Pump Storage Hydro Expert Group:

FINAL REPORT – UPDATED WITH PHASE 2 RESULTS

Purpose: The Pump Storage Hydro Expert Group was created to identify specific characteristics / constraints for this kind of Power Generating Module (PGM) for each operation mode (generation, pumping, synchronous compensation), which may have impact on the connection requirements as defined by Commission Regulation (EU) 2016/631 of 14 April 2016 establishing a network code on requirements for grid connection of generators (NC RfG).

Phase 1 (finished in June 2019), aimed at better distinction of the applicability of the RfG requirements in the different operation modes and different types of pump storage facilities while in Phase 2 (finished in June 2020) the Expert Group used the findings of their investigation to provide a proposal for a revised wording in the relevant NC Articles – mainly Article 6 (2) of NC RfG.

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ABOUT THIS DOCUMENT

This is the final report of the Pump Storage Hydro (PSH) Expert Group, established by the Grid Connection European Stakeholder Committee (GC ESC) in the autumn of 2018 to consider and recommend possible future improvements to the Connection Network Codes (CNCs) and in particular the RfG which had been raised by stakeholders during the CNC implementation.

The report includes the results of both phase 1 and phase 2 of the work as described in the respective Annex of the Terms of Reference[1].

DOCUMENT CONTROL

Version	Date	Change Reference
Initial draft in preparation	18 January 2019	Incorporate first results from the analysis of the table of requirements
Improved first draft	07 February 2019	First comments to the initial draft
Second draft	15 March 2019	Discussion of received comments - text improvements
Improved second draft	19 March 2019	Continuation of discussions - reply to comments - further suggestions for improvements
Improved second draft	25 April 2019	Consistency check between table of requirements and analysis in the report
Third draft	24 May 2019	Finalization of all technologies apart from variable speed, improvement of conclusions, recommendations and observations chapter
Final draft	August - September 2019	Additions in variable speed technologies and replies to open points
Improved final draft	October - November 2019	Incorporation of final comments - update of conclusions before final submission to the GC ESC
Final report	4 December 2019	Including final editorial changes
Updated Final report	15 July 2020	Including the proposals for amending the current NC RfG and NC DC

Any Questions?

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[1] https://www.entsoe.eu/Documents/Network%20codes%20documents/GC%20ESC/PSH/Annex_EG_PSH_final.pdf

INTRODUCTION

On 11 June 2018, the Grid Connection European Stakeholder Committee (GC ESC) decided to establish three Expert Groups (EG) to consider and clarify the requirements on particular groups of users as applicable under the three European Connection Codes (CNCs); namely, Requirements for Generators[2] (RfG), HVDC[3] and Demand Connection[4] (DCC).

The areas to be considered by the three EGs were:

- Pumped Storage[5] (hydro);
- Storage (non-pumped Storage); and
- Mixed Customer Sites (MCS), which could be a combination of generation, demand and/or storage facilities.

The creation of these EGs was proposed by ENTSO-E to elaborate on the three CNCs issues which had been raised by stakeholders during the national implementation of the CNCs; including as a result of a stakeholder survey to identify priority topics for which future revisions to the CNCs could be considered.

The full terms of reference for the EG PSH[6] were approved by 14 Sept 2018 GC ESC, while the revised version including phase 2 work was approved by GC ESC on 12 December 2019.

[2] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:JOL_2016_112_R_0001

[3] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32016R1447

[4] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2016.223.01.0010.01.ENG&toc=OJ:L:2016:223:TOC

[5] Defined in RfG Article 2(21).

[6] https://www.entsoe.eu/Documents/Network%20codes%20documents/GC%20ESC/PSH/Annex_EG_PSH_final.pdf

PURPOSE

Legislative background

NC RfG, Article 6 (2) foresees that: *"Pump-storage power-generating modules shall fulfil all the relevant requirements in both generating and pumping operation mode. Synchronous compensation operation of pump-storage power-generating modules shall not be limited in time by the technical design of power-generating modules. Pump-storage variable speed power-generating modules shall fulfil the requirements applicable to synchronous power-generating modules as well as those set out in point (b) of Article 20(2), if they qualify as type B, C or D.";*

Objectives

The main objective of the EG PSH, as agreed by the Grid Connection European Stakeholder Committee on 14 September 2018 and extracted from the paper submitted to the GC ESC for approval, is:

- to identify specific characteristics / constraints for this kind of Power Generating Module (PGM) for each operation mode (generation, pumping, synchronous compensation), which may have impact on the connection requirements as defined by the Commission Regulation (EU) 2016/631 of 14 April 2016 establishing a network code on requirements for grid connection of generators (NC RfG).
- to propose improvements to the NC RfG where needed

Task description

The EG PSH is commissioned with the following actions:

- Discussions with stakeholders / responses received during consultations / stakeholder interventions at the GC ESC / workshops have revealed that this provision of the regulation is probably too generic and leads to requests for exemptions or to compliance issues. A better distinction of the applicability of the RfG requirements in the different operation modes (generating, pumping, synchronous compensation) and different types of pump storage facilities needs to be investigated;
- Challenges in complying with the NC RfG requirements shall be identified for each operation mode separately and, if applicable, depending on the technology (e.g. specific features of variable speed pumps);
- Clarifications shall be provided on technical capabilities of these PGMs to specify if they comply with operational requirements from System Operation Guidelines (SO GL) and Emergency and Restoration Network Code (NC ER); and

- Suggestions of improvements or mitigation of shortcomings concerning the requirements and designs of the PGM.
- Proposals for amending Article 6 (2) and any other relevant Articles of NC RfG according to the results and observations of the technical assessment.
- List and briefly assess any possible implications to other NCs/GLs that those revisions to NC RfG may have.

Deliverables

The EG PSH is tasked to submit a report in which the stakeholder issues, as described above, are explored and to propose possible solutions.

METHODOLOGY

The group has chosen the following methodology to reach this goal:

- Identification of the relevant PSH technologies based on their different properties and capabilities regarding the behavior towards the grid.
- Assessing whether the technical requirements of RfG NC can be met for each technology and each operation mode separately.

In practice, a spreadsheet file has been created[7] where this assessment is detailed in a well-arranged manner. The technical requirements are split into four separate sheets distinguishing between frequency requirements, voltage requirements, system restoration requirements, and instrumentation and protection requirements.

The assessment takes into consideration that the RfG applies to new PSH as defined by the national implementation in each Member State.

[7] The spreadsheet can be found here: https://www.entsoe.eu/network_codes/cnc/expert-groups/ in the EG PSH space as part of the final report folder – named as “EG PSH table of requirements”

IDENTIFICATION OF THE RELEVANT TECHNOLOGIES

The following technologies have been identified and considered for this assessment:

- Fixed speed pump turbine
- Single shaft ternary
- Variable speed pump turbine - Double Fed Induction Generator (DFIG)
- Variable speed pump turbine - Full converter

Fixed speed pump-turbine

A fixed speed pump-turbine is a set of a synchronous motor/generator and a pump/turbine mounted on the same shaft. This set can work in either turbine or pump mode, depending on the rotation direction. In turbine mode, fixed speed pump-turbines work as standard hydro turbines. In pump mode, the phase sequence and the rotation direction are changed. In this mode, once the unit is synchronized, the pump consumes a fixed amount of power, which cannot be controlled, depending on the available head. Typical fixed speed pump-turbine units cover a capacity range from 40 to 400 MW per unit.

Single shaft ternary pump-turbine

A single shaft ternary is a set of a motor/generator, a turbine, and a pump mounted on the same shaft. The main difference to the standard reversible pump-turbine technology, single-shaft ternary pump-turbines rotate in only one direction. By adjusting valves within the waterways, it is possible to seamlessly switch between turbine and pump-mode. Typical single shaft ternary units cover a capacity range from 40 to 300 MW per unit.

Note: Similar features to ternary pump-turbines can be achieved by two fixed speed pump-turbines operated in a hydraulic-short circuit. In order to limit the complexity of the discussion, it was decided to not consider this case since conclusions can be derived from the evaluations of the capabilities of fixed speed and ternary pump-turbines already.

Variable speed pump turbine – Doubly Fed Induction Machine (DFIM)

A reversible pump-turbine is attached to a doubly fed motor/generator which together with a converter allows for a certain speed variation. The converter is changing amplitude and frequency/phase of the three-phase current system that is fed to the rotor of the machine. The stator is connected to the grid like in a conventional fixed speed setup. Typical applications of this technology are above 100 MW and can reach 400 MW. The technology allows a regulation of active power in pump mode.

Variable speed pump turbine – Full converter

A reversible pump-turbine is attached to a synchronous motor/generator that is connected to the gird by a converter. Using the converter, the generator frequency and its speed can be adjusted. Applications of this technology are known for unit power below 100 MW, but the technology can be scaled to reach higher outputs. The solution allows a regulation of active power in pump mode.

Note: It is technically possible to bypass of the converter and use the machine as normal fixed speed pump-turbine. In order to reduce the complexity of the discussion it was decided to not consider this option separately, since it is covered by the evaluations of the capabilities of fixed speed pump-turbines already.

ASSESSMENT OF THE CAPABILITIES ACCORDING TO RFG REQUIREMENTS

The EG assessed the applicability of the requirements of the RfG NC regarding the four selected PSH technologies. As mentioned above, a spreadsheet was used as a tool. For better structure, the RfG requirements are classified into the following categories:

- Frequency requirements
- Voltage requirements
- System restoration requirements
- Instrumentation and Protection requirements

In the spreadsheet, requirements that can typically be met by the technologies considered in this report are marked with **"x"**. No further explanation is given in this report.

Requirements that cannot be met are marked as **"N/A".**

Brief notes are provided for certain requirements in the respective cells of the spreadsheet (conditional application of the requirement).

In this report, the reasoning for assessing the application as "N/A" is provided. For certain requirements that the application is "conditional", explanations are also outlined.

Fixed speed pump-turbine capabilities

Frequency Parameters (generation mode)

Frequency restoration control – aiming at restoring frequency to its nominal value or maintaining power exchange flows between control areas at their scheduled values – is in principle possible. Since the RfG does not define corresponding connection requirements, the functionality needs to be individually specified by the relevant TSO.

Frequency Parameters (pumping mode and synchronous compensation mode)

The fulfilment of the frequency control requirements includes the possibility of changing the active power generated or consumed by the unit, depending on the system frequency. For that purpose, it is necessary to control the kinetic power supplied by the primary energy source. As fixed speed pumps can only control the kinetic power in generation mode, the frequency control requirements need to be revised for both pump and synchronous compensation mode. Therefore:

- All requirements related to a change of the active power output are not applicable in synchronous compensation mode, because there is no supply of primary energy.
- All requirements related to a change of the active power output are not applicable for fixed speed pump turbines in pumping mode, because the active power consumption cannot be controlled.
- According to emergency plans, PSH in pumping mode are either disconnected or changed to generation mode during low frequency events at several thresholds between normally 49,2 Hz to 49,8 Hz. Therefore, the requirement of RfG Article 13,1 (a), which states that PSH must remain connected to the grid across the whole frequency range as listed in Table 2, is not applicable for PSH in pumping mode for frequencies below 49,0 Hz. However, when connected, they shall be capable of operation in a frequency range between 49.0 Hz and 51.5 Hz, unless a higher value of the lower range is defined by the relevant TSO.

Voltage Parameters (all three modes)

Fixed speed pump-turbines are based on synchronous PGMs. Therefore:

- They can comply with all voltage requirements in all modes of operation – generation, pump and synchronous compensation mode. All requirements for voltage control applicable to synchronous power generating modules can also be met in pump operation mode.

System Restoration (generation mode)

- House load operation is not applicable for fixed speed pump-turbines because the time for re-synchronization after disconnection from any external power supply is considered to be less than 15 min.

System Restoration (pumping mode and synchronous compensation mode)

System restoration refers to the activities carried out after a black-out to recover the power system. In this situation, it is necessary to have power generating modules that can control frequency and voltage in weak power systems. Therefore, no pump or synchronous compensator should be connected to the network during system restoration. More specifically:

- Island detection is aiming at the ability of stably balancing and feeding an island after a system split. Only generators can do so. This requirement is not applicable to synchronous compensation and for pumping mode.
- Black start and post-fault active power recovery is not applicable in synchronous compensation mode because of lack of primary energy.

Instrumentation and Protection (all three modes)

Fixed pump turbines can comply with all instrumentation and protection requirements in all three operation modes.

Single shaft ternary pump-turbine capabilities

Frequency Parameters (generation mode)

Frequency restoration control – aiming at restoring frequency to its nominal value or maintaining power exchange flows between control areas at their scheduled values – is in principle possible. Since the RfG does not define corresponding connection requirements, the functionality needs to be individually specified by the relevant TSO.

Frequency Parameters (pumping mode and synchronous compensation mode)

- All requirements related to a change of the active power output are not applicable in synchronous compensation mode, because there is no supply of primary energy.
- If the pump is only operated in pump mode, the same requirements apply as to the fixed speed pump-turbines.
- In hydraulic short circuit mode frequency control requirements can be equally fulfilled as in generation mode.
- According to emergency plans, PSH in pumping mode are either disconnected or changed to generation mode during low frequency events at several thresholds between normally 49,2 Hz to 49,8 Hz. Therefore, the requirement of RfG Article 13,1 (a) of remaining connected to the grid across the whole frequency range listed in Table 2, is not applicable to PSH in pumping mode for frequencies below 49,0 Hz. However, when connected they shall be capable of operation in a frequency range between 49,0 Hz and 51,5 Hz, unless a higher value of the lower range is defined by the relevant TSO.

Voltage Parameters (All three modes)

Singe shaft ternary pump-turbines are based on synchronous PGMs. Therefore:

- Similar to fixed pump-turbines they can comply with all voltage requirements in all modes of operation-generation, pump, and synchronous compensation mode. All requirements for voltage control applicable to synchronous power generating modules can also be implemented in pump operation mode.

System Restoration (generation mode)

- House load operation is not applicable for single shaft ternary pump-turbines because the time for synchronization after disconnection from any external power supply is considered to be less than 15 min.

System Restoration (pumping mode and synchronous compensation mode)

As in the case of fixed speed pump-turbines no pump or synchronous compensator should be connected to the network during system restoration. More specifically:

- Island detection is aiming at the ability of stably balancing and feeding an island after a system split. Only generators can do so. This requirement is not applicable for synchronous compensation and for pumping mode.
- Black start and post-fault active power recovery is not applicable in synchronous compensation mode because of the lack of primary energy.

Instrumentation and Protection (All three modes)

Single shaft ternary PSH can comply with all instrumentation and protection requirements in all three operation modes.

Variable speed pump-turbine – Doubly-fed induction machine (DFIM) capabilities

Frequency Parameters (generation mode)

Frequency restoration control – aiming at restoring frequency to its nominal value or maintaining power exchange flows between control areas at their scheduled values – is in principle possible. Since RfG does not define corresponding connection requirements, the functionality needs to be specified by the relevant TSO as the case may be.

Frequency Parameters (pumping mode)

- According to emergency plans, PSH in pumping mode are either disconnected or changed to generation mode during low frequency events at several thresholds between normally 49,2 Hz to 49,8 Hz. Therefore, the requirement of RfG, Article 13,1(a) about remaining connected to the grid across the whole frequency range listed in Table 2 (RfG) makes no sense for PSH in pumping mode for frequencies below 49,0 Hz. <u>However, when connected they shall be capable of operation in a frequency range between 49,0 Hz and 51,5 Hz, unless a higher value of the lower range is defined by the relevant TSO.</u>
- Variable speed pump-turbines in pump mode in principle can contribute to the limited frequency sensitive mode - underfrequency (LFSM-U), but within a rather narrow active power range only. Therefore, a pump disconnection or a change to generation mode provides a typically more efficient frequency support.
- Frequency restoration control is in principle possible in pumping mode too. Since RfG does not define corresponding connection requirements, the functionality needs to be specified by the relevant TSO as the case may be.

Frequency Parameters (synchronous compensation mode)

- All requirements related to a change of the active power output are not applicable in synchronous compensation mode, because there is no supply of primary energy. Synthetic inertia can be supplied by DFIMs in all three operating modes. It is worthwhile mentioning that in contrast to Power Park Modules (PPMs) these types of machines have physical inertia. The inertia of a DFIM is even bigger compared to a similar synchronous machine for the same output. The amount of "additional" synthetic inertia depends on the project specific characteristics.

Voltage Parameters (all three modes)

- Concerning the robustness towards low voltages during faults, the technology of DFIM has more in common with synchronous PGM (SPGM) than with PPM and thus is not able to fulfil the fault-ride through (FRT) requirements for PPM but can comply with SPGM. For example, RfG currently reflects this by requiring FRT requirements for SPGM from DFIM.
- If it comes to fast reactive current injection, the technology of DFIM is significantly different from SPGM. Therefore, fast current injection needs to be required similarly to PPM units[8].
- The RfG requirements for reactive power capabilities as applicable to PPMs can be used for variable speed pump-turbines as well. It has to be noted, that the P/Q-diagrams of RfG for PPM will be limited not in Q but in P, because of there are minimum operating levels for active power in pump and turbine mode.
- There is no specific need for a Power System Stabilizer (PSS) for variable speed pump-turbines, since the mechanical and electrical part of the system are decoupled in non-synchronous power generation.
- Requirements for Automatic Voltage Regulator (AVR) are not applicable for PPMs because PPMs are regulating voltage in a different and more dynamic way.

System Restoration (generation mode)

- House load operation is not applicable for DFIM because the time for synchronization after disconnection from any external power supply is considered to be less than 15 min.

System Restoration (pumping mode and synchronous compensation mode)

Like for fixed speed pump-turbines no pump or synchronous compensator should be connected to the network during system restoration. More specifically:

[8] In theory, the reactive current injection by DFIM is not identical either with SPGM or PPM.

- Island detection aims at the ability of stably balancing and feeding an island after a system split, which can be achieved in generation mode only. This requirement is not applicable for synchronous compensation and for pumping mode.
- Black start and post-fault active power recovery is not applicable in synchronous compensation mode because of the lack of provision of active power.

Instrumentation and Protection (all three modes)

- An agreement for technical capabilities to aid angular stability is not applicable for DFIM an variable speed pump-turbines because the stability of the units is provided by the control of the converter for these technologies,
- DFIM can comply with all instrumentation and all protection requirements in all three operation modes.

Variable speed pump turbine – Full converter capabilities

Frequency Parameters (generation mode)

Frequency restoration control – aiming at restoring frequency to its nominal value or maintaining power exchange flows between control areas at their scheduled values – is in principle possible. Since RfG does not define corresponding connection requirements, the functionality needs to be specified by the relevant TSO as the case may be.

Frequency Parameters (pumping mode)

- Variable speed pump-turbines with full converter technology in pump mode can contribute to the limited frequency sensitive mode (LFSM-U). That is why they could be exempted from the underfrequency pump disconnection. As a consequence, they would have to have the capability to be synchronized across the whole frequency range listed in Table 2 (RfG).
- Frequency restoration control is in principle possible in pumping mode too. Since RfG does not define corresponding connection requirements, the functionality needs to be specified by the relevant TSO as the case may be.

Frequency Parameters (synchronous compensation mode)

- All requirements related to a change of the active power output are not applicable in synchronous compensation mode, because there is no supply of active power.

Frequency Parameters (all operation modes)

- Synthetic inertia can be supplied by variable speed pump-turbines in full converter technology in all three operating modes. If this feature shall be applied, a special control structure must be used.

Voltage Parameters (all operation modes)

- All requirements concerning voltage parameters can be met by variable speed pump turbines in full converter technology.

System Restoration (generation mode)

- House load operation is not applicable for variable speed pump-turbines in full converter technology because the time for synchronization after disconnection from any external power supply is considered to be less than 15 min.

System Restoration (pumping mode)

- As variable speed pump-turbines in full converter technology are able to work as a controllable load, they can contribute to the stability of the weak grids during system restoration.

System Restoration (synchronous compensation mode)

As in the case for fixed speed pump-turbines no synchronous compensator should be connected to the network during system restoration. More specifically:

- Island detection aims at the ability of stably balancing and feeding an island after a system split, which can be achieved in generation mode only. This requirement is not applicable for synchronous compensation and for pumping mode.
- Black start and post-fault active power recovery is not applicable in synchronous compensation mode because of the lack of active power.

Instrumentation and Protection (all three modes)

- An agreement for technical capabilities of the PGM to aid angular stability is not applicable for converters and DFIM because the stability of the units is provided by the control of the units for these technologies.
- Variable speed pump turbines in full converter technology can comply with all instrumentation and all protection requirements in all three operation modes.

OBSERVATIONS

In the process of assessing the technical capabilities of the different PSH technologies, the EG discussed certain observations that are useful for future consideration. Those can be found below:

General:

- Low inertia machines and FRT:

  The ability to stay connected during a fault and being able to stabilize operation after fault clearance is mainly given by the electrical machine inertia. Consequently, inertia needs to be increased in some cases to satisfy FRT requirements. Generally, on machines increasing the inertia is a matter of economic impact, however on smaller machines such as lower output bulb generators technical limits are reached.

- Protection and auxiliaries;

  Stringed requirements are defined in the RfG when it comes to fault conditions during which the machines need to remain connected to the grid. In certain situations, purely, theoretical faults (solid three-phase fault at terminals) are leading to economic impacts on the machines while not adding value. Furthermore, little or no consideration is given to the fact that all auxiliary and protection systems including their sensors, need to be able to fulfil the same requirements in order not to lose the power generating module during such an event. It can be claimed that most power stations machines would not remain connected because of such secondary effects, rather than the machines not being able to withstand the faults.

- Variable speed pump-turbines (DFIM and full converter):
  - ➢ The opportunity to have “controlled load” (and not just on and off control) is not reflected in RfG. § 15.2.f could be adapted for this purpose: Variable speed pump-turbines provide the possibility to control load in the grid.
  - ➢ In contrast to fixed speed units it is possible to change the active power in pump mode. Consequently, variable speed pump-turbines can contribute to frequency regulation in pump mode as well. This is an important point that is not well enough known and understood. Further discussions and information sessions are needed. This point should be understood at TSO level to make best use of these new technologies.
  - ➢ System restoration: Due to their flexibility in operation and the fact that in open loop voltage vectors can be easily controlled by the power electronics, make these machines

a valuable asset in grid restoration after black out. In fact, having such a unit in a part of the grid to be synchronized with another island, will greatly simplify the task for the TSO. Variable speed pump-turbines can be used to create almost ideal synchronization conditions between islands before re-connecting them.

CONCLUSIONS

The review of the technical requirements defined by NC RfG with regard to their applicability to Pump Storage Hydro power generating modules has demonstrated that a distinction between the relevant generation technologies and the operation modes is necessary for assessing and evaluating whether these requirements can reasonably be applied.

Any conclusion or proposal resulting from the work of this Expert group shall however not prejudge or replace any kind of stakeholder interaction/consultation, which is foreseen in the formal amendment procedure for network codes and guidelines according to the relevant EU legislation. It merely may be quoted when submitting a formal request for amendments.

In general terms the analysis done by this Expert Group has revealed:

- Pump Storage Hydro power generating modules can largely meet the RfG technical requirements in turbine operation mode irrespective the generation technology. The general technical requirements and the requirements which are specific to synchronous power generating modules, shall be applied to fixed Pump Storage Hydro power generating modules with fixed speed pumps and single shaft ternary machines. To Pump Storage Hydro power generating modules with variable speed pumps, may it be DFIM or full-converter connected machines, the general technical requirements for fixed speed units and some of the requirements which are specific to power park modules need to be applied in turbine operation mode.
- Pump Storage Hydro power generating modules however show larger restrictions in pumping operation mode, in particular where pumps cannot be regulated (fixed speed pumps), but the operating setpoint depends on the actual boundary conditions. Consequently, fixed speed pumps cannot contribute to most of the requirements related to frequency stability. This inevitable effect can partially be overcome by single shaft ternary machines by using their ability to "regulate" the active power demand of pumps by hydraulic short-circuit operation. If however only the pumps of these ternary machines are operated, the same restriction like for fixed speed pumps apply. Pump Storage Hydro power generating modules with variable speed pumps, may it be DFIM or full-converter connected machines, can generally fulfil the frequency-stability requirements, because of the ability of regulating the active power demand of the pumps. However, it needs to be considered that the active power range, which can be regulated in pumping mode is rather small and typically covers 70 – 100% of the active power capacity.

- In synchronous compensation mode all generation technologies are largely able to meet the NC RfG requirements related to voltage stability. DFIM show a specificity: They can meet the FRT requirements for SPGM whereas the fast fault current injection according to the PPM requirements has to be applied Most of the other requirements do not apply in this operation mode.

RECOMMENDATIONS ON AMENDING NC RFG WITH REGARD TO APPLICABILITY OF PUMP - STORAGE POWER GENERATING MODULES

NC RfG, Article 6 (2) currently defines:

Pump-storage power-generating modules shall fulfil all the relevant requirements in both generating and pumping operation mode. Synchronous compensation operation of pump-storage power-generating modules shall not be limited in time by the technical design of power-generating modules. Pump-storage variable speed power-generating modules shall fulfil the requirements applicable to synchronous power-generating modules as well as those set out in point (b) of Article 20(2), if they qualify as type B, C or D.

The request for fulfilling all relevant requirements in both generating and pumping mode is not feasible in its generality. It is therefore recommended when revising NC RfG to distinguish better between the different operation modes and to state explicitly which requirements shall apply in each mode emphasizing the limitations in pumping mode.

The NC RfG principle of distinguishing between synchronous power generating modules and power park modules can in principle be applied to Pump Storage Hydro power generating modules as well. It could however be stated, to which category the relevant generation technologies are assigned. It might be necessary to assign one technology as synchronous power generating module for some requirements and as power park modules for others.

As part of the work of phase 2 of this Expert Group, the members have discussed and elaborated a proposal for amending the existing text of Article 6(2) of NC RfG.

NC RfG, Article 6 (2) – new proposal based on Expert Group findings:

Pump-storage power-generating modules shall fulfil the requirements in generating operation, pumping operation and synchronous compensation mode as described below.

a) *Synchronous compensation operation of pump-storage power-generating modules shall not be limited in time by the technical design of power-generating modules. Synchronous compensation operation of full-converter variable speed machines is performed by the converters.*

b) Pump-storage power-generating modules with fixed speed machines and single shaft ternary machines shall be considered as synchronous power generating modules.

c) Pump-storage power-generating modules with variable speed machines shall be considered as power park modules. For doubly-fed induction machines, the parameters of Table 3.1 or Table 7.1 shall apply to define the voltage-against-time profile with regard to fault-ride-through capability.

d) The requirements of this regulation (with respect to the exceptions in this article), that apply to pump-storage power-generating modules in pumping mode and concern active power, shall apply in a way that the same effect as to behavior of active power generation is achieved by the behavior of active power consumption.

e) In pumping mode no technical capability to remain connected and continue operation is requested for frequencies below 49 Hz, unless a higher value of this threshold is defined by the relevant TSO.

f) To pump-storage power-generating modules with fixed speed machines in pumping operation mode and synchronous compensation operation mode, Articles 13(2), 13(3), 13(4), 13(5), 13(7), 14(2), 15(2), 15(5) and 15(6) (e) shall not apply. In pumping operation mode, the second sentence of Article 17(3) shall not apply; in synchronous compensation operation mode, Article 17(3) shall not apply entirely.

g) To pump-storage power-generating modules with single shaft ternary machines in pumping operation mode, Articles 13(4), 13(5) and 15(5) shall not apply. In addition, Articles 13(2), 13(3), 13(7), 14(2), 15(2), 15(6)(e) and the second sentence of Article 17(3) shall not apply, if only pumps are operated. Where Articles 13(2) or 15(2) are applicable, the reference active power for LFSM-O or LFSM-U respectively is the maximum capacity of the turbine.

h) To pump-storage power-generating modules with single shaft ternary machines in synchronous compensation operation mode, Articles 13(2), 13(3), 13(4), 13(5), 13(7), 14(2), 15(2), 15(5), 15(6)(e) and 17(3) shall not apply.

i) To pump-storage power-generating modules with variable speed machines in pumping operation mode, Articles 13(4), 13(5) and 15(5) shall not apply.

j) To pump-storage power-generating modules with variable speed machines in synchronous compensation operation mode, Articles 13(2), 13(3), 13(4), 13(5), 13(7), 14(2), 15(2), 15(5) and 15(6)(e) shall not apply.

RECOMMENDATIONS ON AMENDING NC DC WITH REGARD TO APPLICABILITY OF PUMP - STORAGE POWER GENERATING MODULES

NC DC, Article 5 (2) currently defines:

Any pumping module within a pump-storage station that only provides pumping mode shall be subject to the requirements of this Regulation and shall be treated as a demand facility.

NC DC, Article 5 (2) – new proposal based on Expert Group findings:

Article 5 (2) to be deleted.

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Fernando Perán Montero	Iberdrola	EURELECTRIC
Christina Flaskühler	BNetzA	BNetzA (only for phase 1)
Vincenzo Trovato	ACER	ACER
Tobias Thurnherr	ABB	WindEurope (only for phase 2)
Rafael Portales	ABB	WindEurope (only for phase 2)