Nordel

Operational Performance Specifications for Thermal Power Units larger than 100 MW

1995

Introduction

In 1975 the Operating and Planning Committees of NORDEL prepared a report with proposals, justifications, and comments on a set of operational performance specifications for thermal power units regarding such aspects of performance which are of importance for operation of the total electrical power system. The same year NORDEL recommended the proposed specifications for implementation.

Revision No 1 of the specifications was accepted by NORDEL in 1982.

Admendment no. 1 August 1990 for small thermal units was accepted 1990 and a new version 1995 has been compiled with references valid for this current specification.

The present specifications, revision No 2, were accepted by NORDEL on recommendation from the System Committee in 1995.

As regards justifications for and comments on the specifications, reference is made to the report from 1975.

Revisions of this specification will be initiated by the System Committee.

Application

NORDEL recommends that utilities apply these specifications to new thermal power units which will be connected to the synchronous Nordic Power System. This specification shall be applied to existing units, when new installations or modifications are introduced, whenever applicable and reasonable. The specifications apply to all thermal units larger than 100 MW_e equipped with steam or gas turbines. However, exceptions will be allowed in back-pressure units, if the back-pressure operation renders the specifications inapplicable.

The requirements given for coal-fired plants shall also apply to conventional plants firing fuels other than gas, oil or coal.

The specifications should be regarded as minimum requirements. An improvement on the minimum requirements is always of value to the power system. If better performance can be obtained without significant increases in cost and complication, equipment offering such better performance should be selected. One such example of better performance relates to coordination of relay setting as compared to the wishes from the grid operator.

Local specifications may supersede this specification by more demanding requirements.

Operational Performance Specifications for Thermal Power Units[1]

1. Operational Characteristics

1.1 Minimum Output

The minimum output power shall be as low as possible. As a practical guideline, the minimum output power[2] should be 40% of full output power in coal-fired units, 20% of full output power in oil-fired units, and 20% of full output power in nuclear units.

1.2 Overload Capacity

Fossil-fired units should be prepared for overload capacities only to the extent that intrinsically available sources are present. For a steam turbine unit this could be the bypassing of high-pressure preheaters.

[1]Unit is one or more generation plants combined in a way that one internal fault to the unit will cause the disconnection of all the generation plant

[2]In the following the term power means active power supplied to the grid

It is recommended to utilise the overload capacities to a certain limit only, because of reductions in the efficiency and/or the lifetime of the unit.

The unit including auxiliary equipment should be designed to utilise these overload capacities up to 2 h/day and up to 500 h/year. No overload capacity is specified for nuclear power units.

1.3 Starting Time

For all types of thermal power units, the starting time shall be defined according to planned utilisation.
In addition, the following guidelines shall apply to gas turbines for emergency and peak load generation, from rolling-up to full output power:

- gas turbines of jet engine type 3 to 3.5 minutes
- industrial gas turbines 10 to 15 minutes.

1.4 House Load Operation

House load operation is the unit operating with its own auxiliary supply as the only load.

2. Power Control Equipment Characteristics

2.1 Operational Modes

The change of output power of a thermal power unit at the rates and within the ranges specified, during normal control and during disturbances control, is normally activated as follows:

- By manual operation
- By the unit controller

The unit controller shall have an adjustable frequency set point in the range from 49.9 Hz to 50.1 Hz. The set point resolution shall be 50 mHz or better.

The statics set point shall be adjustable in the range from 2% to 8%. The normal operation is generally with setting in the range from 4% to 6%.

An adjustable frequency dead band of the unit controller within the setting range of 0-50 mHz is acceptable. It shall be possible to disengage this dead band.

2.2 Power Step Change Limiter

The units shall be equipped with adjustable devices for limiting the magnitude and rate of the power change, so that it will be possible to set these set points at any values from zero up to the maximum specified, both for normal conditions and for disturbance conditions.

2.3 Power Control - Normal Operation and Disturbances[3]

The required power output during normal operation is the manually preset power output, modified by a frequency-sensing unit controller (or turbine governor) and this power output shall meet the specifications in section 3.

[3]The frequency values defining normal and disturbance operating conditions is to be agreed upon with the grid operator

The need for disturbance control shall be governed by frequency-sensing equipment (eg consisting of a frequency relay set at a certain value below normal frequency). The power output shall meet the specification in section 4 when the unit is operated under these conditions.

3. Power Response Capability during Normal Operation of the Power System

3.1 Load Following

All condensing units shall be designed so that they can be used for daily and weekly load following during certain periods of the year, using the rates of load change specified in 3.2 - 3.6.

The units shall also be designed so that, if necessary, they can participate in following the occasionally varying loads that cause frequency variations on the interconnected power system. This implies that the units shall be capable of accommodating power changes without intervals by plus or minus 2% of full output within periods of 30 sec. The units shall be capable of performing these changes within the ranges specified. Power changes for nuclear units may be agreed with the grid operator to be less than plus or minus 2 %.

3.2 Power Response Rate and Range - Oil and Gas

Oil-fired and gas-fired units shall be designed for a power response rate of at least 8% of full power per minute.

The above power response rate of change shall be applicable to any range of 30% between 40% and

100% of full power according to the load schedule. The power response rate may be limited to the maximum power response rate permissible for the turbines or the steam boilers in the range below 40% and above 90%.

3.3 Power Response Rate and Range - Coal

Coal-fired units shall be designed for a power response rate of at least plus or minus 4% of full power per minute.

The above power response rate of change shall be applicable to any range of 30% between 60% and 100% of full power according to the load schedule. This range may be restricted to 20% in certain cases. The power response rate may be limited to the maximum power response rate permissible for the turbines or the steam boilers in the range below 60% and above 90%.

3.4 Power Response Rate and Range - PWR Nuclear

PWR nuclear power units shall be designed for a power response rate of at least plus or minus 5% of full power per minute within the output range of 60% to 100% of full power. At outputs below 60%, the power response rate may be limited to the maximum power response rate permissible for the turbines.

3.5 Power Response Rate and Range - BWR Nuclear

BWR nuclear power units shall be designed for a power response rate per minute of at least plus or minus 10% of the initial output value. This shall be maintained throughout all the output range within which the power can be controlled by the speed of the main circulation pumps. This output range shall be at least 30% of the initial output power. In the remainder of the power range between minimum load and full load, the power response rate shall be at least 1% of full power per minute.

Comment on items 3.4 and 3.5: The power response rates of the units equipped with standard versions of light water reactors are usually sufficient. However, it should be noted that the power response rate is subject to some restrictions at the present time, due to the current design of fuel elements. It is expected that these problems will be solved, and the units should therefore be designed to conform with the recommended power response rates. However, in order to limit the stresses imposed, the power changes during normal daily and weekly load following should be carried out gradually over a period of about two hours.

4. Power Response Capability during Power System Disturbances[4]

4.1 Instantaneous Power Response

The demand from the power system is that the instantaneous power response shall be available within

[4] Power system disturbances are frequency or voltage disturbances and include in severe cases stability disturbances as well

and after 30 sec after a sudden frequency drop to 49.5 Hz. Half of that power response shall be available within 5 sec after the frequency drop.

4.2 Power Step Change - Fossil Fuel

Fossil-fired thermal units shall be designed with an operating mode allowing an instantaneous step change in output power of at least 5% of full output within the range of 50-90% when requested. Half of that power shall be available within 5 sec after the frequency drop. Units without or with one reheater shall be designed in such a manner that this power step will be accommodated within 30 sec. If a unit includes more than one reheater, a further delay corresponding to the time constants of such additional reheaters is acceptable.

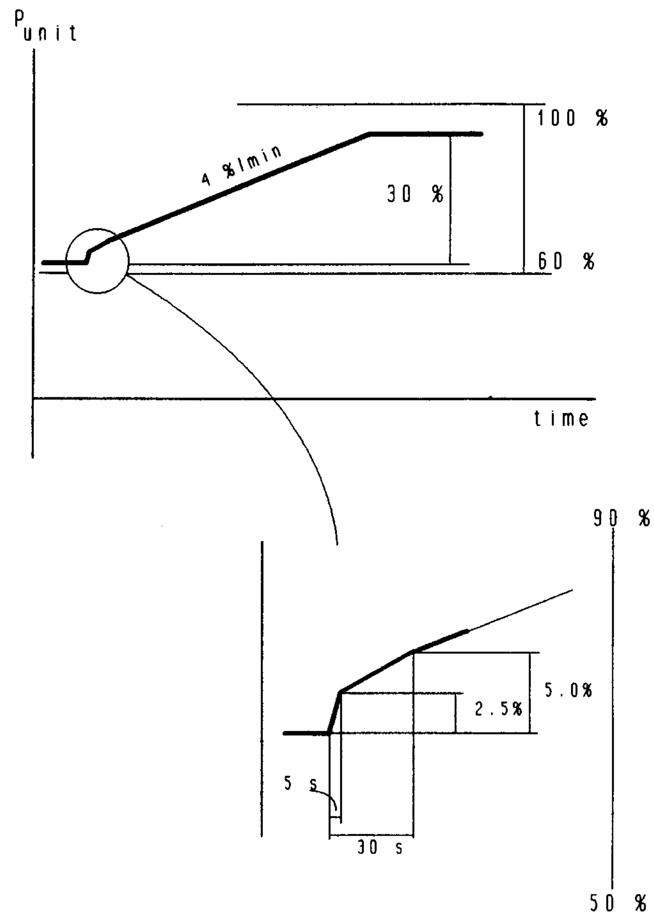
4.3 Power Step Change - Nuclear

PWR nuclear power units to which the power change signal is applied directly to adjust the turbine control valve shall be designed so that a power step of 10% of full power can be accommodated within 30% of the power range. BWR nuclear power units operating on pressure control shall be designed so that, within the range of pump control, they will be capable of accommodating a power change of 10% of the initial value within 30 sec.

4.4 Subsequent Power Response Rate

After the power step changes specified above, thermal power units shall also be capable of accommodating a load change at the rates specified in section 3. However, the total change in load may then be limited to the values specified in 3.2 - 3.5 above.

Example for a coal fired unit



Power step change and subsequent power response rate.

4.5 Spinning Disturbance Reserve

All units of the condensing type shall be made so that they at times can be used as spinning disturbance reserves and then perform the above mentioned power variations, if serious disturbances occur on the grid.

4.6 Island Operation

In case of very serious (and exceptional) disturbances, where the power system is separated into smaller grids, the units shall also initially be capable of performing the above-mentioned power changes (upwards or downwards), and then achieving stable operation and normal power control capability according to section 3.

5. Tolerance to Frequency Variations

5.1 Frequency Range 49 Hz to 51 Hz

It shall be possible to operate the unit continuously at full output power within the **grid** voltage range of 90-105% of the **normal**[5] voltage, and at any frequency between 49 and 51 Hz. A maximum operating time of 10 h/year and a duration of 30 minutes maximum per case can be assumed within the frequency range of 50.3-51 Hz. At a frequency above 50.3 Hz a small power reduction is accepted, if stable operation at full power can be reestablished when the frequency again drops below this value. See appendix A.

5.2 Frequency Range 49 Hz to 47.5 Hz

It shall be possible to operate the unit under disturbance conditions for 30 min within the **grid** voltage range of 95-105% of the **normal** voltage, at any frequency down to 47.5 Hz. The output power may then be reduced by 0% at 49 Hz and a maximum of 15% at 47.5 Hz, and by a value found by linear interpolation at frequencies between these two limits. Efforts should be

[5]The base value (100 %) for normal voltage must be defined in each case - as base value may be different from nominal value. Locally other voltage ranges can be applied, if these are accepted by the grid operator.

made to lower this reduction in output power, if this can be achieved without high additional costs.

5.3 Transitory Frequency Variations 51 Hz to 52 Hz

It shall be possible to operate the unit for 5 sec during **transitory conditions** of the network in connection with exceptional disturbances within the **grid** voltage range of 95-105% of **normal** voltage at any frequency between 51 and 52 Hz. During such transients the power may be reduced, if stable operation at full power can be reestablished when the frequency again drops below 50.3 Hz.

5.4 Frequency Range 51 Hz to 53 Hz

On a separate electrical network it shall be possible to operate the unit at strongly reduced output power within the **grid** voltage range of 95-105% of **normal** voltage, at any frequency between 51 and 53 Hz for 3 min.

5.5 Frequency Below 47.5 Hz

The unit may be tripped from the network at frequencies below 47.5 Hz. The unit shall then be capable of changing over to house load operation. However, this should not take place instantaneously, the time delay being determined by the design limits of the unit and so that reliable changeover to house load operation will be obtained.

5.6 Frequency Gradients

The control system shall be designed so that the unit will not trip because of the transient frequency gradients occurring in case of short-circuit on the high-voltage network to which the unit is connected.

6. Tolerance to Voltage Variations

6.1 Grid Voltage Range 90% to 105% of Normal Voltage

It shall be possible to operate the unit continuously at full load within the frequency range of 49-51 Hz and at a **grid voltage** between 90 and 105% of **normal**[6] voltage. At a frequency above 50.3 Hz, a small power reduction is accepted, if stable operation at full power can be reestablished when the frequency again drops below this value. A maximum operating time of 10 h/year and a duration of 30 minutes maximum per case can be assumed within the frequency range of 50.3-51 Hz. (Same requirements as in 5.1). See appendix A.

6.2 Grid Voltage Range 85% to 90% of Normal Voltage[7]

It shall be possible to operate the unit for 1 h within the frequency range of 49.7-50.3 Hz at a **grid** voltage between 85 and 90% of the normal voltage, and an output power reduction of up to 10% of full output may then be acceptable.

[6]The base value (100 %) for normal voltage must be defined in each case. Locally other voltage ranges can be applied, if these are accepted by the grid operator.

[7] These conditions are assumed to take place very rarely.

6.3 Grid Voltage Range 105% to 110% of Normal Voltage[8]

It shall be possible to operate the unit for 1 h at a frequency within the range of 49.7-50.3 Hz and at a **grid** voltage between 105 and 110% of **normal** voltage. A small output power reduction may then be acceptable.

6.4 Consequences of Nearby Grid Faults

6.4.1 Ability to Withstand Mechanical Stresses Due to Line Side Faults

Thermal power units shall be designed so that the turbine generator set can withstand the mechanical stresses associated with any kind of single-, two- and three-phase earth or short circuit fault occurring on the grid on the high voltage side of the step-up transformer. The fault can be assumed to be cleared within 0.25 sec. No damage nor need for immediate stoppage for study of the possible consequences are allowed.

6.4.2 Line Side Faults of Clearing Time up to 0.25 Sec

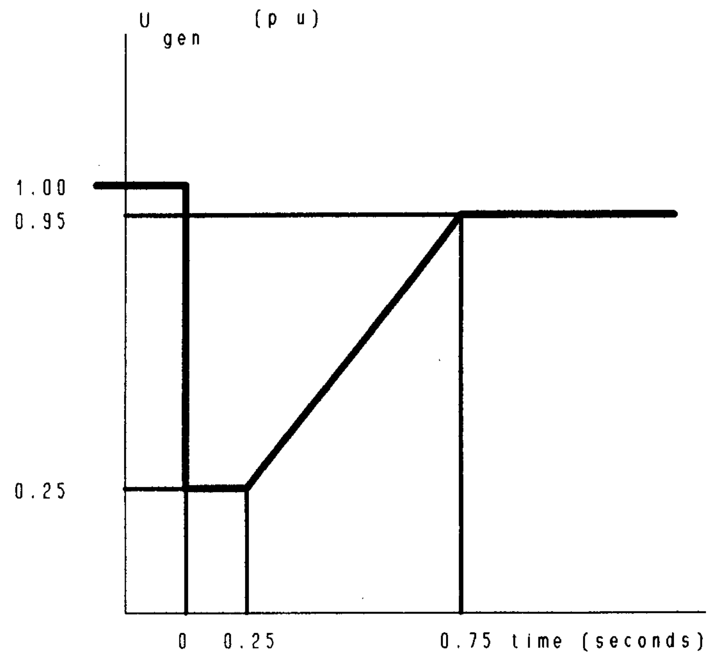
The faults occurring beyond the line breaker of an outgoing line will normally be isolated from the grid within 0.1 sec, in exceptional cases the clearing time may, however, extend to 0.25 sec. In this case it is a back up protection that clears the fault.

The unit shall be designed so that it remains connected to the grid and continues its operation after isolation of line side fault within 0.25 sec.

[8] These conditions are assumed to take place very rarely

A unit equipped with a large single-shaft turbine generator may be disconnected from the grid at a shorter time limit, if it is obvious that it will be impossible to maintain stability anyway. In this case a solution must be agreed upon with the grid operator.

6.4.3 Deep Voltage Transient[9]



Nordel specifications 1995
Tolerance to voltage variations
Deep Voltage Transient (6.4.3)

The units shall be designed so that they can withstand the following generator voltage variation resulting from faults in the grid, without disconnection from the grid:

- step reduction to 25% of the rated generator voltage lasting for 0.25 sec,

[9] The generator voltage is used in this section to point on the multi-factor nature of grid faults to the unit in total

- followed by linear increase to 95% in 0.5 sec,

- followed by constant generator voltage 95%.

Consequently, only a small power reduction can be accepted.

It shall be noted that the design criteria for the voltage protection may be different as the unit must manage several kinds of other faults for various generator/network conditions.

6.5 Large Voltage Disturbances

The unit may be disconnected from the power system, if larger voltage variations or longer durations than those for which the unit has been designed occur, and shall, in each case, be disconnected if the unit falls out-of-step.

The unit and its auxiliary power system shall be designed for such voltage variations that a safe changeover to house load operation can take place after disconnection from the network.

6.6 Reactive Power Output at Low Voltages

Thermal power units shall be equipped with such excitation systems and shall be designed for such a power factor that the generator will be capable of providing a reactive power output of about the same magnitude as the rated active power output for 10 sec, in conjunction with network disturbances and at a generator busbar voltage of 70% of the rated generator voltage.

6.7 Reactive Power Capability

The thermal power unit shall be able to generate and to consume reactive power in adequate amounts within their capabilities for the voltage control of the power system.

The unit shall be designed so that at the normal grid voltage the generators can be operated at the reactive power output and input within the limits defined by the capability diagrams of the generators or by static stability.

At the grid voltages higher than the normal voltage the underexcited capability of the generators shall be fully available according to the capability diagram or static stability, whichever is more limiting.

7. Generator and Voltage Regulator Characteristics

7.1 Generators

The generator reactance shall be as low as technically and economically possible in order to support the static stability and reactive power control.

Generators with outputs below 500 MVA shall have

- no-load short circuit ratio Kc (saturated) of at least 0.5,
- direct axis transient reactance Xd' (saturated) of less than 0.35.

Generators with outputs above 500 MVA may deviate from these values, the allowable limits being $Kc \geq 0.43$ and $Xd' \leq 0.42$.

Each generator shall be capable of operating on the rated active power continuously at power factor down to at least 0.95 underexcited, and 0.9 overexcited. This shall be possible in connection with voltage and frequency conditions as described in section 6.1, however, at underexcited conditions normal grid voltage is applied instead of 90 % voltage.

7.2 Voltage Regulation

The preferred dynamic characteristics for steady state are defined in a measurable way as follows:

The 10% step response of generator voltage is recorded in no-load conditions, disconnected from the grid. The set value of the voltage is changed by plus and minus stepwise changes causing change of generator terminal voltage from 95 to 105%, and from 105 to 95%. In both cases the step response of the generator terminal voltage shall be as follows:

- response is non-oscillating

- rise time from 0 to 90% of the change is 0.2 ... 0.3 s in case of static exciter, or in case of brushless exciter: 0.2 ... 0.5 s at a step upwards, 0.2 ... 0.8 s at a step downwards:

- overshoot is less than 15% of the change.

7.3 PSS, Power System Stabiliser

PSS shall be included in each generator. The PSS shall be tuned to improve the damping of the oscillations of generator and power system, especially the damping of low frequency (0.2 ... 1.0 Hz) interarea oscillations.

7.4 Additional Voltage Control Equipment

Current limiters (for generator rotor and stator) shall have invert time characteristics to utilise the generator overcurrent capability to a good extent for various network conditions.

7.5 Voltage Control Priority

The normal way of operation is automatic control of generator voltage with the effects of reactive current statics.

In case of needs for different type control, like control according to power factor or reactive output, these additional controls shall affect at lower priority than the regulation of voltage.

8. House Load Operation

8.1 Design Characteristics

All power units shall be designed to change over safely to house load operation from conditions as specified in 5.4, 5.5 and 6.5 of this recommendation.

8.2 Operating Time

Thermal power units shall be designed so that they can operate in house load operation for at least 1 h. Nuclear power units shall be capable of operating in house load operation for a duration determined by the nuclear safety conditions.

9. Verification

To the largest possible extent the specifications shall be verified by full-scale test.

This test shall be made at commissioning and by the owner at regular intervals throughout the entire lifetime of the power plant, if it is assumed that characteristics have changed. Recordings of data from actual operation shall be reviewed regularly in order to prove compliance with the specification.

9.1 Verification during Commissioning

This verification shall include:

- Full output power
- Minimum load
- Overload capacity
- Starting time
- Load following
- Power response rate including range
- Power step change
- Deep voltage transients by short circuit if possible
- Changeover to house load operation
- House load operation for 1 h
- Step response of generator voltage
- PSS test

Appendix A

Performance Requirements in Relation to Voltage (requirements section 5) and Frequency (requirements section 6)