

EUTurbines' technical explanation and interpretation on European Directive 2016/631 establishing Network Code on Requirements for Generators Art 13(4) and 13(5)

This document aims at providing an explanation on the limitation of Gas Turbines due to their intrinsic properties to deal with requirements related to active power profile at falling frequencies.

The current RfG requirement Art 13 (4), in combination with Art 13 (5) (a) and (b), gives room for interpretation regarding the possible implementation into national rules. The intention of Art 13 (5) (a) and (b) is to reflect technological limitations under certain ambient conditions, in particular for gas turbines. Those intrinsic technological limitations have been extensively communicated during the drafting phase of the NC RfG. Details are described in this updated document.

1. Power Reduction at falling frequencies: Current Art.13(4) and 13(5) of NC RfG

Here is an extract of the relevant article.

4. The relevant TSO shall specify admissible active power reduction from maximum output with falling frequency in its control area as a rate of reduction falling within the boundaries, illustrated by the full lines in Figure 2:

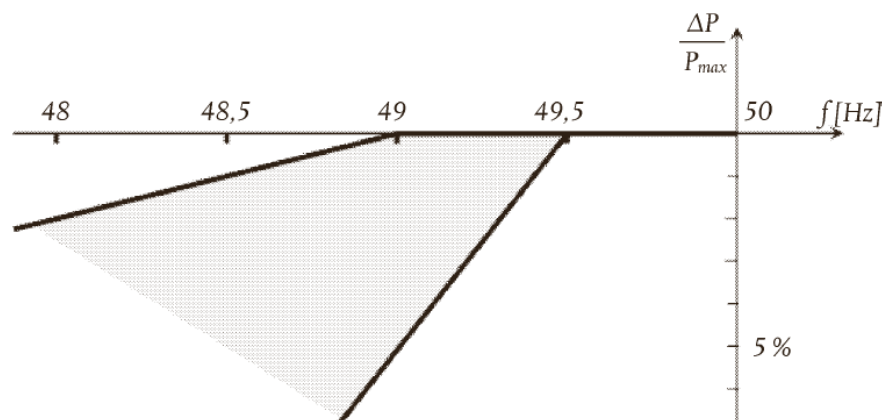
- (a) below 49 Hz falling by a reduction rate of 2 % of the maximum capacity at 50 Hz per 1 Hz frequency drop;
- (b) below 49,5 Hz falling by a reduction rate of 10 % of the maximum capacity at 50 Hz per 1 Hz frequency drop.

5. The admissible active power reduction from maximum output shall:

- (a) clearly specify the ambient conditions applicable;
- (b) take account of the technical capabilities of power-generating modules.

Figure 2

Maximum power capability reduction with falling frequency



The requirements become relevant when gas turbines are operating at their maximum power, which, however, can be considered the most common point of operation for the gas turbine technology, since the maximum power corresponds to the most efficient point of operation and maximum production of heat in the exhaust when embedded in cogeneration plants.

2. Physical behaviour of a gas turbine at low frequencies

A turbine in any type of configuration (single shaft, dual shaft, etc.) has at least one shaft coupled with the generator.

Therefore, as a direct and immediate consequence of the decreasing grid frequency, and hence of the turbine rotational speed, a gas turbine shows a reduced air mass flow.

In order to have stable combustion conditions and not to risk any combustion disturbance with a consequent trip (for example due to flame out), the turbine outlet temperature is kept constant, adapting the fuel mass flow to the reduced air mass flow.

Both effects lead to a nearly immediate output power reduction of the turbine when the frequency drops. This behaviour can be highly nonlinear (depending on the turbine's technology), and strongly depends on the ambient conditions. If two parameters (e.g. ambient temperature and frequency) deviate largely from design conditions, the effect is overlayed.

The following figure shows the typical behaviour of a utility-sized gas turbine (detailed values depend on the individual machine).

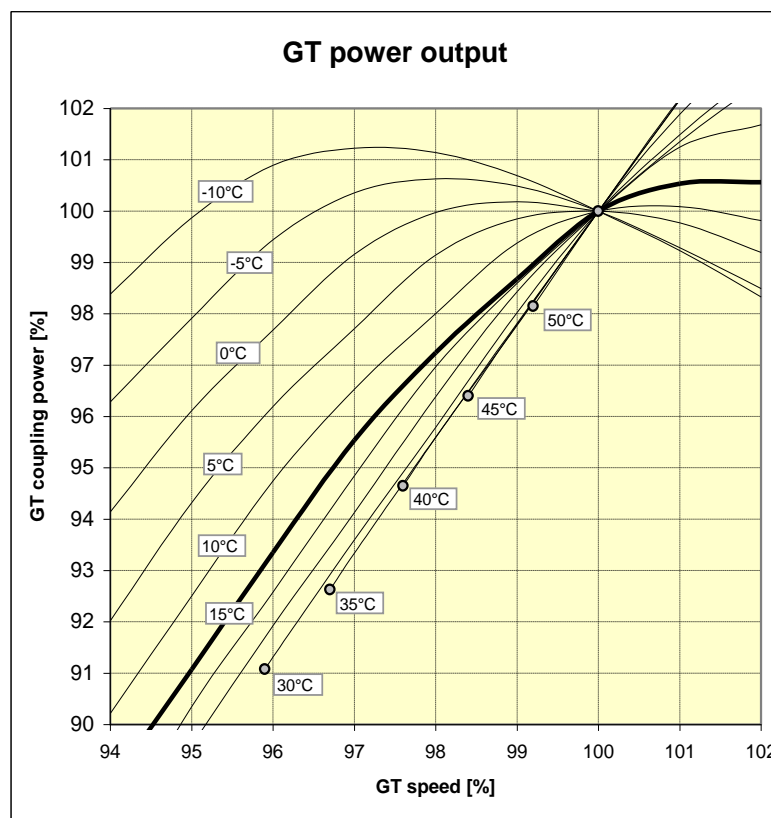


Figure 2: Typical Gas Turbine behaviour

Additionally to the compressor thermodynamics, the compressor operation is limited by the protection scheme against compressor pumping, which has to be avoided in any case and limits the under-frequency operation at very high ambient temperatures.

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3. Interpretation and consequences of the Requirements

EUTurbines understanding of the present article 13(5) is that system operators shall consider the technical capabilities of the power module when defining the requirements, eventually differentiating them based on technologies.

In this sense, the expected behaviour of specific machines can be predicted and related information provided to the system operator for information.

Art 13(4), where the power reduction limit is described by a curve, is not really describing the behaviour of a gas turbine technology, unless complemented by Art 13(5). Based on the understanding that the NC drafting team already considered the information provided during the drafting activities, then the assumption is that Art 13(4) and Art 13(5) have the same level of importance.

The present situation has been recognised in many MS, where wordings similar to the one here below have been considered:

... Technologies which are not capable to comply with this limit (art 13(4) figure 2) under certain circumstances shall document this limitation and the relevant underlying ambient conditions ...

In the case all relevant stakeholders have different interpretations of this very important topic, further discussion and, potentially, an amendment of the NC RfG in the future is needed, ensuring a common understanding.

In case of a grid disturbance with consequent falling frequency, the power plant's main target shall be to remain connected to the grid and in operation.

For the Gas Turbine technology to cope with the requirements presented in Fig 2 of art 13(4), it would mean to introduce specific countermeasures modifying the typical behaviour of the generating unit.

In the past, some countermeasures had been considered to cope with the requirements. It is not possible, however, to test these solutions in real conditions, since it is extremely complicated to evaluate all the variables applicable to a disturbed grid and reproduce them. These countermeasures affect the normal behaviour of the generating unit and can lead to possible flame-out with the realistic risk to incur in a shut-down of the generating unit itself.

For this reason, it is not possible for manufacturers to guarantee that the solution will work properly and therefore be compliant with the requirements.

For grid stability reasons, being the main objective under such conditions, the generating unit should rather stay connected than bearing the risk of a total trip due to the necessary fast activation of power compensation measures.

The expected behaviour of specific generating units can be provided and therefore considered by system operators (e.g. in system simulations). The summarised output drop of the connected plants will cause the frequency to drop with a predictable rate, which is more accurate in case the real behaviour of the plants is incorporated. This can be taken into account in measures from the network side, e.g. for implementation into demand disconnection schemes.

5. Evolution of the requirement's considerations

During the drafting of the NC RfG the requirements, a definition to limit the reduction of the power output in case of frequency drop was not present in the majority of national grid codes. A general indication was provided - proof by testing - only in the UK, where, however, reference to 25°C ambient condition was made.

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It is obvious that such tests cannot take place under real conditions, because the real grid frequency cannot be reduced as required and also the real reduction of base load output of the plant cannot be seen. The test, therefore, just allows to show the possible activation of countermeasures, triggered by a suitable signal (e.g. simulated frequency decrease), and possibly the effect of some output increase.

CCGTs installed in UK during the past years had to comply with this requirement and, therefore, the manufacturers have been developing technical measures to compensate the physical output drop. Despite the fact that manufacturers have been pointing out this issue in other countries several times for specific projects, there has been and still is no clear statement and definition to determine under which conditions compliance has to be ensured and how it should be demonstrated.

Only in the last very few years, the focus of the TSOs has been shifting more towards disturbed conditions, but, in our perception, only countries with a significant fraction of GT-based generation have identified this as a relevant topic.

The principles of technical countermeasures range from increasing the flame temperature (i.e. increasing the enthalpy difference available in the turbine), to increasing the mass flow by further opening the inlet guide vanes (higher air mass flow with consequent increase of fuel gas) or injecting steam or water to the compressor (combined effect of total mass flow increase and cooling). Often, one measure is not sufficient and a suitable combination has to be foreseen.

6. Additional remarks on the Requirements and Countermeasures

Activation time of specific countermeasure

Neither in the NC RfG nor in the drafting standards and rules under development, a timeframe is defined, in which the necessary countermeasures to avoid power decrement have to be activated and have to reach the required compensation level.

In the view of network stability, it can be expected that the activation should take place within very few seconds, in particular in case of fast frequency drops.

However, for some countermeasures (in particular temperature increase, activation of water or steam injection through specific additional systems) reaching the required output level and at the same time ensuring stable operation takes more than several seconds and are, therefore, useless for this purpose. Countermeasures with a very short or negligible activation time are currently not available.

Ambient temperature limitation

The current limitation in UK to 25°C ambient temperature is beneficial regarding the capability of compliance for the turbine (see Chapter 2). However, no rationale can be seen why the grid is not needing the capability above 25°C with the same strictness as it is below 25°C. In the NC RfG, there is no such limitation, which is reasonable from grid stability point of view, but it makes compliance much more difficult.

Reliability of countermeasures, risk of trip, no testing procedure possible

As mentioned, many of the additional measures are being installed only for the purpose of compliance with the requirement and are not used under normal operation. Additionally, as also already mentioned, the test of the system is done only once and not under realistic conditions.

Therefore, manufacturers cannot absolutely ensure the correct function and effectivity in case of a real frequency drop under disturbed grid condition.

Even more, such extremely disturbed frequency conditions are not easy to be handled and controlled by a complex system like a gas turbine – even without additional measures. Therefore, there is a not negligible risk of causing a trip of the machine by activation of such system exactly in the moment when all efforts should focus on keeping generation reliably connected to the grid.

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Unfortunately, there is absolutely no statistical data available about reliability during such incidents (they are extremely rare), but with the knowledge about the sensitivity of the gas turbine combustion systems regarding disturbances, we see quite a probability to cause a trip, being then possibly the reason for the final black out of the system.

Cost of compliance with requirement on generation side

The existing additional systems and measures to compensate the output drop (but with the above-mentioned limitations!) require additional hardware with a certain investment volume.

Any further development in this area will be still only an additional measure to compensate a physical behaviour of a very valuable grid component with the same principle restrictions as mentioned above.

As a theoretical alternative, GT based power plants might be obliged to limit their output all the time in normal operation to a value far below their current maximum output in order to have a reliable headroom for compliance with the requirement for a hypothetical situation which possibly never occurs. It is obvious that the cost of this theoretical option, considering the necessary flexibility and efficiency reduction of CCGTs, cannot be acceptable.

Brussels, 1 September 2017

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.

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