PROCEDURE FOR VERIFICATION VALIDATION AND CERTIFICATION OF THE REQUIREMENTS OF THE PO 12.3 ON THE RESPONSE OF WIND FARMS AND PHOTOVOLTAIC PLANTS IN THE EVENT OF VOLTAGE DIPS

Version 9

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1. PURPOSE

The purpose of this document is to provide a procedure for measuring and assessing the response of wind farms in the event of voltage dips. This procedure must ensure the uniformity of tests and simulations, the precision of measurements and the assessment of the response of wind farms in the event of voltage dips. The requirements for the response to dips are specified in the electrical system Operational Procedure 12.3.

2. FIELD OF APPLICATION

Voltage dips are sudden falls in voltage, mainly caused by faults in the grid. Voltage dips are random events and may be described in terms of the level of the voltage during the dip and its duration. A fault may also cause a phase jump in the voltage wave. Different types of dips may therefore be specified to assess the response of a wind farm.

This document contains:

- The testing and measurement procedures for the individual response of a Wind Turbine Generator (WTG) or Flexible Alternating Current Transmission Systems (FACTS) device in the event of voltage dips.
- The validation procedures for computer models of WTGs or FACTS devices based on the measurements recorded in the field tests.
- The procedures to check compliance of wind farms with the response requirements in Operational Procedure 12.3.

In order to issue certified reports in each of the procedures described above, the laboratory must be accredited according to the ISO/IEC 17025 standard, or certification bodies accredited according to EN45011 standard.

These verified reports will be the technical basis that allows the Ministry of Industry and Commerce or any delegated authority to check compliance according to the fourth additional disposition of Royal Decree 436/2004, relating to the continuity of supply during voltage dips.

The creation of a Technical Verification Committee is proposed, in order to verify and follow the compliance with this procedure. The specific works of this committee are specified in section 5.1 of this document.

3. DEFINITIONS AND ABBREVIATIONS

The following definitions are used in this document:

WTG: A system for converting the kinetic energy of wind into electrical energy.

Note: The WTG includes the wind turbine, the mechanical transmission system, the electrical generator, the control system and all its power systems (which may include electronic converters, reactive compensation systems, transformer, etc.).

WTG terminals: The point of the WTG identified by the supplier as the point for connecting the WTG to the power collecting system (IEC 61400-21).

Accredited certifier: Public or private entity, that exists for the purpose of establishing conformity - which is voluntarily solicited by a specific company, product, process, service or person - with the requirements defined in norms or technical specifications in accordance with the Royal Decree 2200/1995

Technical Verification Committee: Grouping of representatives of the different agents that participate in the execution and operation of wind farms, whose mission is to supervise and follow compliance with the present procedure.

Fundamental component: Component with the fundamental frequency (IEC 61000-4-30).

Wind farm configuration: The electrical characteristics of the wind farm that define its behaviour within the grid. This includes the WTGs, the power lines (overhead and underground), the transformers and any other element, which may influence the electrical performance of the wind farm.

Continuity of supply of a WTG during a voltage dip: The capability of a WTG to remain connected to the electrical system during a voltage dip, complying with Operational Procedure 12.3.

Nominal current of a WTG (I_n A): The WTG's line current when the WTG is operating at the nominal power with nominal voltage and frequency.

Reactive current of a WTG: Net reactive current (I_r A) obtained each period as:

$$I_r = I^+ \cdot sen(\varphi)$$

Where:
I^+: is the magnitude of the fundamental component of the positive sequence of the current in (A)

φ: Angle between the fundamental component of the positive sequence of the voltage and the current (rad).

Total Current: net current I_{tot} (A) obtained each period as:

$$I_{tot} = I^{+}$$

Where:

I^{+} is the magnitude of the fundamental component of the positive sequence of the current in (A)

FACTS (Flexible AC Transmission System) device: System based on power electronics and other static devices whose purpose is to improve the control of electrical transmission systems in AC and improve its power transmission capability. This device may be used to compensate for the effects of voltage dips in electrical installations. In this document this term is used to designate installed electrical equipment in a WTG, wind farm or the grid connection point.

Note: There are various systems for this on the market, such as, for example, dynamic voltage restorers (DVRs), static synchronous compensators (STATCOMs), static VAr compensators (SVCs), etc.

Dip duration: In a three phase system, a dip starts when the voltage $\mathbf{U_{ef(1/4)}}$ of one of the phases drops below the dip threshold and ends when the voltage $\mathbf{U_{ef(1/4)}}$ in all of the channels measured, is equal to or higher than the dip threshold (IEC 61000-4-30).

Net active energy: Active energy obtained from the numerical integration of the active power in a given period of time.

Net reactive energy: Reactive energy obtained from the numerical integration of the active power in a given period of time.

Voltage dip: A temporary voltage reduction at a point in the electrical power grid below the dip threshold (IEC 61000-4-30).

Note 1: Typically, a dip is associated with the start and end of a short circuit in the grid.

Note 2: A voltage dip is an electromagnetic disturbance characterized by two parameters, the voltage and the duration of the dip. Furthermore, a fault can produce a phase jump in the voltage wave, although its characterization is more complex because it depends on the ratio between the angle of the grid impedance and the angle of impedance of the fault.

Accredited laboratory: Entity accredited according to UNE EN ISO/IEC 17025, to perform field tests in WTG and/or FACTS, granted by ENAC (*Entidad Nacional de Accreditación*) or another accreditation company with which ENAC has signed an agreement of mutual recognition. This accreditation can be extended for the completion of corresponding simulations by the same laboratory.

Endorsed laboratory: Institution that complies with the requirements fixed by the accredited certifier for the completion of only the wind farm simulations required in this document and which receives the corresponding guarantee by this same accredited certifier.

Wind farm: A group of several WTGs at a specific site with one single grid connection point, which owns an administrative authorization and a definitive registry code as special regime.

Note: A wind farm is made up of WTGs, electrical lines connecting them and the transformer sub-station for connecting the wind farm to an electrical energy transport or distribution grid, together with all of the power systems in it, up to the grid connection point (transformers, reactive compensation systems, FACTS, etc.).

Net active fundamental power: Active power obtained each period as:

$$P = 3 \cdot U^{+} \cdot I^{+} \cdot \cos(\varphi)$$

Where:

U^{+} is the magnitude of the fundamental positive voltage sequence component.

I^{+} is the magnitude of the fundamental positive current sequence component.

φ existing angle between the positive sequence component of the voltage and the current.

Apparent power assigned to a WTG: Apparent power (S_n) of a WTG when operating at its assigned power and at nominal voltage and frequency (IEC 61400-21).

Assigned reactive power of a WTG: Three phase reactive power (Q_n) of a WTG when operating at its assigned power and at nominal voltage and frequency.

Net reactive fundamental power: Reactive power obtained each period as:

$$Q = 3 \cdot U^{+} \cdot I^{+} \cdot sen(\varphi)$$

Where:

U^{+} is the magnitude of the fundamental positive voltage sequence component.

I^{+} is the magnitude of the fundamental positive current sequence component.

φ existing angle between the positive sequence component of the voltage and the current.

Nominal registered power of a WTG: declared active power (P_n) that the WTG can supply in its terminals under normal working conditions.

Developer or generation company: legal entity that either owns a wind farm, or has delegated powers to subject the wind farm to the verification process.

Grid connection point: A node in the transport or distribution grid used to transmit the power produced by the wind farm.

Test point: Any point between the terminals of the element to be tested and the grid connection point as long as it includes less than or equal to the number of elements equivalent to those in a wind farm (sub-station transformer, step-up transformer for the elements to be tested, medium and high voltage lines).

WTG power collecting system: An electrical system which takes the energy produced by a WTG and supplies this to an electrical power transport or distribution grid (IEC 61400-21).

Reference voltage (U_{ref}): Threshold of tolerance of U_{res} +3%, to guarantee that overlapping among the areas defined in O.P. 12.3 does not occur, which allows the consumption of active and reactive power to be determined.

Effective voltage updated every quarter of a cycle ($U_{ef(1/4)}$): Value of the effective voltage measured in a period and updated every quarter of a cycle (IEC 61000 - 4 -30).

Nominal voltage of a WTG (U_n kV): The designated or identified voltage between phases of the WTG at the terminals (IEC 61000-4-30).

Residual dip voltage U_{res}: The minimum value of the voltage $U_{ef(1/4)}$ recorded during the dip (IEC 61000-4-30).

Dip threshold: Voltage value specified for detecting the beginning and end of the dip (IEC 61000-4-30). OP 12.3 specifies 0.85 pu as the dip threshold.

ABBREVIATIONS

3f , 2f	Three phase, Two phase
CNE	Comisión Nacional de Energía (National Energy Commission)
CS	Energy Collecting System
GCP	Grid Connection Point
HV, MV, LV	High Voltage, Medium Voltage, Low Voltage
MITYC	Ministry of Industry Tourism and Trade
OP	Operational Procedure
PVVC	Procedure for Verification Validation and Certification
REE	Red Eléctrica de España (Spanish Electrical system operator)
TP	Test Point

TVC	Technical Verification Committee
WTG	Wind Turbine Generator

4. VERIFICATION PROCESS

The end purpose of this procedure for measuring and evaluating the response of wind farms in voltage dips is to certify its conformity with the response requirements specified in Operational Procedure 12.3 for the electrical system.

Generally, the certification process includes the following verifications of specified requirements:

- Verification that the wind farms do not disconnect as a consequence of voltage dips in the GCP associated with correctly cleared short circuits according to the voltage time curve indicated in the OP 12.3.

- Verification that the power and energy consumption (active and reactive) in the GCP, for balanced and unbalanced faults, are less than or equal to the levels marked in OP 12.3.

Figure 1 shows the verifying process flow diagram, which may be completed by executing two optional processes:

- General verification process.
- Particular verification process.

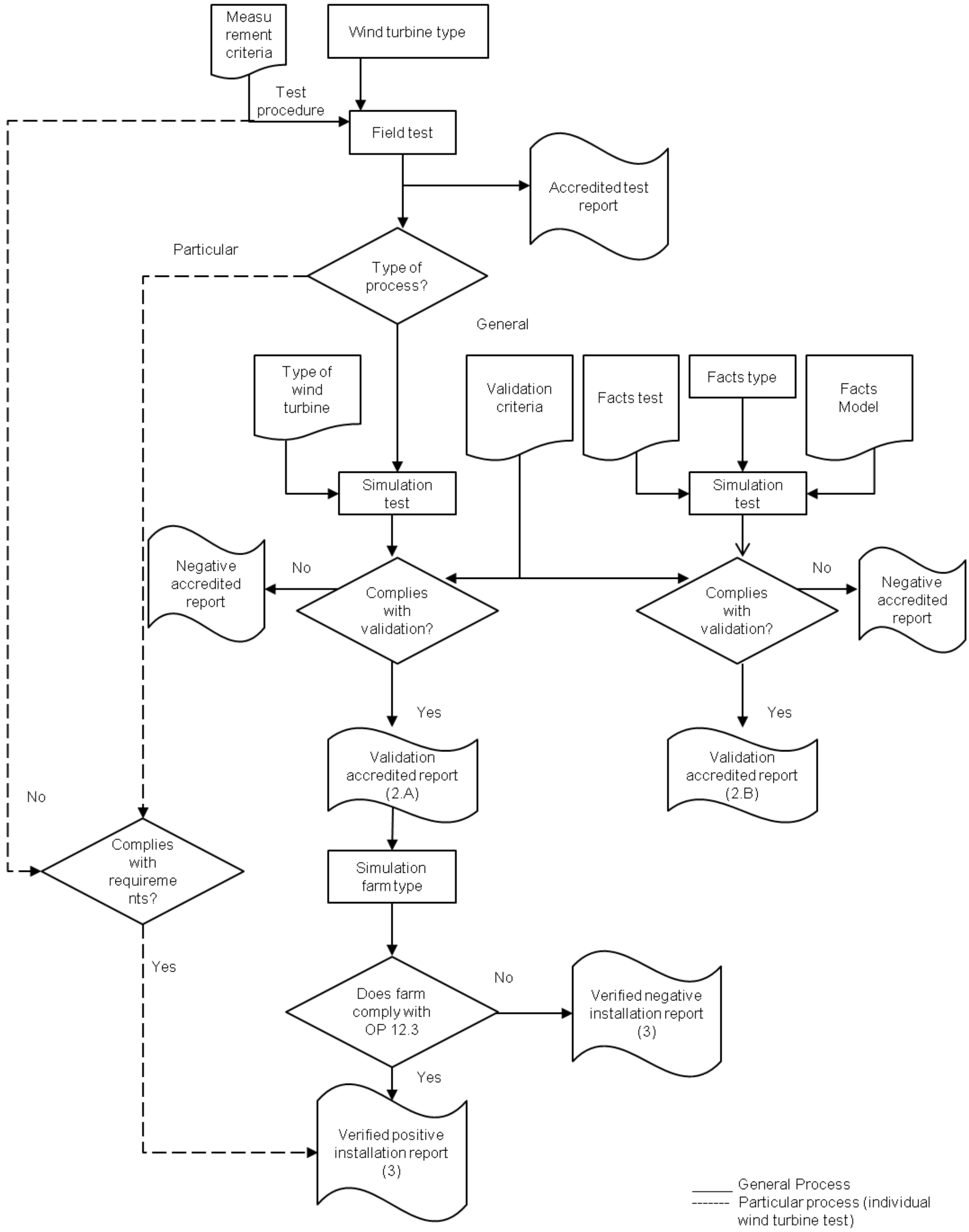

Figure 1. Flow chart of the stages of the verification process

The owner of the wind farm to be verified will be able to choose between the general and particular processes. If it is necessary to follow the general process the manufacturer is obligated to supply the model for new wind farms as well as existing ones.

4.1. GENERAL VERIFICATION PROCESS

The general verification process consists of verifying that the wind farm does not disconnect and that the requirements stated in the OP 12.3 are met, by means of the completion of the following actions:

1. WTG and/or FACTS test
2. WTG and/or FACTS simulation
3. Wind farm simulation.

Upon satisfactory execution of these actions the following reports will be obtained:

(1) ACCREDITED TEST REPORT

It includes the field test and the corresponding measures that allow the response of the WTG and FACTS during a voltage dip to be verified.

For FACTS, laboratory tests could be accepted, if the manufacturer demonstrates that the conditions are similar to those which present themselves in the field, provided that the certifier does not have a contrary opinion. When the FACTS is included in the WTG, the tests carried out are those of the WTG itself.

Upon completion of this stage, a verification of the completed tests will be carried out and an ACCREDITED TEST REPORT (1) will be issued by the accredited laboratory with the format included in ANNEX I. For FACTS and in the case of laboratory tests, the results will also be verified and accepted by an accredited laboratory.

(2) ACCREDITED REPORT OF MODEL VALIDATION

In accordance with the measurement criteria described below in this document, a simulation model will be produced whose validity must be confirmed by the measurements recorded and accredited in the field tests. These validation criteria are set by comparing these measurements with those from the reproduction of the tests in simulation. The validation criteria are given in Section 7 of this document. Upon completion of this stage, an ACCREDITED REPORT OF MODEL VALIDATION will be issued by the accredited laboratory, be it the same or a different one that carried out the field tests.

The accredited reports of model validation are classified as:

- type 2.A for WTGs
- type 2.B for FACTS

(3) VERIFIED WIND FARM SIMULATION REPORT

The simulation models of all dynamic elements of the wind farm (WTGs and/or FACTS), once their validation reports have been obtained, will be integrated inside a wind farm simulation model. Using this model, a wind farm simulation will be carried out evaluating the response of the wind farm in the GTP as it is described in the section 8. From the results of the simulations, the endorsed laboratory will produce a VERIFIED WIND FARM REPORT (3).

4.2. PARTICULAR VERIFICATION PROCESS

As alternative to the general procedure, it will be possible to obtain the direct wind farm verification, by testing the dynamic elements of the wind farm and without having to carrying out computer simulations. In this case, the conditions in the field test will be harsher than those that would have to be endured in the event of a voltage dip in the GCP, as indicated in OP 12.3 and it is required in the General Process of Verification.

The requirements that the WTG should meet during the field tests for this particular process are indicated in the section 6.2.2 of this document.

4.3. WIND TURBINE GENERATOR TYPE

A type of WTG is defined as one that possesses the ACCREDITED TEST REPORT, as a result of the pertinent tests and simulations.

In order to avoid having to repeat field tests, for WTGs of the same manufacturer, of similar characteristics and components, a WTG TYPE is defined as that which includes WTGs that meet the following specifications:

- Electrical generator with the same design specifications:
    - Nominal power ±25%
    - Same type[1]
    - Same stator connection voltage (only asynchronous WTGs)
    - Transformation ratio ±20% (only asynchronous WTGs)
    - Same number of poles

- Electronic converter(s), if existing, with the same hardware and specifications to withstand voltage dips.

[1] The generator type must be: asynchronous with winding rotor or short-circuited rotor or synchronous with independent excitation or permanent magnets.

- Transformer short circuit voltage percentage, based on the assigned power of the WTG, within a range of ±20% of the value shown on its data plate. This point will not apply to WTGs without transformers connecting them to the medium voltage circuit.

- Compensation system with the same properties and technology and with an assigned reactive power equal to or greater than that of the WTG being tested.

- Nominal registered power for the WTG (P_n MW) within a range of ±25% of the value for the WTG being tested.

- Specific software for complying with the continuity of supply and voltage dip requirements, including protections and control. This software will be endorsed by the manufacturer.

If a software update takes place that may affect the programming code for the response to voltage dips, the manufacturer will declare these modifications and will verify that they do not affect the compliance of the solution to voltage dips. The manufacturer has to submit the simulations and additional information considered necessary. The accredited certifier will produce the corresponding report on the compliance of the changes proposed to the WTG.

The ACCREDITED TEST REPORT (1) and the ACCREDITED MODEL VALIDATION REPORT (2.A) will be valid for any other WTG considered to be within its type category.

Whenever a group of WTGs share a common MV/LV transformer, it is possible to carry out a single field test of said WTG group, which would be treated as a single unit. It is necessary that at the moment of the test, all of the turbines comply individually with the requirements set on Table I on operation point.

Each WTG group may be treated as a single unit to the effect of validating an equivalent model (section 6.2.1) or tested according to the particular procedure for compliance with P.O. 12.3 (section 6.2.2).

4.4. WIND FARM TYPE

The response to voltage dips of many of the wind farms connected to the Spanish electrical system is similar when they are comprised of WTGs of the same type and when the electrical properties up to the GCP meet a series of common requirements.

A wind farm is considered a **wind farm type** if it possesses the VERIFIED WIND FARM REPORT (section 4.1 (3)) according to the general process for pertinent tests and simulations.

In order to avoid unnecessarily simulating wind farms similar to those included in the category of **wind farm type**, a wind farm will be accepted as valid (and therefore with VERIFIED WIND FARM REPORT (3)) whenever it can be declared as belonging to a certain **wind farm type**. A wind farm cannot be considered to be a **wind farm type** unless it has completed all the pertinent tests and simulations.

The definition of **wind farm type** will be proposed by the owner of the wind farms to be verified, accepted previously by accredited certifier, and will include at least the following data:

- The normalized short circuit impedance[2] of all of the electrical elements (transformers and lines) between the medium voltage side of the wind farm and the GCP.

- Connection group of the transformers and neutral of the electric system between the MV side of the wind farm and the GCP.

- The assigned power of the reactive compensation systems in ratio to the registered power of the wind farm.

- WTGs of the wind farm type

The validation criteria of the given parameters for which a wind farm can be considered to belong to a **wind farm type**, are the following:

- The normalized short circuit impedance[3] of the wind farm in a margin of ±20% of the defined magnitude for the wind farm type.

- Connection group of the transformers and neutral: the wind farm should have equal connection groups and neutral as those defined in the wind farm type.

- The assigned power of the reactive compensation systems in ratio to the registered power of the wind farm greater than or equal to that of the wind farm type.

- The relative quantity[4] of WTGs of the same type or belonging to that type must be identical to those in the **wind farm type**.

The accredited certifier will verify that each new wind farm belonging to the same owner meets the configuration on wind farm type defined by him.

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[2] The base magnitudes will be the nominal power of the wind farm and the voltage level of the GCP
[3] The base magnitudes will be the nominal power of the wind farm and the voltage level of the GCP.
[4] The relative quantity will be the quotient between the number of the WTGs of the same type (or belonging to the type) with respect to the total number of WTGs in the wind farm.

The VERIFIED WIND FARM REPORT (3), in the category of **wind farm type** will only be valid for wind farms meeting the following requirements:

- The WTGs and/or FACTS must have an ACCREDITED TEST REPORT (1). It will also be necessary for the WTGs to have an accredited model certification report (2.A). The FACTS devices must have an accredited model validation report (2.B).

- The electrical characteristics are within the tolerances and specifications indicated in the definition of **wind farm type.**

Wind farm type simulation will be carried out only once and will be done with the characteristics and topology indicated by the owner whose wind farms are to be verified, using validated models for all dynamic elements inside the wind farm (WTGs and/or FACTS).

All those installations that meet the above requirements will directly receive a verified wind farm simulation report without needing additional simulations. Each installation that is not within the wind farm type category must carry out a specific simulation of the wind farm.

4.5. MIXED WIND FARMS

This section covers the case of wind farms consisting of several wind turbine models suitable and not suitable for which the not suitable capacity exceeds 5% of the total power of the wind farm.

The solutions used in such mixed wind farms can be for individual wind turbines or for the wind farm as a whole and the certification procedure can be performed by general or particular procedure. The rules to be followed in both cases are:

- Certification by the general procedure of verification. In this case a partial adjustment is allowed, accepting that the non suitable turbines can trip during the simulation. The certification of the suitable part of the farm will be made according to the overall verification procedure defined in paragraph 4.1. Not suitable turbines may be fitted with trigger devices or other devices, which promote compliance with the needed requirements of the general procedure for the suitable part. The certificate is issued by the suitable part of the wind farm, clearly indicating the turbines to which it applies.
- Certification by the particular procedure. In this case the solution should be turbine-level with the accredited report for the wind turbines that have it, and a trip relay (set at 100 ms) for not suitable turbines. The trip relay of the turbines will be installed to avoid that the active and reactive consumption of the not suitable turbines causes the tripping of the suitable machines."

In those cases where all the wind turbines of the wind farm meet the requirements, except for any that may be considered non adaptable and when the non-adapting power does not exceed 5% of the nominal power of the wind farm, the complete installation is considered as verified. For wind turbines that remain to be adapted, the developer must ensure that they are provided with a system that ensures disconnection in less than 100 ms in case of voltage dip.

5. VERIFICATION AND CERTIFICATION BODIES

5.1. THE TECHNICAL VERIFICATION COMMITTEE

A specific TECHNICAL VERIFICATION COMMITTEE (TVC) will be created, that will supervise the execution of this PVVC and will make decisions and propose appropriate correction mechanisms in the specific topics mentioned in this document. In general terms the TVC will be comprised of and governed by statutes created for this purpose.

All of the wind energy sector representatives will participate in this body: the electrical system operator, REE; WTG and FACTS manufacturers; wind farm promoters and test laboratories.

In general terms, the functions of this TVC will be at least the following:

- To follow the correct application of this PVVC.
- To arbitrate in the event of disagreement and based on specific elaborated reports.

Which are specified as:

(1) To propose the criteria for the validation of the laboratories that produce the VERIFIED WIND FARM VALIDATION REPORTS (3).

(2) To include the pertinent modifications of the present PVVC in accordance with the obtained results. Once modified it must be presented to the Subdirección General de Energía Eléctrica of the MITYC.

(3) To assist in the completion of the functions of the accredited certifiers and more specifically, to arbitrate in the case of disagreement (in the most anonymous and confidential manner possible), on modifications to established WTG types, FACTS and wind farms.

The statutes for the specific operation of this TVC will determine the internal operation, the issuing of reports and the election of representatives with highest precision.

5.2. THE ACCREDITED CERTIFIER: FUNCTIONS

The accredited certifier has the task of ensuring that the aforementioned documents for the verification and validation of compliance of a wind farm with the requirements set in the OP 12.3 comply with what is established in this document and subsequently certify it. If the conditions are not met, a report specifying the reasons for this noncompliance must be produced.

The accredited certifier will sign an agreement with the petitioner in which economic considerations, timeline and compromises of the signatories will be established.

The accredited certifier will also endorse the laboratories that carry out the wind farm simulations based on corresponding accredited reports and certified models, on the basis of the criteria defined by the TVC.

In case of variations on the established types, the accredited certifier will:

(1) Approve that the modifications proposed by the manufacturers are within the WTG type certificates available and do not affect the requirements set in OP 12.3.
(2) Approve changes in the type or configuration of FACTS in such a way that they do not affect the type described in the FACTS' ACCREDITED MODELS VALIDATION REPORT (2.B)
(3) Approve the wind farm type proposed by the promoter and to determine if the wind farms to be validated fit this type.

The accredited certifier will periodically check the effect of the configuration changes to the initially produced certificate, when needed. If differences are observed, the Certifier will issue a corresponding report to the Subdirección General de Energía Eléctrica, which will determine the action to be taken.

The certification process will be the following:

- Reception of the petition of the corresponding certification, together with the documents specified in this PVVC. The petitioner must identify the contact person for later steps.
- Checking of documentation and issuing of the corresponding acknowledgement of receipt.
- Opening the file, assigning the corresponding code and initiating the processing, if the information is valid according to this PVVC.
- Issuing the invoice.
- Producing the pertinent confidential reports prior to certification, based on the present documentation and the controls that are considered necessary.
- Any additional information that is considered necessary to complete the certification will be required of the petitioner, as well as any appropriate correcting actions for the completion of the requirements of this PVVC.

The issues that are not addressed in this PVVC will be regulated by the specific guidelines of each accredited certifier.

6. TEST PROCEDURE

This section specifies the conditions and validity criteria for field tests as well as defining the equipment needed to carry out this test. It also specifies the measurements required to determine the typical properties of the WTG or FACTS response to dips.

The procedures described in this section are valid for WTGs and FACTS devices of any power with a three phase connection to an electrical grid.

The measurements will be used to check the typical parameters for the response to voltage dips throughout the operating intervals of the WTG or FACTS device tested.

The properties measured are only valid for each WTG type. Variations in the configuration that could affect its response to voltage dips will affect their type classification and will require another test.

6.1. TEST EQUIPMENT

The use of test equipment including a voltage dip generator using an inductive divider (Figure 2) is recommended. This figure shows a single line diagram of the voltage dip generator located among the power collecting system SC and the equipment to test (WTG or FACTS).

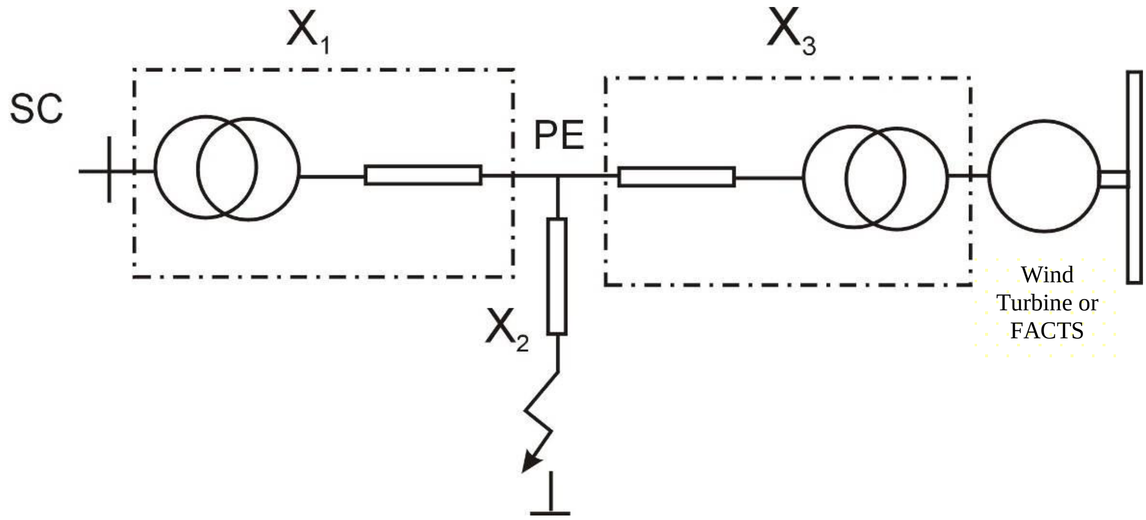


Figure 2. Voltage dip generator equipment

This dips generator must comply, at least, with the following requirements:

- The function of the impedance X_1 is to limit the short circuit current contributed by the electrical network in which the test is carried out. It may represent a combination of reactances or transformers and will be of such value that the short circuit power in the test point, TP, is greater than or equal to 5 times the registered power of the WTG or FACTS being tested. In case it is unviable to realize a test with a short circuit power higher than 5 time the registered power of the WTG or FATS then tests with a lower power can be carried out if requirements on sections 6.2 and 6.3 are met.
- The impedance X_2 will be adjusted in such a way that the voltage at TP is the same as that for the three-phase and two-phase faults (see section 6.2)
- In the branch where the impedance X_2 is found, there must be a switch that operates in such a way as to generate three-phase and isolated two-phase voltage dips.
- Impedance X_3 will be the following may be a transformer or a combination of reactances and transformers. The impedance X_3 will take the one of the following values:

  - Without step-up transformer: X_3 =0

  - With step-up transformer there are two cases:

    a. X_3 will take the value of the short circuit impedance of the transformer.
    b. X_3 will take the value of the short-circuit impedance of the step-up transformer in normalized value with a tolerance of ±20%

- If additional transformers are used, in the position of reactance X_3, these may have any transformation ratio and will have the same connecting group as the step-up transformer of the WTG or FACTS (if any exists).

In the case of dip generators that do not have the inductive divider, it is necessary to check that the residual voltages in the magnitude and argument in the three phases are similar to those that result from simulating or testing three and two-phase short circuits with an inductive divisor as defined in this document.

The equipment described in this section only applies to the WTG field testing.

6.2. WIND TURBINE GENERATORS TEST

The definition and conditions in which the WTG test will be carried out will depend on the objective that is sought with the test. Therefore, the tests may be

- Tests for validating the simulation model (general verification process).
- Tests for direct observance of the O.P. 12.3 (particular verification process)

The following are the characteristics common to both tests.

For each of the two cases, the complete WTG should be tested in the field and the test should be carried out considering the following operation points (Table I)

Table I. Operation points prior to the test

	registered active power	Power factor
PARTIAL LOAD	10%-30% Pn	0,90 inductive -0.95 capacitive
FULL LOAD	>80% Pn	0,90 inductive -0.95 capacitive

The accredited laboratory will confirm that neither a particular moment for the short circuit and later clearance, nor a power factor that would be especially favourable to the permanency of the WTG coupled during the voltage dip, have been chosen.

The test must be carried out using the dip generator to apply three-phase and isolated two-phase faults that cause voltage dips in the affected phases whose properties, based on Operational Procedure 12.3, are specified below. The specified properties of the voltage dip must be independent of the response of the WTG being tested. Depending on the existing short-circuit power at the test point (TP); the way to get the voltage dip profile to apply has to be identified:

- If the short circuit power in the TP is equal to or greater than 5 times the power of the wind turbine registered to be tested, the dip is to be obtained by testing it with the wind turbine generator disconnected from the dip generator (“no load test” from now on). In the on-load test the adjustment of the impedances of the voltage dip generator will be the same as in the no load test

- If the short circuit power in the TP is less than 5 times the registered power of the wind turbine to be tested, the profile of the dip must be obtained through the load test.

Four categories of test must be carried out in the procedure (Table II)

Table II. Test categories

CATEGORY	Operating Point	DIP TYPE
1	PARTIAL LOAD	THREE PHASE
2	FULL LOAD	THREE PHASE
3	PARTIAL LOAD	TWO PHASE ISOLATED
4	FULL LOAD	TWO PHASE ISOLATED

As a result of the test, the ACCREDITED TEST REPORT (1) will be produced in accordance with the format that is included in ANNEX I.

6.2.1. Test conditions for model validation

The WTG test conditions for validating the model are the following:

- Point of measurement: for the validation of the WTG or FACTS model, the point of measurement may or may not coincide with the testing point. The model to be validated will include all the elements downstream of the point of measurement. For example if a test is chosen with the test and measuring points in MV, the dynamic behaviour of the WTG plus the step-up transformer will be validated. However, if the test is carried out in MV and the measure point is in LV only the WTG model will be validated.

- **Test characteristics:**

It has to be differentiated depending on the existing short-circuit power at the test point (TP):

- If the short circuit power in the TP is equal to or greater than 5 times the registered power of the wind turbine to be tested, for each of the four categories of trial, described in Table II, it has to be checked that the U_{res} voltage recorded during the duration of the dip test during the no load test of the fault phases is less than 90%. Subsequently, and without changing the configuration of dips generator, the test in which load voltages and currents at the measuring point will be registered shall be conducted.

- If the short circuit power in the TP is less than 5 times the registered power of the wind turbine to be tested, for each of the four categories of trial, described in Table II, it has to be checked that the voltage $U_{ef(1/4)}$ registered during the duration of the dip test during the no load test of the fault phases is less than 90%, registering voltages and currents at the measuring point.

The validity of the test will subsequently be carried out in section 7.3 where it will be proven that the voltage and current levels at the point of measurement are more severe in the field test than during the wind farm simulation procedure.

In the particular case of asynchronous WTGs, without dynamic compensation (or FACTS devices that act during the dip), the accredited certifier will decide whether it is necessary to carry out the field test of this kind of WTG depending on information supplied regarding the electric parameters and dynamic characteristics of the mechanical part that influence the behaviour of the machine during the voltage dip.

6.2.2. Test conditions for direct observance of O.P. 12.3. Particular process

WTG test will be accepted as valid for direct observance of OP 12.3 as stated in section 4.2 of this document (particular verification process) when for each of the four test categories on Table II, the following requirements are met:

(1) <u>Guarantee of continuity of supply:</u>

The WTG is not disconnected during the application of the voltage dip in three consecutive tests in the same category (see Table II). If at least one disconnection occurs in this test sequence (the first three consecutive tests), the continuity of supply condition will only be considered valid, if the WTG does not disconnect in the four following tests in the same category. If a disconnection occurs in this last series of tests, the test will be considered invalid.

(2) <u>Operation point</u>

An essential condition of each test category is that the active and reactive power recorded before the voltage dip test (see Table I), are within the interval that defines partial load and full load

(3) <u>Residual voltage level and time during the no load test</u>

The requirements for the tests, differentiated depending on the short circuit function of the TP, are stated in Table III for each of the categories (see Table II).
When the power of the short circuit in the TP is equal to or 5 times greater than the registered power of the wind turbine to be tested, the evaluation must be done through no load tests, but when this value is less than 5, the evaluation must be carried out through load tests.

Table I Voltage dips characteristics for wind turbine tests

Short circuit power in TP	Type of dip	Voltage dip	Voltage tolerance (U_{TOL})	Dip time (ms)	Time tolerance (T_{TOL}) (ms)
$\geq 5xP_n$	THREE PHASE (NO LOAD)	$\mathbf{U_{res}} \leq (20\%+U_{TOL})$	+3%	$\geq(500-T_{TOL})$	50
	ISOLATED TWO PHASE (NO LOAD)	$\mathbf{U_{res}} \leq (60\%+U_{TOL})$	+10%	$\geq(500-T_{TOL})$	50
$<5xP_n$	THREE PHASE (LOAD)	$\mathbf{U_{ef(1/4)}} \leq (20\%+U_{TOL})$*	+3%	$\geq(500-T_{TOL})$	50
	ISOLATED TWO PHASE (LOAD)	$\mathbf{U_{ef(1/4)}} \leq (60\%+U_{TOL})$*	+10%	$\geq(500-T_{TOL})$	50

* *During the whole duration of the dip from T_2 to T_3 (see zones characterization during the dip, Section 9.1). In the table that specifies the characteristics of the voltage dip to be included in the report prepared by the laboratory, it will show the maximum value of $U_{ef(1/4)}$ between the period T_2 and T_3.*

(4) Conditions of power and energy exchange at test points

The necessary voltage and current measurements for the subsequent power and energy calculations (active and reactive), as indicated on OP 12.3, will be registered at the test point TP.

If the WTGs installed in a given wind farm are capable of meeting the requirements set in OP 12.3 for two-phase dips, with the test conditions defined in this section 6.2.2., it will not be necessary to carry out a simulation of a two-phase short circuit at the GCP.

Also, if the WTGs installed in a given wind farm are capable of meeting the requirements set in OP 12.3, (with reduced reactive power consumption) with the test conditions defined in this section 6.2.2., it will not be necessary to carry out a simulation of a three-phase short circuit at the GCP.

To use this particular process for three-phase dips:

– The reactive power consumption in zone A (see zone characterization during voltage dips, section 9.1.) must not be greater than 15% of P_n for every 20 ms. In zone B, this value must not exceed 5% of P_n for every 20 ms.

– During the period between the fault clearance starting time (T_3, see section 9) and T_3+150 ms it must be verified that the net reactive current consumption at the test point in each cycle (20 ms) must not be greater than 1.5 times the current at nominal power, even when the voltage has reached 0.85 p.u. within that period.

The mean value of the current measurements carried out in zone B of the dip, according to section 9.1, will be used to verify compliance with the requirement on the ratio between the reactive part of the current during the dip and the total current (section 4.1 of OP 12.3).

6.3. FACTS TEST

The test of a FACTS device is performed in order to establish its dynamic response and to allow validation and verification of a simulation model. The test is never performed in order to check continuity of supply.

Generally, a full size FACTS device or a scalable module will be tested in a laboratory and will include all the associated control and power elements. The test characteristics and validity are the following:

It must be differentiated depending on the existing short-circuit power at the test point (TP):

- If the power in the short circuit in the TP is equal to or 5 times greater than the registered power of the FACTS to be tested, only two test categories will be needed: THREE PHASE AND ISOLATED TWO PHASE. In each of them, the overload capacity of the device during the voltage dip will be proven, the initial load is not considered to be relevant to the test. For each of the test categories, the U_{res} voltage registered during the dip in the phases in fault in the no load test must be shown to be less than 90%

- If the power in the short circuit in the TP is 5 times less than the registered power of the FACTS to be tested, only two test categories will be needed: THREE PHASE AND ISOLATED TWO PHASE. In each of them, the overload capacity of the device during the voltage dip will be proven, the initial load is not considered to be relevant to the test. For each of the test categories, the minimum voltage $U_{ef(1/4)}$ registered during the dip in the phases in fault in the no load test must be shown to be less than 90%.

In the case of FACTS devices connected in series, the way to proceed is:

During the test, the voltage on both sides of the FACTS equipment will be measured as well as the intensity that goes through it.

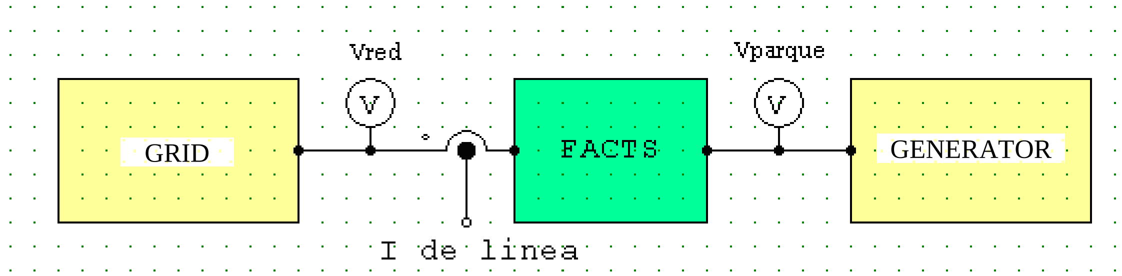


Figure 3. Voltage and current measurements during FACTS test.

Tests to be carried out: two phase and three phase dip. If the FACTS power is of less than 1.5 MW a market generator whose power is of at least a third of the power controlled by the FACTS or the module to be applied must be used. If the power of the FACTS equipment or the module is of more than 1.5 MW, the market generator must have a power of at least 500KW. The dips to be tested will be done in two different ways of functioning, one over 80% and the other one under 40% of the nominal power of the generator

Table II Characteristics of the voltage dip for FACTS tests

Short circuit power in TP	Voltage dip	Dip voltage	Dip time (ms)	Operation point of generator
$\geq 5xP_n$	Isolated three phase (no load)	$U_{res} \leq 23\%$	≥300	$\geq 80\%\ P_{nominal\ generator}$
				$< 40\% P_{nominal\ generator}$
	Isolated two phase (no load)	$U_{res} \leq 70\%$	≥300	$\geq 80\%\ P_{nominal\ generator}$
				$< 40\% P_{nominal\ generator}$
$<5xP_n$	Isolated three phase (load)	$U_{ef(1/4)} \leq 23\%$*	≥300	$\geq 80\%\ P_{nominal\ generator}$
				$< 40\% P_{nominal\ generator}$
	Isolated two phase (load)	$U_{ef(1/4)} \leq 70\%$*	≥300	$\geq 80\%\ P_{nominal\ generator}$
				$< 40\% P_{nominal\ generator}$

** During the whole duration of the dip from T_2 to T_3 (see zones characterization during the dip, Section 9.1). In the table that specifies the characteristics of the voltage dip to be included in the report prepared by the laboratory, it will show the maximum value of $U_{ef(1/4)}$ between the period T_2 and T_3.*

At least one of the tests may last for over 450sms.

If a FACTS has not been tested to its full potential or in a scalable module, as stated at the beginning of this section, it must be approved by the TVC.

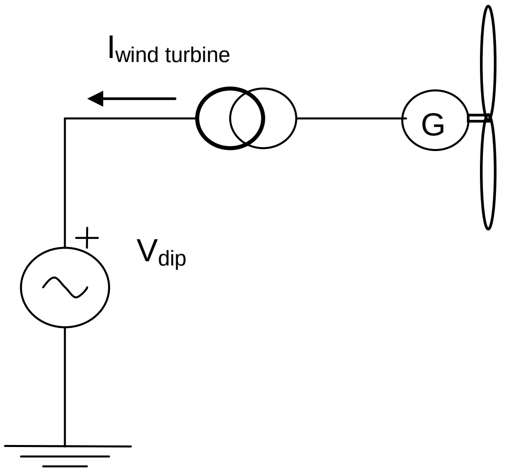
7. MODELS VALIDATION PROCESS

7.1. WIND TURBINE GENERATOR MODEL

The validation of the WTG model requires the following steps:

1.- The instantaneous voltage and current values in each phase at the test point are recorded and rms values determined for the fundamental harmonic of these variables, as well as the values of the active and reactive power according to the calculation procedure described in Section 9.2 of this document. This is carried out for each of the three data series recorded in the four test categories specified in this PVVC (three-phase and two-phase faults at partial and full load). The duration of the comparison window will be of a second, with an initial time of 100 ms before the start point of the dip (T_1). This is only applicable in the General Procedure.

2.- The manufacturer's WTG model must be used by the endorsed or accredited laboratory to reproduce each of the tests carried out in the field, for that, the test bench will be modelled as a voltage source, so that it is set as a time series of measured values in the experimental test, thus giving exactly the same voltage during this test.



It is convenient to compare the measurements of the test field with the results of the simulation model being this as detailed as possible and also manageable enough so that simulation programmes can be integrated into electrical systems. They use the same computer model for comparison in the four categories of tests.

3.- The results of the simulation model must be the same instantaneous variables as those recorded in each of the four field tests. The integration step should be equal to or less than the time interval for the sampling frequency in the measurements recorded during the field tests. The rms values of the fundamental harmonic of these variables are determined from the simulation values of voltage and current in each phase, as well as the active and reactive power values, as described in point 1 of this section.

Compliance with the validation criteria will result in the issuing of an ACCREDITED TYPE MODEL VALIDATION REPORT 2.A by the accredited laboratory.

7.2. FACTS MODEL

The validation process for FACTS devices in the wind farm (except those in the WTG, with which it must be jointly tested) will be the same as that described in the above points in section 7.1, and will also be applicable to the laboratory tests described in section 6.3. Compliance with the validation criteria will result in the issuing of an ACCREDITED TYPE MODEL VALIDATION REPORT 2.B by the accredited laboratory.

7.3. VALIDATION CRITERIA

A WTG or FACTS model will be considered validated when, for 85% of each of the data series corresponding to the first block of consecutive tests without disconnection (section 6.2.1), the difference between the values of the following variables measured in the field test and those measured in the computer platform does not exceed 10%:

- Three phase active power.
- Three phase reactive power.

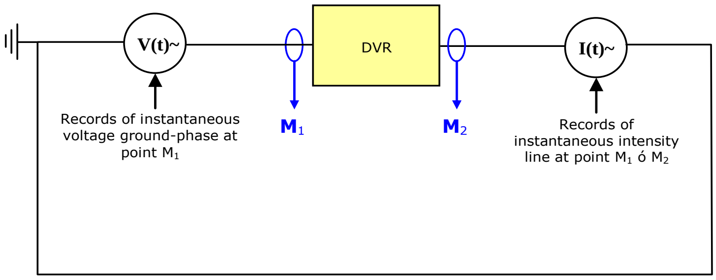
The calculation of this index Δx(%), is understood to be the ratio between the absolute value of the difference of the measurements recorded in the field x_{med} and those obtained in the computer platform x_{sim} with respect to those recorded in the field multiplied by 100. The rms values calculated at least each quarter cycle with an integration window of one cycle must be compared.

$$\Delta x(\%) = \left| \frac{x_{med} - x_{sim}}{x_{nom}} \right| \cdot 100 \leq 10\% \qquad (1)$$

Once the simulation model has been validated, the accredited laboratory will provide a physical copy of the simulation model with the accreditation seal, the properties of the WTG tested (Table I.1 of Appendix I) and the properties of the computer tools that allow it to be used. The model stored on this physical medium may be used in as many wind farm simulations as necessary with any accredited laboratory.

The TVC may decide that these criteria need modification depending on the obtained results.

In the simulation for validation of the model to use, in the case of a series FACTS device, the test bench can be modelled as a voltage source and a current, so that they give exactly the same voltage and current during the test.



The value of the voltage on the side of the "farm" (current source) of the FACTS equipment will be used to validate the model by comparing the simulation result and that obtained during the test, following the mathematical criteria of this section.

8. PROCESS FOR SIMULATING WIND FARMS

To carry out the wind farm simulation study, a tool must be used that allows the components of the electrical system to be modelled by phase, since dynamic studies with balanced and unbalanced faults will be carried out. This tool must be able to use the validated WTG model without needing to make modifications to it.

8.1. TOPOLOGY OF ELECTRICAL SYSTEM

In order to carry out wind farm simulations, an electrical configuration as described in Figure 3 will be used, which must contain at least the following elements:

- Wind farm and FACTS devices.
- Medium to high voltage step-up transformer.
- Evacuation line (AT - PCR).
- Grid equivalent.

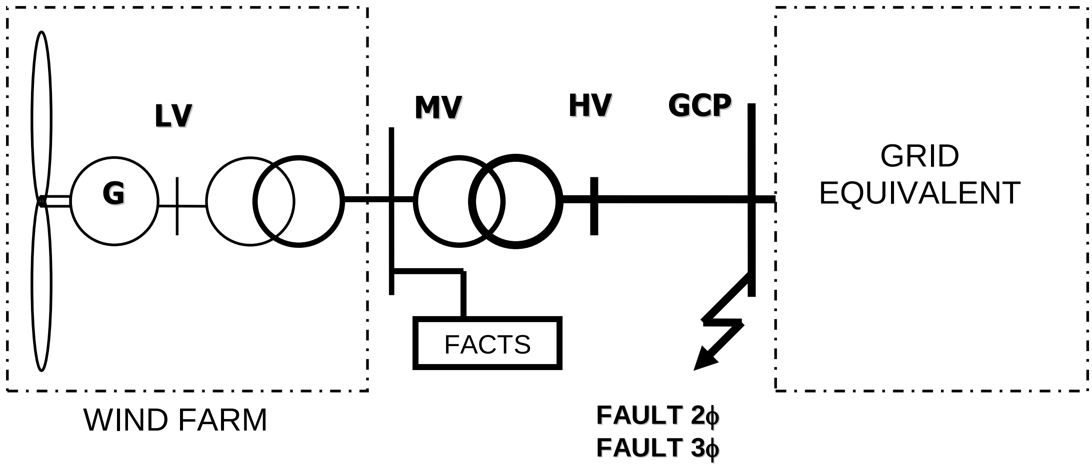


Figure 4. Single-line schematic of the layout of the electrical system.

All of the groups of WTGs connected through electrical power circuits will be connected to the medium voltage (MV) point. If additional loads or other wind farms are connected between the high voltage (HV) point and the grid connection point (GCP), those additional loads or wind farms will be taken out of the simulation, in order to avoid any modification of the equipment that connects to the GCP (transformers and lines).

8.1.1. Wind farm and FACTS devices

In the wind farm simulation process, validated WTG and/or FACTS models will be used. Figure 3 shows a parallel connection for the FACTS in the medium voltage (MV) node; however, serial type connections are also possible although they are not shown.

Generally, a wind farm will include any WTG, FACTS and existing reactive compensation devices, cables, step-up transformers (LV/MV) and internal lines. The internal layout of the wind farm used in the simulation will be accepted as valid for verifying other wind farms included in the type category (section 4.4).

Particularly, a wind farm might be represented by only one equivalent WTG provided that all WTGs in the wind farm are of the same type. If the wind farm contains more than one type of WTG, aggregation might still be valid if each equivalent WTG represents a grouping of WTGs connected to the same power equipment and belonging to the WIND FARM TYPE configuration selected by the owner in the actual wind farm.

8.1.2. Medium / high voltage transformer

The electrical properties of the MV/HV transformer used in simulating the wind farm are:

- Ratio of medium (kV) / high (kV) voltages
- Apparent nominal power S_n(MVA)
- Connection group
- Power of losses in the short circuit test P_{cc}(kW)
- Power of losses in the no load test P_o(kW)
- Short circuit voltage in U_{cc}(%)
- No load current I_o(%)

8.1.3. Evacuation line

The electrical properties of the evacuation line from the high-voltage point to the grid connection point (GCP) to be used in the process of wind farm simulation are:

- Voltage level (kV)
- Power transmission capacity (MW)
- Cross section of conductors
- Resistance R_{AC} (50 Hz - 20º C) (Ω/km)
- Reactance X_{AC} (50 Hz) (Ω/km)
- Susceptance (μS/Km)
- Length and number of circuits in the line

8.2. EQUIVALENT ELECTRICAL GRID

The rest of the electrical grid that does not belong to the wind farm being studied must be modelled so that the fault clearance at the grid connection point reproduces the usual voltage profile in the Spanish electrical system - a sudden increase on the clearing of the fault and a slower recovery afterwards. Said profile will be considered fixed and independent of the geographic location of the wind farm to be studied.

In order to simulate the equivalent electrical grid, a dynamic system has been chosen consisting of one node in which the equivalent dynamic model of the UCTE (UCTE node) is modelled, along with another node in which an equivalent model reflecting the dynamic characteristics due to the hypothetical closest electrical grid (RED node) and a third that represents the GCP (GCP node). Said nodes are separated by impedances of predetermined values in a way in which the typical voltage profile of the Spanish electrical system is reproduced. In this way, it is guaranteed that all of the wind farms are tested, by simulation, for short-circuits with equal characteristics.

The UCTE equivalent includes a synchronous generator (Generator 1) of an apparent power that reflects a realistic value for the interconnected apparent power and therefore the inertia of the UCTE system. Said generator is modelled in 20 kV bars with a step-up transformer. The demand of the UCTE system is modelled as a load in the equivalent node of said system.

In order to considerate the dynamic side of the equivalent of the closest grid, a synchronous generator has been included (Generator 2) and a demand. The generator (Generator 2) is modelled in 20 kV bars with a step-up transformer and the demand is modelled as a load in 20 kV bars connected to the RED node through a transformer.

The properties of the equivalent electrical grid must include at least the following elements represented in figure 4:

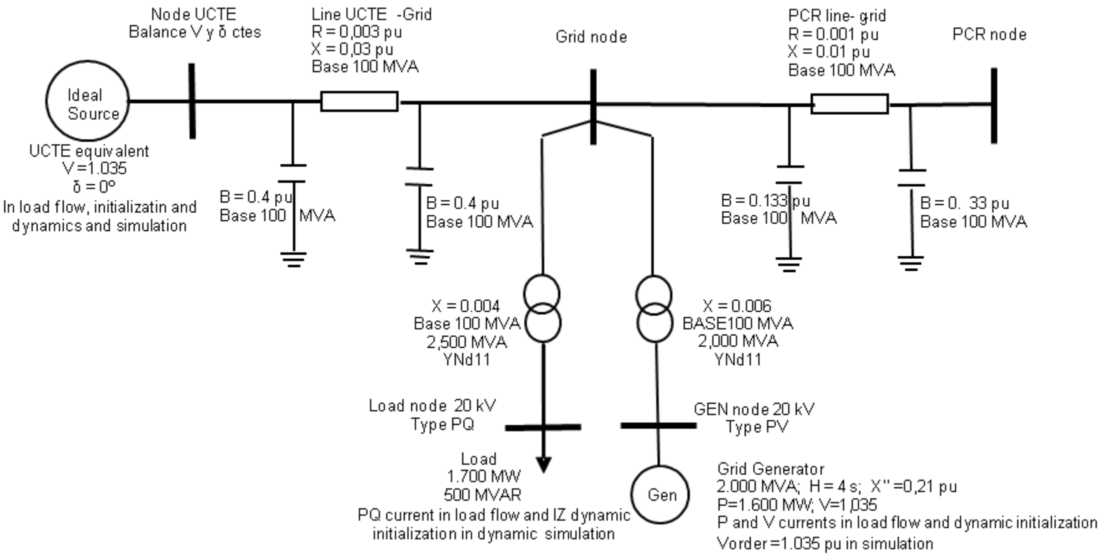


Figure 5. Model of the equivalent electrical grid (single-line scheme)

8.2.1. Data of nodes and passive elements of the grid equivalent

In accordance with the nomenclature considered in Figure 4, the following data are considered.

Nodes:

For the GCP node, the base voltage is considered to be the nominal voltage of the grid to which, in reality, the connection node to the corresponding grid belongs.

For the UCTE node, as well as the RED node, the same base voltage will be taken as that assigned to the GCP node.

Lines:

"Л" models with the fixed characteristics indicated in Figure 4 will be used. Said resistance, reactance and susceptance characteristics will be expressed in per unit values with base power of 100 MVA. Additionally, it will be considered that the corresponding values indicated in Figure 4 are already expressed in the base voltage of the extreme nodes, independently from the nominal voltages of the same nodes. This will guarantee that the voltage dip and the recuperation profile are always the same independently from the actual voltage of the GCP node.

Transformers:

Simple reactances with the fixed characteristics indicated in Figure 4 will be used. Said reactances are expressed in per unit values with a base power 100 MVA and base voltage of 20 kV. All of the transformers are considered to be part of the connection group YNd11.

8.2.2. Data of the synchronous generator and its excitation system

Generators 1 and 2 must have the active and reactive production values indicated in Figure 4.

The parameters needed to correctly model the synchronous generator 1 for the UCTE equivalent, as well as the synchronous generator 2 of the RED equivalent, are the same with the exception of the inertia constant. Said values are indicated in Table V, in per unit with machine base and with unsaturated characteristic values. Additionally, the model to be used must not consider magnetic saturation:

Table V. Data of the generators

S_n (generator 1)	400,000 MVA	Apparent nominal power of the generator (MVA)
S_n (generator 2)	2,000 MVA	Apparent nominal power of the generator (MVA)
U_n	20	Nominal Voltage between phases (kV)
T'_{do}	5.0 s	Transient, open-circuit time constant d-axis (s)
T''_{do}	0.038 s	Subtransient, open-circuit time constant d-axis (s)
T'_{qo}	0.65 s	Transient, open-circuit time constant q-axis (s)
T''_{qo}	0.075 s	Subtransient, open-circuit time constant q-axis (s)
X_d	2.1 p.u.	Synchronous, d- axis reactance (p.u)
X_q	2.0 p.u.	Synchronous, q- axis reactance (p.u)
X'_d	0.25 p.u.	Transient, d- axis reactance (p.u)
X'_q	0.45 p.u	Transient, q- axis reactance (p.u)
$X''_d = X''_q$	0.21 p.u.	Subtransient, d- axis and q-axis reactance (p.u)

Xl	0.16 p.u.	leakage reactance (p.u.)
H (generator 1)	4.5 s	Inertial Constant (s)
H (generator 2)	3.0 s	Inertial Constant (s)

The data needed for the excitation systems of both synchronous generators are those included on Table VI (see figure 6).

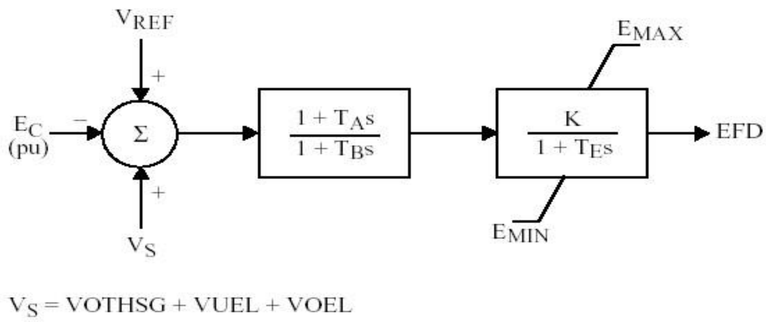


Figure 6. Synchronous generator excitation system

Table VI. Synchronous generator excitation system data

T_E	0.1 s	Time constant of the excitation controller
K	40	Gain of the excitation controller
E_{min}	0 p.u.	Lower limit of excitation voltage (p.u)
E_{max}	5 p.u.	Upper limit of the excitation voltage (p.u)
T_A	0.5 s	Time constant (1) of the lead-lag compensator
T_B	10 s	Time constant (2) of the lead-lag compensator

It will be assumed that the generators are under a constant mechanical torque at all times, which makes it unnecessary to model the speed regulators or the respective turbines.

8.2.3. Load power

With regard to the load, independently for each one, the active part must be modelled as a constant current ($P(v) = P_1V$) and the reactive power as a constant impedance ($Q(v) = Q_1V^2$).

Where P_1 and Q_1 are the load values corresponding to a voltage of 1 p. u. Said values are calculated from the initial load values P_0 and Q_0 corresponding to the initial node voltage V_0. If V_0 is expressed in p.u. then:

$$P_1 = \frac{P_0}{V_0} \cdot (p.u) \qquad (2)$$

$$Q_1 = \frac{Q_0}{V_0^2} \cdot (p.u)$$

The values V_0 for the nodes of the module will vary slightly depending on the current operation point and whether or not the wind farm is modelled at the GCP node, as well as the working regime. Therefore it will be necessary to make a load distribution considering its own particular effects.

- The generation node "Generator 1" will be the balancing node (V,δ) with the data:
  - V=1.042 p.u. (generator 1 voltage instructions)
  - Δ=0º (angle reference)

- The generation node "Generator 2" will be considered as a PV node with the data:
  - P=1,600 MW (generated power)
  - V=1,042 p.u. (voltage instructions for generator 2)

- The remaining nodes will be considered to be PQ nodes with fixed power loads in its active and reactive parts.

Once the load distribution is completed, the reactive power of the generators will be able to vary slightly; however, it is most important that voltage instructions are maintained at the generation bars (20kV).

8.2.4. Fault reactance

For the dynamic simulation of a balanced fault, a three-phase fault at the GCP will be simulated, with a ground reactance reference of $8.4034 \cdot 10^{-3}$ p.u. with a 100MVA base. Said reactance is such that the voltage at the GCP node falls to 0.2 p.u. in the moment in which the fault clears (500 ms).

For the dynamic simulation of an unbalanced fault, an isolated two-phase fault at the GCP node will be simulated, with a reactance between phases such that the phase-ground voltage of the phases in the fault, in the GCP node, fall to 0.6 p.u. in the moment in which the fault clears (500 ms).

The voltage at connecting node during the balanced fault and subsequent recovery can be observed in the following figures:

In the case of a three-phase balanced fault simulation, the fault is applied when the voltage of one of the phases is at a peak.

In the case of an isolated two-phase fault simulation, the fault is applied when the voltages of the phases in which the fault will be simulated coincide. The fault will clear through an automatic switch that opens at a zero crossing of the current.

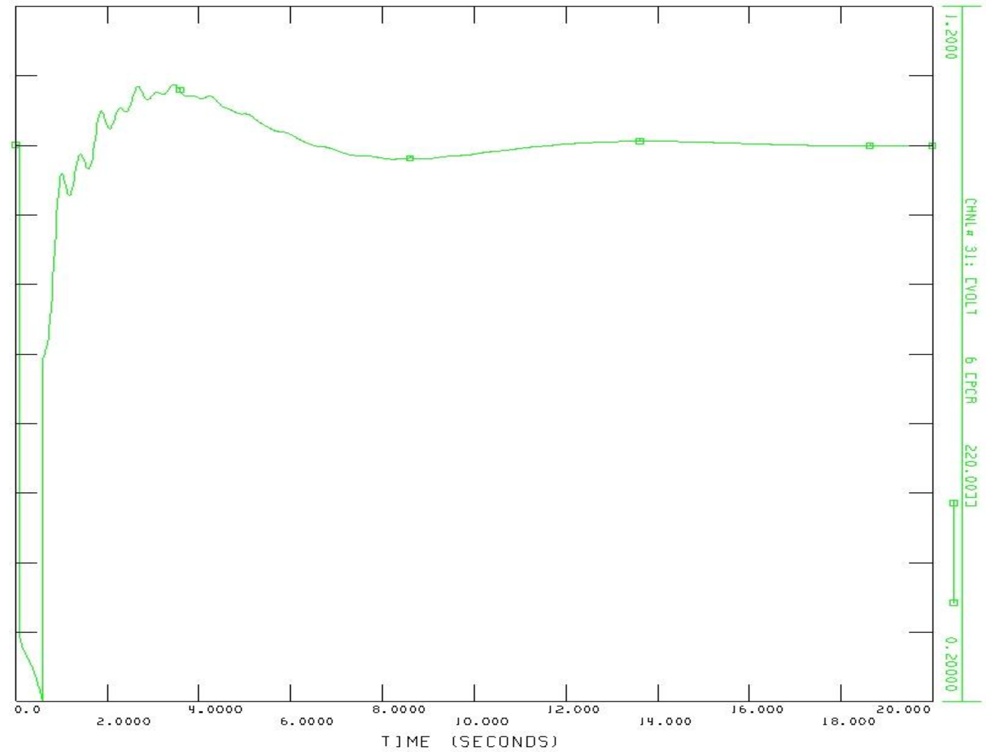


Figure 7. Voltage in a connection node during the balanced fault and fault recovery

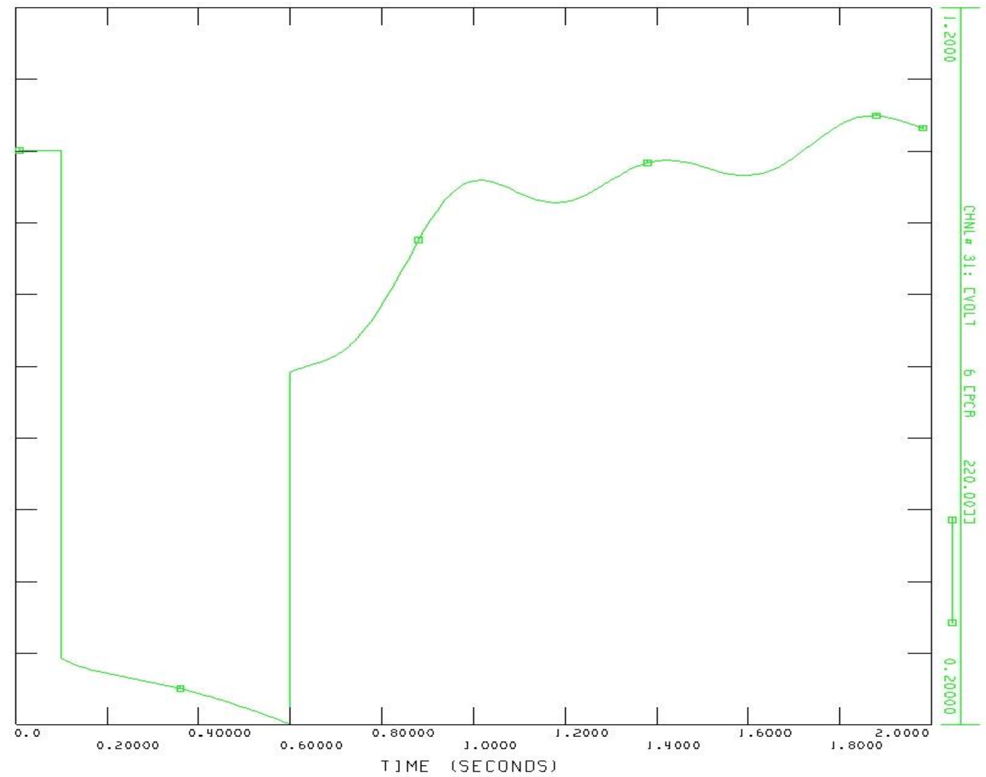


Figure 8. Voltage in a connection node during the balanced fault and fault recovery. (detail of the first 2 s)

8.3. EVALUATION OF RESPONSE TO VOLTAGE DIPS

The final part of the simulation procedure consists of the strict evaluation of the wind farm's response to voltage dips. Once the electrical system, its associated dynamic elements and the starting conditions before simulation have been defined, a fault can be applied to the grid connection point for the four test categories (see Section 6.2).

Once the initial conditions are adjusted at the WTG terminals, for which the active generated power correspond to the full or partial-load and the reactive power is zero, the conditions indicated in Section 8.2.3 will be considered to be the initial conditions prior to the simulation.

Once the simulations have been carried out, the fulfilment of the following requirements must be proven for each test category:

(1) Continuity of supply

During the simulation, it must be shown that the wind farm withstands the specified dips in the test procedure without disconnection. To carry out these simulations, it is necessary that the simulation model includes the protections internally, which determines the triggering of the WTG in case of voltage dips and return the resulting disconnection signal.

If the entire wind farm (without aggregation) is simulated, the simulated installation guarantees the continuity of supply if the number of machines remaining connected during the dip is such that the loss of generated active power does not exceed 5% of the power previous to the fault. If an equivalent wind farm (with aggregation) is used, the triggering of the WTG will determine the continuity of supply for the complete wind farm.

(2) Voltage and current levels at the WTG terminals

After checking the voltage level required, the voltage and current values in each phase for the four categories described (see Table II) must be measured and recorded during the load tests (WTG connected during the short circuit).

The field test will be considered valid when, during the simulations of the wind farm at the GCP, it is found that:

- The calculated residual voltage levels at the test point $V_{RES\_PE\_SIM}$ (WTG terminals or step-up transformer if included in the test) are greater than or equal to those recorded in the field test $V_{RES\_PE\_TEST}$ minus a 2% tolerance.

$$V_{RES\_PE\_SIM}(p.u) \geq \left(V_{RES\_PE\_TEST}(p.u) - 0.02\right) \quad (3)$$

- The calculated current levels at the test point (WTG terminals or step-up transformer if included in the test) for each phase during the simulation are lower than those recorded in the field test. This requirement will be confirmed for the maximum values registered in zones A and C (see definitions of zones in section 9.1)

(3) Exchanges of active and reactive power as described in OP 12.3 which is calculated according to the calculation method in Section 9.2 of this document. The average value of the current measurements in zone B of the voltage dip defined in section 9.1 will be considered in order to verify the compliance with the requirement for the ratio between the reactive component current during the fault and the total current (Section 4.1 of OP 12.3).

In the wind farm simulation, it must be shown that neither a specific beginning or clearance point for the voltage dip, nor a power factor for the WTGs, which are especially favourable for the compliance with the requirements set in the OP 12.3 have been chosen.

For existing wind farms, if during the simulation, the voltage remains above 85% of the nominal voltage of the machine at all times, the WTGs can be represented through a simplified model according to the test described in section 6.2.1. The over-speed protection and over-intensity that could disconnect the machine must be included.

The simplified models will be modelled according to their technology:

- Asynchronous squirrel cage generator and asynchronous with switched rotor resistance insertion. A fifth order model will be used:
    - With the parameters supplied by the manufacturer, it will be checked that the nominal operating characteristics of plaque with a margin of 10% for P and Q can be obtained.
    - If the manufacturer does not supply parameters, the data will be taken from the table in Annex II, and the rest will be calculated to obtain the nominal characteristics.
    - For the inertia, if you do not have the manufacturer's data, a constant of value H = 4s will be taken.
- Double-feed induction generators: designed from a simplified model that considers at least the electric dynamic of the rotor in order to determine the trip of the machine in case of overcurrents.
- Synchronous generator with total converter: modelled a constant current source

In the special case of asynchronous squirrel-cage generators, an invalidated model could be used even if the turbine's voltage is lower than 85% of the nominal voltage, except that the model parameters must be supplied by the manufacturer. In the case having the values contrasted with a tolerance, the simulation should be performed in the worst case scenario (a sensitivity analysis should be conducted in order to define this). The mechanical model used will be dual-mass.

For existing farms, the wind turbines that have proven to have an accredited test report shall be allowed the use of simplified models as follows:

- General model for wind turbines with an accredited report. This model will consist of a current / voltage source and protections that exactly meet the limits for obtaining the accredited report (see section 6.2.2):
    - The wind turbine will be triggered by the under voltage obeying the voltage values and time shown in the following table:

Voltage (pu)	Time(s)
0.19	Instant
0.3	0.58
0.5	0.75
0.7	0.9
0.8	1

    - The consumption of reactive power in zone A (see zones characterization during the dip, section 9.1) will be higher or equal to 15% of its nominal power and in zone B it is greater than or equal to 5% of its nominal power.
    - The value of active power generated by the machine in zone A should be such that the module of the the current from the turbine is the same than the one that existed before the fault.
    - The active power consumption in zone B is greater than or equal to 10% of its nominal power.
    - In the zone between the time of clearance of the fault (T_3, see section 9) and T_3 + 150 ms, the consumption will be less than 1.5 times the corresponding intensity to its registered nominal power, even when the voltage exceeded 0.85 p.u at that time. Also, the active current is zero during this time period.

- Model for this particular turbine type. This model is similar to the above but using the values obtained in testing the adjustment of the shot for under voltage and the consumption of power / reactive intensity. The higher values that have been measured in the tests will be used.

9. MEASUREMENT TECHNIQUES

Both in the field tests and in the simulation procedure, all of the records of voltage and current sampled for each phase must be carried out at a sampling frequency (or equivalent integration step) of at least 5 kHz. For each test, the instant values of voltage and current recorded must include at least the 10 seconds prior to the beginning of the dip and at least 5 seconds after T_4. In the registered values prior to the fault, the frequency will be determined, that is going to be used as starting data for determining the $U_{rms(1/4)}$.

9.1. CLASSIFICATION OF ZONES DURING THE DIP

O.P. 12.3 defines three zones during the voltage dip, as shown in Figure 8, that are classified as a function of the dip threshold and of the residual voltage of the dip:

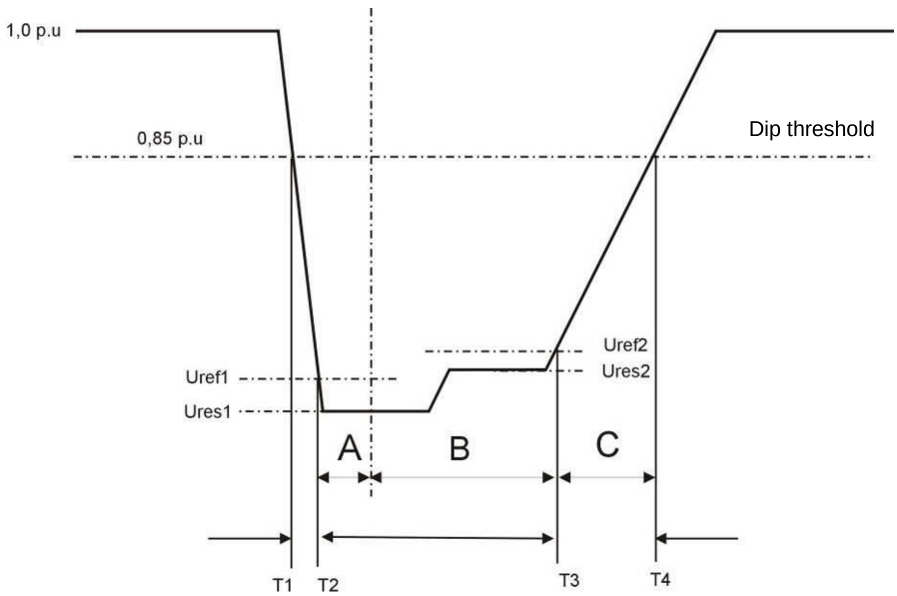


Figure 9. Classification of the voltage dip in the field test

The typical points on the voltage $U_{ef(1/4)}$ are determined as follows:

- Instant of start of dip (T_1): the instant in which the voltage $\mathbf{U_{ef(1/4)}}$ of one of the phases falls below the dip threshold (IEC 61000-4-30).

- Instant of the end of dip (T_4): the instant in which the voltage $\mathbf{U_{ef(1/4)}}$ in all of the channels measured is equal to or greater than the dip threshold (IEC 61000-4-30).

- Instant of start and end of the bottom of the dip (T_2 and T_3): the instants T_2 and T_3 are determined from the voltage values $\mathbf{U_{ef(1/4)}}$ measured.

Because during the voltage dip the residual voltage may be modified by the reactive power exchanges, a distinction will be made between the calculation for T_2 (start of the bottom of the dip) and T_3 (end of the bottom of the dip).

The point T_2 is determined by the calculation of a reference voltage $\mathbf{U_{ref1}}$ as shown in Figure 8, such that at all times the value of $\mathbf{U_{ref1}}$ does not differ by more than 3% from the voltage reached at the start of the bottom of the dip $\mathbf{U_{res1}}$.

Similarly, the point T_3 is determined by the calculation of a reference voltage $\mathbf{U_{ref2}}$ (see figure 8), such that at all times the value of $\mathbf{U_{ref2}}$ does not differ by more than 3% from the voltage reached both at the end of the bottom of the dip $\mathbf{U_{res2}}$.

$\mathbf{U_{ref1}}$ and $\mathbf{U_{ref2}}$ will be determined by an algorithm which detects changes in the $\mathbf{U_{ef(1/4)}}$ voltage slope measured with great accuracy to correctly determine dip zones.

Once the values of $\mathbf{U_{ref1}}$ and $\mathbf{U_{ref2}}$ as well as the associated times T_1, T_2, T_3 and T_4 are obtained, areas A, B and C are considered as:

-Zone A: all of the values of voltage $\mathbf{U_{ef(1/4)}}$ between the instant T_2 and T_2 + 150 ms.

-Zone B: all of the values of voltage $\mathbf{U_{ef(1/4)}}$ between the instant T_2 + 150 ms and T_3.

-Zone C: all of the values of voltage $\mathbf{U_{ef(1/4)}}$ between the instant T_3 and the lesser of the following values, T_4 and T_3 + 150ms.

Once the zones have been obtained, the following calculated values are updated each period. Measuring equipment for obtaining the measurements will be according to IEC 61400-21 standard.

For the purpose of calculation, the first cycle from which the above values are calculated will be fixed by the first value of $U_{ef(1/4)}$ after the start threshold of the dip.

9.2. METHODOLOGY FOR CALCULATING POWER

This section describes the method for calculating the active power, reactive power, reactive current and rms voltage values to be used to determine compliance with the response to voltage dips as specified in OP 12.3 of the electrical system. This method must be applied to both the field tests and to the simulations referred to in this document.

The method for measuring the instantaneous values of voltage, current and frequency must be carried out according to the standard IEC 61000-4-30: Electromagnetic compatibility (EMC). Part 4-30: Test and measurement techniques. Methods for measuring the quality of supply.

1.- It is recommended that the frequency determined in the 10 cycles before the dip is used to calculate the phasor during the dip. The value of the frequency calculated per phase, f(Hz), allows the calculation window of the period to be determined for T(s),(T=1/f) and must remain constant throughout the test or simulation.

2.- Using a sampling frequency f_s(Hz) that is constant and greater than 5 kHz, the number of samples N must be determined for each calculation window as the even and integer number nearest to the product of the period of the window by the sampling frequency $T*f_s$.

3.- Using the N samples of the instantaneous values of phase voltage u(n) and of phase current i(n), the complex values of these magnitudes are determined for the fundamental harmonic using the following expressions:

$$\underline{U}_1 = \frac{\sqrt{2}}{N} \cdot \sum_{n=0}^{N-1} u(n) \cdot e^{-j \cdot (\frac{2 \cdot \pi \cdot n}{N})} \qquad \underline{I}_1 = \frac{\sqrt{2}}{N} \cdot \sum_{n=0}^{N-1} i(n) \cdot e^{-j \cdot (\frac{2 \cdot \pi \cdot n}{N})} \tag{4}$$

4.- The values of the three-phase active P and reactive Q powers are calculated using the magnitude and argument of the complex values from expression (4) for each of the three phases. In the calculation process of the active and reactive power, only the positive sequence component of the voltage ($\underline{U}^+$) and current ($\underline{I}^+$) whose values are determined by the phase values according to expression (5) will be considered:

$$\begin{aligned} \underline{U}^+ &= \frac{1}{3} \cdot (\underline{U}_{1A} + \underline{U}_{1B} \cdot e^{+j\frac{2\cdot\pi}{3}} + \underline{U}_{1C} \cdot e^{-j\frac{2\cdot\pi}{3}}) \\ \underline{I}^+ &= \frac{1}{3} \cdot (\underline{I}_{1A} + \underline{I}_{1B} \cdot e^{+j\frac{2\cdot\pi}{3}} + \underline{I}_{1C} \cdot e^{-j\frac{2\cdot\pi}{3}}) \end{aligned} \tag{5}$$

Where:

$I_{1A,B,C}$: the complex expression corresponding to the rms value of the fundamental component of the current (A) in phases A, B and C each period.

$U_{1A,B,C}$: the complex expression corresponding to the rms value of the fundamental component of the phase-neutral voltage (V) in phases A, B and C each period.

The three-phase active and reactive power expressions will be obtained from the positive sequence component of the voltage and current as

$$P = 3 \cdot U^{+} \cdot I^{+} \cdot \cos(\varphi)$$
$$Q = 3 \cdot U^{+} \cdot I^{+} \cdot sen(\varphi) \quad (6)$$

Where:

$U^{+:}$ the magnitude of the positive sequence component of the voltage in (V).
I^{+}: the magnitude of the positive sequence component of the current in (A).
φ: the angle between the positive sequence component of the voltage and the current (rad).

5.- The value of the reactive current and total current referred to in OP 12.3 are determined using the following expressions:

$$I_r = I^{+} \cdot sen(\varphi) \quad (7)$$

$$I_{tot} = I^{+} \quad (8)$$

6.- The rms value of the voltage of each phase U_{rms} is determined using the expression:

$$U_{rms} = \sqrt{\frac{1}{N} \cdot \sum_{n=0}^{N-1} (u(n) - \bar{u})^2} \qquad \bar{u} = \frac{1}{N} \cdot \sum_{n=0}^{N-1} u(n) \quad (9)$$

The average value of the voltage in the period $\bar{u}$ shows the continuous component recorded in the period.

7.- The values described in points 3 to 6 must be calculated by moving the calculation window each quarter of a period, while maintaining the number of samples N constant (4 records per period).

The laboratory may increase the sampling frequency or the number of times the data window is moved each period in order to increase precision of the measurement.

8.- For both the balanced and unbalanced faults, the three-phase power must be calculated using the algebraic sum of each phase as described in point 4 of this section.

10. REFERENCES

- O.P. 12.3: Requirements for response in the event of voltage dips in wind farms.

- UNE-EN ISO/IEC 17025: General requirements for the competence of testing and calibration laboratories.

- IEC 61000-4-30: Electromagnetic compatibility (EMC). Part 4-30: Test and measurement techniques. Methods for measuring the quality of supply.

- IEC 61400-21: Measurement and evaluation of supply quality properties of WTGs connected to the grid.

ANNEX I: REPORT MODEL

The tables needed to complete the reports for each of the following processes are below:

- *Process:* Test and measurement of the individual response of a wind turbine or a FACTS device in the event of voltage dips.

  Report to issue: (1) ACCREDITED TEST VERIFICATION REPORT

  Tables to complete: Table AI.1 for the report Type 1.A for wind turbines in the general process.

  Table AI.1, Table AI.7 and Table AI.8 for the report Type 1.A for wind turbines in the particular process for direct compliance with the O.P. 12.3.

  Table AI.2 for the report Type 1.B for FACTS.

- *Process:* Validation of wind turbine computing models or FACTS devices based on the registered measurements in the in field tests.

  Report to issue: (2) ACCREDITED MODEL VALIDATION REPORT

  Tables to complete: Table AI.3 for the report Type 2.A for wind turbines.

  Table AI.4 for the report Type 2.B for FACTS.

- *Process:* Verification of the conformity of the wind farms with response requirements stated on the O.P. 12.3.

  Report to issue: (3) VERIFIED REPORT OF THE WIND FARM

  Tables to complete: Table AI.5, Table AI.6 and Table AI.8.

Tables AI.1 and AI.5 state the technical specifications of the wind turbines, FACTS devices or wind farms, depending on the type of report to complete.

Tables AI.6 and AI.8 state the registers of power and energy during the three or two phase faults depending on the verification process being general or particular.

Table AI.1. Data that define the tested wind turbine

REPORT OF THE TEST IN FIELD OF WIND TURBINES	
No. of test report in field:	
Date of test report in field:	
Name of wind turbine (Brand and model):	
Technology:	
Date of wind turbine manufacturer:	
Test place and ate:	
Manufacturer:	
WIND TURBINE SPECIFICATIONS	
Electrical generator:	
Type, brand and model of the electrical generator:	
Registered nominal power Sn (kVA):	
Nominal voltage (V):	
Electronic converter:	
Type, brand and model of the electrical converter:	
Nominal power (kW):	
Nominal voltage (V):	
Transformer LV/MV:	
Type, brand and model of the LV/MV transformer:	
Nominal power (kVA):	
Voltage relations (V/V):	
Connection group:	
Short circuit voltage (%):	
Control:	
Control type, brand and model:	
Control software version:	

Table AI.2. Data that define the tested FACTS device

FACTS DEVICES TEST REPORT	
No. of test report:	
Date of test report:	
Name of the FACTS device:	
Manufacture date of the FACTS device:	
Place and date of test:	
Manufacturer:	
SPECIFICATIONS OF THE FACTS DEVICE	
FACTS device:	
Brand and model:	
Technology:	
Nominal power (kW):	
Nominal voltage (V):	
Control software of the FACTS device:	
Control software manufacturer:	
Control type, Brand and model:	
Control software version:	

Table AI.3. Data for the technical identification of a wind turbine to validate of its simulation computing model

WIND TURBINE MODEL VALIDATION REPORT	
No. of model validation report:	
Date of model validation:	
Issuer accredited laboratory model validation report:	
TEST IN FIELD VERIFICATION REPORT	
No. of in field test verification report:	
Place and date of test:	
Issuer accredited laboratory model of in field test report:	
WIND TURBINE SPECIFICATIONS	
Tested wind turbine:	
Manufacturer:	
Brand and model:	
Technology:	
Electrical generator:	
Type, Brand and model of the electrical generator:	
Registered nominal power Sn (kVA):	
Nominal power (V):	
Electronic converter:	
Type, brand and model of the electronic converter:	
Nominal power (kW):	
Nominal voltage (V):	
LV/MV Transformer:	
Type, brand and model of the LV/MV transformer:	
Nominal power (kVA):	
Voltage relations (V/V):	
Connection group:	
Short circuit voltage (%):	
Control:	
Control type, brand and model:	
Software control version:	
SPECIFICATIONS OF THE WIND TURBINE SIMULATION MODEL	
Name of the wind turbine simulation model:	
Simulation software and software version:	
Supplier of simulation model:	

Table AI.4. Data for the technical identification of a FACTS device to validate its simulation computing model

FACTS DEVICE MODEL VALIDATION REPORT	
No. of model validation report:	
Date of model validation:	
Issuer accredited laboratory of model validation report:	
TEST VERIFICATION REPORT	
No. of test verification report:	
Place and ate of test:	
Issuer accredited laboratory of test report:	
SPECIFICATIONS OF THE FACTS DEVICE	
FACTS Device:	
Manufacturer of the FACTS device:	
Brand and model:	
Technology:	
Nominal power (kW):	
Nominal voltage (V):	
Control software of the FACTS device:	
Control software manufacturer:	
Control type, brand and model:	
Control software version:	
SPECIFICATIONS OF THE SIMULATION MODEL OF THE FACTS DEVICE	
Name of the simulation model of the FACTS device:	
Simulation software and software version:	
Supplier of the simulation model:	

Table AI.5. Data for the technical identification of a wind farm for its verification according to O.P. 12.3

SPECIFICATIONS OF THE WIND FARM	
Name of the wind farm:	
Developer:	
Location of wind farm:	
Installed power in the farm (MW):	
Connection to the substation:	
Relation of voltages of the MV/HV transformer of the substation (kV/kV):	
WIND TURBINES SPECIFICATIONS	
No. of wind turbines:	
Manufacturer:	
Brand and model:	
Technology:	
Power per unit (kW):	
SPECIFICATIONS OF FACTS DEVICES	
No. of FACTS devices:	
Manufacturer:	
Brand and model:	
Technology:	
Power per unit (kW):	
Placement of FACTS equipments:	

Table AI.6.- Register of power and energy. Three phase faults general process

THREE PHASE FAULTS	O.P. 12.3 REQUIREMENTS	RESULTS
ZONE A		
Net consumption Q < 60% Pn (20 ms)	-0.6 p.u.	
ZONE B		
Net consumption P < 10% Pn (20 ms)	-0.1 p.u.	
Ir/Itot average	0.9 p.u.	
ZONE C		
Net consumption Er < 60% Pn *150 ms	-90 ms.pu	
Net consumption Ir < 1,5 In (20 ms)	-1.5 p.u.	

Table AI.7.- Register of power and energy. Three phase faults particular process

THREE PHASE FAULTS	O.P. 12.3 REQUIREMENTS	RESULTS
ZONE A		
Net consumption Q < 15% Pn (20 ms)	-0.15 p.u.	
ZONE B		
Net consumption P < 10% Pn (20 ms)	-0.1 p.u.	
Net consumption Q < 5% Pn (20 ms)	-0.05 p.u.	
Ir/Itot average	0.9 p.u.	
ZONA C extended (T_3+150ms)		
Net consumption Ir < 1,5 In (20 ms)	-1.5 p.u.	

Table AI.8.- Register of power and energy. Isolated two phase faults

TWO PHASE FAULTS	O.P. 12.3 REQUIREMENTS	RESULTS
ZONE B		
Net consumption Er < 40% Pn *100 ms	-40 ms.pu	
Net consumption Q < 40% Pn (20 ms)	-0.4 p.u.	
Net consumption Ea < 45% Pn *100 ms	-45 ms.pu	
Net consumption P< 30% Pn (20 ms)	-0.3 p.u.	

Power consumption is expressed in standardized value (pu) to the registered nominal power of the wind turbine tested. Energy consumption is also expressed in standardized value of the power per unit of time in milliseconds (ms * pu).

The voltage registers and the current of the tests carried out are included in the model report.

ANNEX II: TYPICAL VALUES OF THE ELECTRICAL PARAMETERS OF AN ASYNCHRONOUS SQUIRREL CAGE GENERATOR OF MEGAWATT POWER

Table: Typical parameters of the equivalent circuit of the generator in p.u

Stator resistance	*0.005 – 0.007*
Rotor resistance	*0.005 – 0.007*
Stator leakage reactance	*0.1 – 0.15*
Rotor leakage reactance	*0.04 – 0.06*
Magnetizing reactance	*4 – 5*

When unaware of the equivalent circuit parameters of the generator, the values of stator resistance, the stator leakage reactance and the magnetizing reactance will be taken from the table, and the values of rotor resistance and rotor leakage reactance will be calculated to provide the active and reactive nominal power at voltage and nominal speed of the generator.

Example: Being a generator of 900 kW, 690 V, 1510 rpm, $\cos\varphi$=0,91.

Values to be taken:
R_s= 0.006 p.u.
$X_{\sigma s}$= 0.125 p.u.
X_{μ}= 5 p.u.

In S.I units

$S = P/\cos\varphi$ = 989 kVA
$Z_b = U^2/S = 0.48\ \Omega$

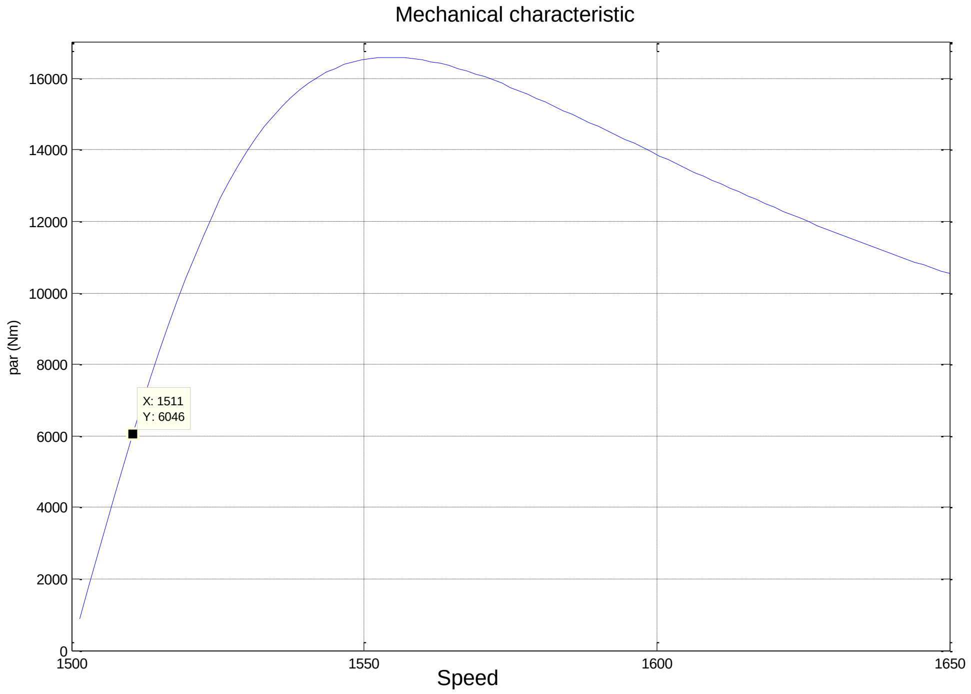
R_s= 2.88 mΩ
$X_{\sigma s}$= 60 mΩ
X_{μ}= 1.92 Ω

With the values of these parameters, it is possible to calculate the value of the other two parameters using the equivalent circuit equations and the values of the magnitudes of voltage and current at the nominal operating point.

$$\vec{U}_s = R_s\vec{I}_s + jX_s\vec{I}_s + jX_m\vec{I}_r$$
$$\vec{U}_r = \frac{R_r}{s}\vec{I}_r + jX_r\vec{I}_r + jX_m\vec{I}_s$$

R_s= 5.8 mΩ
$X_{\sigma s}$= 11.4 mΩ

With these values of the parameters, the mechanical characteristic of the resulting generator is shown in the figure below, which indicates the operating point approximately.


Mechanical characteristic
par (Nm)
16000
14000
12000
10000
8000
6000
4000
2000
0
1500
1550
1600
1650
Speed
X: 1511
Y: 6046

ANNEX III: PHOTOVOLTAIC PLANTS

1 INTRODUCTION

This annex establishes procedures for the verification of the requirements established in the Operating Procedure O.P 12.3 “response requirements to voltage dips of wind farms" in photovoltaic plants.

The aim is to provide a particular method of measurement and evaluation of the response of Photovoltaic Conversion Systems (PVCS) to voltage dips to verify the compliance with the requirements specified in the O.P 12.3.

The General Procedure is described in the main body of the PVVC in point 4.1.

For everything else not covered in this Annex III, what appears on the main part of the PVVC should be used, as long as it applies to PV.

2 SPECIFIC DEFINITIONS AND ABBREVIATIONS

Photovoltaic Conversion System (PVCS).

There are different types of conversion systems:

1. PV Inverter
2. PV + FACTS Inverter
3. Set of PV inverters + FACTS

Accredited laboratory**:** Testing laboratory accredited according to the ISO/IEC17025 standard for this Annex III.

Test Report**:** Report issued by an accredited testing laboratory of a PVCS.

Certification Authority**:** Certification Body accredited according to EN 45011 standards in compliance with this Annex III.

Accredited Inspection Body**:** Legal entity, accredited as an inspection body according to type A UNE-EN ISO / IEC 17020 for the verification of voltage dips in photovoltaic plants, by ENAC or any other accreditation body that signs mutual recognition agreements.

Compliance Certificate**:** Document issued by a Certification Authority or an accredited Inspection Entity on any plants or group of facilities.

Installation, PV plant**:** In this Annex, it is understood as a photovoltaic power generation plant, comprising one or more Photovoltaic Conversion Systems, irrespective of their size and type of administrative authorisation.

Power output of an inverter (**Pout):** Active power of AC terminals of an inverter at a given time.

Report on the inspection of the facility**:** Report on the inspection of a photovoltaic system for compliance with the O.P 12.3.

3 STRUCTURE OF CERTIFICATION

To ensure compliance with the requirements set forth in this document, you will need to obtain a certificate of conformity of the photovoltaic plant or group of photovoltaic plants. The certificate will be issued by a Certification Authority or accredited inspection body, to ensure compliance with said requirements.

The certification structure will be made according to the following outline:

1. An accredited laboratory for this Annex III conducts the tests
2. A Certification Body or Inspection Body accredited that issues the certificate of conformity. This certification shall be reviewed every 5 years.

4 VERIFICATION PROCEDURE

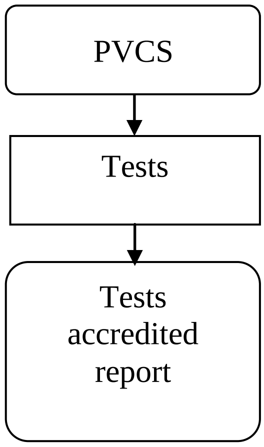
A PV plant will meet the requirements of the O.P 12.3 when all photovoltaic conversion systems that form the plant have the compliance report of the test procedure here explained and then the certification body or accredited inspection body, after analysing the plant, issue the certificate.

In case the photovoltaic conversion systems used in a facility do not have this report, the validation tests described in this document can be made at the facility by an accredited laboratory, either the entire system or those photovoltaic conversion systems that do not have the report.

During the procedure the following checks are carried out:

1. Verify that the PVCS do not disconnect due to voltage dips in the net connection point associated with faults properly cleared by the tension-time curve indicated in the O.P 12.3.
2. Verify that the power and energy (active and reactive) consumption in the connection point to the net, for balanced and unbalanced faults, are within the levels marked on the O.P 12.3.

This process of verification of the PVCS will be carried out by the validation of the PVCS, as shown in the figure below:



4.1 VERIFICATION PROCEDURE FOR PVCS OF INVERTER TYPE

In the event that the PVCS are of the inverter type, the process is applied to each photovoltaic inverter.

All inverters that have the following characteristics with respect to the inverter type tested are considered equivalent inverters to a PV inverter:

1. Same topology of power stages.
2. Same kind of isolation (low frequency transformer, high frequency or without transformer).
3. Same regimen of AC connection (single phase or three phase).
4. Nominal AC +- 50% compared to the type tested.
5. Same control algorithm regarding the behaviour when voltage dips.
6. Groups of several power stages (modular systems) will be considered valid, without requiring retesting.

The entire control algorithm that has to do with the dips must be identified and documented (control algorithm and firmware version).

The manufacturer is obliged to maintain the control algorithm regarding of the behaviour when voltage dips and in future firmware revisions. In the event of any changes that may have an impact on investor behaviour when voltage dips must be communicated to the Certification Body.

In case of inverters who can work with different AC voltages, the test will be carried out at the minimum rated voltage AC of inverter type.

As a result of the implementation of this verification process, an accredited report of the inverter type will be obtained from the accredited laboratory. This report will include the PV inverter test and test results required to check the response of the inverters during a voltage dip.

The verified test report of the typical inverter will be used by the Certification Body and the accredited Inspection Body to issue certificates of conformity to the plants done with equivalent inverters to the typical inverter.

4.2 VERIFICATION PROCEDURES FOR PVCS TO INCLUDE FACTS

If the PVCS incorporate FACTS, the process will be applied to each inverter + FACTS or group of inverters + FACTS.

The validation procedure of the PVCS that incorporate FACTS must meet the following tests:

- Test at full power of FACTS that includes all the elements of control and associated power.
- Report of result of operation of each inverter or group of inverters + FACTS. In cases in which the inverters used have these features, the test may be performed on only one or a set of them being the results accepted for the validation of the group:

    - Same manufacturer.
    - Same topology of power stages.
    - Same kind of isolation (low frequency transformer, high frequency or without transformer).
    - Same connection or AC regimen (single or three phase).
    - Nominal AC +- 50% compared to the type tested.
    - Equal protection under voltages.
    - Groups of several power stages (modular systems) will be considered valid, without requiring retesting.

It is allowed to combine one FACTS with several types or brands of inverters, when they have been tested with said FACTS.
The typical FACTS the one defined in the earlier part of this procedure.

As a result of the implementation of this verification procedure there will be a verified test report of the FACTS and its inverters associated from the laboratory. This report will include the testing of FACTS and the results of testing to verify the response of the PVCS during a voltage dip.

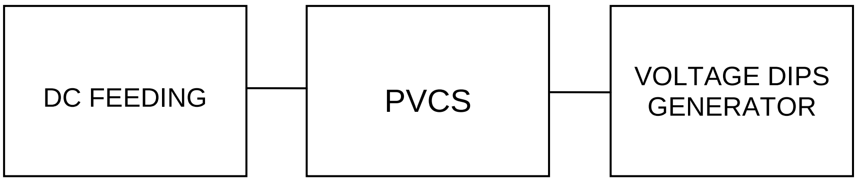
5 TESTING PROCESS

This section established the conditions and validity criteria of the test of the PVCS, as well as the definition of the necessary equipment to carry out this test. It also specifies the steps required to determine the characteristic parameters of the response to dips in the PVCS to be tested.

The measurements will be used to verify the characteristic parameters of the response to voltage dips throughout the operating range of the PVCS.

5.1 TEST CIRCUIT

The figure below shows a wiring diagram of the circuit used for the verification of the O.P 12.3. The PVCS to be tested will be fed at its DC part by a continuous source. AC-side will be fed by a system that simulates voltage dips.



5.1.1 DC power requirements

To carry out the proposed tests in this verification procedure, these may be used:

PV array consisting of a set of photovoltaic modules.

DC power supply.

The operation of the DC source will not interfere with the operation of the PVCS to be tested, so that the test results will not differ from reality.

5.1.2 Requirements of the voltage dips generator

The voltage dips generator can be done through:

1. Inductive divider the following characteristics:

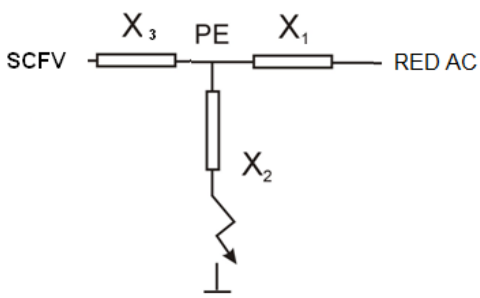


Figure AIII.1 Dips generator equipment

The impedance X1 is meant to limit the short circuit power supplied by the grid on which the test is carried out, it may represent a combination of reactance and / or transformers.

The impedance X2 is adjusted so that the residual voltage at the point TP (Test Point) corresponds with the values set in three-phase and two-phase faults.

In the branch where the impedance X2 is located there should be a switch that must be operated in such a way that is possible to generate two-phase and three-phase isolated dips. The starting point and subsequent recovery of the fault should be generated so that the times are equivalent to those used in the opening and closing of a circuit breaker.

The impedance X3 should be a transformer or a combination of reactance and transformers. The value X3 will take will be as follows:

- If the PVCS does not have a lifting transformer: X3 = 0.
- If the PVCS has a lifting transformer, two cases can occur:
    a) X3 will take the value of the impedance of the lifting transformer short circuit
    b) X3 will take the value of a +- 20% of the value of the impedance of the lifting transformer short circuit standard value
- In the case of using additional transformers in the position of the reactance X3, these may have any ratio and shall have the same group of connection than the lifting transformer of the PVCS, if it exists.

2. Power electronic device or other device capable of simulating a variable AC voltage grid, which curves (voltage-time) required on the O.P 12.3 are implemented. The point TP (Test Point) is the AC connection of the PVCS to be tested.

5.2 PVCS TESTING WITH VOLTAGE DIPS

The test will be performed applying with the generator of dips a three-phase fault and a two-phase isolated fault that causes a voltage dip on the affected phases whose characteristics, based on the O.P 12.3, are explained below.

The tests to be performed for three-phase inverters are attached in the following table (Table I):

Table AIII.1. Characteristics of the voltage dip for three-phase PVCS tests

Voltage Time	Faults	PVCS power before the dip
Ures < 20% Un > 500 ms	Three-phase	Pout>80%
		10%<Pout<30%
Ures < 60% Un	Two-phase	Pout>80%

> 500 ms	(isolated)	10%<Pout<30%

In the case of single-phase inverter being tested, two options are allowed:

- Perform the tests described in Table I with three single-phase inverters connected to a three-phase voltage dip generator.
- Perform the tests described in Table II with a single-phase inverter with a voltage dip generator capable of reproducing following faults:

Table III.2. Characteristics of a voltage dip for single-phase PVCS tests

Voltage Time	PVCS power before the dip
Ures < 20% Un > 500 ms	Pout>80%
	10%<Pout<30%
Ures < 60% With a movement of Phi angle= 30 degrees at the entry of the dip and -30 degrees at the exit > 500 ms	Pout>80%
	10%<Pout<30%

During the tests the active, reactive, currents and voltages at the point TP are recorded.

The moment of application of the dip will be random.

In both, tests and in the simulation process, all sampled records of voltage and currents for each phase are carried out at a sampling rate (or step size equivalent) of at least 5 kHz. They will record the moments before the start of dip and the 5 seconds immediately after the recovery period.

5.3 TEST VALIDATION CRITERIA

The PVCS will have passed the test for direct fulfilment of O.P 12.3, when for each test categories listed in Table I or Table II what is specified in this paragraph is achieved:

(1) Residual stress level and time during the load test

Depending on the existing short-circuit power at the test point (TP) the way to get the voltage dip profile to apply has to be differentiated:

- If the short circuit power in the TP is equal to or 5 times greater than the power of the PVCS registered to test, the dip may be obtained by testing with the PVCS disengaged from the dips generator (hereinafter "vacuum test"). In the load test (with the PVCS attached), the adjustment of the impedances of the generator set of dips should be the same as that performed in the vacuum test. In the vacuum test it will be found that the residual voltage of the dip corresponds to the value indicated in Table I.

- If the short circuit power in the TE is less than 5 times the power of the PVCS registered to test, it necessarily has to measure the dip profile during the test load. In this case we see that the residual voltage of the dip corresponds to the value indicated in Table I.

(2) Point of operation

For each test category (see Tables I and II), it is a necessary condition that the active power recorded prior to the completion of the voltage dip is within the range that defines partial load (10% <Pout <30%) and full load (Pout> 80%).

(3) Ensuring continuity of supply:

If PVCS disconnection occurs during the application of the voltage dip in one of three consecutive tests for each test category (see Tables I and II), the test of the PVCS shall not passed.

(4) Conditions of exchange of power and energy in the test point.

The current value injected by the PVCS during the fault must meet the specified in the O.P 12.3 in terms of values of reactive power, active and reactive power consumption.

Voltage measurements and current required for the subsequent calculation of power and energy (active and reactive) as indicated in the O.P 12.3 were recorded in the TP test point.

The methodology of calculating the active power, reactive power, reactive intensity and voltage value that will be used to determine the requirement conformity of the response to voltage dips according to the O.P 12.3 of the Electric System, is defined in Appendix C of the standard UNE-EN 61400-21: 2009 "Measurement and evaluation of the characteristics of quality of supply of wind turbines connected to the grid."

ANNEX III: PHOTOVOLTAIC PLANTS

1 INTRODUCTION

This annex establishes procedures for the verification of the requirements established in the Operating Procedure O.P 12.3 “response requirements to voltage dips of wind farms" in photovoltaic plants.

The aim is to provide a particular method of measurement and evaluation of the response of Photovoltaic Conversion Systems (PVCS) to voltage dips to verify the compliance with the requirements specified in the O.P 12.3.

The General Procedure is described in the main body of the PVVC in point 4.1.

For everything else not covered in this Annex III, what appears on the main part of the PVVC should be used, as long as it applies to PV.

2 SPECIFIC DEFINITIONS AND ABBREVIATIONS

Photovoltaic Conversion System (PVCS).

There are different types of conversion systems:

4. PV Inverter
5. PV + FACTS Inverter
6. Set of PV inverters + FACTS

Accredited laboratory**:** Testing laboratory accredited according to the ISO/IEC17025 standard for this Annex III.

Test Report**:** Report issued by an accredited testing laboratory of a PVCS.

Certification Authority**:** Certification Body accredited according to EN 45011 standards in compliance with this Annex III.

Accredited Inspection Body**:** Legal entity, accredited as an inspection body according to type A UNE-EN ISO / IEC 17020 for the verification of voltage dips in photovoltaic plants, by ENAC or any other accreditation body that signs mutual recognition agreements.

Compliance Certificate**:** Document issued by a Certification Authority or an accredited Inspection Entity on any plants or group of facilities.

Installation, PV plant**:** In this Annex, it is understood as a photovoltaic power generation plant, comprising one or more Photovoltaic Conversion Systems, irrespective of their size and type of administrative authorisation.

Power output of an inverter (**Pout):** Active power of AC terminals of an inverter at a given time.

Report on the inspection of the facility**:** Report on the inspection of a photovoltaic system for compliance with the O.P 12.3.

3 STRUCTURE OF CERTIFICATION

To ensure compliance with the requirements set forth in this document, you will need to obtain a certificate of conformity of the photovoltaic plant or group of photovoltaic plants. The certificate will be issued by a Certification Authority or accredited inspection body, to ensure compliance with said requirements.

The certification structure will be made according to the following outline:

3. An accredited laboratory for this Annex III conducts the tests
4. A Certification Body or Inspection Body accredited that issues the certificate of conformity. This certification shall be reviewed every 5 years.

4 VERIFICATION PROCEDURE

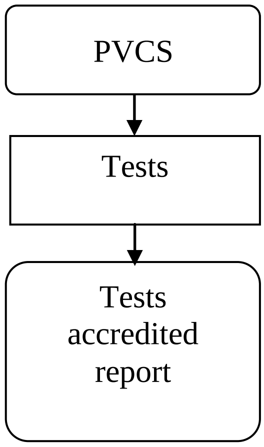
A PV plant will meet the requirements of the O.P 12.3 when all photovoltaic conversion systems that form the plant have the compliance report of the test procedure here explained and then the certification body or accredited inspection body, after analysing the plant, issue the certificate.

In case the photovoltaic conversion systems used in a facility do not have this report, the validation tests described in this document can be made at the facility by an accredited laboratory, either the entire system or those photovoltaic conversion systems that do not have the report.

During the procedure the following checks are carried out:

3. Verify that the PVCS do not disconnect due to voltage dips in the net connection point associated with faults properly cleared by the tension-time curve indicated in the O.P 12.3.
4. Verify that the power and energy (active and reactive) consumption in the connection point to the net, for balanced and unbalanced faults, are within the levels marked on the O.P 12.3.

This process of verification of the PVCS will be carried out by the validation of the PVCS, as shown in the figure below:



4.1 VERIFICATION PROCEDURE FOR PVCS OF INVERTER TYPE

In the event that the PVCS are of the inverter type, the process is applied to each photovoltaic inverter.

All inverters that have the following characteristics with respect to the inverter type tested are considered equivalent inverters to a PV inverter:

7. Same topology of power stages.
8. Same kind of isolation (low frequency transformer, high frequency or without transformer).
9. Same regimen of AC connection (single phase or three phase).
10. Nominal AC +- 50% compared to the type tested.
11. Same control algorithm regarding the behaviour when voltage dips.
12. Groups of several power stages (modular systems) will be considered valid, without requiring retesting.

The entire control algorithm that has to do with the dips must be identified and documented (control algorithm and firmware version).

The manufacturer is obliged to maintain the control algorithm regarding of the behaviour when voltage dips and in future firmware revisions. In the event of any changes that may have an impact on investor behaviour when voltage dips must be communicated to the Certification Body.

In case of inverters who can work with different AC voltages, the test will be carried out at the minimum rated voltage AC of inverter type.

As a result of the implementation of this verification process, an accredited report of the inverter type will be obtained from the accredited laboratory. This report will include the PV inverter test and test results required to check the response of the inverters during a voltage dip.

The verified test report of the typical inverter will be used by the Certification Body and the accredited Inspection Body to issue certificates of conformity to the plants done with equivalent inverters to the typical inverter.

4.2 VERIFICATION PROCEDURES FOR PVCS TO INCLUDE FACTS

If the PVCS incorporate FACTS, the process will be applied to each inverter + FACTS or group of inverters + FACTS.

The validation procedure of the PVCS that incorporate FACTS must meet the following tests:

- Test at full power of FACTS that includes all the elements of control and associated power.
- Report of result of operation of each inverter or group of inverters + FACTS. In cases in which the inverters used have these features, the test may be performed on only one or a set of them being the results accepted for the validation of the group:
    - Same manufacturer.
    - Same topology of power stages.
    - Same kind of isolation (low frequency transformer, high frequency or without transformer).
    - Same connection or AC regimen (single or three phase).
    - Nominal AC +- 50% compared to the type tested.
    - Equal protection under voltages.
    - Groups of several power stages (modular systems) will be considered valid, without requiring retesting.

It is allowed to combine one FACTS with several types or brands of inverters, when they have been tested with said FACTS.
The typical FACTS the one defined in the earlier part of this procedure.

As a result of the implementation of this verification procedure there will be a verified test report of the FACTS and its inverters associated from the laboratory. This report will include the testing of FACTS and the results of testing to verify the response of the PVCS during a voltage dip.

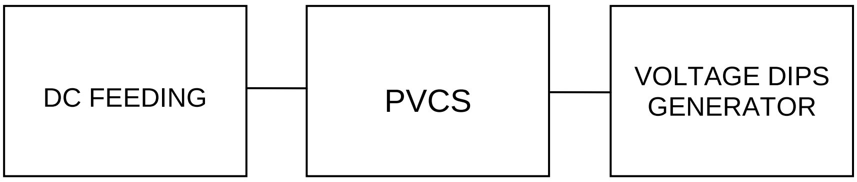
5 TESTING PROCESS

This section established the conditions and validity criteria of the test of the PVCS, as well as the definition of the necessary equipment to carry out this test. It also specifies the steps required to determine the characteristic parameters of the response to dips in the PVCS to be tested.

The measurements will be used to verify the characteristic parameters of the response to voltage dips throughout the operating range of the PVCS.

5.1 TEST CIRCUIT

The figure below shows a wiring diagram of the circuit used for the verification of the O.P 12.3. The PVCS to be tested will be fed at its DC part by a continuous source. AC-side will be fed by a system that simulates voltage dips.



5.1.1 DC power requirements

To carry out the proposed tests in this verification procedure, these may be used:

PV array consisting of a set of photovoltaic modules.

DC power supply.

The operation of the DC source will not interfere with the operation of the PVCS to be tested, so that the test results will not differ from reality.

5.1.2 Requirements of the voltage dips generator

The voltage dips generator can be done through:

1. Inductive divider the following characteristics:

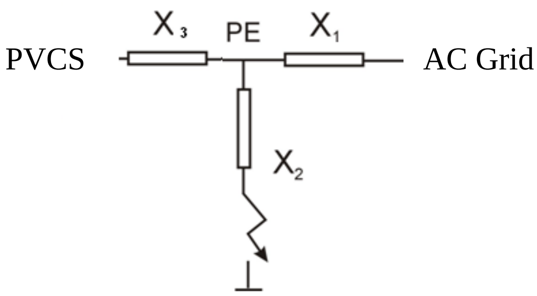


Figure AIII.1 Dips generator equipment

The impedance X1 is meant to limit the short circuit power supplied by the grid on which the test is carried out, it may represent a combination of reactance and / or transformers.

The impedance X2 is adjusted so that the residual voltage at the point TP (Test Point) corresponds with the values set in three-phase and two-phase faults.

In the branch where the impedance X2 is located there should be a switch that must be operated in such a way that is possible to generate two-phase and three-phase isolated dips. The starting point and subsequent recovery of the fault should be generated so that the times are equivalent to those used in the opening and closing of a circuit breaker.

The impedance X3 should be a transformer or a combination of reactance and transformers. The value X3 will take will be as follows:

- If the PVCS does not have a lifting transformer: X3 = 0.
- If the PVCS has a lifting transformer, two cases can occur:
    a) X3 will take the value of the impedance of the lifting transformer short circuit
    b) X3 will take the value of a +- 20% of the value of the impedance of the lifting transformer short circuit standard value
- In the case of using additional transformers in the position of the reactance X3, these may have any ratio and shall have the same group of connection than the lifting transformer of the PVCS, if it exists.

3. Power electronic device or other device capable of simulating a variable AC voltage grid, which curves (voltage-time) required on the O.P 12.3 are implemented. The point TP (Test Point) is the AC connection of the PVCS to be tested.

5.2 PVCS TESTING WITH VOLTAGE DIPS

The test will be performed applying with the generator of dips a three-phase fault and a two-phase isolated fault that causes a voltage dip on the affected phases whose characteristics, based on the O.P 12.3, are explained below.

The tests to be performed for three-phase inverters are attached in the following table (Table I):

Table AIII.1. Characteristics of the voltage dip for three-phase PVCS tests

Voltage Time	Faults	PVCS power before the dip
Ures < 20% Un > 500 ms	Three-phase	Pout>80%
		10%<Pout<30%
Ures < 60% Un	Two-phase	Pout>80%

> 500 ms	(isolated)	10%<Pout<30%

In the case of single-phase inverter being tested, two options are allowed:

- Perform the tests described in Table I with three single-phase inverters connected to a three-phase voltage dip generator.
- Perform the tests described in Table II with a single-phase inverter with a voltage dip generator capable of reproducing following faults:

Table III.2. Characteristics of a voltage dip for single-phase PVCS tests

Voltage **Time**	**PVCS power before the dip**
Ures < 20% Un > 500 ms	Pout>80%
	10%<Pout<30%
Ures < 60% With a movement of Phi angle= 30 degrees at the entry of the dip and -30 degrees at the exit > 500 ms	Pout>80%
	10%<Pout<30%

During the tests the active, reactive, currents and voltages at the point TP are recorded.

The moment of application of the dip will be random.

In both, tests and in the simulation process, all sampled records of voltage and currents for each phase are carried out at a sampling rate (or step size equivalent) of at least 5 kHz. They will record the moments before the start of dip and the 5 seconds immediately after the recovery period.

5.3 TEST VALIDATION CRITERIA

The PVCS will have passed the test for direct fulfilment of O.P 12.3, when for each test categories listed in Table I or Table II what is specified in this paragraph is achieved:

<u>(1) Residual stress level and time during the load test</u>

Depending on the existing short-circuit power at the test point (TP) the way to get the voltage dip profile to apply has to be differentiated:

- If the short circuit power in the TP is equal to or 5 times greater than the power of the PVCS registered to test, the dip may be obtained by testing with the PVCS disengaged from the dips generator (hereinafter "vacuum test"). In the load test (with the PVCS attached), the adjustment of the impedances of the generator set of dips should be the same as that performed in the vacuum test. In the vacuum test it will be found that the residual voltage of the dip corresponds to the value indicated in Table I.

- If the short circuit power in the TE is less than 5 times the power of the PVCS registered to test, it necessarily has to measure the dip profile during the test load. In this case we see that the residual voltage of the dip corresponds to the value indicated in Table I.

(2) Point of operation

For each test category (see Tables I and II), it is a necessary condition that the active power recorded prior to the completion of the voltage dip is within the range that defines partial load (10% <Pout <30%) and full load (Pout> 80%).

(3) Ensuring continuity of supply:

If PVCS disconnection occurs during the application of the voltage dip in one of three consecutive tests for each test category (see Tables I and II), the test of the PVCS shall not passed.

(4) Conditions of exchange of power and energy in the test point.

The current value injected by the PVCS during the fault must meet the specified in the O.P 12.3 in terms of values of reactive power, active and reactive power consumption.

Voltage measurements and current required for the subsequent calculation of power and energy (active and reactive) as indicated in the O.P 12.3 were recorded in the TP test point.

The methodology of calculating the active power, reactive power, reactive intensity and voltage value that will be used to determine the requirement conformity of the response to voltage dips according to the O.P 12.3 of the Electric System, is defined in Appendix C of the standard UNE-EN 61400-21: 2009 "Measurement and evaluation of the characteristics of quality of supply of wind turbines connected to the grid."

6 TEST REPORT MODEL

The following are the minimum information necessary to complete the corresponding test report:

- *Process:* Test and measurement of the individual response of a typical inverter converter (PVCS) or a FACTS device in a voltage dips situation

Report to be issued: ACCREDITED VERIFICATION TEST REPORT INFO

If the FACTS is tested with different types of inverters, it should be included in tables AIII.3 and AIII.1 for each of them.

Table AIII.3. Data that defines the PVCS of the tested inverter type.

TEST REPORT OF THE PVCS OF INVERTER TYPE	
No. of test report:	
Date of test report:	
Place and date of test:	
SPECIFICATIONS OF THE INVERTER TYPE	
Manufacturer:	
Model:	

Manufacture date:	
Topology:	
Type of galvanic isolation:	
Connection regime (single-phase or three-phase):	
Modular (Yes/No):	
Inverter models assimilated to the typical inverter:	
CC Input:	
Input voltage range (V):	
Maximum input current (A):	
CA Output:	
Output voltage (V):	
Rated output (A):	
Nominal power (kW):	
Maximum power (kW):	
Control:	
Version of the software control:	
Start date of the software control:	

Table AIII.4. Data that define the tested FACTS device.

FACTS DEVICES TEST REPORT	
No. of the test report:	
Date of the test report:	
Name of the FACTS device:	
Manufacture date of the FACTS device:	
Place and date of the test:	
Manufacturer:	
SPECIFICATIONS OF THE FACTS DEVICE	
FACTS device:	
Brand and model:	
Technology:	
Nominal power (kW):	
Nominal voltage (V):	
Control software of the FACTS device:	
Manufacturer of the software control:	
Type, brand and control model:	
Version of the software control:	

Table AIII.5. Data of the technical identification of a PVCS of an inverter type for the validation of its simulation computer model

INVERTER TYPE MODEL VALIDATION REPORT	
No. of the model validation report:	
Date of model validation:	
Accredited laboratory which issued the model validation report:	
TEST VERIFICATION REPORT	
No. of the model verification report:	
Test place and date:	
Accredited laboratory issuing test report:	
INVERTER´S SPECIFICATIONS	
Manufacturer:	
Model:	
Manufacture date:	
Topology:	
Type of galvanic isolation:	
Connection regime (single-phase or three-phase):	
Modular (Yes/No):	
Inverter models assimilated to the typical inverter:	
CC Input:	
Input voltage range (V):	
Maximum input current (A):	
CA Output:	
Output voltage (V):	
Rated output (A):	
Nominal power (kW):	
Maximum power (kW):	
Control:	
Version of the control software:	
Start date of the software control:	

Table AIII.6. Data for the technical identification of a FACTS device for the validation of its simulation computer model.

MODEL VALIDATION OF A FACTS DEVICE REPORT	
No. of the model validation report:	
Date of the model validation:	
Accredited laboratory which issued the model validation report:	
TEST VERIFICATION REPORT	
No. of the model verification report:	
Test place and date:	
Accredited laboratory issuing test report:	
FACTS DEVICE SPECIFICATIONS	
FACTS device:	
FACTS device manufacturer:	
Brand and model:	
Technology:	
Nominal power (kW):	
Nominal voltage (V):	
FACTS device Software Control:	
Software Control manufacturer:	
Type, brand and model of the control:	
Control software version:	
SPECIFICATIONS OF THE SIMULATION MODEL OF THE FACTS DEVICE	
Name of the simulation model of the FACTS device:	
Simulation software and software version:	
Simulation model supplier body:	

Table AIII.7. Register of power and energy. Three-phase faults in general and particular processes.

THREE-PHASE FAULTS	O.P 12.3 REQUIREMENTS	RESULT
ZONE A		
Net consumption Q < 60% Pn (20 ms)	**-0.6 p.u.**	
ZONE B		
Net consumption P < 10% Pn (20 ms)	**-0.1 p.u.**	
Ir/Itot average	**0.9 p.u.**	
ZONE C		
Net consumption Er < 60% Pn *150 ms	**-90 ms.pu**	
Net consumption Ir < 1,5 In (20 ms)	**-1.5 p.u.**	

Table AIII.8. Register of power and energy. Two-phase isolated faults (power and reactive power consumption limits are only applicable to new plants)

TWO-PHASE FAULTS	O.P 12.3 REQUIREMENTS	RESULT
ZONE B		
Net consumption Er < 40% Pn *100 ms	-40 ms.pu	
Net consumption Q < 40% Pn (20 ms)	-0.4 p.u.	
Net consumption Ea < 45% Pn *100 ms	-45 ms.pu	
Net consumption P< 30% Pn (20 ms)	-0.3 p.u.	

The power consumption is expressed in normalized value (p.u.) to the recorded nominal power of the equipment tested. Energy consumption is also expressed in normalized value of the power per unit in milliseconds (ms * pu).

7 REPORT OF THE PLANT INSPECTION MODEL

The minimum information, unless justified, that the report of inspection of a plant will include, as the following:

1. IDENTIFICATION OF THE POINT OF CONNECTION TO THE GRID
   a. Voltage level:
   b. ID:
   c. Location: Region, Province, Municipality, spot
   d. Ownership: Company, VAT no.

2. IDENTIFICATION OF FACILITIES (Detailed for each of them)
   a. CIL no.:
   b. No. of the Administrative Records Special Regime Production facilities:
   c. Location: Region, Province, Municipality, spot
   d. Ownership: Company, VAT no
   e. Legal representative: name, ID no., e-mail, telephone no.
   f. Interlocutor: name, ID no., e-mail, telephone no.

3. PLANT CHARACTERISTICS (as applicable)
   a. Joint nominal power (kW).
   b. Support Structure: Fixed, follow up to 1 or 2 axis.
   c. Voltage level of individual measuring point.
   d. Voltage level of total measuring point (multiple plants).
   e. Under Voltage: level calibration and timing.

f. Relays of maximum and minimum frequency.
g. Telemetry: Not applicable, individual, in group.
h. Control centre or telemetry to which it is attached: Company and VAT no.

4. COMPOSITION OF THE PLANTS (Detailed where applicable).
   a. Trafo AT / MT: apparent power, transformer ratio, connection group and short-circuit voltage.
   b. Trafo MT / BT: apparent power, transformer ratio, connection group and short-circuit voltage.
   c. Inverters: brand, model, serial number, power, AC voltage rating, firmware version.
   d. FACTS: brand, model, serial number, power, AC voltage rating, firmware
   e. Test report of inverters and “typical” FACTS in the event of voltage dips: Laboratory, VAT no., author, date.

      Certificate of adhering to a "standard model" of the serial numbers of inverters and FACTS: Company, CIF, author, date.