MIGRATE – MASSIVE INTEGRATION OF POWER ELECTRONIC DEVICES

Stakeholder Workshop, Brussels, 6 April 2017
AGENDA

1. Introduction
2. Roundtable with the audience
3. Increasing PE penetration in today’s grid
4. System protection strategies under high PE penetration
5. Operating a network with 100% PE penetration
6. Real time monitoring and control in tomorrow’s grid
7. Mitigation of power quality disturbances
8. MIGRATE results & Industry Associations involvement
9. Wrap up
INTRODUCTION

MIGRATE at a glance
FACTS

– Horizon 2020 – LCE-6: Transmission Grid & Wholesale Market
– Funding Scheme: Collaborative project
– Type of Action: Research & Innovation

– Acronym: MIGRATE
  Massive InteGRATion of power Electronic devices

– Framework Conditions:
  + Publication Date: 2013-12-11
  + Deadline Date: 2015-05-05; 17:00:00 (Brussels local time)
  + Main Pillar: Societal Challenges
  + Duration of Project: 48 month (Project Start on 1st January 2016)
  + Budget: 17.9 mio. € for the consortium (16.8 mio.€ Horizon 2020 founded)
The objective of MIGRATE is:

To develop and validate innovative, technology-based solutions in view of managing the pan-European electricity system experiencing a proliferation of Power Electronics (PE) devices involved in connecting generation and consumption sites.
OVERARCHING GOAL

Stability of the power system

Minimum acceptable stability level

Transit zone
System stability is addressed within the existing framework: controllers and grid codes

Improvement of system stability within the existing framework

Technology leap
System stability is addressed with breakthrough methodologies and controllers with modified grid codes

Power electronics penetration

L₃%

L₁%

L₂%

100%
EXPECTED IMPACT

Support to facilitate a low carbon energy system by

+ Maximisation of the amount of Renewable Energy Sources installed in the system while keeping the system stable.
+ Anticipation of future potential problems and challenges.
+ Clarification of the need of new control/protection schemes and possibly new connection rules to the grid

MIGRATE will provide requirements for future measures, methods and tools for a secure operation of the upcoming converter dominated power system.
THE CONSORTIUM

Estonia

Iceland

Finland

Germany

Scotland (UK)

England (UK)

Ireland

Netherlands

France

Switzerland

Slovenia

Italy

Spain
## TSO PARTNERS

<table>
<thead>
<tr>
<th>Participant No.</th>
<th>Participant legal name</th>
<th>Country</th>
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<tbody>
<tr>
<td>1 (Coordinator)</td>
<td>TenneT TSO GmbH</td>
<td>Germany</td>
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<td>2</td>
<td>Amprion GmbH</td>
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<td>12</td>
<td>Terna S.p.A.</td>
<td>Italy</td>
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THE GOVERNANCE
THE WORK PACKAGES

WP1
Power System stability issues under high penetration of PE

WP2
Real Time Monitoring and Control

WP3
Control and operation of a grid with 100% converter based devices

WP4
Protection schemes in transmission networks with high PE penetration

WP5
Power quality in transmission networks with high PE penetration

WP6 – Exploitation

WP7 – Communication and Dissemination

WP8 – Management
WORKLOAD DISTRIBUTION PER WP

WP 1: 18%
WP 2: 10%
WP 3: 25%
WP 4: 21%
WP 5: 15%
WP 6: 3%
WP 7: 3%
WP 8: 5%

per WP based on person month
WORKLOAD PER TYPE OF PARTNER

- Universities: 60%
- TSOs: 35%
- Industrials and IT: 5%

based on person month
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INCREASING PE PENETRATION IN TODAY’S GRID

Strategies to mitigate power stability issues

Sven Rüberg

MIGRATE Stakeholder Workshop • Brussels • 06th April 2017
STRUCTURE OF WP1

- Systemic issues
- Load modelling
- Power system analysis
- Generic test cases
- PMU monitoring
- Mitigation
- Validation
- CC implementation
MAIN OBJECTIVES OF WP1

1. Identification and prioritization of stability issues related to the increasing share of PE devices

2. Development of novel analysis methods and mitigation schemes by theoretical approaches, simulations, and laboratory experiments

3. Suggestion of new control strategies taking into account existing control and protection devices as well as existing/upcoming operating rules and network codes

4. Validation of the suggested mitigation measures by laboratory and real-life experiments using PMU data
RESULTS/CURRENT STATUS OF WP1: CURRENT AND ARISING SYSTEMIC ISSUES (1/)

+ Existing requirements for grid-connected PE and assessment of PE capabilities
  – Summary of NC RfG, NC HVDC, NC DCC
  – PE capabilities were preliminarily assessed, detailed analysis will follow in D1.2
+ Current and arising issues
  – TSO questionnaire and literature survey
  – 11 issues identified and described in detail
  – Prioritisation questionnaire and issue ranking
+ High level description of the model problems

-> D1.1 is public! <-
www.h2020-migrate.eu
RESULTS/CURRENT STATUS OF WP1:
CURRENT AND ARISING SYSTEMIC ISSUES (2/)

33 addressees  
21 answers

TSO Questionnaire

Identification of current and arising stability issues

11 issues identified

Prioritisation questionnaire

Detailed description of identified issues

12 addressees  
8 answers

Input for subsequent tasks

List of prioritised issues

Input for subsequent tasks

Sven Rüberg, TenneT
RESULTS/CURRENT STATUS OF WP1: CURRENT AND ARISING SYSTEMIC ISSUES (3/)

+ MIGRATE TSOs were asked to rate each issue in three dimensions

- Severity
- Probability
- Timeframe

<table>
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<th>Severity</th>
<th>Probability</th>
<th>Timeframe</th>
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<td>severe</td>
<td>3</td>
<td>high</td>
<td>≤5 years 3</td>
</tr>
<tr>
<td>medium</td>
<td>2</td>
<td>medium</td>
<td>≤10 years 2</td>
</tr>
<tr>
<td>slight</td>
<td>1</td>
<td>low</td>
<td>≤15 years 1</td>
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<tr>
<td>none</td>
<td>0</td>
<td>none</td>
<td>&gt;15 years 0</td>
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+ As a result, the issues were ranked:

1. Decrease of inertia
2. Resonances due to cables and PE
3. Reduction of transient stability margins
4. Missing or wrong participation of PE-connected generators or loads in frequency containment
5. PE controller interaction with each other and passive AC components
6. Loss of devices in the context of fault-ride-through capability
7. Lack of reactive power
8. Introduction of new power oscillations and/or reduced damping of existing power oscillations
9. Excess of reactive power
10. Voltage dip-induced frequency dip
11. Altered static and dynamic voltage dependence of loads
+ From the ranked issues, ‘model problems’ for further study/analysis are derived

**Model Problem**

- **Modelling**
  - ‘How are the system and components modelled?’
    - Necessary modelling features (EMT/RMS)
    - For PE devices and other components in generation, transmission and load
    - Geographical extend (system size)

- **Case Study**
  - ‘Under which conditions is instability going to occur?’
    - Grid topology / power flow
    - Occurrence of disturbance (type/situation)
    - Operating conditions

- **Simulation/Quantification**
  - ‘How will the simulation be performed?’
    - Simulation method (e.g. frequency scan, time domain simulations, etc)
    - Assessment criterion to quantify proximity to instability
RESULTS/CURRENT STATUS OF WP1: ANALYSIS AND SIMULATION TESTBED (2/)

+ One consistent set of simulation models in all time domains
  – Test cases (UK+Ireland grid)
    + PowerFactory for stationary and dynamic simulations
    + PSCAD for EMT simulations
    + RTDS for RT simulations
  – transition scenarios
  – detailed RMS/EMT/RT models for type-3 and type-4 wind turbines
  – updated load models
INTERFACES BETWEEN WP1 AND THE STAKEHOLDERS

– project website www.h2020-migrate.eu

– Public deliverables
  + D1.1: „Report on systemic issues“ (already online and available for download)
  + D1.6: „Recommendations for connection code implementation“ (End of 2019)

– Stakeholder workshops

– Conferences and other dissemination events
THE STAKEHOLDER’S WAY TO CONTRIBUTE

– Participate in the Stakeholder’s Questionnaire for D1.1!
  + Executive summary / synthesis designed for external stakeholders for download
  + Is there a stability issue missing?
  + Do you agree with the ranking?
  + Do you have other comments?
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SYSTEM PROTECTION STRATEGIES UNDER HIGH PE PENETRATION

WP4

Santiago López Barba (REE)

Brussels, 6th April 2017
INDEX

WP4: Protection Schemes in Transmission Networks with High PE Penetration

+ Objectives
+ Members
+ Main tasks
+ Deliverables
+ Current WP Status
+ The value of WP4
OBJECTIVES

- Provide a detailed insight into the ability of present protection practices to properly operate during system disturbances under very high penetration of PE.

- Evaluate and test emerging technologies together with new system protection strategies and develop new ones in order to overcome the identified threats when operating at 100% of PE penetration.

- Give recommendations for the design of protection schemes for future power systems with very high penetration of PE.
MEMBERS

Réseau de transport d’électricité
DE ESPAÑA

elering
GENERATING OPPORTUNITIES

circe
RESEARCH CENTRE FOR ENERGY RESOURCES AND CONSUMPTION

MANCHESTER 1824
The University of Manchester

TU Delft
Delft University of Technology
4.1 • Accurate models for desktop protection studies and HiL tests
   • Task Leader: TU Delft
   • (M1-M12)

4.2 • Assessment of the existing protection function/solutions under high PE penetration
   • Task Leader: CIRCE
   • (M12-M21)

4.3 • Development and testing of the new protection solutions when reaching 100% PE penetration
   • Task Leader: University of Manchester
   • (M21-M34)

4.4 • Proof of concepts
   • Task Leader: Schneider
   • (M34-M46)

4.5 • Power system design for a secure system with high PE penetration
   • Task Leader: REE
   • (M47-M48)
DELIVERABLES

D 4.1
- Grid and PE models validated for protection studies to perform HiL tests with RTDS
  - M12

D 4.2
- Limitations of present power system AC protection schemes and System Integrity Protection Schemes (SIPS) to properly operate in systems with high penetration of PE during AC faults
  - M21

D 4.3
- New developments, technologies and solutions proposed to overcome constraints identified in task 4.2
  - M34

D 4.4
- Analysis of the behaviour of the new protection concepts proposed in task 5.3 in a HiL facility with real protection equipment
  - M46

D 4.5
- Power system design for a secure system with high penetration of PE
  - M48
THE STATUS OF WP2

• Benchmark grid model fully developed for the RTDS simulations
• Validated generic scalable models for real time protection studies:
  • Full Converter Wind Turbine
  • Doubly Fed Induction Generator
  • Photovoltaic Generator
  • Back-to-Back HVDC
• Fault-Ride-Through algorithms according to National Grid Codes
• Implementation of strategies related to negative sequence control/ injection
• Definition of the test protocol and protection functions to be tested (87, 21, 67N)
• Definition of the test protocol and SIPS to be tested (Out-of-Step, Load Shedding)
• Development of script files for the automation of the analysis (1,584 cases will be analyzed during the first stage)
• Hardware-in-the-Loop (HiL) RTDS platform ready
THE STATUS OF WP2

400 kV
33 kV
13.8 kV
13.2 kV
0.69 kV
0.48 kV

FC: FULL CONVERTER WIND TURBINE GENERATOR
DFIG: DOUBLY FED INDUCTION GENERATOR
PV: PHOTOVOLTAIC GENERATOR
HVDC: HIGH VOLTAGE DC LINK
G1, G2, G3: SYNCHRONOUS GENERATORS
BUS 13: NETWORK EQUIVALENT

6th April 2017/ MIGRATE project
THE STATUS OF WP2

What is next?

• Testing of main protection functions commonly employed in present transmission systems (87, 21, 67N, Out-of-Step, Load Sheeding) → (T4.2 – 09/2017)

• Development and testing of new protection solutions when reaching 100% PE penetration → (T4.3 – 10/2018)

• Proof of concepts → (T4.4 – 10/2019)

• Power system design for a secure system with high PE penetration → (T4.5 – 12/2019)
THE VALUE OF WP4

WP4 will deliver:

• Lessons learnt from the HiL tests carried out. Assessment of potential impacts on present protection practices in scenarios with high PE based generation.

• Possible solutions based on novel protection practices.

• New algorithms developed to overcome the constraints detected.

• Technical and economical feasibility of the solutions proposed.

• Guidelines for the design of protection systems towards 100% PE penetration.

• Possible requirements for future PE based generators (LVRT, negative sequence...).
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OPERATING A NETWORK WITH 100 % PE PENETRATION

WORKSHOP “More power electronics into the grid: Innovative solutions for operations, and impacts on connection rules”

6th April 2017, Brussels
Is inertia a real need? And what is inertia?

How would inertia be defined on a stand alone system only fed by inverters with fixed frequency? Zero inertia or infinite inertia?

“Inertia” is only one possible solution!

- Today’s system inertia is the consequence of the existence of large synchronous generators. Nobody ever defined the required level of inertia, which is only an uncontrolled by-product.
- Emulating “synchronous generators with identical inertia” with inverter-based devices is technically possible but requires over-sized inverters.

Requirement: stability at an acceptable cost

- Acceptable level of stability for large transmission system while keeping costs under control
- Stable operation of large transmission system should not depend on telecommunication system: we must keep something like “frequency” to synchronize inverters
Today inverters connected to the grid are “grid-following”: they measure the frequency and adapt their current injection to provide active/reactive power with the same frequency.

What if there is nothing to “follow”? Inverters (at least some of them) need to be “grid forming”, they have to create the voltage waveform on their own.
WHAT IF THERE IS NO ONE TO “FOLLOW”? 

Some inverters need to be “grid forming”, they have to create the voltage waveform on their own.

Going from a system driven by physical laws to a system driven by the controls of inverters

Power Electronics are fully controllable BUT they only do what is in their control system!

There is no natural behavior of inverters, this is very dependent on manufacturers.

There is a need for all inverters to be synchronized (same frequency),
- all over the grid
- regardless to the topology of the grid
- in a distributed and very robust way (try to avoid telecommunication)
- even when transient disturbance happening

A priori, this relation is lost (linked to rotating masses equations).
GRIDS WITH 100% POWER ELECTRONICS

This has already been achieved:

- on distribution system of household/ship/industry
- on offshore DC connected windfarm

But transmission systems have specific features:

Microgrids & Offshore grids

- Hierarchical relationship between generating units possible
- Radial, fixed and known topology
- Location and consumption of loads well known

Transmission grids

- No master/slave relationship between generating units
- Meshed, highly variable and unknown* topology
- Location and consumption of loads unknown*

* from a producer’s point of view

Thibault Prevost, RTE
Objectives of WP3:

- To propose and develop novel control and management rules for a transmission grid to which 100% converter-based devices are connected while keeping the costs under control;
- To check the viability of such new control and management rules within transmission grids to which some synchronous machines are connected;
- To validate the control rules on reduced-size inverters;
- To infer a set of requirement guidelines for converter-based generating units, as far as possible set at the connection point and technology-agnostic, which ease the implementation of the above control and management rules.

Partners:

- 5 TSOs: EirGrid, REE, RTE, TenneT TSO GmbH, Terna
- 3 universities: ETH Zürich, L2EP, University College Dublin
MIGRATE WP3: 3 STEPS

Completed
Deliverable D3.1 available on MIGRATE’s website

Definition of system needs

• Requirements about the global behaviour of a system with 100% power electronics

Ongoing

Development of new control and management rules

• Fulfilling the system needs

Scheduled in 2019

System integration and requirement guidelines

• Validation of the controls and management rules on reduced-size inverters
• Definition of requirement guidelines for next version of grid codes to enable a transition towards 100% power electronics
OVERVIEW OF DELIVERABLE 3.1
DEFINITION OF SYSTEM NEEDS FOR GRIDS WITH 100% PE

System needs: requirements about the global behaviour of a large transmission system, while forgetting about synchronous machines

10 system needs are identified:

- Possible migration path
- Synchrony
- Balance between load and generation
- Possibility to implement market-driven setpoints
- Stability
- Acceptable ranges of frequency and of voltage amplitude
- Load sharing between generating units
- Robustness to system split
- Black start capability
- Alternating Current System

Controls developed in WP3 will fulfil these requirements.
Today’s classification of power system stability may not be relevant for power systems with 100% PE.

Ensuring stability of such systems implies checking their behaviour for all disturbances which the system must be able to withstand.

The list of disturbances that grids must be able to withstand was elaborated:

- A list of disturbances likely to happen on power systems was made. It includes, on purpose, events with both high and low probability.
- Disturbances considered by at least one of the TSOs involved in WP3 as dimensioning (i.e. nowadays considered for system design) were selected.
In the deliverable outline of system design is given:

- We will try to apply the principle of **hierarchical controls** decoupled in time and space which is used today;

- We will **minimize the required additional hardware** to bring the most social welfare;

- We will need additional criteria to evaluate the performance of inverters during transients.
ONGOING WORK

Development of controls that enable the self-synchronization of inverters

Protection of inverters against grid transients:

- Inverter over current limitation is very close to nominal capability (over current of 120% for 1 cycle)

![Diagram](image)

The 2 inverters are operated in grid-forming mode.

- A control that protects the inverter from over currents without switching from grid-forming to grid-following was elaborated outside of the MIGRATE project. It is being applied on the above mentioned self-synchronizing controls.

Other questions: what share of inverters need to be grid-forming? Are there any requirements on their location?
Controls developed by WP3 will:

• take advantage of the specificities of converters: e.g. possibility to have faster controls than synchronous machines

• while taking into account their physical capabilities: e.g. maximum overcurrent ~120% nominal current

Benefits of the interactions with stakeholders:

✓ Shared assumptions about specificities and capabilities of converters
✓ Minimization of the costs associated to grids with 100% power electronics

Enabling a smooth transition path to grids with up to 100% power electronics will imply new requirements for converter-based generating units:

• guidelines for some of these requirements will be an output of WP3

• will it be possible to define these requirements at PCC ?

• if not, how to specify potentially “intrusive” requirements?

✓ Pave the way for the definition of future versions of RfG grid code
Frequency is now a physical value but will become a control output:

• How to define it and measure it during fast transients (i.e. for time $t < 1/f$)?
• A common definition will be needed.

✓ Pave the way for the future implementation of the developed control and management rules
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REAL TIME MONITORING AND CONTROL IN TOMORROW'S GRID

James Yu  Brussels - April 2017
CONTENTS

1. The Objectives of WP2
2. The Current status of WP2
3. The Value of WP2
4. The Interfaces of WP2
Complementary approach to other WPs - Under WP1. Real-time monitoring and forecast of:
• PE penetration,
• Area (local) inertia
• Short Circuit Capacity

Software will be developed that can make these solutions available to TSOs and knowledge will be generated regarding the ICT requirements and the issues encountered during deployment and operation.

Pilot testing of Closed Loop Wide Area Control in the Landsnet system (Iceland) as a world premiere. Lessons learned and knowledge generated by the field trial can be exploited by ENTSO-e.
The research and development will address the following issues:

- New **KPIs** (key performance indicators) (including area inertia, wide band oscillation characteristics and short-circuit capacity) will provide a new dimension to the analysis of system performance during the transition to a low carbon transmission network mainly based on PE connected generation;

- New monitoring and forecasting tools can be developed using **modern sensors** (e.g. PMUs) and communication technology to provide **real-time information on KPIs** to more accurately assess the true stability limits of a system;

- The step change to a **world first live implementation of a real time wide area control** algorithm can be developed and tested in the GB and Icelandic networks;

- Demonstrate that the solutions created are capable of maintaining a high level of accuracy and reliability for a range of **different power systems**, beyond those they were originally envisioned for, and as such are ready for pan-European application. Furthermore, by trialling the solutions in different systems, valuable insights into the **interoperability** between hardware from different suppliers, and between different hardware and software platforms will be generated to facilitate further development and help ensure the **solutions can be up taken by any EU TSO.**
THE OBJECTIVES OF WP2

Three key objectives:

- To develop new monitoring and forecasting tools using modern technology, so to provide real-time information on stability KPIs which will more accurately assess the stability limits of a system;
- To develop and test a world-first real time wide area control algorithm in the GB and Icelandic networks;
- To demonstrate the ability of the solutions to be accurate and reliable in a pan-European application with a period of trialling the solutions across various power systems.
THE STATUS OF WP2

WP2 Face-to-Face meeting

FAT of Area Inertia & SCC modules

SAT of Area Inertia & SCC modules (T2.3 & T2.5)

TSO Training Workshop (T2.3 & T2.5)

Submission of Deliverable 2.2 & 6 month progress summary

Load shed design finalised for East Iceland (T2.7)

Period of Pilot Testing on GB System begins (T.2 & T2.5)

SAT for Fast Ramp installation in Iceland (T2.7)

Load shed design finalised for East Iceland (T2.7)

Period of Pilot Testing on GB System begins (T.2 & T2.5)

SAT for Fast Ramp installation in Iceland (T2.7)

James Yu, April 2017
THE STATUS OF WP2

What is next?

- Bench testing of WACS schemes, East Iceland Load shed equipment put in operation and tested by using Substation system (T2.7 – 04/2017)
- SAT of solutions for monitoring and estimating Area Inertia & Short-Circuit Capacity (T2.3 and T2.5 - 02/05/2017)
- Final design and bench testing of control schemes in Landsnet control centre (05/2017)
- Fast ramp scheme equipment installed in generator substation (05/2017)
- Submission of Deliverable 2.2 (06/2017)
- Submission of Work Package Progress Summary (06/2017)
- East Iceland Load shed finalized with hardware and control scheme replacement with SAT conducted (T2.7 - 06/2017)
THE STATUS OF WP2

Available documents to date:
- Progress summaries (06/2016 & 01/2017)
- Functional Design Specification for Estimation Modules
- Infrastructure required for pilot testing estimation modules
- Estimation Software User Manuals
- Factory Acceptance Test documents
- Area Inertia Overview
- Short-Circuit Capacity Overview

D2.2 will be available to the consortium in June
Are we on track?

▪ Yes, all deliverables are still on track to being delivered by their due date.

▪ In some cases, we hope to deliver sections early and have enhanced the deliverables with additional content.
THE VALUE OF WP2

Work Package 2 will deliver:

- The solutions to monitor PE-based KPIs;
- The solutions to forecast PE-based KPIs;
- The establishment of the required infrastructure to monitor and forecast these PE-based KPIs;
- The lessons learned from the pilot test period;
- The documentation of the implementation of Wide Area Control in Iceland;
- Future recommendations for further development of measurement technology and deployment across Europe.
THE VALUE OF WP2

The value in these outcomes is:

1. TSOs will be enabled to assess the impact of PE-penetration;

2. Recommendations for the direction of further development will be given;

3. Relationships between TSOs have been fostered and developed, promoting a culture of learning between project partners.
THE INTERFACES OF WP2

3 key ways that our stakeholders can get involved:

- **Face-to-face meeting on the 9th & 10th of May (including TSO training opportunity)** – This will be our next physical progress meeting, which aligns with our training workshop which has been extended to the MIGRATE consortium.

- **Dialling into our regular progress calls** – We hold monthly teleconferences to discuss the current status of the project.

- **Get in touch** - SPEN will always be happy to talk to any of our stakeholders and share in our latest developments.
SUMMARY

- We are on track with our progress
  - Through consistent and effective communication with project partners, SPEN as the work package leader are comfortable with the progress made to date and anticipate a timely submission of all deliverables.

- Our contribution to MIGRATE holds significant and unique value
  - We are aiming to provide a useful tool for our TSO colleagues and to realise the benefits as soon as possible.

- We welcome opportunities to meet and discuss with our stakeholders under the coordination of Tennet and WP7.
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MITIGATION OF POWER QUALITY DISTURBANCES

MIGRATE WP5

MIGRATE WS, 6 April 2017. Brussels
CONTENT

1. PQ definition & MIGRATE WP5 objectives
2. MIGRATE WP5 overview (structure&tasks)
3. Power quality phenomena
4. MIGRATE WP5 – Deliverables
5. MIGRATE WP5 - Gantt chart
6. Deliverable 5.1 content
7. Task 5.2 and 5.3 description
8. PQ phenomena Visualisation – example
9. Added value for stakeholders
PQ DEFINITION & WP5 OBJECTIVES

**PQ definition:** In general, PQ can be defined as the characteristics of the power supply required to ensure that all equipment works properly and efficiently.

The increasing penetration of PE-interface renewables has already resulted in PQ challenges as evidenced by harmonic distortion, voltage sags and other disturbances. PE devices are one of the major sources of PQ disturbances in power systems but they are also very sensitive to PQ disturbances themselves. Therefore MIGRATE WP5 is dedicated to investigate power quality in transmission networks with high PE penetration.

**Main objectives**

- Evaluation of PQ related issues
- Developing numerical simulation models of PE devices for PQ studies
- Evaluation of PQ level in future PE rich power networks
- Mitigation options for keeping PQ levels within affordable values
MIGRATE WP5 OVERVIEW

• **Partners:**

<table>
<thead>
<tr>
<th>TSOs</th>
<th>Institutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELES</td>
<td>TUT (D5.1)</td>
</tr>
<tr>
<td>TenneT</td>
<td>TUB (D5.5)</td>
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<tr>
<td>EirGrid</td>
<td>UNIMAN (D5.3)</td>
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<td>Elering</td>
<td>EIMV</td>
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<tr>
<td>SPEN</td>
<td>UL (D5.2, D5.4)</td>
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</table>

• **List of tasks under WP5:**
  
  • T5.1 - Identification of critical PQ phenomena and sources of PQ disturbances under the scenarios studied in WP1
  
  • T5.2 - Development of PE numerical simulation models for PQ studies
  
  • T5.3 - Propagation of PQ disturbances through power networks
  
  • T5.4 - Assessment of the influence of PQ disturbances on operation of PE rich power networks
  
  • T5.5 - Mitigation of PQ disturbances and provision of differentiated PQ
  
  • T5.6 - Technical Management
POWER QUALITY PHENOMENA RELATED TO PE

• Voltage dips and temporary power frequency over-voltage

  **Harmonic distortion** (PE harmonic injections, device susceptibility to voltage harmonics, grid resonance, poor controllers performance causing excessive harmonic distortion)

• Supraharmonics

• Flicker and voltage fluctuation

• Harmonic resonance

• Voltage Unbalance

  • Voltage variation (high and low)

  • Frequency variation

• Frequency fluctuations

Main focus of WP5
WP5 - DELIVERABLES

+ **D5.1 (TUT)**: Critical PQ phenomena and sources of PQ disturbances in PE rich power systems (31.12.2016) – **Delivered on time**

+ **D5.2 (UL)**: Simulation models for power-quality studies in power-electronics rich power networks (1.7.2017) – **in progress**

+ **D5.3 (UNIMAN)**: Propagation of PQ disturbances through the power networks (1.1.2018) – **in progress**

+ **D5.4 (UL)**: Influence of PQ disturbances on operation of PE rich power networks (1.1.2019) – **not started yet**

+ **D5.5 (TUB)**: Mitigation of PQ disturbances and provision of differentiated PQ (1.1.2020) – **not started yet**
## MIGRATE WP5 - GANTT CHART

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Tasks in WP5</th>
<th>start</th>
<th>end</th>
<th>Task duration</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
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<td>30.12.2016</td>
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*Task duration in days.*

06.04.2017
In D5.1, critical PQ issues in power systems (harmonics, flicker, voltage and frequency variations) are analysed on the basis of the WP1 scenarios, thus involving the contribution of different network components (PE-interfaced wind and PV generation, thyristor-controlled devices, VSC, FACTS, etc.) to generate disturbances.

It involves:

+ a critical assessment of PQ issues in transmission power networks considering real-world issues as well as studies published by research laboratories;

+ Categorizing the PQ disturbance causes, types (such as harmonics, frequency variations, voltage-level violations), and reported impacts while considering the temporal variation of the level of disturbances due to renewable generation and load;

+ Experience of partner TSOs with PQ phenomena in their grids

+ Evaluating the influence of harmonics on PMU accuracy (in particular, if the PMUs are installed close to sources of harmonics and inter-harmonics, e.g., generation buses with PE-connected generation)
TASK 5.2 – DEVELOPMENT OF PE NUMERICAL SIMULATION MODELS FOR PQ STUDIES

• Started 1.1. 2016, end date 31.6.2017

• To perform simulation studies and to analyse PQ disturbances and their propagation in electric networks with a high penetration of PE devices (T5.4), numerical models of the integrated PE devices will be developed. Based on the required accuracy of simulation models and type of simulations, load flow, RMS and EMT models will be considered.

• WP5 is modeling the following PE devices: HVDC; WTG T3&T4; STATCOM; SVC; PV

• focusing on really new phenomena and knowledge related to TSO added value information (e.g. level of THD as a functions of PE devices share in the network, harmonic stability risks and mitigation)

<table>
<thead>
<tr>
<th>WP5</th>
<th>HVDC - MMC</th>
<th>PSCAD</th>
<th>EMT / RMS</th>
<th>Harmonics, steady state, transients</th>
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<td>EMT / RMS</td>
<td>Harmonics, steady state, transients</td>
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<tr>
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<td>WindGen - Type4</td>
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<td>SVC</td>
<td>PSCAD</td>
<td>EMT / RMS</td>
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<td>PV inverter (3LVL)</td>
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<td>EMT / RMS</td>
<td>Harmonics, steady state, transients</td>
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<tr>
<td></td>
<td>Aggregated PE models at 110 kV and above</td>
<td>DigSilent</td>
<td>LF</td>
<td>propagation of active and reactive power variation and the resulting frequency and voltage violations</td>
</tr>
</tbody>
</table>
TASK 5.3 – PROPAGATION OF PQ DISTURBANCES THROUGH POWER NETWORKS

• Started 1.7. 2016, end date 31.12.2017

• Milestone M5.2, M5.3

• Deliverable D5.3

• Task proposes probabilistic methodology for analysis of propagation of PQ disturbances (harmonics, frequency and voltage variation)

• The main idea of Task 5.3 is to evaluate the expected THD levels as a function of PE devices share in transmission grid

• Main effort was devoted to set up of proper network model (EirGrid) and the methodology how to set up the harmonic sources for harmonic LF calculations
Voltage: 110 kV, Ireland: Lambert proj.
110_ire_sim_test_0.rlf

+video: Flicker in ELES grid
ADDED VALUE FOR STAKEHOLDERS

• Overview of existing and future PQ issues in transmission networks and identification of main sources for PQ issues (T5.1).

• Methodology for the assessment of the Influence of PQ Disturbance on Operation of PE Rich Power Networks will be proposed in line with the developed scenarios in MIGRATE project WP1 (T5.4)

• Mitigation techniques for PQ disturbances will be proposed, techniques include device based solutions (passive and control) in order to improve the level of PQ in the electric networks. During this task, penetration limits for PE devices will be assessed in cooperation with MIGRATE project WP1. (T5.5)
AGENDA

1. Introduction
2. Roundtable with the audience
3. Increasing PE penetration in today’s grid
4. System protection strategies under high PE penetration
5. Operating a network with 100% PE penetration
6. Real time monitoring and control in tomorrow’s grid
7. Mitigation of power quality disturbances
8. MIGRATE results & Industry Associations involvement
9. Wrap up
MIGRATE RESULTS & INDUSTRY ASSOCIATIONS INVOLVEMENT

C. Coujard and Eric Peirano, TECHNOFI, WP6 leader
MIGRATE RESULTS & INDUSTRY ASSOCIATIONS INVOLVEMENT

1. EXPECTED PROJECT RESULTS
2. WHY AND HOW TO GET INVOLVED
3. PUBLIC DELIVERABLES FOR FEEDBACK
4. NEXT DISSEMINATION ACTIVITIES
EXPECTED PROJECT RESULTS

Incremental approach:

1. Mitigating system stability issues in existing grids with high PE penetration

   Methodology to appraise distance to instabilities due to PE proliferation
   Grid code evolutions
   Adapted power system control laws to cope with increased PE penetration

2. Real time monitoring and control:

   Wide area control loop using data from PMU networks in low inertia power systems
EXPECTED PROJECT RESULTS

Incremental approach:

3. Protection schemes:

- Improved protection schemes to cope with increasing PE share

4. Power Quality (PQ) in transmission networks with high PE penetration

- Integration of PE models in existing simulation tools to appraise PQ issues
- Solutions for mitigation of PQ disturbances and provision of differentiated PQ
EXPECTED PROJECT RESULTS

Breakthrough approach:

1. Operating transmission networks with 100 % PE:
   - New power system control laws able to cope with the absence of synchronous machines
   - New Grid Connection rules allowing the safe implementation of the new control laws
   - New types of PE requiring further R&D on system dynamics issues

2. Protection schemes:
   - New protection schemes for 100% PE penetration
WHY SHOULD YOU GET INVOLVED?

✓ Because your industry will be impacted by MIGRATE’s final recommendations on grid code evolutions

✓ Because some of the tools developed might be useful to you

✓ Because your inputs will help the MIGRATE partners better grasp the needs of the power system stakeholders
INvolving external stakeholders

**Who should you get involved?**

- **TSOs**
  - EU projects
  - Other ENTSO-E projects

- **Regulators**
  - ACER: Agency for the Cooperation of Energy Regulators

- **Other Stakeholders**
  - ✓ DSOs
  - ✓ Generators
  - ✓ Large consumers
  - ✓ Manufacturers
  - ✓ Certif./standard bodies
HOW TO GET INVOLVED?

- Provide the contact details for the relevant experts (questionnaire distributed today, or later by email to ccoujard@technofi.eu)
- Get informed via email about the release of public deliverables
- Get informed via email when a feedback is requested for some deliverables through questionnaires
- Fill in the dedicated questionnaires
- Participate in the coming MIGRATE workshops
Deliverables already available

**D3.1** Description of system needs and test cases for 100% PE grid

**D1.1** Report on systemic issues: description and ranking of system issues caused by increasing power electronics

Your feedback is requested!
D1. 1 Report on systemic issues

- Description of systemic issues within the pan-European transmission network resulting from an increased penetration of PE (based on inputs from 22 TSOs)
- Ranking of the 11 issues identified according to severity, probability and time frame of impact, by the 11 TSOs of MIGRATE

- D1.1 Full deliverable is available on www.h2020-migrate.eu
- 5-page synthesis also available
- 3 questions to gather your feedback:
  - Any issue to be added? Any issue not relevant to you?
  - Any issue that you would rank differently?

Your active participation will be highly appreciated!
To be released later this year (2017):

Your feedback will be requested

- **D5.1** Critical PQ phenomena and sources of PQ disturbances in PE rich power systems [under validation process]

- **D5.2** Simulation models for power-quality studies in power-electronics rich power networks [June 2017]

- **D5.3** Propagation of PQ disturbances through the power networks [December 2017]
To be issued next year (2018)

D2.1 Requirements for monitoring and forecasting PE-based KPIs

D2.3 Lessons learned from the pilot testing of monitoring and forecasting KPIs enabling TSOs to assess the impact of PE-penetration

D2.5 Recommendations for the future evolution of the synchronized measurement technology and deployment in Europe

D3.3 New options for existing system services and needs for new system services

D5.4 Influence of PQ disturbances on operation of PE rich power networks
Key final deliverables available to the public (end 2019)

- **D1.6** Recommendations for connection code implementation
- **D3.6** Requirement guidelines for generating units that enable to operate a grid without synchronous machines
- **D5.5** Mitigation of power-quality disturbances and provision of differentiated PQ
- **D6.5** Recommendations for a deployment roadmap of grid connection rules and novel power system control laws

Your inputs will be requested
The MIGRATE Project

AN EU-FUNDED PROJECT UNDER THE FRAMEWORK OF EUROPEAN UNION’S HORIZON 2020

MIGRATE stands for Massive InteGRAtion of power Electronic devices and is an EU-funded project under the framework of Horizon 2020. The aim of MIGRATE is to find solutions for the technological challenges the grid is currently and especially in future faced with.

– actual project news

– Subscribe the project newsletter

– Find all public Deliverables

– learn more about the project

– Questionnaires
Workshops with ENTSO-E and Stakeholders will take place every year (next February/March 2018)

We will keep you informed!
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WRAP UP
Thank you for coming!

The MIGRATE Team
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