WIND FARMS
General Conditions for Connection to HV networks
Control, Set-Up, and Protection Systems

Revision History		
Rev. 00	7 August 2008	First issue
Rev. 01	25 July 2018	Update and general revision

1. PURPOSE

This document describes the mandatory requirements for the connection of Wind Plants in terms of general performance, adjustments, and functionality.

More precisely, the requirements contained in the following document describe:
- The general characteristics of the installation and the operating range required for connection to the HV networks;
- The characteristics of the protection systems for safe operation of the electrical system;
- The characteristics of the control and management systems that the Wind Plants must provide in normal and emergency conditions;
- The requirements for visibility of the Network Operator's (hereinafter referred to as the Operator) control system and for the monitoring of the systems.

2. SCOPE

This document applies to Wind Plants connected directly to the National Transmission Grid or indirectly to the National Transmission Grid through a portion of the network with a rated voltage equal to or greater than 110 kV.
This document does not deal with the requirements relating to systems with accumulation systems, for which reference must be made to the specific annex to the Grid Code.
This document is also applicable to existing plants subject to significant changes, partial or total renovation of the plant. In such cases, Annex A.17 applies only to the parts of the system subject to replacement or only to the requirements for which it is not necessary to replace elements of the system other than those subject to significant modification or refurbishment. In order to assess the significance of changes and renovations, any changes must be notified in advance to Terna. Within 60 days, Terna validates the request, assessing the impact of the modernization on technical performance. After this deadline, the modification can be considered not significant and therefore the plant continues to be considered an existing plant.

The following are to be considered as significant changes, for example:

- The replacement of a number of wind turbines for a power equal to at least 10% of the efficient power;
- The renewal of plant control systems.

Compliance with the requirements contained in this annex (e.g. voltage regulation) is also required for existing plants in cases where they already have the technical requirements necessary to support their implementation.

3. REFERENCES

[A.2] Wiring Diagram Guide

[A.4] General protection requirements for networks with a voltage equal to or greater than 110 kV

[A.6] Remote control and data acquisition criteria

[A.7] Specifications for power supply monitoring systems having a voltage equal to or greater than 120 kV

[A.11] General criteria for calibrating the protections of networks with a voltage equal to or greater than 110 kV

[A.12] Calibration criteria for frequency relays of the electrical system

[A.13] Criteria for connection to Terna's control system

[A.15] Participation in frequency and frequency/power adjustment

[A.52] Peripheral unit of defense and monitoring systems. Functional and communication specifications

[A.64] How to use the remote detachment applied to wind farm production plants

[A.69] Criteria for connecting production plants to Terna's defence system

[IEEE 519] IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems ed. 2014

4. ACRONYMS AND NUMERICAL CODES

Acronyms used

HV: High Voltage (greater than 35 kV and less than or equal to 220 kV)

VHV: Very High Voltage (greater than 220 kV)

BC Capacitor Bank

CSC Switch Under Load

RS Reactor Shunt

WTG Wind Turbine Generator

Numeric Codes

26: Maximum temperature protection

27: Minimum voltage protection

50: Fast acting phase current maximum protection

51: Maximum delayed-action phase current protection

52: Switch

59: Maximum voltage protection 59N: Homopolar maximum voltage protection

63:	Minimum and maximum fluid pressure protection

81:	Minimum and maximum frequency protection

87:	Differential protection

97:	Buchholz protection

Suffixes to numeric codes

Below is a list of the suffixes used to uniquely specify the device in cases where there may be ambiguity. In cases where the treatment refers clearly to a single element, they are omitted for brevity of notation.

G	Generator

T	Transformer

5. DEFINITIONS

For the purposes of this document, the definitions in the Glossary of the Network Transmission, Dispatching, Development and Security Code (hereinafter referred to as the Network Code) shall apply. The following list contains some of these definitions, which have been suitably integrated.

Wind Turbine Generator (WTG). Power generation unit for the conversion of wind kinetic energy into electrical power. It includes the rotor, speed multiplier, power generator, conversion system and its control, LV/MV elevator transformer, auxiliary services, and the support structures.

Start up of a Wind Turbine Generator. from a state of quietness, or no-load operation, to the state of normal operation. The start-up phase ends when the instantaneous efficient power of the Wind Turbine Generator is reached.

Shutdown of a Wind Turbine Generator. Transition state of a Wind Turbine Generator from power output to a state of quiet or no-load operation.

Wind Power Plant (Wind Farm). A plant comprising one or more wind turbines and all the infrastructure required to connect them to the power grid and ensure their operation. All the electrical components are part of the Wind Power Plant, i.e. wind turbines, internal network, lift transformers, devices and equipment, including the main switch.

Main Switch. Switch whose opening ensures the separation of the entire Wind Power Plant from the grid of the Operator. A Wind Power Plant can also be connected to the network with more than one Main Switch.

Generator Switch. Switch (or possibly switches) whose opening ensures the separation of an individual Wind Turbine Generator from the internal network of the power generation plant.

Normal operating conditions of a Wind Turbine Generator. Condition in which the parameters of the grid connection (voltage and frequency) and the wind speed are included in the normal operating ranges of the Wind Turbine Generator.

Pitch-Control. Adjustment of the angle of incidence (pitch angle) of the wind turbine blades.

Normally, when the rated power is reached, and until the maximum rotation speed is reached, pitch angles other than zero are used to limit the power delivered to the rated value.

Rated Power of the Wind Turbine Generator (P_{n-ag}). Maximum active power at the rated voltage of each individual Wind Turbine Generator that can be continuously delivered under normal operating conditions. It is shown on the machine's nameplate. It is expressed in kW.

Rated Power of the Wind Power Plant (P_n). It is the sum of the rated powers P_{n-ag} of individual wind turbines. It is expressed in MW.

Available Rated Power of the Wind Power Plant (P_{nd}). Sum of the rated powers of the wind turbines available at a given time. It is expressed in MW.

Potential Output Power of the Wind Turbine Generator (P_{e-ag}). Maximum output power of the Wind Turbine Generator in current wind conditions. It is expressed in kW.

Potential Output Power of the Wind Power Plant (P_e). Power that can be supplied by the plant in current wind conditions. This is the sum of the output powers of the wind turbines available at a given time. It is expressed in MW.

Active power fed into the grid from the Wind Power Plant (P_i). Power output from the Wind Power Plant to the grid, measured at the point of connection. It is expressed in MW.

Reactive power fed into the grid by the Wind Power Plant (Q_i). Power output from the Wind Power Plant to the grid, measured at the point of connection. It is expressed in MVAr. The following sign conventions are used below: positive if fed into the grid (capacitive effect), negative if absorbed (inductive effect).

Connection point (or Delivery point). Physical boundary between the transmission network and the user system through which the physical exchange of electricity takes place.

Cut-in wind speed of the Wind Turbine Generator. Minimum wind speed at which the Wind Turbine Generator starts to deliver power.

Cut-off wind speed of the Wind Turbine Generator. Maximum wind speed at which the Wind Turbine Generator stops delivering power.

6. CONDITIONS FOR GRID CONNECTION

6.1. General Requirements

For the purposes of specifications on the subject of adjustment and protection, these specifications require that the insertion and connection diagrams, as well as the structure of the system, comply with the Network Code and in addition that:

- The Power Plant is equipped with at least one switch (main switch), which carries out the functional separation between the activities falling within the competence of the Operator and those falling within the competence of the Power Plant owner (hereinafter, the User)[1];
- The HV line switches (if present) are of the uni-tripolar control type for the uprights of the

[1] In the event that the connection to the National Transmission Grid is common to wind farms of different owners, the main switch will be the one that makes the separation between the grid and all the underlying plants.

lines so as not to prevent the adoption of unipolar automatic quick closures;

- The HV windings of the MV/HV transformer(s) are uniformly insulated and connected in a star pattern, with a neutral terminal accessible and prepared for any ground connection, and the MV windings are connected in a triangle. The ground connection of the HV winding is decided by the Operator in relation to the needs of the network at the connection point and must be carried out without the interposition of switching devices (switches or disconnectors);
- The HV winding of the MV/HV transformer(s) is equipped with a voltage variator under load with automatic regulator capable of allowing, with several steps, a variation of the no-load voltage between at least ±12% of the rated voltage;
- The MV/HV transformer(s) is/are suitably sized to allow the simultaneous transit of the maximum active and reactive power, and in any case with an overall apparent power equal to at least 110% of the plant P_n[2];
- Similarly, the LV/MV machine transformers are suitably sized to allow the simultaneous transit of the maximum active and reactive power;
- In correspondence to the active power P=0 and in the absence of voltage regulation, the system must be designed in such a way that the exchanges of reactive power with the grid are minimized so as not to have a negative effect on the correct regulation of the voltage. Therefore, when the plant is at a standstill, in the case of reactive power exchanged above 0.5 MVAr, systems must be provided to balance the capacitive reactive power produced by the MV network of the wind farm so as to ensure a degree of compensation at the connection point between 110% and 120% of the reactive power produced by the MV network at V_n. Typically, these balancing systems will be represented by shunt reactances; in the presence of very large wind farms, they will have to be split up in order to guarantee the compensation indicated for the out-of-service of part of the wind farm. Above certain values of active power produced by the Wind Power Plant, these compensation systems may be automatically excluded in order to balance, at least in part, the greater absorption of reactive power of the transformers of the wind turbines and of the MV/HV transformer(s) of the plant and ensure compliance with the capabilities required at the Delivery Point as specified in paragraph 8.3.1;

For the purposes of the provisions of the Network Code regarding the management of the power system, connection to the grid is subject to compliance with the requirements of this document.

The following are some of the obligations on the part of the User, who in particular is required to:

- Sign the appropriate Operating Regulations which contain, among other things, the functional relations with the Operator and any other parties involved;
- Carry out the maneuvers on the plant under its responsibility and execute in real time the orders given by the Operator for the safety of the power system, by means of a remote control system or through the monitoring of the plants active 24 hours a day; in particular, the User must have authorized personnel who can always be reachable;
- Carry out all the necessary actions so that the plant is integrated into the control processes (in real time and in deferred time) and management of the National Transmission Grid;
- Provide the Operator with remote measures and remote signals of the plant required for the observability and remote control of the grid;
- Guarantee the efficiency of the switching and cutting devices, automatic systems, interlocks, and protections;
- Guarantee the prompt action and safety of the systems.

For grid safety reasons, the Operator may open the network connections to the Wind Power Plant without prior notice, thus disconnecting the power supply to the site. Therefore, if necessary, it will be up to the User to provide a technical solution to ensure the power supply of its essential

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[2] In the event that the elevator transformer is shared between wind farms of different manufacturers, compliance with the requirements must in any case be guaranteed by specific agreements between the parties involved.

services (e.g. secondary backup or emergency connection in MV).

6.2. Operating Limits

The Wind Power Plant and its machinery and equipment must be designed, built and operated in such a way as to remain in parallel even in conditions of emergency and network restoration. In particular, the Plant must be able to remain parallel to the HV grid in all load conditions, for voltage values at the point of delivery, within the following range:

$$85\%\ V_n \leq V \leq 115\%\ V_n$$

with V_n being the rated voltage of the connection point.

For parallel operation with the HV grid depending on the frequency, the Plant must remain connected to the grid for an indefinite period of time, for frequency values within the following range:

$$47.5\ \text{Hz} \leq f \leq 51.5\ \text{Hz}$$

If the construction characteristics allow it, the Owner must declare any extended limits of the operating range.

6.3. Insensitivity to Voltage Variations

For wind turbines, characteristics of insensitivity to voltage variations in Fault Ride Through (FRT) are required, which are identical in all grid connection configurations (in/out, in antenna, in rigid shunt) to avoid conditioning the commissioning of the machines to the connection diagram of the Power Plant.

The wind turbines must be able to maintain the connection to the grid in the event of external faults, observing the under-voltage and over-voltage profiles shown in **Fig. 1**. The voltages considered are those linked to the connection point[3]. The disconnection logic is of type 1 on 3; it must be activated both for symmetrical faults and for dissymmetrical faults when one of the three voltage measurements exceeds the permitted voltage hole (or peak) in depth (or height) and duration.

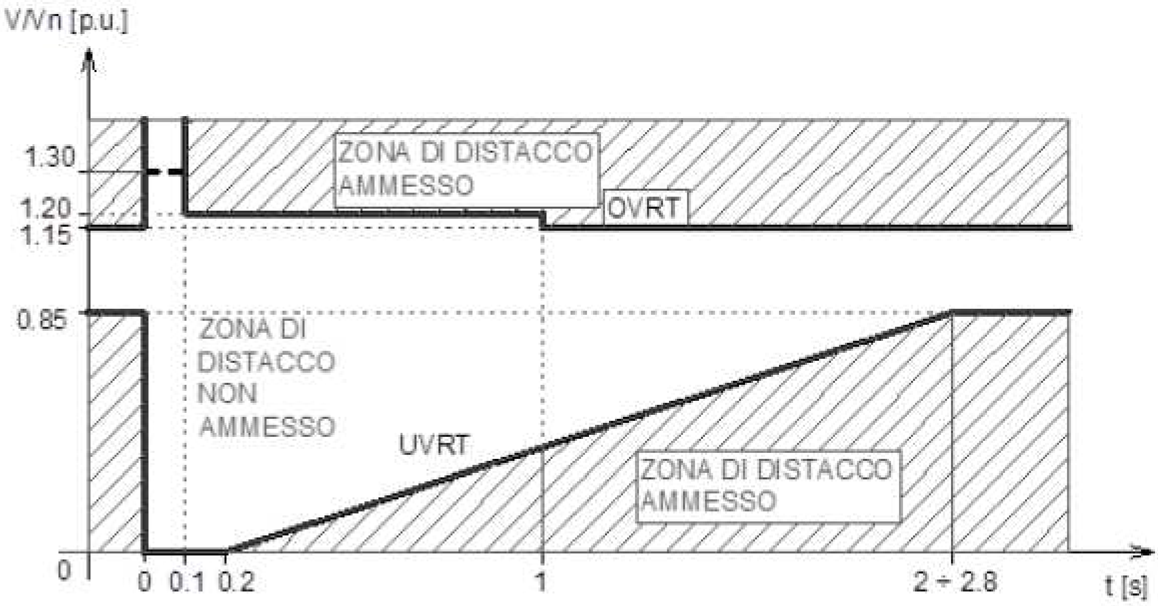
These profiles take into account both the need to pass through voltage dips caused by grid failures (Under Voltage Ride Through characteristic) and the need to resist transient voltage increases in the post-fault phases (Over Voltage Ride Through characteristic).

It is required to be able to withstand total voltage cancellation for 200 ms.

In the first 100 ms section, the upper limit is defined by the manufacturer, but must not be less than 130% of the rated voltage V_n.

The final time of the inclined section of the UVRT characteristic depends on the nominal voltage level of the Connection Point: 2s for 132/150 kV grids and 2.8 s for 220 kV grids.

[3] The grid separation characteristic shown in Fig. 1 can be reproduced in a similar way to the wind turbine terminals. In any case, it is possible to reduce the voltage at the wind turbine terminals to values close to the rated voltage and in any case within the range $V_n \pm 10\%\ V_n$ in a time of less than 60s by using the on-load switch (CSC) of the elevator transformers.



ZONA DI DISTACCO AMMESSO = PERMITTED DISCONNECTION ZONE

ZONA DI DISTACCO NON AMMESSO = NON-PERMITTED DISCONNECTION ZONE

Fig. 1 – FRT Characteristic at the Connection Point for Wind Power Plants

Within the Non-Permitted Disconnection Zone, if the voltage at the connection point is less than 0.85 V_n or more than 1.15 V_n, no strict requirements are imposed on the supply of active and reactive power within the prohibited disconnection area. In any case, it is required that the limitation of the active power delivered is related to the depth of the voltage hole/peak and with limited involvement of the phases not affected by voltage lowering/raising. In any case, the techniques for managing the active power delivered during voltage drops must be specified and the related adjustments must be agreed with the Grid Operator. The expected behavior of the wind turbines in this mode of operation shall be described in the models provided in paragraph 10. When returning within this interval, the set reactive power regulation and at least 90% of the active production prior to the transient must be restored in a time not exceeding 2 seconds. This recovery must be completely completed within 4 seconds.

6.4. Harmonic Distortion

The inverter used for adjustment of modern wind turbines is made with devices with high-frequency switching semiconductors. For this reason, these switches can cause interference and/or disturbance to utilities.

In compliance with the power quality required by the Grid Code, the owner provides, at the time of the request for connection, all the design data relating to the emission of harmonics; on the basis of these data, the Operator evaluates the effects on the network, in conditions of minimum power short circuit on the network itself.

Voltage Distortion

The harmonic emissions of the Wind Power Plant shall be such that the maximum level of total harmonic distortion (THD_V) of the voltage (calculated up to the 50th harmonic) at the Connection Point does not exceed the following values, in accordance with the [IEEE 519] standard:

- $THD_V \leq 2.5\%$ for networks with a rated voltage of less than 220 kV;
- $THD_V \leq 1.5\%$ for networks with a rated voltage greater than or equal to 220 kV.

Current Distortion

The harmonic emissions of the Wind Power Plant must be such that the maximum level of total harmonic distortion of current (THD_I), calculated up to the 50th harmonic and considering as a basis the nominal current of the Wind Power Plant at the Connection Point does not exceed the values indicated in the table below, in accordance with the [IEEE 519] standard.

I_{cc}/I_n	$3 \leq h < 11$	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h \leq 50$	THDI
<25	1	0.5	0.38	0.15	0.1	1.5
<25<50	2	1	0.75	0.3	0.15	2.5
≥50	3	1.5	1.15	0.45	0.22	3.75

where I_n is the maximum input current of the Wind Power Plant and I_{cc} is the short circuit current at the Connection Point.

The Operator reserves the right to request the User, depending on the site of connection, the installation of additional systems to compensate for the distortion of voltage produced in order to ensure the quality standards required by the grid.

The user must also provide mathematical models of the harmonic emission as prescribed in paragraph 10.

7. CRITERIA FOR PROTECTION AND CALIBRATION OF THE WIND FARM

The protection system of the Wind Power Plant includes the equipment normally dedicated to the protection of the plants and the network both for internal failures and for external failures.

The Power Plant must be able to remain connected to the grid in the event of external faults except in cases where the selection of the fault leads to the loss of the connection.

The wind turbines of a Wind Power Plant must be able to withstand the transient regime caused by subsequent grid failures such that the no-input power due to the failures in the last 30 minutes is less than $P_n \cdot 2s$.

In the event that these faults are properly removed from the grid protections and that their depth and duration are compatible with the FRT characteristic, the Power Plant protections must not control in advance the separation of the Power Plant from the grid itself or the shutdown of the wind turbines[4].

[4] This requirement is necessary in view of the normal cycles of rapid and slow automatic reclosing of the switches applied by the automatisms of the relevant network in the event of an in-line fault.

Each Wind Power Plant must contribute to the removal of grid failures within the time limits set by the protection system, in accordance with the Grid Code.

For the removal of internal failures at the Power Plant, which could involve other plants in the grid, it is necessary to provide for rapid disconnection of main switches. In addition, the Plant must be equipped with protections capable of detecting external faults, the intervention of which must be coordinated with the other network protections, in accordance with the document [A.11]. Also the intervention of the protections for external faults must provide for disconnection of the main switches and at the same time of the switches of each Wind Turbine Generator.

The calibrations of the protections against external faults are defined by the Operator and must be set on the equipment by the Owner of the system, ensuring the traceability of operations according to agreed procedures.

Calibrations of the protections against internal faults, which require coordination with the other protections of the network, must be agreed with the Operator in the agreement prior to the first start-up of the Plant.

In any case, the Operator may request justified modifications or additions to these requirements with the aim of maintaining or increasing the level of continuity of the typical withdrawal, power supply and operational safety of the connection network.

With a minimum frequency of 4 years, the User must check the protective equipment and keep a register of such tests, to be provided to Terna on request.

The protection system, and the related calibrations, also have the objective of maintaining the stability of the entire power system. Therefore, all the calibrations requested by the Operator, or proposed by the Owner, must be consistent with the guaranteed operating range indicated in paragraph 6.3 “Insensitivity to voltage variations”. Within this field, the system must be able to operate without damage.

Below are the protection requirements of the systems and the calibration values of the equipment that are normally prescribed for Wind Power Stations.

Wind Power Stations consisting of full-converter wind turbines are required to support rapid and slow closures in the grid without synchronism control and therefore also in asynchronous network conditions.
For Wind Power Plants consisting of DFIG wind turbines, the portion of the network adjacent to it is equipped with unipolar rapid reclosure and automatic slow reclosure with synchronism control.

Fig. 2 shows a typical connection with overhead HV section with the main protections provided. The Operator may request adaptations of the protective system according to the needs of the network to which the system is connected.

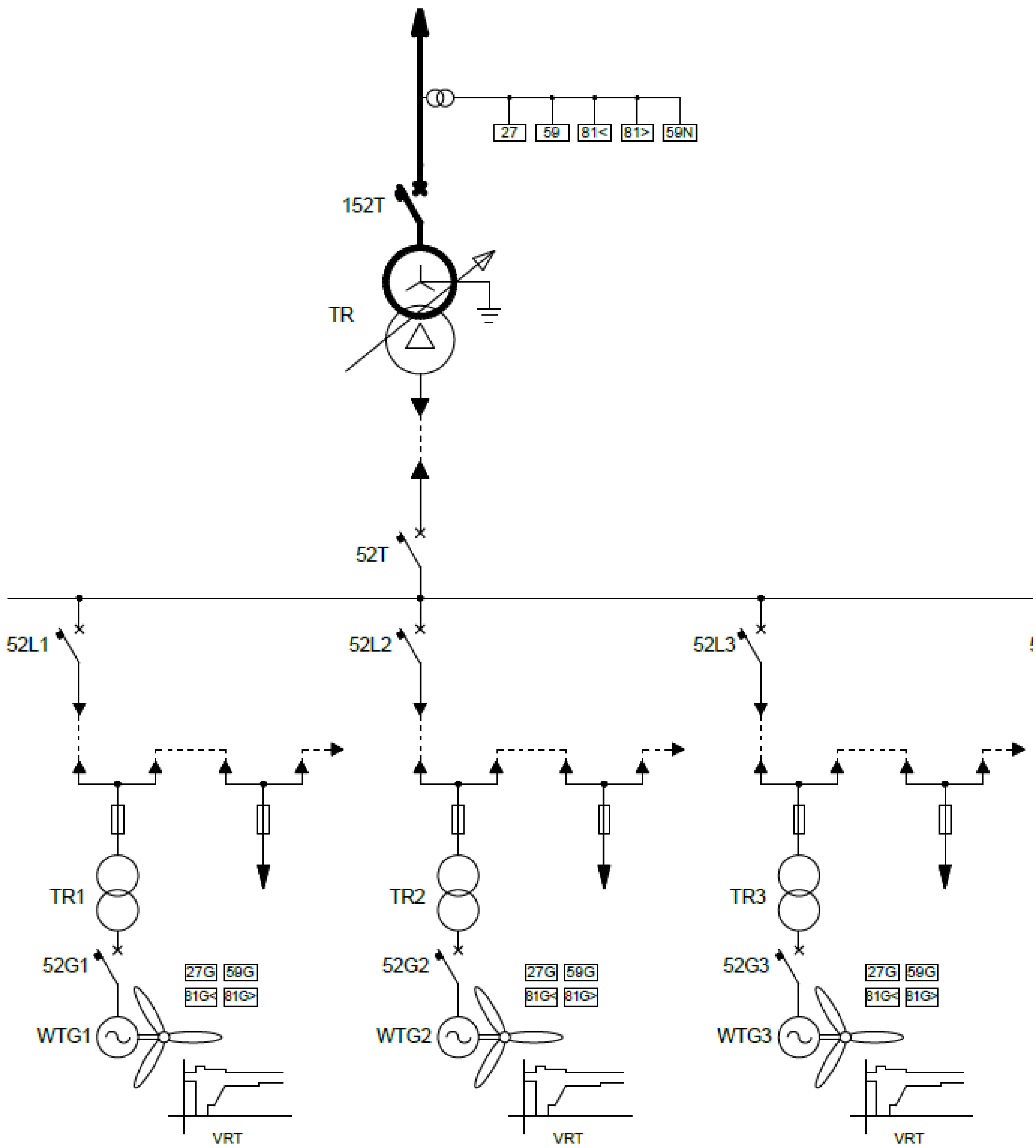


Fig. 2 – Arrangement of the protections against faults and disturbances in the network of a Wind Power Plant

7.1. Protection of the Wind Farm against External Damage

Below are the types of protections sensitive to external faults and grid disturbances with the typical adjustment fields and calibration values to be installed in the HV section of the Wind Power Plant and on board the wind turbines.

- Minimum Mains Voltage Protection (27)
- Maximum Mains Voltage Protection (59)
- Minimum Mains Frequency Protection (81<)
- Maximum Mains Frequency Protection (81>)
- Maximum Network Homopolar Voltage Protection (59N)

For the first four protections, the power supply of the voltmetric circuits with linked voltages is required. For the fifth, present only on the HV side, a voltmetric power supply is required from TV with open delta connection, or, for relays capable of obtaining the homopolar voltage inside them, from the normal phase voltages supplied by TVs with star connection.

The action of the above-mentioned protections must command the opening of the main switch. The Wind Power Plants must be designed to receive commands from the station facing the opening of the HV switches.

The Owner of the Wind Power Station may adopt additional protections, compared to the previous list, as long as they are consistent with the above mentioned protection criteria and do not limit the guaranteed operating range. In this case, the Owner will inform the Operator of the presence of additional equipment and will agree with the Operator the related calibrations.

Calibrations are established by the Operator in accordance with the criteria set out in Annex [A.11] to the Grid Code. In relation to the needs of the electrical system to which the Wind Power Plant is connected, the calibrations may also differ from those specified in the following paragraphs.

Other protections sensitive to network events other than those specified (e.g. unbalanced load protections, etc.) must be declared by the Owner and the related calibrations agreed with the Operator in order to ensure coordination with the calibrations of the network protections.

7.1.1. Mains Protections in the HV Section

The reference calibrations of the network protections sensitive to external faults to be set on the interface post with the HV network are described below, having differentiated two typical configurations of connection to the grid in accordance with the provisions of Annex [A.2] to the Grid Code:

<u>CASE "A"</u>: Power Station connected to incoming Delivery Plant in input/output on HV line or connected to adjacent Station or Primary Cabin

<u>CASE "B"</u>: Power Station on line in antenna or in rigid shunt on HV line

Any changes to the calibration values proposed below must be agreed with Terna.

The following values are provided for the calibration of the relays installed in the HV section of the Wind Power Plant:

Wind Power Plant – Protection against external faults – HV Section						
PROTECTION	ADJUSTMENT FIELDS		REFERENCE CALIBRATIONS			COMMAND
	Adjustment Range	Delay	Threshold	Calibration Values	Delay	
Minimum Voltage (27)	0.3 ÷ 1.0 V_{nR} (1)	0.0 ÷ 10.0 s	Single	80 % V_{nR} (1)	A) 2.0 ÷ 2.8 s (2)	Elevator Transformer Trip MV/HV HV side.
					B) 0.6 s	
Maximum Voltage (59)	1.0 ÷ 1.5 V_{nR} (1)	0.0 ÷ 10.0 s	Single	115 % V_{nR} (1)	1.0 s	
Maximum Homopolar Voltage (59N)	0.05 ÷ 1.5 V_{RES_MAX}	0.0 ÷ 10.0 s	First threshold	10 ÷ 20% $V_{RES\ MAX}$ (3)	A) 2.0 ÷ 2.8 s (2)	
					B) 1.2 s	
			Second threshold (4)	70% $V_{RES\ MAX}$	0.1 s	
Minimum Frequency	45.0 ÷ 50.0	0.0 ÷ 10.0 s	First threshold	47.5 Hz	4.0 s	

(81<) (5)	Hz		Second threshold	46.5 Hz	0.1 s	
Maximum Frequency (81>) (6)	50.0 ÷ 53.0 Hz	0.0 ÷ 10.0 s	First threshold	51.5 Hz	1.0 s	
			Second threshold	52.5 Hz	0.1 s	

Notes:
(1) V_{nR} is the rated voltage of the grid;
(2) Delay Values: 2.0 s in 132-150 kV grids; 2.6 s in 220 kV grids;
(3) $V_{RES} = 3V_0$ is the residual voltage found in the HV grid for single-phase short-circuit to earth. The calibration values lower than the First threshold are associated with cases of power stations with HV/MV neutral transformer isolated on the HV side. In this case, in fact, the maximum residual voltage ($V_{RES\ MAX}$) can reach up to 3 times the nominal phase voltage. On the other hand, the higher values are associated with cases with HV-side neutral to ground transformers in which the maximum residual voltage ($V_{RES\ MAX}$) on a single-phase ground fault assumes, with an Earth Fault Factor (FGT) close to 1, values that vary around the phase voltage.
(4) Threshold applied only to production plants with HV/MV neutral transformer isolated on the HV side
(5) Operating voltage 0.2 V_{nG}
(6) Operating voltage 0.8 V_{nG}

7.1.2. Wind Turbine Protection

The calibrations of the wind turbines shown are independent of the connection diagram.

Wind Power Plant connected to the HV grid - Wind turbine protections

PROTECTION	ADJUSTMENT FIELDS		REFERENCE CALIBRATIONS			COMMAND
	Adjustment Range	Delay	Threshold	Calibration Values	Delay	
Minimum Voltage (27G)	0.3 ÷ 1.0 V_{nG} (1)	0.0 ÷ 10.0 s	First threshold	80 % V_{nR} (1)	2.0 ÷ 2.8 s (2)	Stop of the Wind Turbine Generator with switch opening 52G
		0.0 ÷ 10.0 s	Second threshold (optional)	30% (3) V_{nG} (1)	0.85 s	
		0.0 ÷ 200.0 s	Third threshold (optional)	90% V_{nG} (1)	60 s	
		0.0 ÷ 10.0 s	Second threshold (if present)	120 % V_{nG} (1)	0.1 s	
		0.0 ÷ 200.0 s	Third threshold (optional)	110 % V_{nG} (1)	60 s	
Minimum Frequency (81G<) (4)	45.0 ÷ 50.0 Hz	0.0 ÷ 10.0 s	First threshold	47.5 Hz	4.0 s	
			Second threshold	46.5 Hz	0.1 s(6)	
Maximum Frequency (81G>) (5)	50.0 ÷ 53.0 Hz	0.0 ÷ 10.0 s	First threshold	51.5 Hz	1.0 s	
			Second threshold	52.5 Hz	0.1 s(6)	

Notes:
(1) V_{nR} is the rated voltage of the Wind Turbine Generator;
(2) Delay Values: 2.0 s in 132-150 kV grids; 2.6 s in 220 kV grids;
(3) A different pair of voltage and time values is allowed as long as it coincides with a point of the inclined section of the UVRT characteristic, reported at the terminals of the Wind Turbine Generator.
(4) Recommended operating voltage: 0.2 V_{nG}
(5) Recommended operating voltage: 0.8 V_{nG}
(6) Calibrations with longer intervention times are also accepted.

7.2. Protection of the Wind Farm against Internal Faults

The protections against internal faults must promptly and selectively isolate the only part of the Wind Power Plant that has been affected by the disruption without involving the external network or other Users directly or indirectly connected.

7.2.1. Protections of the HV/MV Transformer

The minimum protections that must be provided for the MV/HV elevator transformer against

system internal failures are as follows:
- Maximum phase current of the transformer on the HV side with two intervention thresholds; one is instantaneous and one delayed (50/51);
- Transformer differential (87T);
- Maximum MV side transformer phase current at one or two delayed trip thresholds (51).

The maximum phase current protections on the HV side and the transformer differential must be allocated to separate devices. The actions determined by the intervention of these protections are the opening of the HV and MV switches of the elevator transformer. It is recommended to trigger the action by blocking the opening of these switches.

For the protection of maximum MV phase current, the action specified is that of opening only the switch on the MV side.

The adjustments of the above protections must be agreed with the Grid Operator.

In addition to the above mentioned electrical protections, there are also those normally provided on board the transformer, for example Buchholz (97), minimum oil level (63), maximum temperature (26), etc... whose intervention levels and relative controls are decided by the machine manufacturer and/or the operator.

In addition to the previous ones, the plant Owner may adopt additional protections, always with the aim of protecting the system.

7.2.2. Protections Installed in the MV Section

The protection systems of the MV section are not subject to this requirement, however, it is required to adopt suitable protection against phase-to-phase and phase-to-ground faults, with settings that ensure proper selection and removal of faults in each compartment or component of the MV section of the plant and the non-interference of intervention with the protections of the HV network.

8. CONTROL AND SET-UP SYSTEMS

The main functions required of wind farms are as follows:

- Production monitoring
- How to start up and reconnect to the grid
- Reactive power adjustment
- Active power adjustment
- Hidden inertia
- Remote production detachment systems

The following paragraphs describe in detail the individual requirements.

8.1. Production Monitoring

The design features of the power plant and of the power management systems must be such as to guarantee a controllable active power input. For the sole purpose of ensuring grid safety, the Operator may, in the cases indicated below, request a temporary limitation of production, including the cancellation of grid input. To this end, the reduction, implemented by the User and under the

User’s responsibility, must take place without delay and in a short time, i.e. within a maximum of 15 minutes from the sending of the communication [A64].

The causes of limitation of production due to security reasons can be summarized as follows, by way of example and not limited to:

- Ongoing network congestion and/or risk of overloading the National Transmission Grid
- Problems of adequacy of the electrical system
- Possible voltage problems
- Potential risks of electrical system instability

The limitation must be implemented by the User remotely and in any case within 15 minutes. It must be possible in all operating conditions of the plant, starting from any point of operation, in compliance with the maximum power value imposed by the Operator.

It must be possible to reduce production according to steps with a maximum amplitude of 5% of the installed power.

The reduction order from the Operator will be sent electronically or through procedures that guarantee the traceability of the request. The User will then execute the order.

The User may request the Operator to send directly, in the manner indicated by the same Operator, a remote signal (set-point) that imposes on the plant the value of power fed into the network for the purpose of providing any network services (for example, secondary frequency regulation).

8.2. How to Start Up and Reconnect to the Grid

In order to avoid unwanted frequency/voltage transients in parallel with the grid of Wind Power Plants, these must be synchronized with the grid by increasing the power fed in gradually.

In order to ensure the gradual introduction of the power fed into the grid, a maximum positive gradient of no more than 20% per minute of the P_n of the wind farm must be observed.

This requirement applies both in cases of return to service of the Plant (return from an intentional stop) and following reconnection after the intervention of protections for failures or transients of frequency.

Connection to the grid may be made, with Terna's prior consent, within the operating voltage and frequency range indicated in paragraph 6.2 “*Operating limits*”.

In the event of a malfunction in progress or unfavorable conditions for the parallel with the grid, Terna may not allow the return to service and the Plant must keep the HV switches of separation from the network open, even in the presence of internal voltage and frequency values at the intervals specified above.

In any case, the entry into service of the Wind Power Plant with power input is conditioned to a grid frequency not exceeding 50.2 Hz. The control system of the power plant, or of the wind turbines, must comply with this.

8.3. Reactive Power Adjustment

The power plant in parallel with the grid must be able to participate in the control of the voltage of the electrical system. This control must be carried out according to the voltage signal taken from the TVs installed in the HV section of the Plant. The reference voltage value will be communicated by the Operator and must be applied by the User (local logic), even in real time (no later than 15 minutes from the request received from Terna); in addition, the control system of the Plant must be arranged so that the value of the reference voltage or reactive power exchanged by the system can be modulated by remote control or remote adjustment signal sent by a remote centre of the Operator (remote logic).

8.3.1. Capability Curves at the Connection Point

At the connection point, the equivalent capability of the plant is affected by the production of any uncompensated reactive power of the MV cable network and, especially for high values of active power produced, by losses of reactive power in the transformers of LV/MV wind turbines and in the MV/HV lift transformer(s). The over- and under-excitation limit curves of the capability therefore have a curved trend depending on the sizing of these transformers and are therefore different from plant to plant.

It is required that the plant as a whole provides a continuous regulation in the minimum area with red field described below and represented in **Fig. 3**.

The dynamic performances required for this area are shown in the following paragraphs 8.3.2 and 8.3.3.

As far as the zone with active power output higher than a threshold of 10÷20% of the P_{nd} is concerned, it is required that:

• The under-excitation capability limit must be at least equal to 35% Pnd for each active power value;
• The over-excitation capability limit can vary according to a curve (different for each plant) from the value of 35% Pnd up to a minimum value of 20% Pnd at an active power value equal to Pnd.

With regard to the zone with active power output lower than the previous threshold of 10÷20% of the Pnd (grey field area in **Fig. 3**), two different operating modes are envisaged.

• If it is possible to deliver reactive power even at zero power, the maximum deliverable/absorbable value must still be equal to 35% P_{nd}.
• If this operating mode is not possible, a progressive decrease in the value of reactive power Q that can be supplied is required until the contribution for active power values P null is cancelled (for example, V characteristic shown in **Fig. 3**). This operation is required to avoid abrupt step changes in reactive power as a result of the system stopping due to the descent of the wind speed below the cut-in value. In this case, no binding instructions are given on the exact form of the capability limits.
If the wind farm is able to provide wider operating ranges than those prescribed, the User is obliged to agree with the Operator on the relative management methods.

Within the red and grey areas shown in **Fig. 3**, step adjustments through insertion/detachment of static compensation elements are excluded, with the exception of the two cases described below.

• Above a threshold of active power agreed between Terna and the User in the Operating Rules ($P_{distaccoRS}$)[5], it may be possible to disconnect the shunt ballasts of the plant MV grid (if any), recovering areas of reactive regulation.
• In the event of the presence of banks of capacitors (if requested by Terna) these must be inserted above an active power threshold ($P_{inserzione\ BC}$)[6] and below a certain voltage ($V_{inserzione\ BC}$)[7]

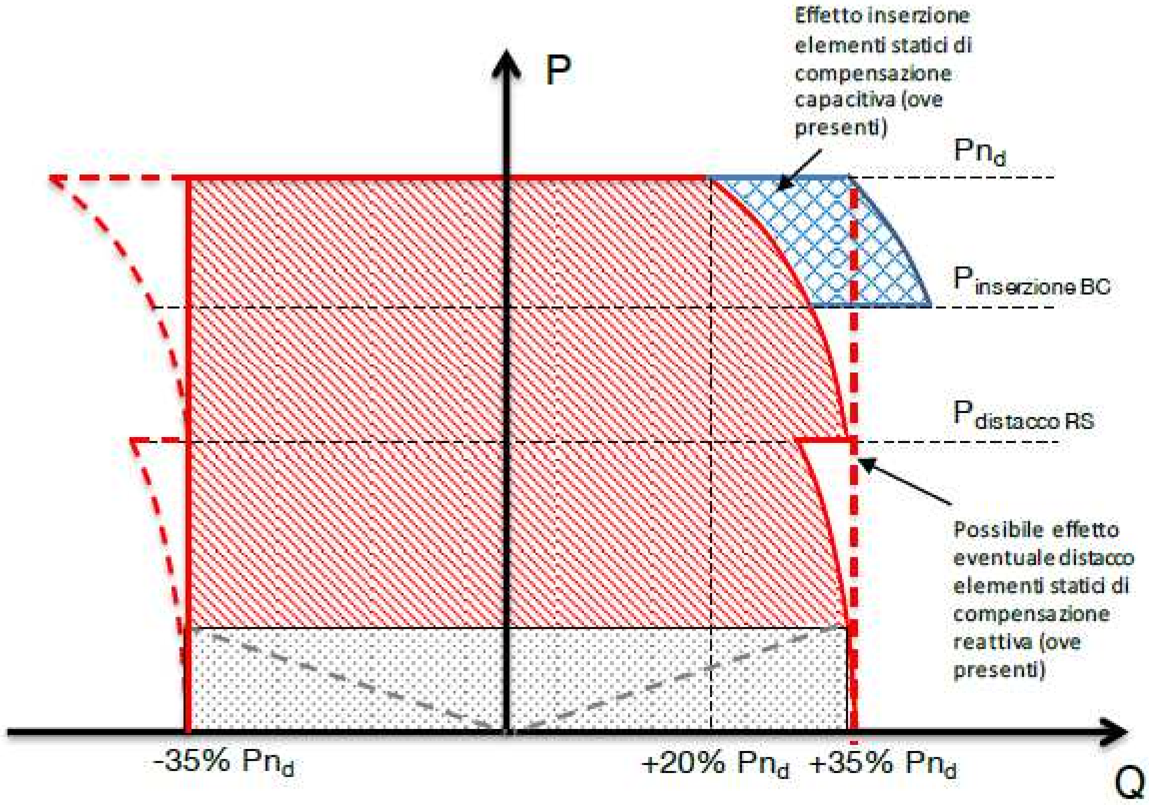
[5] In this case, a hysteresis around this value is allowed (of shared amplitude between Terna and the User) to avoid continuous attacks and disconnections near the threshold value.

[6] As note 4.

agreed between Terna and the User at the level of the Operating Rules in order to partially compensate for the residual inductive losses as indicated by the area spanned in blue in **Fig. 3**. This compensation must guarantee a capacitive reactive power value of 35% P_{nd} for active power P_{nd} values, with a minimum precision of ±2% P_{nd} at V_n.

The capability curve V/Q at the maximum required power P_{nd} (without optional capacitive compensation elements) is shown in **Fig. 4** with red edge.

For voltages outside the ±10% V_n range, reductions on the available capability of the plant are accepted.



Labels translation:

- Effect of insertion of capacitive static compensation elements (if any)
- $P_{\text{insertion BC}}$
- $P_{\text{disconnection RS}}$
- Possible effect of disconnect of reactive static compensation elements (if any)

Fig. 3 – P/Q capability curve of the Wind Power Plant at the HV connection point at rated voltage V_n

[7] As note 4.

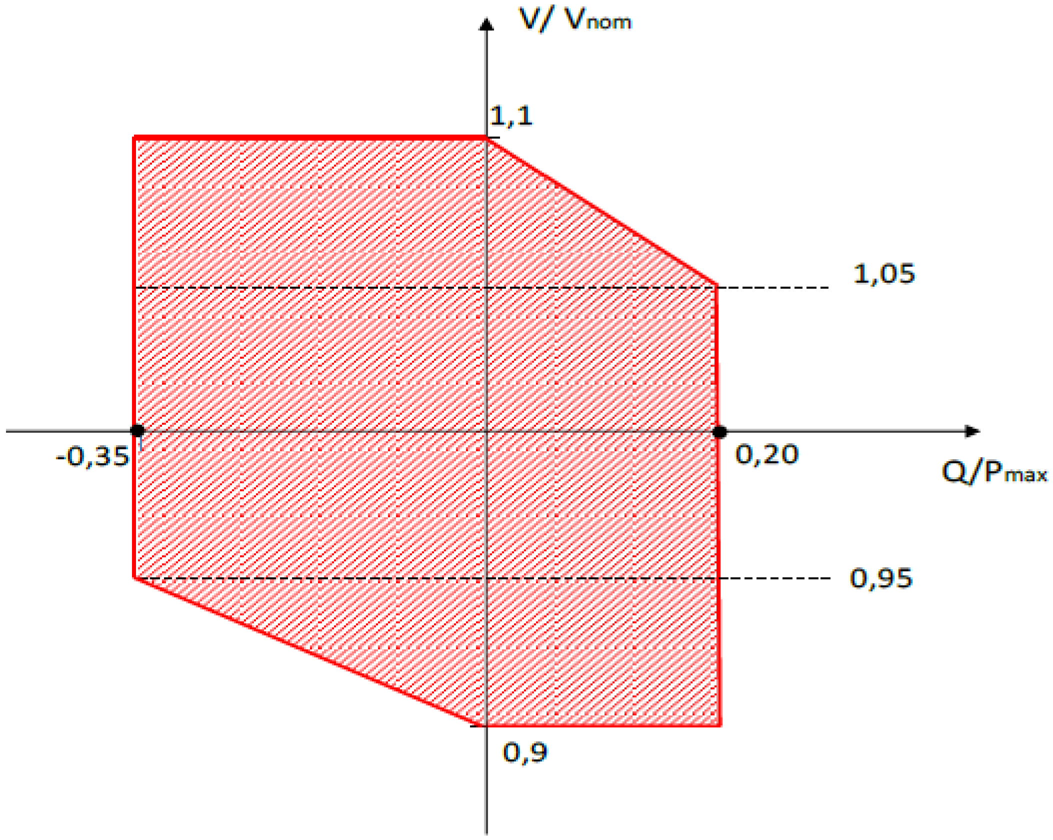


Fig. 4 – V/Q capability curve of the Wind Power Plant at the HV connection point at available rated power P_{nd}

8.3.2. Local Adjustment of Reactive Power (VAT Set-Point)

The reactive power output or absorption of the system must take place according to the characteristic curve Q=f(ΔV) of the type shown in **Fig. 5**. The reactive power output will be proportional to the difference between the set-point and the measured HV value.

The adjustment system must use a V_{rif} value on the HV side communicated by Terna. This V_{RIF} value can be communicated in real time by Terna by means of telephone communication or by computer and/or tele-signal means. will specify in detail the data flow for the set-point exchange in the Operating Rules of each Power Plant. The minimum range of V_{rif} variability must be within the range:

$$95\%\ V_n \le V_{rif} \le 105\%\ V_n$$

The required V_{rif} variability step is less than or equal to 0.1% V_n

The operator will set the voltage values V_{max} and V_{min} according to the connection site. In order to guarantee sufficient precision for voltage regulation, the maximum error accepted on the voltage measurement taken must be 0.5% V_n. The acquisition of the voltage value from the field must take place with a minimum sampling of 1 s. Terna reserves the right to specify update times of the higher values for the need of stability of the control.

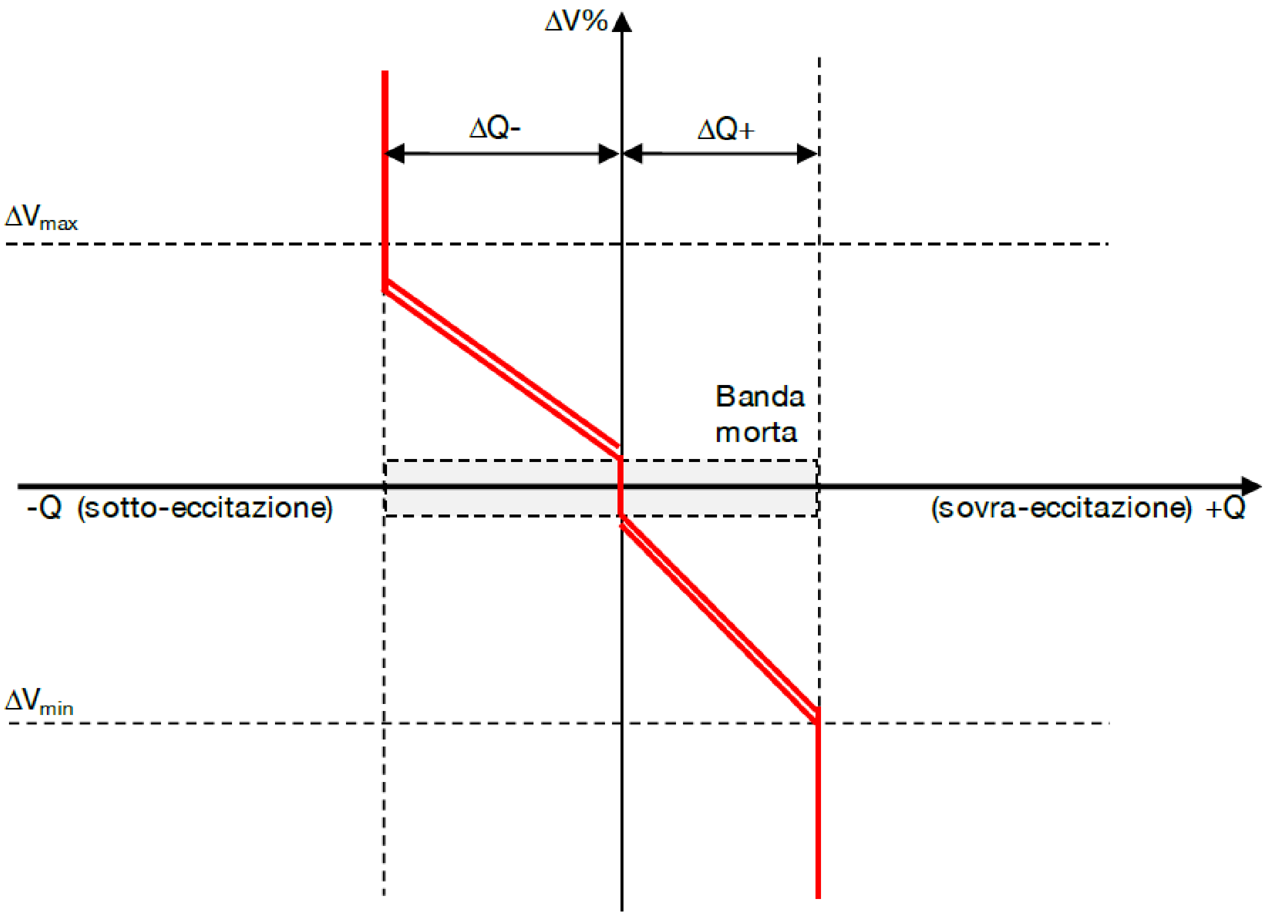
Taking into account the variability of the over-excitation capability limit with the active power, it must be possible to manage different slopes between the over-excitation and under-excitation part.

In this mode, the maximum value required for regulation is 35% P_{nd}; for powers below 10-20% P_{nd} (shaded grey area), the same specifications indicated in the previous paragraphs apply. In these areas, the reactive limits used become lower and lower, approaching zero power.

The adjustment system must make it possible to implement, on request, a dead band around the reference voltage.

Two linear sections are implemented in the inductive and capacitive area as a function of the voltage deviation ΔV% calculated as % of the V_n

In order to limit phenomena of excessive mobility around the point of equilibrium, it is necessary to be able to activate a range of insensitivity of the regulator around the linear characteristic described.



Labels translation:

- -Q (under-excitation) Dead Band (over-excitation) +Q

Fig. 5 – Characteristic curve Q=f(ΔV)

In order to avoid local instability on the reactive adjustment cycle, a proportional/integral closed-loop control must be implemented at the request of the Operator. The parameters will be optimized in the commissioning phase in order to obtain a sufficiently rapid response without overshootings or oscillatory trends. The basic model of this regulation is shown in the block diagram in **Fig. 6**.

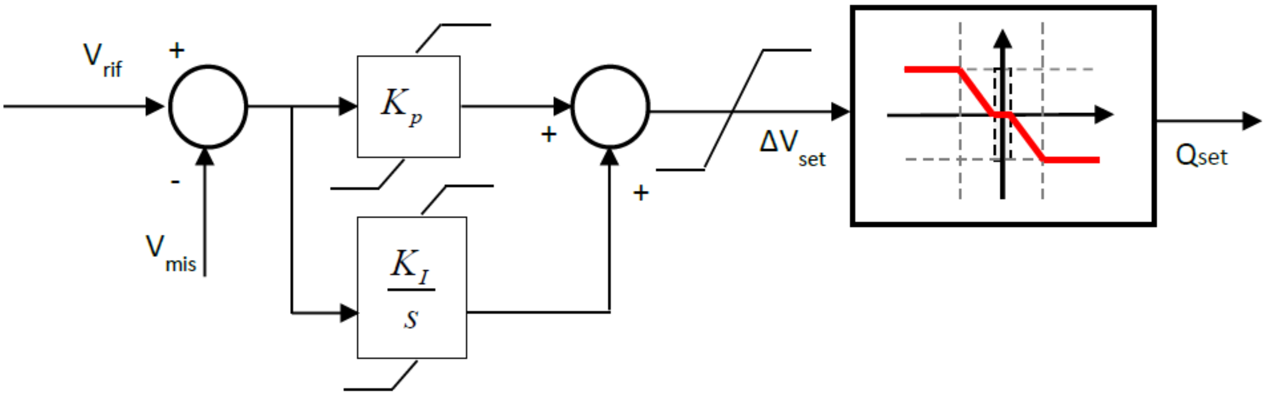


Fig. 6 – Block model of the voltage stabilizing ring

Outside the adjustment range (ΔV_{min}; ΔV_{max}), the Plant must in any case supply the maximum possible reactive power in delivery/absorption as described in the previous paragraph.

The following parameters must be adjustable and calibrated according to Terna's instructions:

- Dead band adjustable from 0 (zero) up to 1% of V_n in steps not exceeding 0.1% V_n
- Controller insensitivity range adjustable from 0 (zero) up to 1% V_n in steps not exceeding 0.1% V_n

Following a mains voltage variation ΔV, the system must be able to deliver 90% of the required reactive power variation within 2 seconds and 100% within 5 seconds with an accuracy of ≤ 5% of the value of the maximum reactive power that can be delivered or ≤ 0.2 MVAr.

8.3.3. Centralized Adjustment of Reactive Power (Set-Point Q)

The wind farm must also be prepared to receive from Terna a reactive power set-point processed by a remote system through suitable telecommunications channels. This reference must be followed through the regulation of the wind turbines up to the limits of plant capability with an accuracy of not less than 5% of the maximum reactive power that can be supplied. In order to allow Terna to calculate the most precise signal to be sent, the plant will supply the maximum reactive power limits available in real time through the same channel. This exchange of information must take place at least every 4 seconds.

Following a change in the required reactive ΔQ, the plant must be able to deliver 90% of the required quantity within 2 seconds and 100% within 5 seconds with an accuracy of ≤ 5% of the value of the maximum reactive power that can be delivered or ≤ 0.2 MVAr.

8.4. Frequency-Dependent Active Power Adjustment

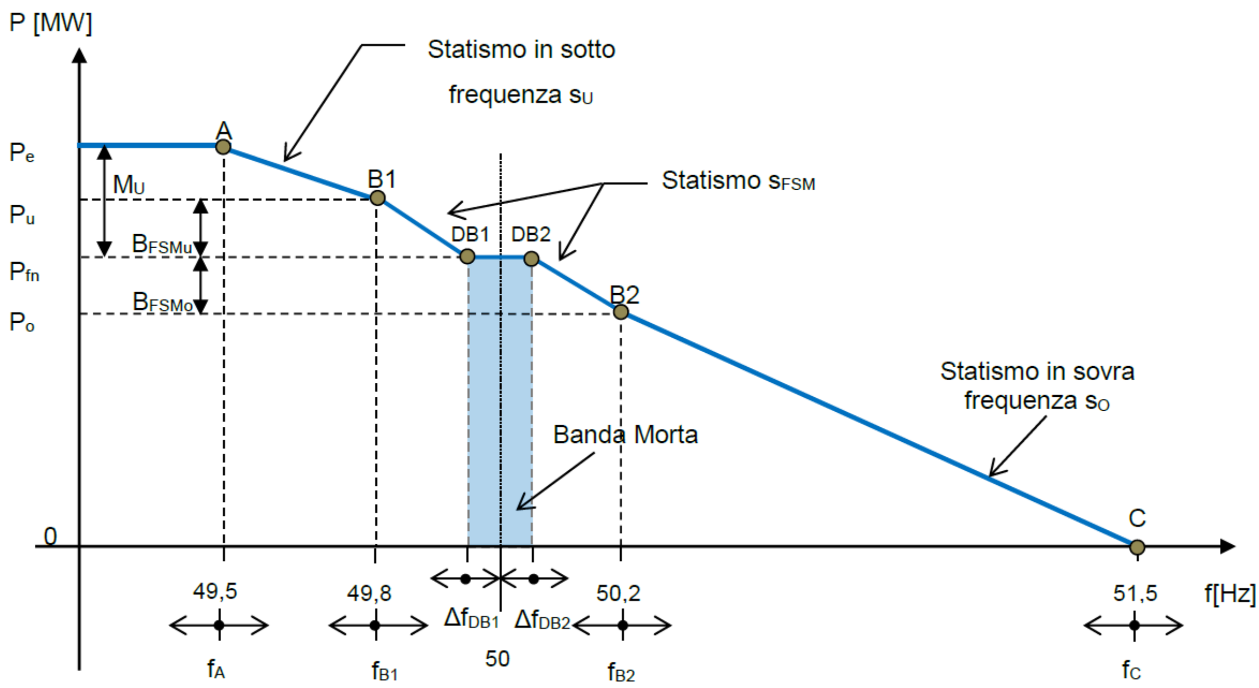
This adjustment is necessary to control the frequency of the electrical system. In consideration of the response times necessary to contain frequency degradation, the actions described cannot be carried out manually by the operator but must be implemented by automatic systems that monitor the grid frequency.

Considering the power P_e that can be supplied, this value must not be reduced in the case of under-frequency transients of less than 1 minute.

The adjustment curve of the active power required is described in **Fig.7**.

There are three zones:

- Adjustment around rated frequency (FSM)
- Adjustment in under-frequency (LFSM-U)
- Adjustment in over-frequency (LFSM-O)



Labels translation:

- Droop in under-frequency s_U
- Droop s_{FSM}
- Droop in over-frequency s_O
- Dead Band

Fig. 7 –P/f curve for a Wind Power Plant

8.4.1. Adjustment around Rated Frequency (FSM)

Wind turbines shall be designed to provide primary frequency control in a manner similar to conventional rotary units around the nominal frequency. This mode, called *Frequency Sensitive Mode* (FSM), must be able to be activated at the request of the Operator.

This adjustment mode must be implemented in a settable range [f_{B1};f_{B2}]

On request, two B_{FSMu} and B_{FSMo} adjustment ranges must be reserved, respectively in under-frequency and over-frequency, between 1.5% and 10% of the value of the available rated power (P_{nd}), avoiding the detachment of the wind turbines in compliance with the declared technical operating limits.

For P_e power values lower than 15% P_{nd}, limitations in the delivery of this regulation are accepted.

The intervention of this mode has priority over the set-points and limitations set.

A maximum insensitivity of 10 mHz is required.

It is required to carry out the adjustment according to a droop straight line s_{FSM} with a dead band Δf_{DB} adjustable in the range [0;500 mHz] according to the indications provided by the Operator.

The time of complete supply (t_2) of this reserve must be less than 2 seconds.

The activation of the response must take place without intentional delays.

8.4.2. Under-Frequency Adjustment (LFSM-U)

Wind farms must be prepared to provide support in under-frequency transients by delivering all the available increasing Margin $M_U = P_e - P_{fn}$ when the under-frequency threshold f_{B1} is exceeded.

This mode, called *Limited Frequency Sensitive Mode Under-Frequency* (LFSM-U), will be provided by the Wind Power Plant whenever the power fed into the grid is lower than the maximum deliverable power as shown in **Fig.7**.

The intervention of this mode has priority over the set-points and limitations set.

If this setting is activated, the system must provide a response according to an under-frequency droop depending on the frequency thresholds f_{B1} and f_A specified by Terna.

The activation of the response must take place in the shortest possible time without intentional delays and the time of supply of this reserve must be less than 10 seconds. In the case of step frequency variations that require power variations of more than 50% P_{nd}, the supply may take place in longer times, but in any case less than 30 seconds.

8.4.3. Over-Frequency Adjustment (LFSM-O)

Wind farms must provide support for over-frequency transients by reducing the power fed into the grid according to the frequency error amount. This mode, called *Limited Frequency Sensitive Mode Over-Frequency* (LFSM-O), is active for frequencies between f_{B2} and f_C according to an s_O droop that cancels the power fed in for a frequency of 51.5 Hz.

The intervention of this mode has priority over the set-points and limitations set.

If FSM mode is not enabled, and the input power is equal to the output power P_e, with activation at f_{B2}=50.2 Hz, the resulting droop value, calculated as a function of P_e, is s_O=2.6%

The activation of the response must take place in the shortest possible time without intentional delays and the time of supply of all the contribution of this reserve must be less than 10 seconds. In the case of step frequency variations that require power variations of more than 50% P_{nd}, the supply may take place in longer times, but in any case less than 30 seconds.

For reasons of mechanical instability, in the case of power reductions below 10% P_{nd}, i the individual wind turbines can be progressively disconnected to approximate the droop line shown in **Fig. 7**.

8.4.4. Adjustment Fields

The following table shows the points of the regulation curve P(f) of **Fig. 7** with their range of calibration and the default values.

Characteristic Point	Frequency Values [Hz]			
	Calibration Range		Adjustment Step	Default Value
A	f_A	47.5 ÷ 50.0	0.1	49.5
B1	f_{B1}	49.5 ÷ 50.0	0.1	49.8
B2	f_{B2}	50.0 ÷ 50.5	0.1	50.2
DB1 – DB2	Δf_{DB1} - Δf_{DB1}	0 ÷ ±0.5	0.05	0
C	f_C	50.2 ÷ 51.5	0.1	51.5

M_U=P_e-P_{fn}, B_{FSMu}, and B_{FSMo} may be included, in case of intentional limitations of P_{fn}, in the calibration ranges shown in the following table:

Parameter	Possible Calibration Range	Adjustment Step	Default Value
M_U	0÷80% P_n	0.1% P_n	0
B_{FSMu} , B_{FSMo}	0÷20% P_n	0.1% P_n	0

With regard to the power values associated with the various points of the P/f curve, the following 3 cases can be distinguished:

Characteristic Point	Associated Power Values [MW]		
	Presence of leading edge M_U and FSM active	Presence of leading edge M_U and FSM not active	Absence of leading edge M_U (FSM not active)
A	P_e	P_e	P_e
B1	P_e-M_U+B_{FSMu}	P_e-M_U	P_e
B2	P_e-M_U-B_{FSMo}	P_e-M_U	P_e
C	0	0	0

8.5. Inertia

Wind turbines must be prepared in order to be able to provide an active inertial response function to the Operator's request in the event of under-frequency transients. The control system of the wind turbines must provide a control loop that allows, depending on the frequency deviation, the delivery of an inertial response by changing the adjustment logic. For a predefined time, higher power values must be supplied at the expense of a lower rotation speed (operating zone for power lower than P_n) or by varying the pitch angle (zone with constant P).

It is required that this system starts to operate by decreasing the frequency below an adjustable reference value in the range [49.5 Hz; 50 Hz] with a step of 0.05 Hz and a default value of 49.8 Hz.

This mode has priority over the set-points and limitations and other frequency adjustments.

The function must be activated in the shortest possible time without intentional delays.

Due to possible mechanical and electrical constraints, this function can be activated if the power supplied at the start of the transient is higher than a limit value specified by the manufacturer of the Wind Turbine Generator and in any case not higher than 30% of the rated power available $P_{nd}.o$ during Fault Ride Through phases.

A surplus of power equal to a value adjustable between [0;10%P_{nd}] with a default value equal to 6% P_{nd} is required.

Following the delivery of the surplus power, in case of operation in the area with a power lower than P_n, it is necessary to restore the optimum conditions by re-accelerating the rotor of the wind turbine. This process (recovery) must take place gradually when one of the following conditions occurs:

a) Return of the frequency above the activation value
b) Upon exceeding an adjustable limit time from the start of the transient (recovery time). This time must be adjustable between the values [0s;30s]; default value 10 seconds.

In case of operation of the wind turbines in the constant power zone, recovery is not necessary. The greater production must therefore be supported as much as possible by the electrical and thermal sizing of the wind turbines, but in any case for a period of at least 10 seconds.

The availability of this inertial response on subsequent under-frequency transients is possible if the power recovery phase has already ended or at least 60 seconds have elapsed since the end of the last additional power delivery.

To implement this function, a suitable frequency filtering system is required.

8.6. Remote Disconnection Systems and Rapid Reduction of Production

Remote disconnection systems allow partial reduction, including the complete cancellation of the production by means of a remote signal sent from a remote center of the Operator.

All plants must be equipped with Peripheral Units of the Defense and Monitoring Systems (UPDM), designed to perform the functions of automatic disconnection, remote triggering, monitoring signals and measurements and, in general, all activities on the plants that allow the emergency control of the electrical system.

The installation and maintenance of the UPDM apparatus in perfect working order are the responsibility of the User. The UPDM must be able to interface with the control systems of the Operator and therefore must belong to the class of equipment described in [A.52]. The User will also be responsible for providing the necessary communication channels with the Operator's control systems according to the criteria prescribed in [A.69].

In order for it to be able to modify the power fed into the grid as required, the Wind Power Plant must be equipped with a system capable of partially disconnecting the wind turbines/rapid reduction to an extent between 0 and 100% of the nominal power, following receipt of a remote signal sent by Terna. At the request of the Operator, the reduction can be divided into 4 blocks.

The disconnection will remain active until the receipt of appropriate revocation commands issued by the same means.

9. MONITORING AND DATA EXCHANGE WITH TERNA’S CONTROL SYSTEM

The User's plant must be integrated into the control processes both in real time and in deferred time to allow:

- In the first case, through the visibility of remote measures and remote signals, the implementation by the Operator of all actions required to safeguard the power system;
- In the second case, through the monitoring systems, the analysis of faults, including verification of proper operation of the protections and the expected behavior of the Power Plant during network disturbances.

9.1. Remote Information

The transmission of remote information[8] to the Operator's control system is necessary to integrate the plant into the control processes. The perimeter of the data and the way in which this information must be acquired by the Operator's system are given in [A.6], while the criteria for connection to it are given in [A.13], to which reference should be made.

In addition, the maximum active and reactive power values available at the connection point must also be sent to Terna in real time with appropriate telemetry with a minimum frequency of 4 seconds.

9.2. Oscilloperturbographic Recording Systems

The monitoring function with the installation of dedicated oscillo-perturbographic recording systems shall be carried out in accordance with the specifications provided in [A.7] for plants of an overall size greater than 50 MW. In particular, the recording of voltages and currents at the Grid Connection Point and the acquisition of signals relating to the protection against internal and external faults at the User's plant are prescribed.

The Operator reserves the right to request dedicated monitoring systems also for smaller plants, if they are of particular importance or according to their Connection Point.

For all systems, the use of protective equipment is still required, provided with systems of internal oscillation-perturbography able to record disturbances of duration equal to the maximum time of intervention of the relays and to return the recordings made in COMTRADE[9] format.

Preliminary tests must be carried out to send oscillo-perturbography files before the plant is put into operation in a manner defined by the Operator.

10. DATA AND MODELS

The owner of the Wind Power Plant shall notify the Operator at least 3 months in advance of commissioning:

a) The plate data and data sheet of all wind turbines, HV/MV and MV/LV transformers, MV cables and reactive compensation systems
b) The models (including firmware version) and serial versions of the guards installed on the HV,

[8] Remote information for the control system is distinguished from measures for commercial accounting purposes (metering).

[9] The prescription relating to the oscilloperturbographs inside the protections is mandatory for the protections installed in the HV section and on the MV side of the Plant MV/ HV transformers, while for those of the MV section it is only recommended.

as well as the related setting files
c) The dynamic simulation models with an appropriate level of detail to simulate the behavior of the installation under steady state and dynamic conditions and during electromagnetic transients.

In relation to point (c), the following shall be provided to the Operator:

- A *detailed* model containing the individual wind turbines, the internal network (MV collection network) and the MV/HV transformer(s);
- An *equivalent aggregate* model consisting of:
  - One Wind Turbine Generator connected in MV, equal in size to the P_n of the wind farm;
  - One MV branch equivalent to the entire internal MV network of the Power Plant;
  - One MV/HV elevator transformer (equivalent if there are several transformers).

The *equivalent aggregate* model must provide responses consistent with those resulting from the *detailed* model in front of load steps, voltage steps, frequency transients and symmetrical and dissymmetrical short circuits. The results of the comparison may be provided in a free format.

The following shall be described in the models:

- The dynamic model of the inverter (Full Converter) or DFIG machine;
- The limits of capability of the wind turbines;
- The dynamic models of the mechanical part; for example, but not limited to: rotor, speed multiplier, pitch controller;
- The dynamic models of the P/f and Q/V regulators of the wind turbines and the Plant Controller;
- The dynamic model of the inertia control module;
- The models (characteristics and parameterizations) of the protection system;
- The mathematical model of the current harmonic emissions.

The models can be provided in free format, i.e. Excel sheets (or text files), block diagrams (without black box) with explicit parameters used, transfer functions, and equations.

The Operator may request complete dynamic models used in widely used standard formats.

11. TESTS

To complete the normal commissioning tests, specific real tests are required to confirm the suitability of the system for the requirements contained in this document.

The results should be contained in a detailed report provided to the Operator.

In particular, the following tests shall be documented:

- Voltage adjustments with steps on the reference voltages;
- P/f adjustments;
- Variations of the power set-point with load steps;
- Plant capability curve;
- Measurement of current harmonic distortion, for each harmonic and total.

The Operator reserves the right to request, in its presence or in the presence of a Qualified Person, the performance of the above-mentioned functional tests under the inspection tests framework.