EUTurbines comments to ENTSO-E Public consultation on Guidance for Connection Code implementation of frequency related parameters

(Overview of questions answered)

2017-06-28

EUTurbines is the European association of gas and steam turbines manufacturers employing more than 70,000 people across Europe with a turnover of around 25 billion Euros. Our members are Ansaldo Energia, Doosan Skoda Power, GE Power, MAN Diesel and Turbo, Mitsubishi Hitachi Power Systems Europe, Siemens and Solar Turbines.

General Context

Please describe briefly the basic assumptions on your technology and your interpretation of the requirements for responding to this survey.

Gas and steam turbines provide inertia, frequency containment, restoration and reserve replacement, all pertaining to frequency related parameters. They are synchronous generators, and are impacted by frequency withstand capability (frequency range, and rate of change of frequency). Also in the future, they can be considered one of the largest contributors for ancillary services in Europe.

In cogeneration mode, they help reducing the CO_2 footprint and provide increased efficiency to the system.

FSM

1. *What are the technical limitations on the frequency step response time (time to reach the target active power following a frequency step) of your generation technology? Please name the fastest response time, which is achievable today at basic design, and precisely the relevant part / apparatus of your power generation process and the frequency measurement system which puts limits on the step response time and describe also differences between active power increase and decrease, if there are any.*

In our thermal system, response is limited by the inherent thermo/mechanical inertia.

In general, the inertial MW support is <u>instantaneous.</u>

FSM capabilities are addressed in the chapters related to LFSM-o and LFSM-U.

For gas turbines (GT), the FSM reaction, when of amplitude of a maximum of ±10% Pn, is not different between active power increase and decrease – possible limitations can come from emission control and temperature control system. Emission control and temperature control are normally embedded in the GT control system.

For steam turbines (ST) in a CCGT unit, the active power increase or decrease can be performed using the steam supply control valves. However, when some simple cycle boilers are operated at their maximum efficiency, the steam controls valves are fully open (a.k.a. sliding pressure mode), and the power increase will follow the increased firing temperature in the boiler, which could bear some inertia. Those may not participate to timely FSM power increase while being able to provide FSM power

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decrease. The FSM capability of steam turbines in a coal fired power plant depends on the availability of special operation modes like e.g. condensate throttling.

Remark over the limitation to provide FSM, LFSM-U and power output at falling frequency in case of installation in CHP or industrial plants: when GTs are installed on industrial or CHP applications and their prime goal is to provide stable steam or heat, the power variation can strongly affect the steam production and the related industrial process. For this reason, limitation coming from the process itself can take place.
As for the ST, they are directly embedded in the process itself and, therefore, the control of the active power is related to the steam process within the CHP plant or of the industry where the generating unit is installed. Restriction and mass derogation shall reasonably apply on those.

2. *Can the frequency step response time be provided from any active power operating point at the moment of FSM activation and independent from the active power step size? If there are any limitations, please describe them precisely.*

The step response can be provided from any operating point between the minimum technical load and the maximum power of the unit and limited by those.
The response time is not necessarily linear.
The response time may depend on the frequency deviation and rate of change of frequency. It is a proportional response, not rate-controlled. The step response is also a function of the load at which the generating unit is working when the event takes place, for example, if the generating is working near minimum and maximum loads, where other logics can be active.
The maximum step response can be in some cases limited when emission compliance is requested.

3. *Which technological improvements on frequency step response times and active power step sizes do you consider feasible within a) the next 5 years and b) within the next 10 years. Please provide target values. What are the p.u. cost implications compared to the basic design?*

It is difficult to predict which technological improvements can come in the next years due to the fast changing system, for which we are continuously developing our products. In order to obtain the best results in terms of developing technical and cost-effective solutions, harmonisation of the settings on parameters is necessary/strongly recommended.

LFSM-O capability

1. *Would you consider an adjustable droop (in the NC RfG range of 2 - 12% with the reference active power being either the maximum capacity or the actual active power output at the moment of LFSM-O activation a technical challenge? If there are any limitations on the droop range, please describe them precisely. What are cost implications linked to the capability to adjust the droop and its actual adjustment? (Consider Figure 1 , Article 13, NC RfG)*

For new installations, droop control and rangeability can be set as specified by the NC RfG.

For existing installations, there are multiple parameters that can influence the implementation of the droop requirements in a cost-effective manner (age of the unit, technology, existing controls/logics, safety related equipment/loops). Therefore, a case-by-case check shall be carried out (eventually through a CBA process).

In general, controls capability to adjust droop is expected to be feasible at marginal cost impact for larger thermal plants, where droop controls with reference as of the maximum capability is common for turbine governor controls (droop control related to nominal power).

It may however be more complex to adapt other units. For example, there are generating units/plants where the droop control is based on actual power. In such case, it can be expected that a new controller is installed to have a droop based on the nominal power and the rangeability of the NC RfG.

The lower droop values of 2%, while possible, are not recommended, as would obviously lead to very high amplitude of response to smaller (and therefore more common) grid frequency events. Continuous large variation of active power could lead also to an increase of the maintenance costs (prime mover and generator) even up to 50% compared to higher droop settings.

CHP and industrial plants, as mentioned before, can face other type of constrains that need to be considered (thermal inertia). Exception and dedicated agreement are already envisaged in the NC RfG.

2. *What are the technical limitations on the frequency step response time (time to reach the target active power following a frequency step) of your generation technology at high frequencies? Please name the fastest response time, which is achievable today at basic design, and precisely the relevant part / apparatus of your power generation process and the frequency measurement system which puts a limits on the step response time and describe also differences between active power increase and decrease, if there are any.*

For gas turbines, the droop response at high frequency is constrained by the capability to hold the flame (while the airflow first increases due to higher rotational speed and the fuel and air delivery shall be reduced to decrease power). The response time also depends on the amplitude of the frequency deviation, its steepness and the droop setting of the unit.

In LFSM-O, the response time to get active power response (i.e. a visible change of output) to a frequency event is typically below 5s, without undue delay. The time to reach the target power can differ depending on technology capabilities and the amplitude of the frequency step, and, therefore, a defined value cannot be stated.

3. *Can the frequency step response time be provided from any active power operating point at the moment of LFSM-O activation and independent from the active power step size? If there are any limitations, please describe them precisely.*

The LFSM-O could be provided from any point between minimum power and maximum capability and limited by those. Due to the thermo/mechanical and proportional nature of the governor response, it is dependent on the frequency deviation and droop selection.

4. *Which technological improvements on frequency step response times and active power step sizes do you consider feasible within a) the next 5 years and b) within the next 10 years. Please provide target values. What are the p.u. cost implications compared to the basic design?*

It is difficult to predict which technological improvements can come in the next years due to the fast changing system, for which we are continuously developing our products. In order to obtain the best results in terms of developing technical and cost-effective solutions, harmonisation of the settings on parameters is necessary/strongly recommended.

For example, the LFSM-O response could be faster and more robust, assuming there is a clear and common method for identification of grid split by the system operator without breaker signals. Assuming that a signal from the system operator is conveyed in the unit in a timely manner (<200 ms), one can expect in the future to be able to step from any load to any load downwards in 5s or less. The cost implications are always difficult to assess, since the methodology needs to be clarified. It, however, also clearly relies on innovation from the grid/transmission operation side, to provide best and fastest information available.

It is to be noted that another way to get to fast response is to open the circuit breaker, keeping the machine in idle mode.

LFSM-U capability

1. *What are the technical limitations on the frequency step response time (time to reach the target active power following a frequency step) of your generation technology at low frequencies? Please name the fastest response time, which is achievable today at basic design, and precisely the relevant part / apparatus of your power generation process and the frequency measurement system which puts a limits on the step response time and describe also differences between active power increase and decrease, if there are any.*

The answer is the same as for question 1/FSM, except that here, only the power increase applies.
In case of GT technology, the maximum power that can be reached is limited by the ambient conditions (ambient temperature). Other limitations can take place depending on machine and technology, in case emission compliance applies during the transient event.
Other (external) limitations can be in place for generating units embedded in CHP and industrial power plant as described above. Overloading is not an option.

2. *Can the frequency step response time be provided from any active power operating point at the moment of LFSM-U activation and independent from the active power step size?*

The answer is the same as for question 2/FSM.
Overloading is not an option.

3. *Are there limiting factors for active power increase at low frequencies other than availability of primary energy resources and operation at maximum capacity at the moment of LFSM-U activation?*

No limitation, except the previously mentioned operation of steam turbines in conventional boilers operating in sliding pressure mode, which may not be able to provide timely response (if dynamic response criteria expressed) due to the minutes of inertia.
Other (external) limitations can be in place for generating units embedded in CHP and industrial power plant as previously described as well.
See also 1/LFSM-U

4. *Which technological improvements on frequency step response times, active power step sizes and limiting factors according to question 3 do you consider feasible within: a) the next 5 years and b) within the next 10 years. Please provide target values. What are the p.u. cost implications compared to the basic design?*

Please see 3/FSM question

Synthetic Inertia and DR very fast APC

1. *What is your plant technology typical inertia constant (H) or H contribution in your basic design? Are you currently able to vary the contribution to system inertia for your plant significantly through design choices? By how much do you foresee the possibility of increasing contribution to system inertia? Are you able to make an inertia contribution even when you are not dispatch for energy contribution (e.g. via prime mover clutch, or from stored energy)? What are the p.u. cost implications?*

Depending on the turbine size, technologies and arrangements (GT or ST gen only + generator, single, dual or tri- shaft with GT/ST/Gen coupled, etc...), H could be ranging from circa 5 to 15s.
H could be marginally modified via the selection of larger generators in portfolio (if available). The related cost depends on many different factors; a minimum of 5% CAPEX impact can be expected when considering the least complex solution. Economic impact will be much higher for other units, if, for example, the generator frame is changed, affecting the overall product design.
The cost impact estimated above can be relevant also for existing units, when it is possible to implement modifications.

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Arrangements for operation in synchronous condensing mode are available (clutch most common). The costs of this modification can vary so much from a generating unit to the other that a case-by-case evaluation shall be carried out.

Rate of Change of Frequency (RoCoF) withstand capability

1. *What are your biggest concerns specific to your power generating module regarding a high df/dt event (e.g. stability of your machine and its control or damage of equipment)?*

The key areas are:

- Plant stability (generator stability, reliable operation of compressor, combustor and turbine)
- Controls and electrical (timely detection, appropriate decision, identify all off frequency and RoCoF protections [avoidance of fast reclosing sequence leading to out-of-synchro condition], manage potential sensor faults)
- Mechanical integrity and long-term impact (shaft line and coupling torsional effect)
- Electrical integrity and long-term impact (excitation overvoltage stresses, generator lifecycle decreasing for repetitive event, electromechanical stress on the rotor shaft)

2. *What is your assumed or calculated value for maximum df/dt withstand capability in your basic design. How do you validate this capability? What parameters have the highest importance/impact when validating this capability?*

RoCoF stakes and df/dt capability have not been historically explicitly part of design requirement. We are looking at grid operators input to understand precisely the definition of the event, based on credible assumptions, as well as test requirements. To be meaningful, the RoCoF value shall be tied to other information, such as frequency versus time profile, measuring method (including rolling average), operating condition (active power, PF) and grid status (grid topology, impedance, voltage profile).
In this case, RoCoF is intended as the system frequency deviating. There are several isolated plants where the frequency changes and where GTs already prove their reliability.
The exact definition of RoCoF shall be considered. For instance, it would be interesting if different ROCOF requirements can be defined in over-frequency and under-frequency (also different operational conditions can be associated to such conditions...).

3. *In case of more stringent requirements for RoCoF withstand capability than those in your basic design, what is needed to achieve the required capability (e.g. different control strategy, new equipment design)? If the solutions depend on the magnitude of the capability, please indicate them (e.g. up to 2Hz/s can be achieved by different control design, up to 2.5Hz/s can be achieved by a combination of controller update and installation of extra equipment, more than 2.5Hz/s is not feasible.)? What is the p.u. cost implication?*

Analysis to understand RoCoF stakes, study and verify could be of a minimum of 10% of plant CAPEX and can exponentially increase depending on the outcome and the complexity of the system.
This shall be considered a very conservative estimation, since costs can quickly increase even for the control and related instrumentations and actuators are to be considered.
If mechanical/electrical integrity (shaft line torsional fatigue…) or system stability (generator stability, excitation voltage surge, compressor surge...) is involved, the cost could be tremendous and just put at stake the plant's viability.

4. *Do you use RoCoF measurement for plant protection or control other than LOM?, If yes, what is your current method and accuracy for measuring df/dt? Please name concerns on functionality and limitations of frequency measurement devices, if there are any.*

The Remote Breaker Open logics sometimes use information of extreme high rate of change of frequency AND over-frequency to guess grid split and necessary load rejection to minimal load or disconnect. This protection is designed as stop gap (not more), in an attempt to reduce load or come

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back to house load before the grid collapses and damages also the unit attached. It is done via the standard control and acceleration calculation method, which may not be the fastest though.

A concern is that when RoCoF protection is used as LOM, (3-phase) fast reclosing logic on the distribution shall be inhibited to avoid reclosing on out-of-synchronisation on the generating unit. Inhibition shall be ensured, for example, through voltage presence.

Admissible active power reduction at low frequencies

1. *Are there any limitations for your technology to maintain active power output constant at low frequencies and are they time-dependent? If yes, what is your assumed or calculated (time-dependent) active power reduction in your basic design. What parameters have the highest impact on this? Beyond this basic design, what are the p.u. cost implications, for minimizing active power reduction at low frequencies?*

The answer is yes, there are limitation to respect the power profile due to the intrinsic characteristic of gas turbine technology. The basic calculations do not consider the upper profile as in RfG, obviously new requirements, never applied in any country. This is a major concern for gas turbines, and an explanatory note can be found on EUTurbines' website for more details (please, note that the document is currently being revised and a new version will be uploaded shortly):
http://www.euturbines.eu/cms/upload/publictaions/positions/EUTurbines_-_NCRfG_Explanatory_note_for_power_output_versus_frequency_2012.pdf

2. *Which ambient conditions have an impact on active power output at low frequencies for your technology (e.g. temperature, air pressure, humidity) in your basic design? What are the reference conditions for your technology and what is the sensitivity of deviations from these reference conditions?*

In general, there can be several parameters that can affect the active power output profile at falling frequency (ambient conditions, etc.). For example, the hotter the ambient temperature, the lower the capability to maintain power output at falling frequency.
By their nature, some gas turbine technologies tend always to reduce their output power at lower frequency, while the decrease of active power is extremely limited when at lower temperature.
The control of the output is not exactly predictable and therefore controllable. The power reduction can be present already when the frequency drops from the 50 Hz value.
The GT output is typically specified at ISO condition.
As an example of reference conditions, the UK requirement and its specific power output vs. frequency requirement is specified applicable up to 25°C ambient temperature in its operating code/testing. The requirement is not to be met above this temperature.