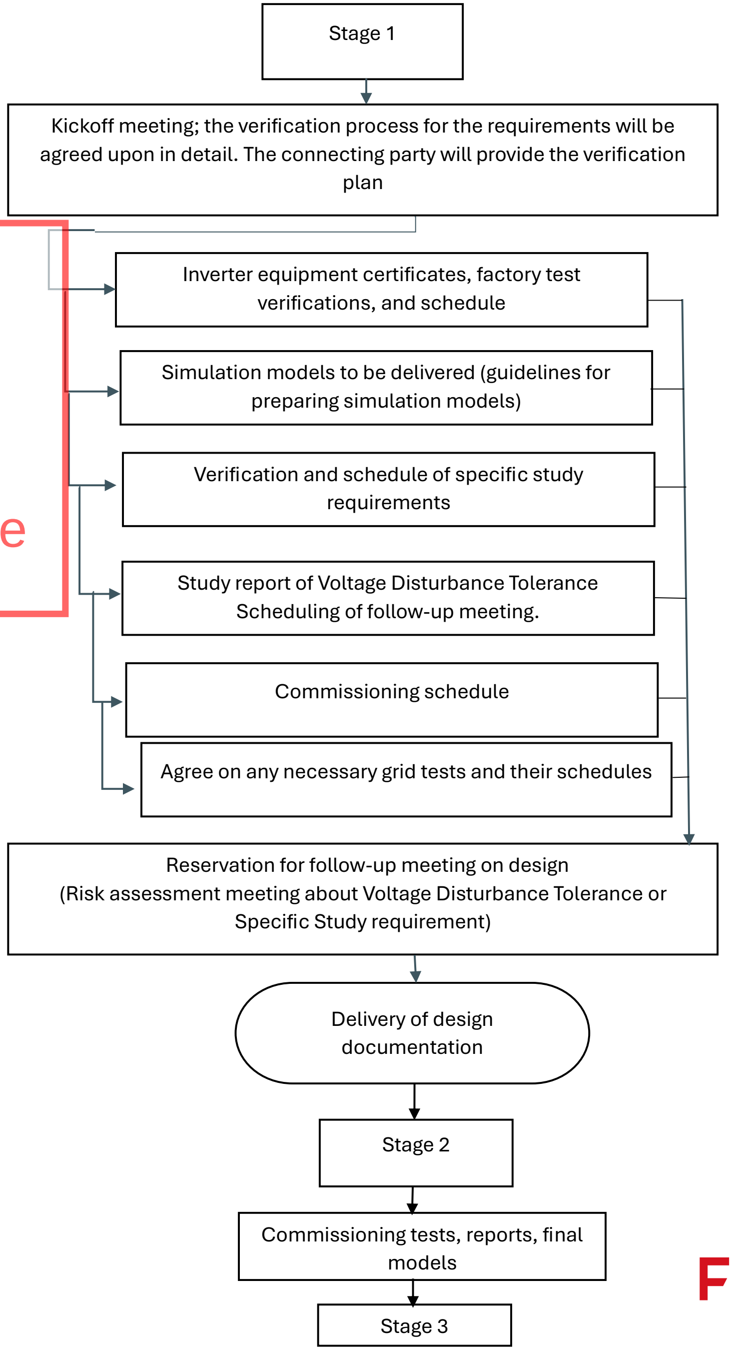

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20. Equipment test certifications

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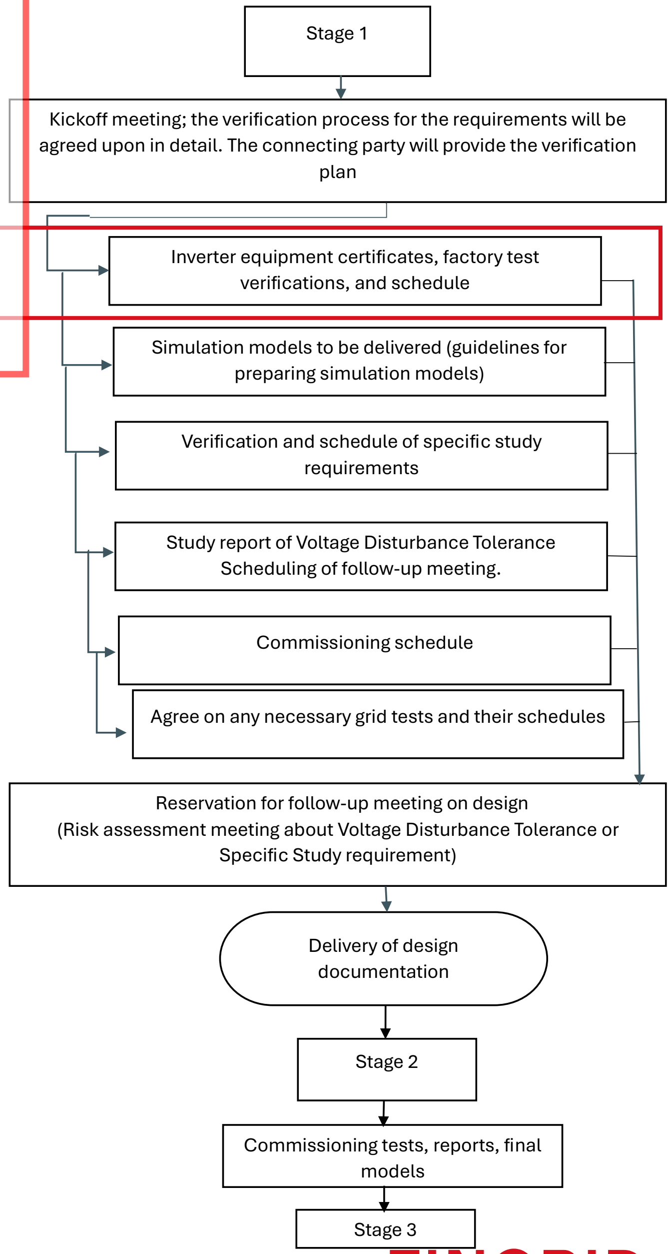
Presentation for stakeholders 12th of June 2026

Demand facilities with converter connected consumptions, examples;

- Datacenter centralized UPS Systems , AC/DC rack converters
- P2X: Thyristors, IGBT's

- Voltage and Frequency window
- RoCoF
- Operation at minimum SCR
- Voltage phase angle jump
- Interactions
- Active power control
- 1-, 2-, 3- phase undervoltages (LVRT)
- Post Fault Active Power recovery
- 1-, 2-, 3- phase overvoltages (HVRT)
- Multiple FRT's (10 cycles over 90 s)
- Current limiters



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Outdated
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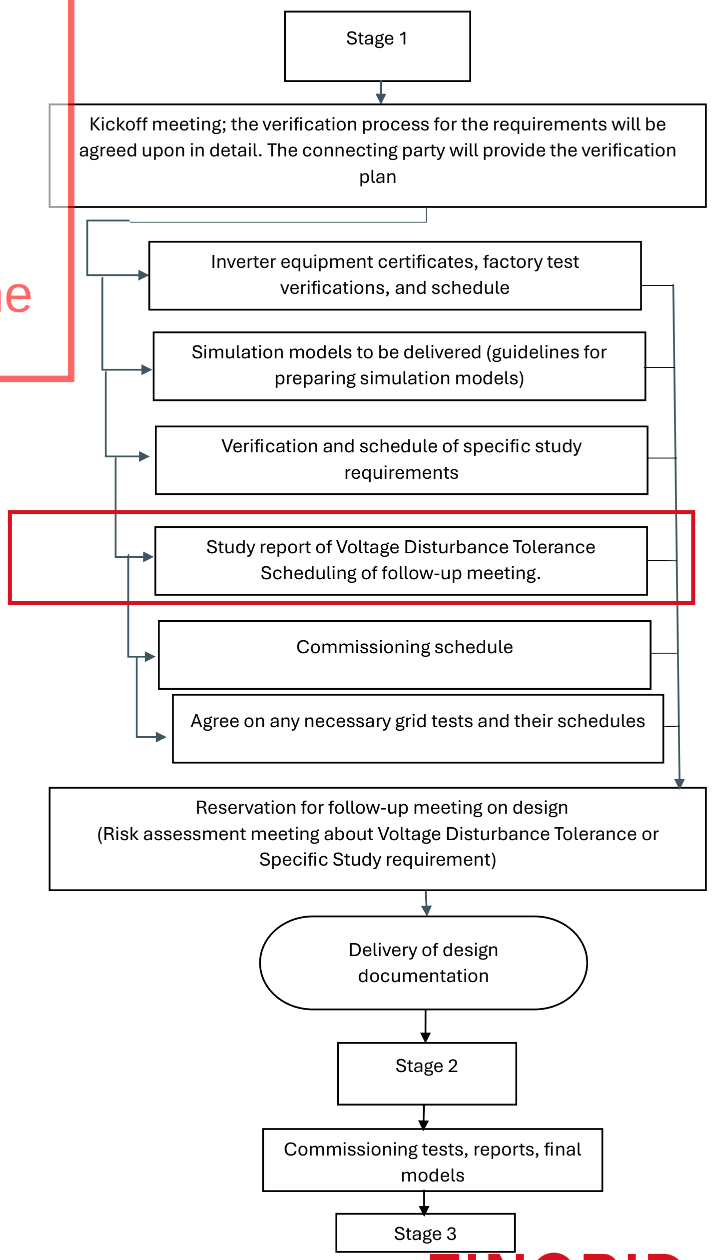
21. Voltage Disturbance tolerance

- Requirements 8 and 9

LVRT and PFAPR

- Voltage disturbance tolerance of the power distribution system, including HV, MV, LV and DC systems.
- Protection, control, and automation systems of electrical drives and electrical actuators
- Critical processes and/or electrical systems that affect compliance with the requirement (risk of cascade trip)
- Fingrid reserves the right to request a separate risk assessment during the connection process, which shall be arranged and covered by the connecting party.



22. How to comply with the requirements; requirements 8 and 11:

Outdated
see: KJV2026 Grid code specifications for Demand Connections
Presentation for stakeholders 12th of June 2026

Phase 0
“Design philosophy”
-
Plan how to design the plant to meet the requirement

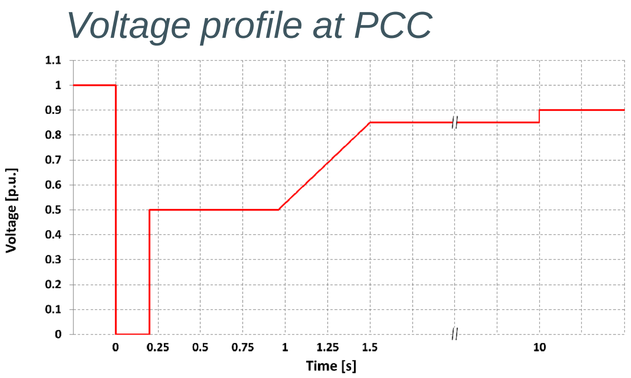
Agree of needed Unit certificates
or FAT type tests for “major” converter units

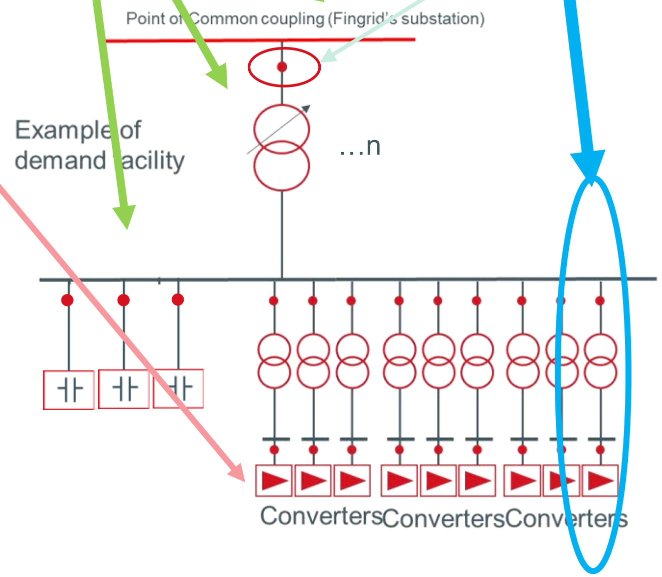
Check-point: Has the engineering “gaps” between different sectors been covered?

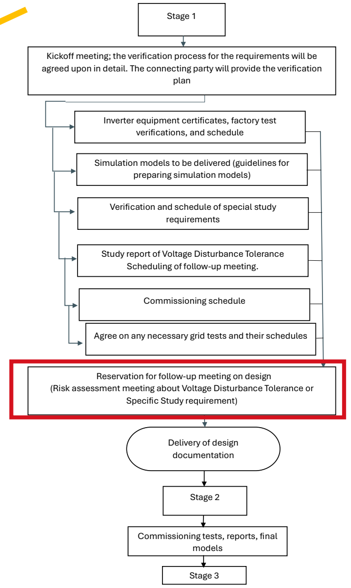
Commissioning phase – single drive trains can be tested

Fingrid might perform a grid test to validate the behavior

Continuous monitoring and validation against grid events







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23. Voltage Disturbance tolerance study

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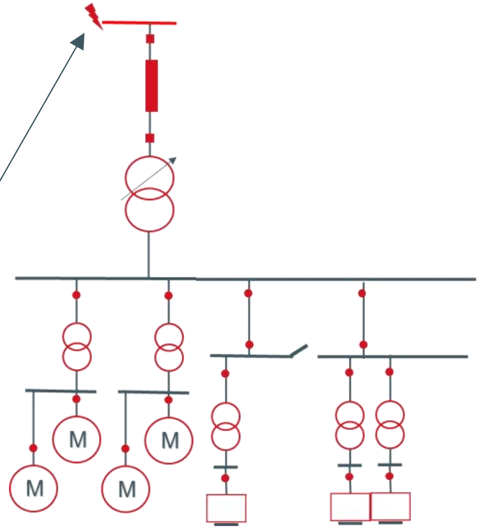
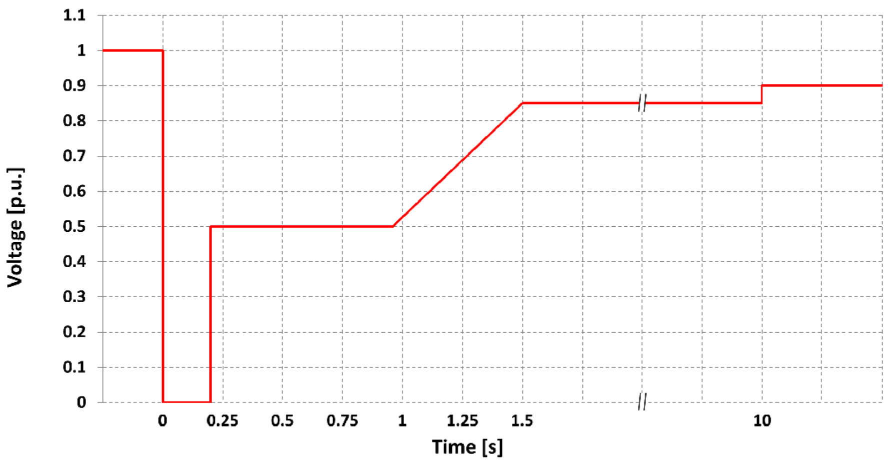
Consider this voltage profile for critical auxiliary systems and process drives, in example;

- Pumps/fans
- Compressors (piston compressor/turbo compressor)
- Frequency converters of different drives (aux power supply, parametrization)
- Auxiliary supply distribution
- Automation/process: example: If critical drive for the process is tripped due to this event, can it be started immediately again ?

- What parts of the demand facility are most vulnerable for voltage dips?
- What is the tolerance (voltage depth and length)?
- What should be done to meet the requirement?





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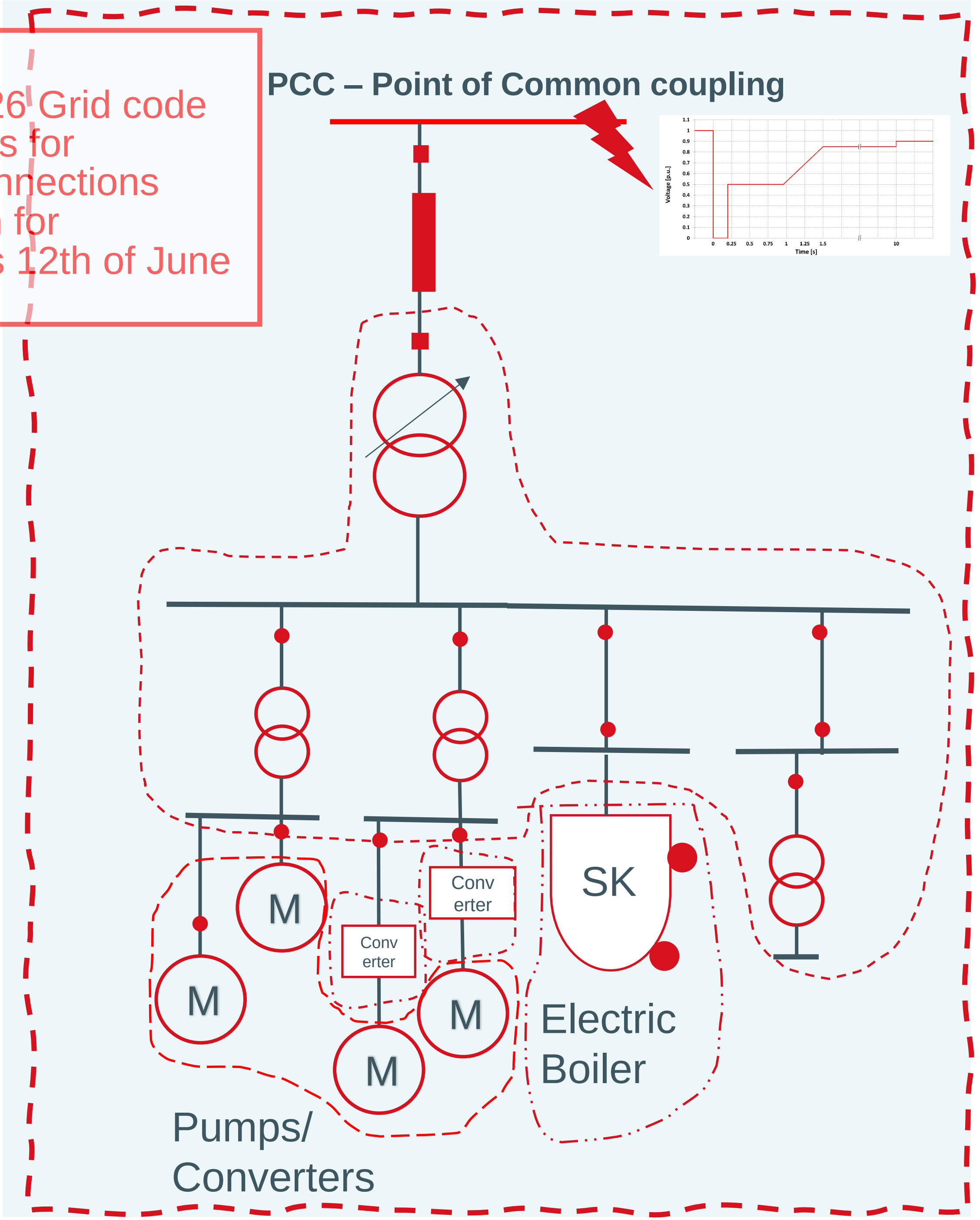
Case Electric Boiler plant

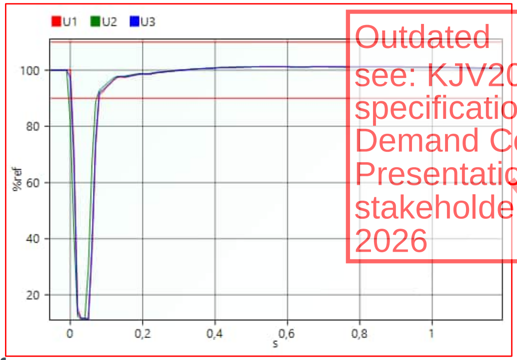
Outdated
see: KJV2026 Grid code specifications for Demand Connections Presentation for stakeholders 12th of June 2026

- Protection settings of the distribution system
  - UV/OV, UF/OF, I>>, Io, Uo etc.
- Drives
  - Frequency converters and parameters, auxiliary power feed (aux power shall not be taken shall not be taken from the converter terminals – must be taken from backup supply!)
  - Process drives: Pumps etc.
- Critical electrical actuators, devices and instruments
- Automation system



Case Datacenter

- Point of evaluation: example grid event; voltage disturbance (LVRT)
- Distribution system: Protections
- Automation: Conditions to move behind the UPS and/or Gensets must be fully understood and controlled
  - Gensets has reaction time of 30-60 seconds -> Since PFAPR requirement is 0,5 s after fault clearance, loads will not move behind Gensets in this event!
  - Assumption: Critical loads will move behind the batteries and returns back to the grid within 0,5 seconds, when voltage has reached 0,90 pu. Cooling system (pumps/fans) can ride through as without trip with correct frequency converter dimensioning and parametrization?
- Focus must be put on Centralized UPS systems or rack level AC/DC+bat converters and their parametrizations.
- Note also: Multiple FRT (Multiple voltage disturbances in short time: 10 during 90 second period)



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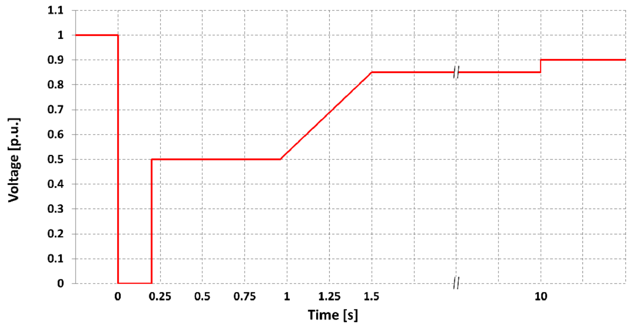

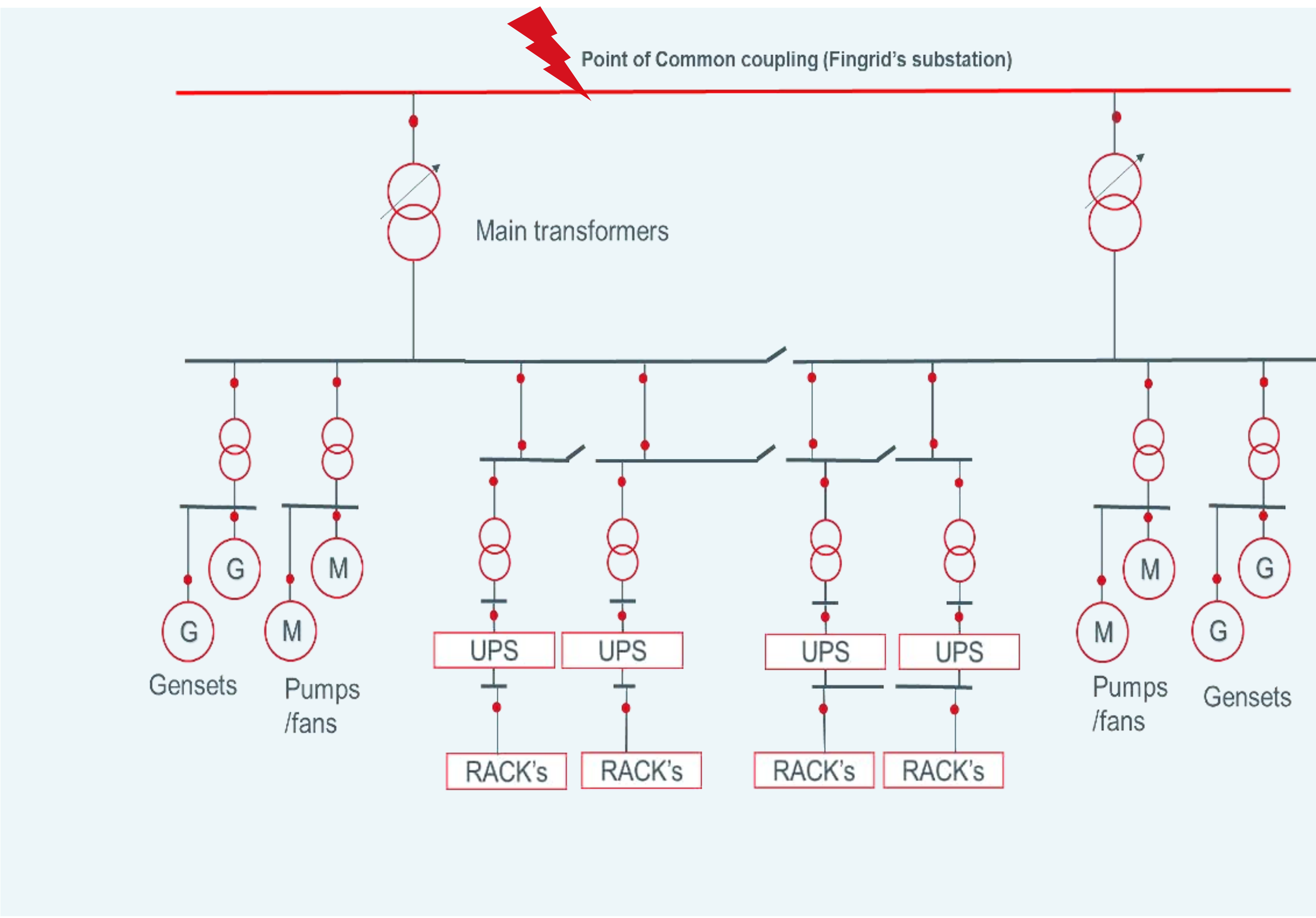

Case Reactive power compensation

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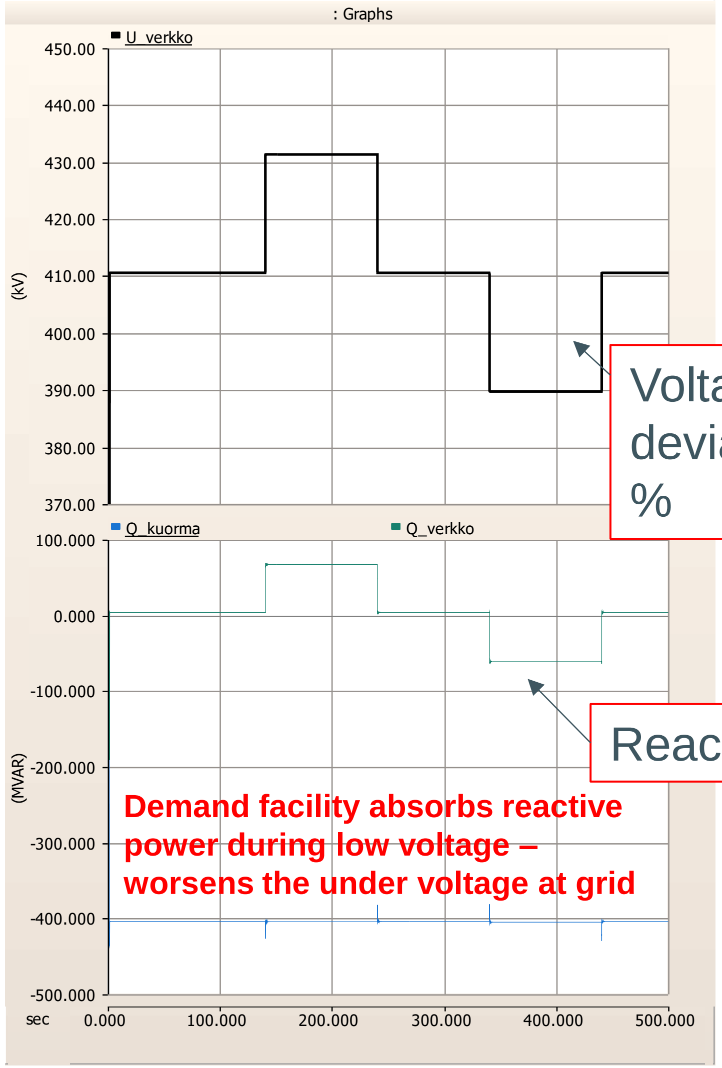
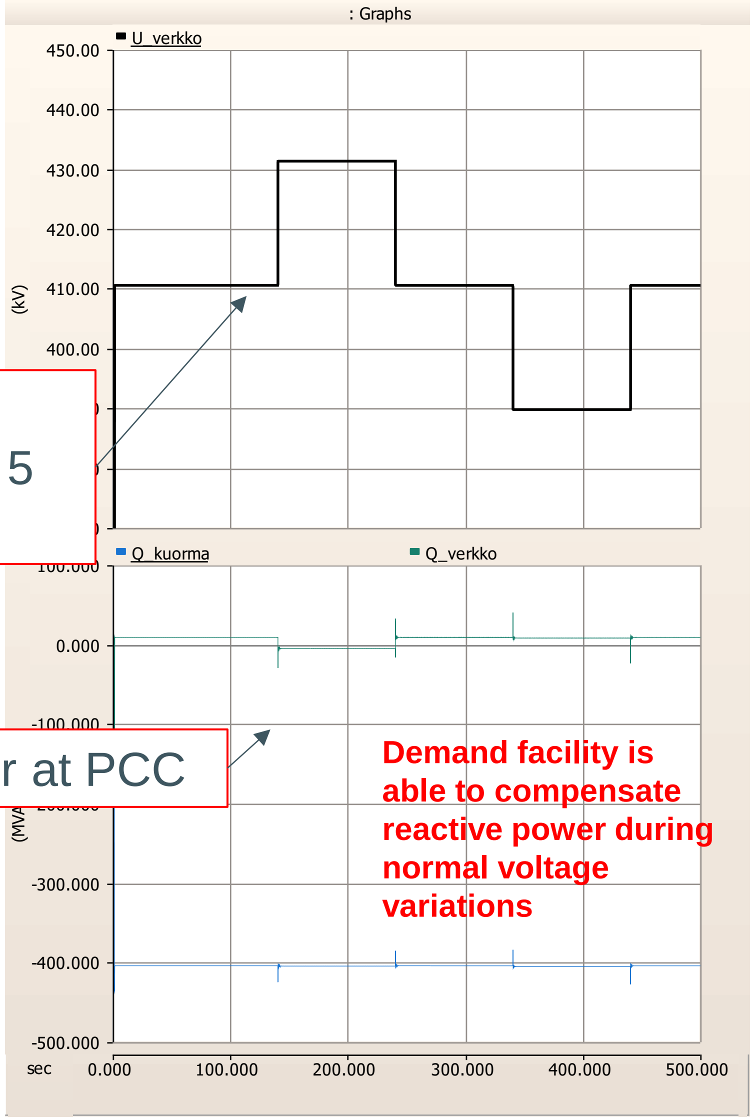
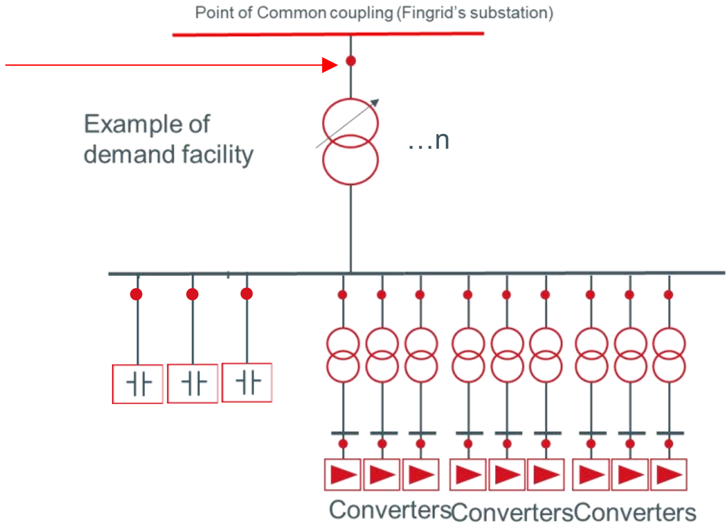


Voltage deviations +/- 5 %

Reactive power at PCC





Case Electrolyzer plant

- AC-DC converters
- Electrolyzers
- Feed Water treatment
- Gas / Liquid loops
- Compressor(s)
- De-oxygen units
- Gas Drying
- Cooling systems, pumps etc.
- Piping, fitting, valves, instruments

- Complex process!

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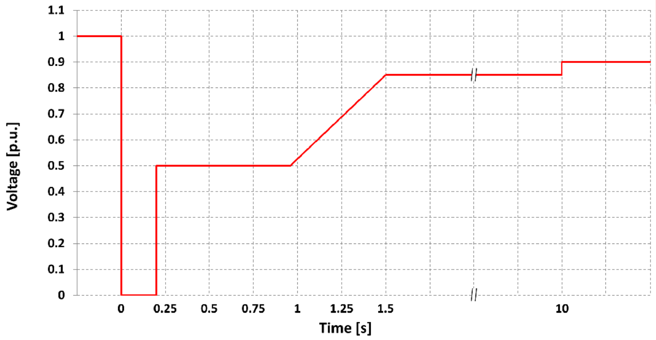

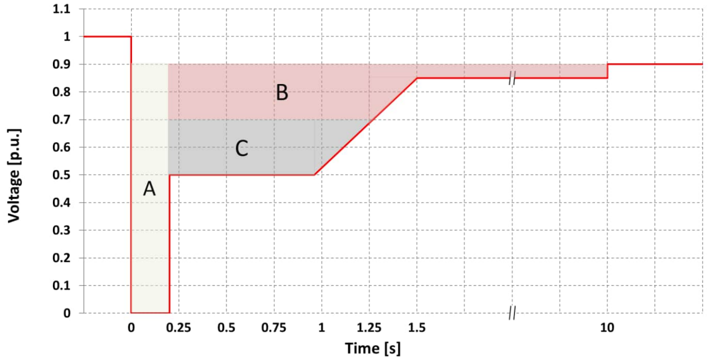

Voltage dips in area A:

- PFAPR = < 1 s

Voltage dips in area B:

- PFAPR = max 6 s *

Voltage dips in area C:

- PFAPR = as technically justified by the technology provider *

Impact on technology?

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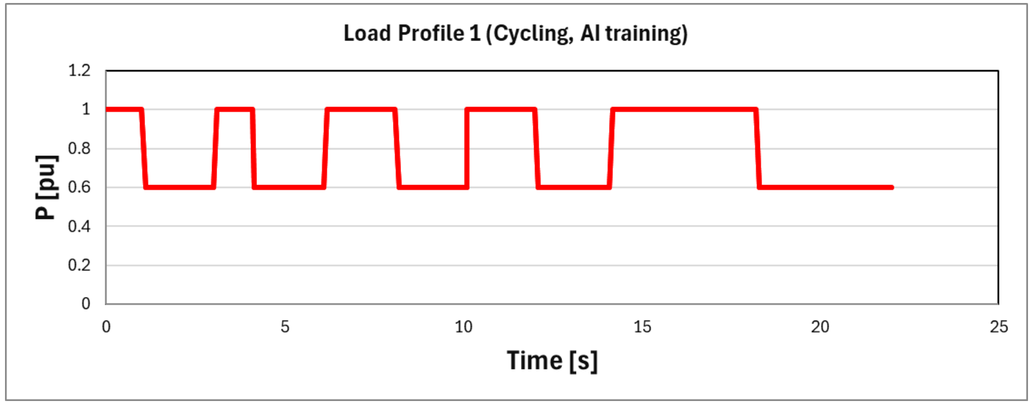
Case AI traning and interactions

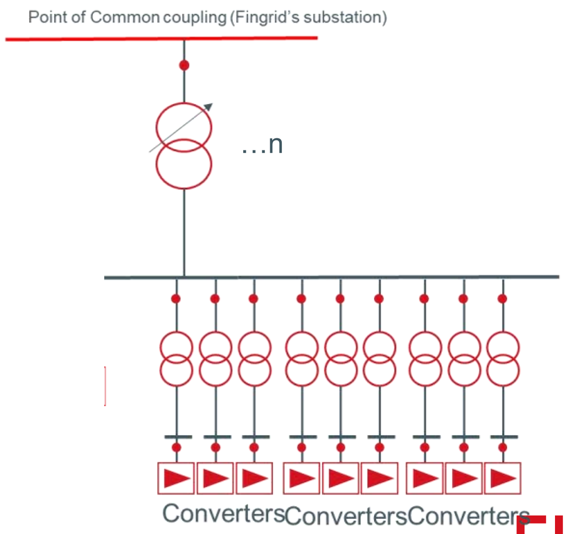
Is the load profile known in design phase?



1. Slow variations = Risk of Interarea oscillation amplification
   a) 0,4 Hz = periodical time of 2,5 seconds

2. Fast variations = Risk of Flicker issues

How to mitiage this?
- Correctly dimensioned BESS solution?
- E-STATCOMs?
- Active Power Dampers?
- Improved AI training (no cycling/forced oscillations in load profile)?



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Thank you!

- We would kindly ask your feedback for the requirements – Please go through the requirements presented in this slide deck and consider what would these mean to your assets, what would be the technical solution and impacts on the design to meet the proposed requirements. Bring as much technical data/background when giving feedback in order to get your message through. You can ask clarifications before giving the feedback.

- This presentation will be available on our web pages in few days. All attendees will get an e-mail containing the link to the material once it has been uploaded to our webpage.

Timeline for sending feedback is 6.6 – 31.8.2025

- Send feedback / ask clarifications via email teemu.rissanen@fingrid.fi in Finnish or English.
- Please name the email topic;
  - “KJV2026 feedback”
  - You can write the feedback in email directly or prepare a document. Please bring out clearly which requirement you refer to e.g “13. Active power Control” or “17. Instrumentation..”

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