Capabilities of Power Electronics Interfaced Devices for Enabling the Energy Transition

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For power system expertise

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cigre
For power system expertise

CIGRE is

- A global community for the collaborative development and sharing of power system expertise in the end-to-end value chain
- Not for profit, established in Paris, France 1921
- A long history as a key player in the development of the power system
- Produces reference publications based on practical experience and analysed data
- An open, engaging, fact-based culture
- Connecting power systems professionals from all over the globe

- There is a ever growing collaboration between CIGRE and IEEE through several WGs

A collaborative global community sharing knowledge and expertise

- 59 National Committees – NCs
- 15,000 members from over 90 countries
- 1,200+ organisations spanning the global power system
- A high number of major utilities
- A unique collaborative culture
- Includes some of the world’s leading experts in power systems
- Diverse perspectives from every corner of the globe

CIGRE's 16 domains of work each has a dedicated Study Committee

Group A – Equipment:
A1 Rotating electrical machines
A2 Power transformers and reactors
A3 Transmission and distribution equipment

Group B – Technologies:
B1 Insulated cables
B2 Overhead lines
B3 Substations and electrical installations
B4 DC systems and power electronics
B5 Protection and automation

Group C – Systems:
C1 Power system development and economics
C2 Power system operation and control
C3 Power system environmental performance
C4 Power system technical performance
C5 Electricity markets and regulation
C6 Active distribution systems and distributed energy resources

Group D – New materials & IT:
D1 Materials and emerging test techniques
D2 Information systems and telecommunication

Context of Joint Working Group JWG C2/B4.38

- The power system is undergoing a transition towards a situation where power electronics interfaced devices are the norm.
- This is driven by the ongoing transition towards a low carbon society where the conventional synchronous generators are phased out and replaced by renewable energy sources that are connected via power electronics.
- In the CIGRE joint working group C2/B4.38, it is identified on the one hand which challenges are caused in system operations by the energy transition and on the other hand how the power electronics can help in solving some of these challenges.
- Important target is to bridge the gap between technologie and operational experts

CIGRE Joint Working Group JWG C2/B4.38

- The joint working group between C2 & B4 started in 2017, named “Capabilities and requirements definition for Power Electronics based technology for secure and efficient system operation and control“ (click here for ToR)

- Final report due April 2020

- Work group members
  - Leading TSO’s from Europe (10), US (2), Africa (1) & Australia (2 corresponding)
  - Key Technology providers (3)
  - Academics and Consultants (2)

Three key challenges identified

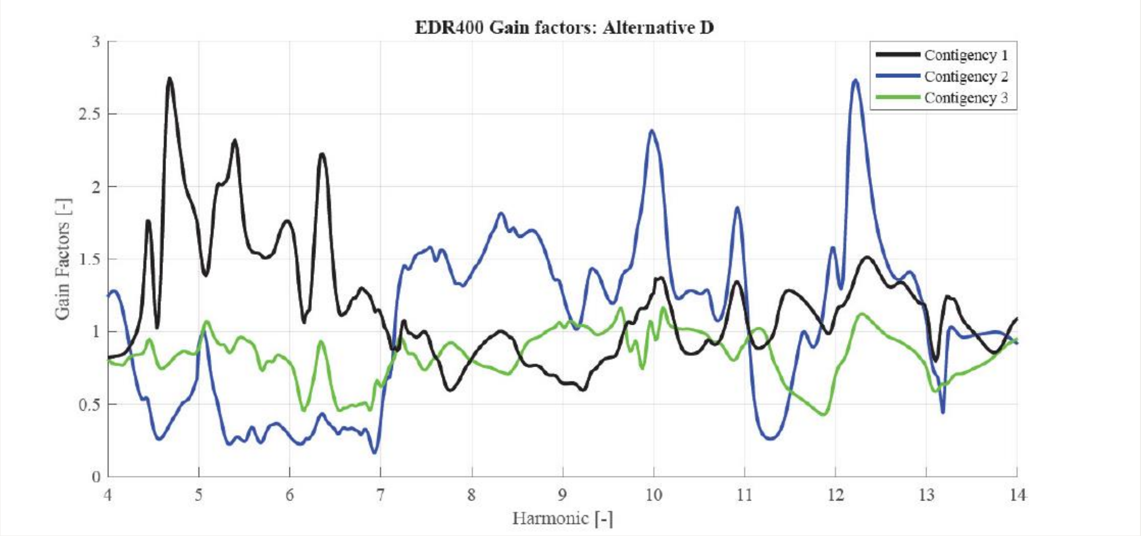
- Challenge 1: New Behaviour of the Power System
  - With increasing penetration of power electronics interfaced devices (PEID), the power system behaviour and response are bound to change
- Challenge 2: New Operation of the Power System
  - This category of issues identifies areas where how we operate the power system needs to change. This includes the people, processes and tools in system operation that observe the bulk electric system and take necessary actions to maintain reliability
- Challenge 3: Guaranteed Provision of Ancillary Services
  - Transient and steady state stability will remain crucial, i.e. frequency, synchronising torque and voltage support requirements of the system will need to be maintained. This category deals with issues that result from lack of ancillary services.

Challenge 1: New Behaviour of the Power System

- Typical challenges identified include
  - Reduction of transient stability
  - Sub-Synchronous Controller interactions
  - Resonances due to cables and power electronics
  - Voltage dip induced frequency dip

Challenge 1 Example: Cable resonance

- Energinet have identified that a complete cable transmission system upgrade increases their harmonics above planning levels[1]
- Concerns that it could overload on existing LCC harmonic filters
- Overloading of LCC HVDC converter station filters with excess harmonic current due to increased distortion will result in the protection system of the filter tripping the filter.



Gain factors for Endrup 400 kV substation calculated a specific scenario under three N-1 contingencies

[1] https://energinet.dk/-/media/2D53496554A5489A88AC7AF9612804A8.pdf?la=da&hash=E1E156BE2A7314EE7C9F18B66782220B3B76FD4F/

Challenge 2: New Operation of the Power System

- Increased congestion / Decrease of redispatch possibilities
- Observability and Controllability of RES
- Increased co-ordination TSO-DSO & TSO-TSO
- Operation of Hybrid HVDC/HVAC systems
- Power system restoration services

Challenge 2 Example: Congestion

- Wind Farms tend to be located at traditionally weaker parts of the grid and away from load centres.
- At times of high wind penetration System Operators may ask generators to stop producing or reduce output.
- In Ireland in 2017 3.7% of Wind resources was curtailed (277GWh)[2]
- The payments in the GB system, for example, have been increasing over the last decade as can be seen below[3]

£m	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19
Payments to Wind powered generation	0.2	34.1	7.6	49.7	65.3	96.8	83.2	108.0	173.2

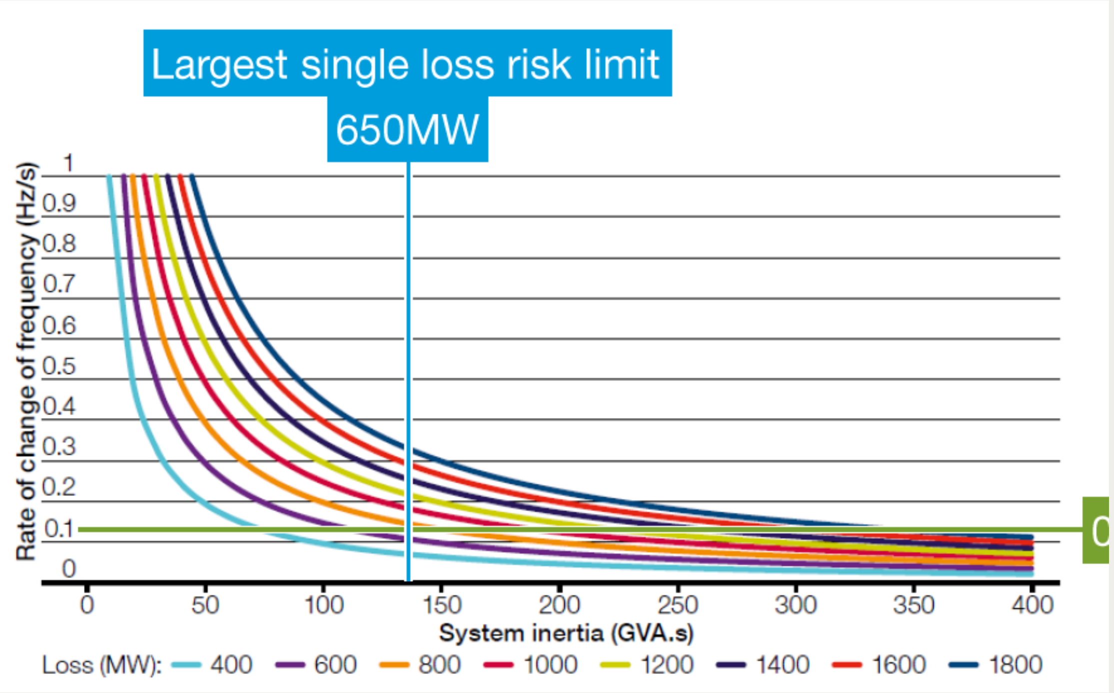
2 http://www.eirgridgroup.com/Annual-Renewable-Constraint-and-Curtailment-Report-2017-V1.pdf
3 https://www.nationalgrideso.com/document/142956/download

Challenge 3: Guaranteed Provision of Ancillary Services

- Decreasing inertia
- Impact of decreasing inertia
  - Increasing Rate Of Change Of Frequency (ROCOF)
  - Excessive frequency deviations
- Decreasing frequency Nadir
- Correct estimation of operating frequency reserves
- Static & dynamic reactive power balance
- Ramps management

Challenge 3 Example: ROCOF

- A reduction in connected synchronous generation reduces the System Inertia
- A reduction in the System Inertia will result in larger ROCOF as seen opposite.
- In 2016 the ESO in the UK estimated that 6GW of distributed generation would trip if the ROCOF exceed 0.125Hz/s[4].
- Distribution code modifications are enforce to change ROCOF setting to 1Hz/s and remove Vector Shift as a Loss of mains protection[5]



4 https://www.nationalgrideso.com/document/63471/download

5 Distribution code modification DCRP/MP/18/08 - DC0079 Frequency Changes during Large Disturbances and their Impact on the Total System.

Capabilities of PE that help mitigation

	TSC	TSR	TCR	SVC	STATCOM	TCSC	SSSC	UPFC	IPFC	VSC HVDC	LCC HVDC	Electric Vehicle	BESS	Utility Scale Storage	Solar PV	WT T3
Reduction of transient stability margins																
Resonance (harmonic) instability																
Sub synchronous controller interaction																
Introduction of new low frequency power oscillations																
Decreased damping of existing																

Deliverables

- Report (Technical Brochure) will be published 2020 end of the summer
- During CIGRE Paris session 2020:
  - A tutorial on 27 August 2020 in the afternoon
  - All info on Paris session (i.e. program and registration) via link below
  - https://www.cigre.org/GB/events/cigre-session-2020
- Webinar in November 2020

Summary

- Significant penetration of power electronic interfaces devices is progressing
- This causes both challenges and possibilities

- System operations will need to evolve

- CIGRE is at the forefront of understanding the issues & developing solutions