TECHNICAL REQUIREMENTS FOR WIND POWER AND PHOTOVOLTAIC INSTALLATIONS AND ANY GENERATING FACILITIES WHOSE TECHNOLOGY DOES NOT CONSIST ON A SYNCHRONOUS GENERATOR DIRECTLY CONNECTED TO THE GRID

OFFPRINT FORM THE O.P. 12.2 OUTLINE

"Facilities connected to the transport grid and generating equipment: minimum design requirements, equipment, operation, deployment and security"

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1. PURPOSE

The purpose of this document is to provide minimum design requirements, equipment, operation, deployment and security of the facilities connected to the transport grid and of those generating facilities included in its field of application. It is not the purpose of the procedure to establish protection adjustment values.

2. FIELD OF APPLICATION

This procedure applies to the following subjects:

- The System Operator and Transport Grid Manager.
- The transporting company.
- Distributors and consumers connected to the transport grid.
- The owners of those generation facilities connected to the transport grid and connected to the distribution grid with significant affect of the transport grid. To this effect all generators or group of generators with registered nominal power higher than 10 MW for each of the associated transport grid nodes, when registered nominal power of the facility is higher than 1MW.

8. TECHNICAL REQUIREMENTS OF THE GENERATION FACILITIES

In the current section, the technical requirements that the generation facilities must comply with are established. The purpose of these requirements is to guarantee the manageability of the electrical system and continuity of supply.

8.1 DEFINITIONS

Grid connection point

A node in the transport or distribution grid used to transmit the power produced of the generation facility.

Correctly cleared short-circuit

A short-circuit is considered to have been correctly cleared when the protection systems have reacted according to the specifications established in operational procedure O.P. 11.1 “General protection criteria”

Fault duration

Time between the start of short-circuit – with a voltage drop under 0.85 p.u. – in the electrical system and the moment when said short-circuit is cleared by the action of the protection systems provided for these effects.

Voltaje Dip

A voltage dip is a sudden reduction of the voltage followed by its recovery a after a short time lapse. By agreement a voltage dip lasts between 10 ms and 1 min.

Duration of voltage recovery following fault clearance

Time between the moment the fault is cleared and the moment the voltage at the grid connection point reaches a level between the admitted variation values for normal system operation.

Nominal apparent power

Is the highest apparent power the facility can provide continuously at nominal voltage.

Nominal current

Electrical current corresponding to the nominal apparent power at nominal voltage.

8.3 TECHNICAL REQUIREMENTS FOR WIND POWER AND PHOTOVOLTAIC INSTALLATIONS AND ANY GENERATING FACILITIES WHOSE TECHNOLOGY DOES NOT CONSIST ON A SYNCHRONOUS GENERATOR DIRECTLY CONNECTED TO THE GRID

The following technical requirements will be of application for new facilities with deployment date later than January 1st, 2011.

The owner of the facility must overtake any necessary design and/or control measures for the facility to comply with the permanent regime and disturbance transient regime technical requirements described here, as well as with those established in the remaining operational procedures.

8.3.1 RESPONSE IN THE CASE OF VOLTAGE DISTURBANCES

The generation facility and all its components must be able to withstand, without disconnection, any voltage disturbance (in magnitude and/or angle) at the grid connection point, provoked by three-phase, two-phase to ground and single phase short circuits or any other cause with the magnitude and duration profile shown in figure 8.3.1.

In the particular case of two-phase to ground short circuits, the magnitude and duration profiles of the voltage dip that the facility must be able to withstand connected to the grid are similar to the one in figure 8.3.1 but with the lower voltage level at 0.5 p.u. instead to 0 p.u. and 0.6 p.u instead of 0.2 p.u.

Additionally, the facility must remain connected in case of overvoltages in one or all phases up to an effective voltage to ground of 1.3 p.u. for 250 ms or 1.15 p.u. for 1 s.

Voltage (p.u.)

Voltage prior to the disturbance

Beginning of the disturbance

Fault clearance and start of the recovery

Lowest admissible voltage level for permanent regime.

Time (s)

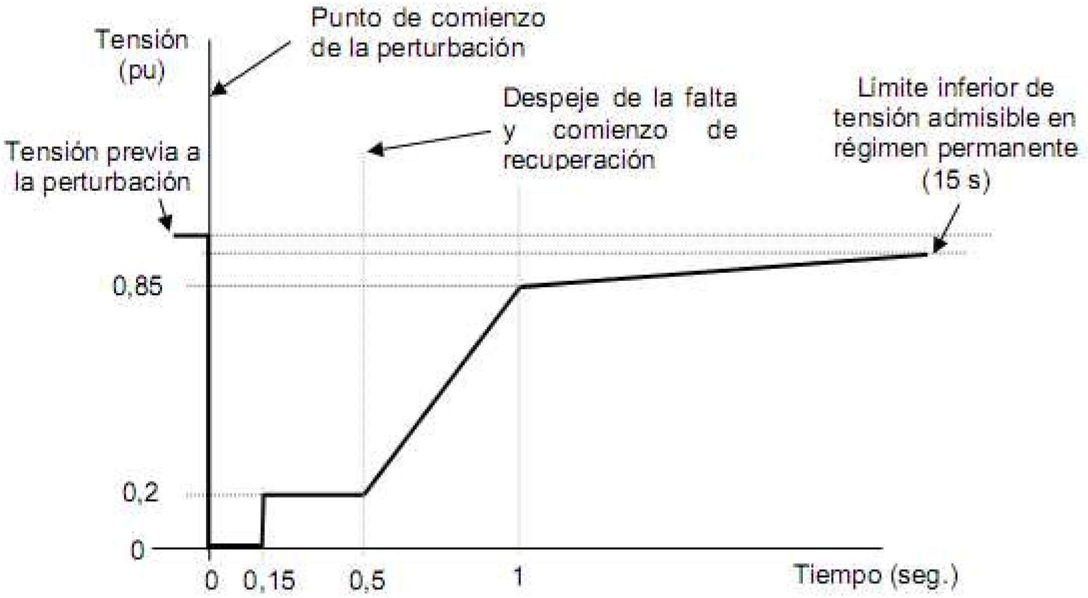


Figure 8.3.1. Time-voltage curve[1] showing the "voltage disturbance" area at the grid connection point that must be withstood by the facility. Phase to ground voltage for the disturbed phases.

8.3.1.1 Balanced faults (three phase)

The facility might not consume reactive power at the grid connection point during both, fault duration and the duration of voltage recovery following fault clearance.

Despite the previous limitation, momentary reactive power consumption is allowed during just the first 40 ms following the beginning of the fault and the first 80 ms following its clearance. Consumption is allowed only when the following conditions are met:

- For the first 40 ms after the beginning of the fault, the net reactive power consumption of the facility for each cycle (20 ms) must be lower than 60% of the registered nominal power.
- For the first 80 ms after fault clearance, the net reactive energy consumption of the facility must be lower than the equivalent reactive power to 60% of the registered nominal power of the facility for an 80 ms period.

[1] Voltage per unit: value in per unit with respect to the nominal voltage level of the system

Equally, the facility might not consume active power at the grid connection point during both, fault duration and the duration of voltage recovery following fault clearance

Despite the previous limitation, momentary active power consumption is also allowed during the first 40 ms following the beginning of the fault and the first 80 ms following its clearance.

During the whole transient regime, the facility must be able to inject to the grid at least the nominal apparent current.

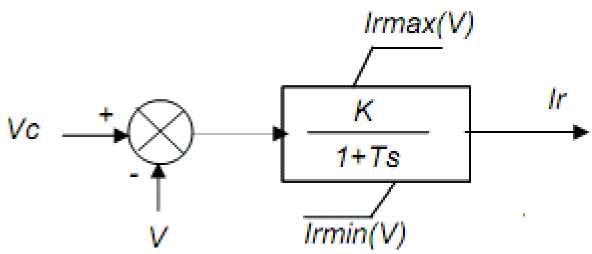
The contribution of current from the facility to the electrical system during the disturbance will be such that the working point is controlled by an automatic voltage control system. This system will work in a similar way to the voltage regulator of the conventional synchronous generators (be it at the grid connection point or at machine level with the corresponding transfer to the machine terminals of the rms voltage values at grid connection point) with the following requirements.

- During the disturbance, the voltage allocation will remain that of the permanent regime if the permanent regime control was set to voltage allocation.

- During the disturbance the voltage allocation will be the voltage prior to the fault is the permanent regime control set to reactive power or power factor allocation.

- The regulator will start its activity as soon as the rms voltage at the grid connection point changes beyond the admissible working levels set by the System Operator, be it undervoltage or overvoltage. Once the disturbance is cleared, it will keep running for at least 30 seconds after the permanent voltage recovers to acceptable limits for the operation of the electrical system. Afterwards, it will return to the working regime prior to the disturbance.

- Regardless of its physical design, it will work as a whole as an error proportional control (deviation by voltage unit with respect to the allocation voltage) according to the following simplified block diagram.



Where "V_c" is the allocated unitary rms voltage. "V" is the unitary rms voltage at the grid connection point (or machine terminals if it were the case). Constant "K" is the proportional gain and "T" is the time constant. The unitary reactive current injected into the grid based on the nominal apparent current is "I_r". This current has upper and lower bounds depending on the voltage "V".

- Inside the voltage margins ±ΔV (defined on section 8.3.3) around nominal voltage, the facility will have the ability to absorb/inject, the same amount of reactive power exacted by the voltage control in the permanent regime (section 8.3.3).
- The two polygonal curves (A-B-C-D-E y A'-B'-C'-D'-E') in figure 8.3.1.1 show the minimum saturation levels for absorbed/injected reactive current "I_r" that the facility must be able to reach through the voltage regulator on disturbance transient regime. Depending on future evolution of voltage dynamics, the system operator might, however, give instructions for modifying said minimum saturation levels, be it for everyone or for individual sites, for others of lower value, losing additionally its minimum trait.

Mandatory saturation for V≤ 0.85

Reactive current levels in the range 1-ΔV ≤ V ≤ 1+ΔV correspond with the permanent regime reactive power injection/absorption capability of the facility.

Maximum voltage level at grid connection point that the facility must withstand for 1 s.

Maximum voltage level at grid connection point that the facility must withstand for 250 ms.

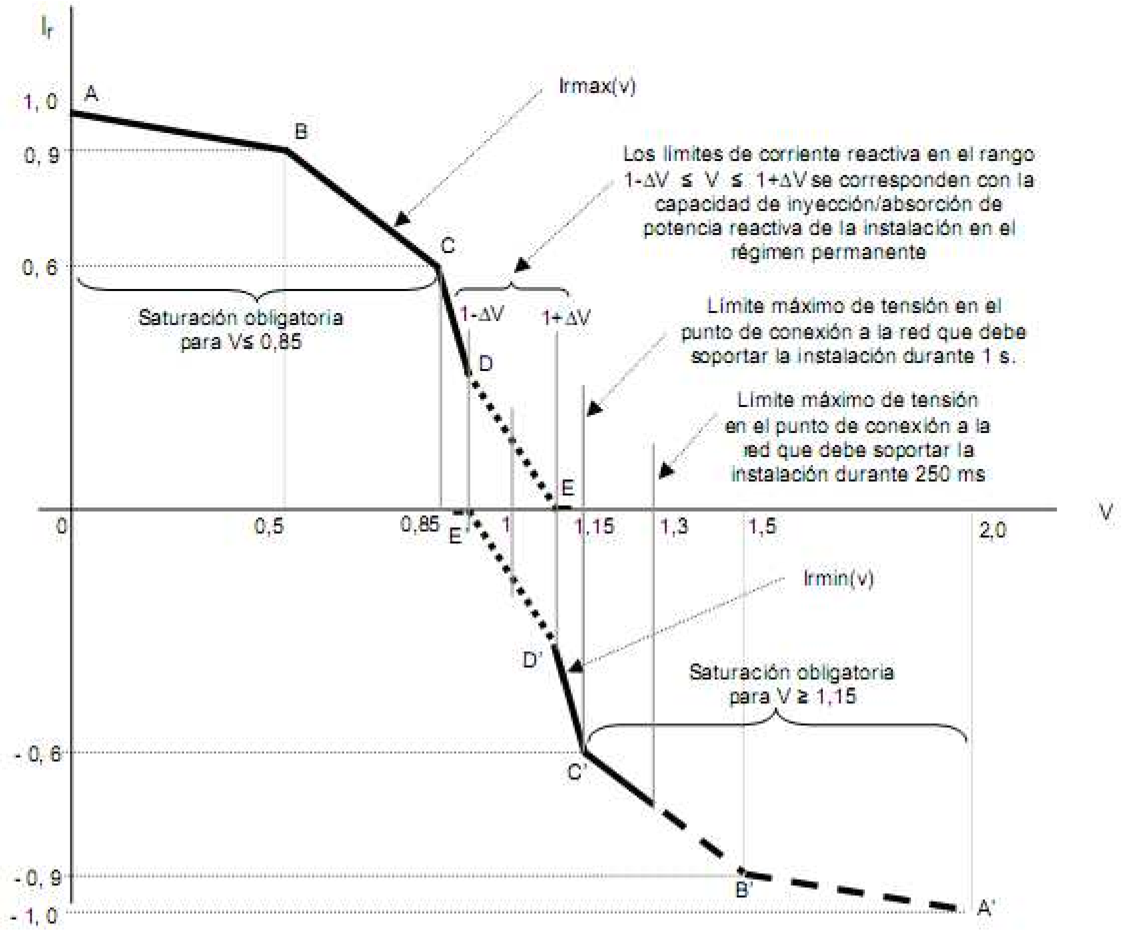


Figure 8.3.1a Minimum saturation levels for reactive current "I_r" injection/absorption

- For rms voltages at grid connection point in the range *0.85 ≤ V ≤ 1.15* p.u., the injected reactive current will react according to the voltage control, possibly saturating the regulator limits. Active power control will however overpower voltage, so that:

- For rms voltages at grid connection point in the range $0.85 \leq V \leq 1 - \Delta V$ the facility will regard a lower and an upper active current limit (excluding the active current increments/reductions that may overcome because of power-frequency control or, if it were the case, the inertia emulation) depending on the rms voltage "V" shown in figure 8.3.1.1b, where "P_{ao}" is the active power that the facility (or the machine) produces prior to the disturbance. Any possible violation of these active current limits must be corrected before 250 ms.
- For rms voltages at grid connection point in the range $1 - \Delta V \leq V \leq 1 + \Delta V$ the facility will seek to maintain the active power levels prior to the disturbance (excluding the active current increments/reductions that may overcome because of power-frequency control or, if it were the case, the inertia emulation).
- For rms voltages at grid connection point in the range $1 + \Delta V \leq V \leq 1.15$ p.u. the facility will seek, when possible, to maintain the active power level prior to the disturbance.

- For rms voltages at grid connection point lower than 0.85 p.u. or higher than 1.15 p.u., reactive current injection/absorption will saturate at the regulator limits, with voltage control topping active current. The facility will nevertheless respect:
  - A lower and an upper active current limits depending on the rms voltage "V" in the range $0 \leq V \leq 0.85$ p.u. as shown in figure 8.3.1.1b. Any possible violation of these active current limits must be corrected before 40 ms (figure 8.3.1.1b).
  - For voltages higher than 1.15 p.u., the facility will seek, when possible, to maintain the active power level prior to the disturbance.

For voltage levels lower than 0.85 p.u., any possible violation of active current limits will be corrected in less than 40 ms from the beginning of the disturbance.

The active current limits in the range $0.85 \leq V \leq 1 - \Delta V$ will be enforced, excluding the active current increments/reductions that may overcome because of power-frequency control or, if it were the case, the inertia emulation. Any possible violation of these active current limits must be corrected before 250 ms.

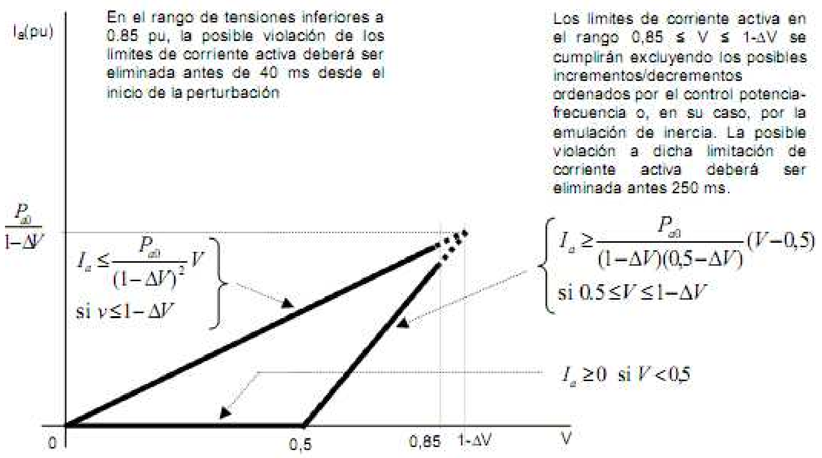


Figure 8.3.1.1b Upper and lower limits for the active current "I_a" in unitary values with regard to the apparent nominal power of the facility

- Gain k and time constant T of the regulator will be such that:
  - For rms voltages at the grid connection point lower than 0.85 p.u. or higher than 1.15 p.u., the response speed will be such that 90% of the control action is reached in less than 40 ms.
  - For rms voltages at grid connection point in the range $0.85 \leq V \leq 1.15$ p.u., the response speed will be such, that 90% of the control action is reached in less than 250 ms. The System Operator might nonetheless expect said response in up to 1 s.
  - The permanent regime error will match the one voltage control at permanent regime.

8.3.1.2 Unbalanced faults (single-phase and two-phase)

The facility might not consume reactive power at the grid connection point during both, fault duration and the duration of voltage recovery following fault clearance.

Despite the previous limitation, momentary reactive power consumption is allowed during just the first 80 ms following the beginning of the fault and the first 80 ms following its clearance. Transient consumption is allowed outside those intervals as long as the following conditions are met:

- The net reactive energy[2] consumption of the facility must be lower than the equivalent reactive power to 40% of the registered nominal power of the facility for a 100 ms period.

- The net reactive power consumption of the facility for each cycle (20 ms) must be lower than 40% of the registered nominal power.

Equally, the facility might not consume active power at the grid connection point during both, fault duration and the duration of voltage recovery following fault clearance

Despite the previous limitation, momentary active power consumption is also allowed during the first 80 ms following the beginning of the fault and the first 80 ms following its clearance.

Transient active power consumption is allowed outside those intervals as long as the following conditions are met:

- The net active energy[2] consumption of the facility must be lower than the equivalent active power to 45% of the registered nominal power of the facility for a 100 ms period.

- The net active power consumption of the facility for each cycle (20 ms) must be lower than 30% of the registered nominal power.

8.3.2 RESPONSE IN THE CASE OF FREQUENCY DISTURBANCES

[2] Consumption is referred to the accumulated total of the three phases

The owner of the facility must overtake any necessary design and/or control measures for the facility to remain connected to the electrical system. The facility might not disconnect due to variations of the frequency in the following ranges:

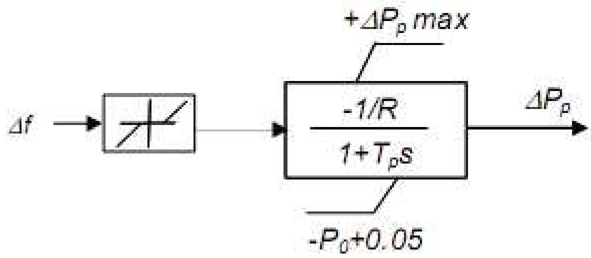
- In the case of underfrequency, the facilities must withstand frequencies lower than 48 Hz for at least 3 s and 47,5 Hz instantaneously.
- In the case of overfrequency, the facilities must withstand frequencies up to 51.5 Hz.
- The facilities must withstand also frequency variations of at least ±2 Hz/s.

Power-frequency regulation:

The generation facility must have the necessary equipment that allow for power-frequency regulation, that is, it will be able give active power increments or reductions proportional to the frequency deviations at the grid connection point.

The power-frequency regulator control system must meet the following requirements:

- Regardless of its physical design, it will work as a whole as an error proportional control (deviation by voltage unit with respect to the allocation voltage) according to the following simplified block diagram.



- The control will respond according to the following value

$$R = -\frac{\Delta f / f_{base}}{\Delta P_p / M_{base}}$$

where Δf is the frequency deviation from the nominal base frequency f_{base} (50 Hz is considered as the base frequency), ΔP_p is the power increment and M_{base} is the nominal apparent power of the facility, being the proportional gain $K_p = -1/R$, so that for falls in the frequency of the grid, the active power injected increases.

- Said value must be adjustable between at least 0.02 and 0.06 p.u.
- The speed of the response will be adjustable. Nevertheless, the facility must be capable to increase active power by at least $\Delta P = 0.1$ p.u. in 250 ms.

- The control must be able to increase the power output of the facility by ΔP_{max}, which is the difference between the power output prior to the disturbance (P_o) and the maximum available power depending on the instantaneous availability of the primary energy source. The control will also, be capable of decreasing the power output down to a minimum of 5% of the apparent nominal power, as long as the active power is higher than this value. The regulation range will, nonetheless, observe the regulation established to this effect for the complementary service of primary regulation in the Operational Procedures 7.1 and 7.5.

- The insensibility range to frequency measurement and the voluntary dead ranges will observe the regulation established in the Operational Procedure 7.1.

- The control will be able to disable itself momentarily, while the voltage level is under 0.85 p.u.

- It will be able to receive in real time power instructions from the System Operator for the reserves to increase and decrease and must answer with the real values of the available reserves.

- The working values of the adjustable parameters described herein will be set to the values the System Operator gives, depending on the evolution of the needs of the electrical system.

- The adjustment of the protections of the facility must be consistent with the required capabilities and the actual needs of the system operation.

8.3.3 CONTROL REQUIREMENT FOR THE PERMANENT REGIME

The facility must allow, on orders from the System Operator, to set the base working power to the whole range of possible power values up to the maximum available power depending on the primary power source. This is made in order to comply with the established requirements to this regard set in the remaining Operational Procedures. In the case that the Operational Procedure O.P. 3.7 is to be applied to this generation facility, the facility shall have the necessary equipment to comply with the requirements set in said procedure and shall additionally be able to set limits to power output increase and decrease slopes (not related a decrease in the availability of the primary energy source). These limits will be set by the System Operator. The facility will also be able to send to the System Operator the difference between the possible power output depending on the available primary energy source and the active power output depending on the orders received from the System Operator.

The generation facility will additionally have the necessary equipment to carry out voltage control at the grid connection point depending on voltage instructions. This voltage control will meet the following requirements:

- Regardless of its physical design, it will work as a whole as an error proportional control (deviation by voltage unit with respect to the allocation voltage) according to the same simplified block diagram detailed for voltage control in the disturbed transient regime (section 8.3.1.1).

- The ability to absorb/inject reactive power will be such that complies at least with the requirements set for ordinary regime in Operational Procedure 7.4, “Complementary voltage control service for the transport grid”. This procedure establishes the requirements for symmetrical voltage range surrounding the nominal voltage (in the following ±ΔV). It is however, variable depending on the nominal voltage at the grid connection point of the facility. The following will also be considered:

    - The minimal ability to absorb/inject reactive power will remain over whenever the facility is connected generating any amount of active power over 20% of the nominal power of the facility. For values of active power lower than 20%, the minimal capacity for absorbing/injecting reactive power may decrease linearly until zero reactive power for zero active power.
    - For grid connection points in the Distribution Grid, the interval ±ΔV will be ±7.5%.
    - Outside the voltage range 1-ΔV ≤ V ≤ 1+ΔV the regulator will keep the control action inside the reactive power injection/absorption margins that the active power production allows.

- The response speed for reactive power of the voltage regulator in permanent regime will be such that the complete reaction must be finished in less than 20 s.

- The error for voltage in the permanent regime will be such that the voltage at the grid connection point will remain inside the admissible variation range defined by the System Operator about the voltage instructions. This as long as the control is not saturated at the reactive power injection/absorption limits.

The control system of the facility will also be able to work on reactive power or power factor instructions with equal speed to the voltage control mode. The particular control mode will be decided by the System Operator according to the operation conditions.

The facility will keep the programmed active power constant, as long as the primary energy source allows it, excluding increments/decreases ordered by the power/frequency control and in its case by the inertia emulation, as long as the permanent regime control it is working, regardless of its working mode, be it voltage, reactive power of power factor instructions.

The control at voltage, reactive power, or power factor instructions will stop working during disturbed transient regime. The voltage control established for disturbed transient regime will take over. Both controls might be the same equipment as long as the response speed is the required one.

The adjustment of the protections of the facility must be consistent with the required capabilities and the actual needs of the system operation.

8.3.4 FUTURE PERSPECTIVE OF THE TECHNICAL REQUIREMENTS

The technological capabilities of this kind of generation facilities should develop to greater technical features, in order to maximize the production of non synchronous generation systems and allow for greater integration of new generation technologies in the electrical system in the future, as well as to minimize the necessity for minimum synchronous generation reserves required to guarantee the minimal save working conditions for the electrical systems. With this goal in mind and in order to lead the sector to a convenient development of these technologies, the following requirements are explained, which could be asked for in the future. Even if the present Operational Procedure does not ask for compliance, it is encouraged. New and more detailed studies carried out by the System Operator could lead later on to the necessity to enforce them.

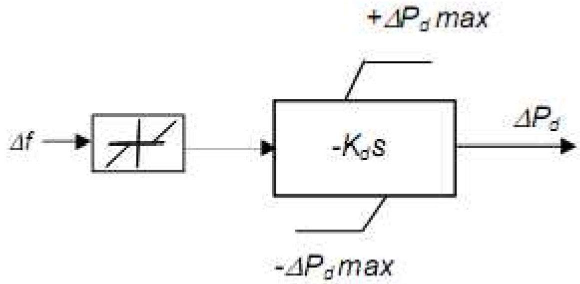
Contribution with inverse sequence current during disturbances

It would be convenient for all generation facilities to contribute with the inverse sequence current that the system might require during disturbances. Those technologies that do not currently comply with this necessity should develop to control techniques allowing compliance.

Inertia emulation

The generation facility might have the ability to emulate inertia. It that case, the equipment for inertia emulation shall generate increments or decreases of active power proportional to the derivative of the frequency at the grid connection point. The inertia emulation system shall meet the following requirements.

- Regardless of its physical design, it will work as a whole as an error proportional derivative control (temporal derivative of the unitary frequency deviation related to nominal frequency) according to the following simplified block diagram:



- The facility will have a derivative gain K_d, which must be adjustable between at least 0 and 15 s (values per unit in machine base).

- The speed of the derivative response should be such that in 50 ms the facility could increase the active power at least by ΔP=0.05 p.u.

- At every moment, the control must be able to increase the power of the facility by the value ΔP_{max} form the value prior to the disturbance (P_o) belonging to a range to increase that might be adjusted between 0 (block not in use) and 10% of the nominal apparent power of the facility. The control will be also able to reduce power output by the same amount than the range to increase.

- In order to be able to generate the increments $\pm\Delta P_{max}$, the facility must own energy storage systems, of any technology, that allow to inject or absorb active power equivalent to 10% of the nominal apparent power of the facility for at least 2 s.

- The insensibility range for frequency measurements will not be higher than ±10 mHz.

- The derivative block must be able to disable itself while the voltage remains below 0.85 p.u.

- The working values of the adjustable parameters described herein will be set to the values the System Operator gives, depending on the evolution of the needs of the electrical system.

Reduction of oscillations of power in the system

The generation facilities might possess the ability to reduce power oscillations of electromechanical nature in the system (know as Power System Stabilizer). In this case, the dumper system will increase or decrease power output such that its magnitude and angle with regard to the external oscillation help to reduce the power oscillations in frequencies between 0.15 and 2.0 Hz.

The dumper system must meet the following requirements:

- The control system will be able to increase or decrease at any moment the active power with the purpose of reducing the oscillations. To this goal, it might use the same power range of the power-frequency regulator sharing the same range to increase and decrease. It could also use the same energy storage systems used for inertia emulation.

- The insensibility range for frequency measurements will not be higher than ±10 mHz.

- The derivative block must be able to disable itself while the voltage remains below 0.85 p.u.

- The working values of the adjustable parameters described herein will be set to the values the System Operator gives, depending on the evolution of the needs of the electrical system.