Reactive power control modes for PPM & HVDC

ENTSO-E guidance document for national implementation for network codes on grid connection

Draft for consultation 1 July -15 August 2016

30 June 2016

DESCRIPTION	
Code(s) & Article(s)	**NC RfG -** Articles: 21 3 d; **NC HVDC -** Article 22
Objective	As a result of conventional power units displacement (by non-synchronous power generating units), the provision of reactive power control options for Power Park Modules (PPMs) and HVDC converters in the medium voltage (MV) to extra high voltage (EHV) level grid becomes critical. Reactive power control is a basic requirement for controlling the voltage in electric networks. The voltage is controlled to operate the network within the voltage ranges and to maintain voltage stability. Functions of power system management (e. g. optimal power flow) can only be achieved by specific reactive power provision. Reactive power control and, thus, voltage control for Types C and D Power Park Modules and HVDC might be a cross-border issue in some cases. The absence of such a facilities can lead to voltage instability which can spread to neighbouring systems and affect cross-border trading. It is the objective of this IGD to provide guidance on the reactive power control modes to be considered when choosing relevant national mode(s) and parameters and to give a transition from steady-state operation to dynamic fast fault current contribution.
NC frame	According to Article 20(2)(a) of NC RfG the RSO can specify requirements for reactive power capabilities of Type B PPM. Article 21(3)(b) and (c) of NC RfG specifies the reactive power capabilities for Type C (and above by default) by defining sizes of inner envelopes which can be placed in a fixed outer envelope. The requirement is defined for operation both at maximum capacity and below maximum capacity. Article 21(3)(d) finally defines the reactive power control modes of Type C and above for PPMs. NC RfG requires three reactive power control modes: (a) voltage control mode (b) reactive power control mode (c) power factor control mode The choice which of the reactive power control mode is to be applied is done by the relevant system operator in coordination with the relevant TSO and the PPM owner. According to Article 20 of NC HVDC the relevant system operator in coordination with the relevant TSO shall specify the reactive power capability of HVDC systems. NC HVDC requires the HVDC systems to be capable of operating in one or more of the three control modes (Article 22(1)) mentioned above. Additional reactive power control modes can be required by the relevant system operator in coordination with the relevant TSO (Article 22(2)). For both codes the relevant TSO shall specify especially: - which reactive power control mode the Power Generating Module (PGM) or HVDC systems shall be operated, - the ranges and parameters for the respective reactive power control mode(s), - the duration until new setpoint values are reached and

- the equipment to set reactive power control mode remotely

Further info	

INTERDEPENDENCIES

Between the CNCs	NC RfG NC HVDC No explicit interdependencies with the DCC is mentioned. However, for PPM connected in distribution grids, the requirements for reactive power capability of type B PPM and the reactive power control modes of type C PPM are linked, based on the sound understanding of the way power system are designed and operated, with the requirement for reactive power exchange at the TSO/DSO interface as stated in article 15 of the NC DCC.
With other NCs	No interdependencies with other NCs.

System characteristics	Reactive power is the main measure to control network voltage in high voltage (HV) and EHV networks. With increasing penetration of non-synchronous equipment these devices will be more important for maintaining voltage stability. Dynamic parameters can be specified by the TSO in such way that they support their system management. The reactive power control modes are intended for steady-state and quasi-steady-state operation. These requirements allow the power system to operate in an acceptable and secure state prior to any perturbation. In case of perturbation such as change in grid loading or generation patterns or in case of outages and maneuver, the reactive power control modes are to be designed to support the voltages while remedial actions are put into place by the system operators. However, since these control modes are not intended for use in –fast transient situations like short circuits, fast fault current contribution is separately defined in other requirements and is dealt in IGD Fault current contribution from PPMs & HVDC converters. Requirement for reactive power control modes have to be defined coherently with other requirements related to reactive power issues.
Technology characteristics	HVDC systems and most PPM are connected via power electronics (PE) interface (either full-size or partial converter). As there is no inherent behaviour on reactive power, requirements one the one hand have to be well defined. On the other hand PE offer a broad flexibility of control modes and parameter even after commissioning. The three reactive power control modes in detail are: <u>Voltage Control Mode (Voltage Droop)</u> This is a proportional voltage controller, allowing a steady-state error between the target voltage value and the actual value. Therefore, the voltage is not kept perfectly constant. It is rather a voltage-dependant reactive power provision (voltage droop). However, the term voltage control usually is applied for this mode, too. The main interest of this voltage control mode is to limit undesirable interaction between

different voltage controllers (such as hunting).The implementation of an equivalent voltage droop at the connection point for a synchronous generator with low voltage (LV) constant voltage control is commonly facilitated by the internal impedance between the unit terminals and the connection point, i.e. the transformer impedance. Should a PPM be designed to control the LV voltage rather than the normal control of the higher connection voltage similar considerations would apply.

The relevant TSO shall specify especially:

	value range NC RfG	value range NC HVDC
setpoint voltage	0.95 p. u. – 1.05 p.u.	as specified by relevant TSO
setpoint voltage stepsize	≤ 0.01 p. u.	as specified by relevant TSO
deadband	0 – ±5 %	0 – ±5 %
deadband stepsize	≤ 0.5 % of nominal voltage	as specified by relevant TSO
slope	2 % - 7 %	as specified by relevant TSO
slope stepsize	≤ 0.5 %	as specified by relevant TSO
rise time	1 s – 5 s	0.1 s – 10 s
settling time	5 s – 60 s	1 s – 60 s
steady-state tolerance	≤ 5 % of maximum reactive power	

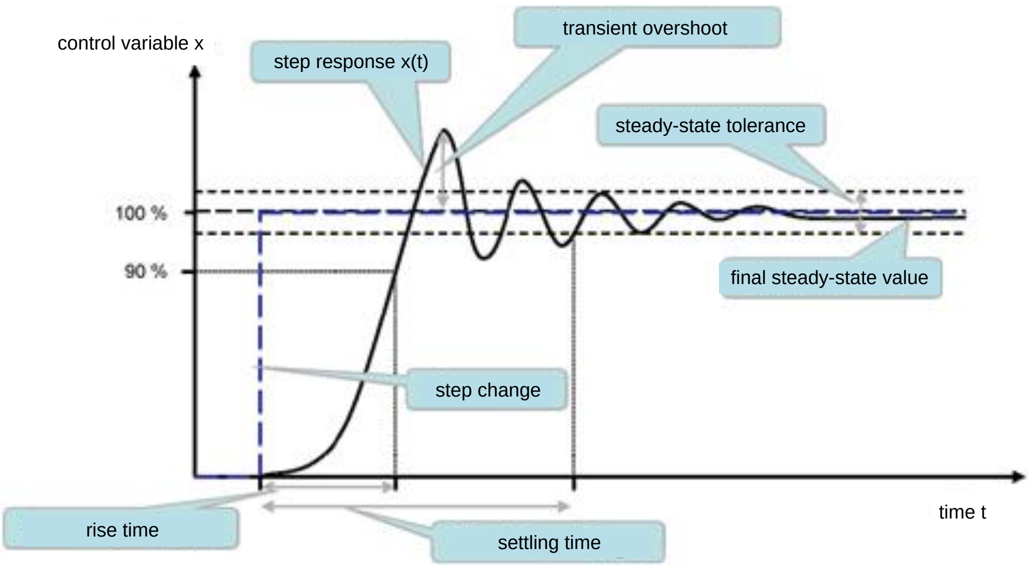

Figure 1: Voltage control mode, dynamic parameters

Reactive power control mode

This mode aims at feeding constant reactive power at the connection point following a setpoint expressed in terms of reactive power.

The relevant TSO shall specify especially:

	value range NC RfG	value range NC HVDC
setpoint	specified in Article 20(2) and 21(3)	as specified by relevant TSO, using HVDC capabilities
setting steps	≤ 5 MVAr or 5 % of maximum reactive power (whichever smaller)	as specified by relevant TSO, using HVDC capabilities
accuracy	≤ 5 MVAr or 5 % of maximum reactive power (whichever smaller)	as specified by relevant TSO, using HVDC capabilities

Power factor control mode

This mode aims at providing a constant power factor (at all active powers) at the connection point.

The relevant TSO shall specify especially:

	value range NC RfG	value range NC HVDC
PF range	within specified reactive power range	with respect to Articles 20 and 21
PF stepsize	≤ 0.01	as specified by relevant TSO
dynamic	specified by relevant TSO	-
tolerance	expressed through corresponding reactive power (absolute value or percentage of maximum reactive power)	-

NC HVDC requires one or more modes to be implemented and relevant TSO specifies equipment for remotely selecting control modes – if applicable – and parameters.

NC RfG requires at least one of the three modes and parameters (specified by relevant TSO) to be implemented. Relevant setpoints should be selectable remotely.

The point of reference for reactive power control is the connection point.

Conclusions

NC RfG and NC HVDC offer a variety of reactive power control modes that can be used for voltage management. While constant reactive power or power factor need

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

	remote adjustment in case of voltage variations, the voltage control mode automatically contributes to a mitigation until new parameters are selected remotely.
COLLABORATION	
TSO – TSO	According to NC provisions RfG TSO – TSO collaboration is not required.
TSO – DSO	According to NC provisions RfG (Article 21(d)(vii)) TSO – DSOs collaboration is required for DSO connected Type C and D PPMs. According to NC provisions HVDC for DSO connected HVDC systems collaboration is required.
RNO – Grid User	According to NC provisions RfG RNO – Grid Users collaboration is not required.

Examples of reactive control scheme in PPM

Germany, to be implemented: Control loop for combining fast fault current contribution and reactive power control modes

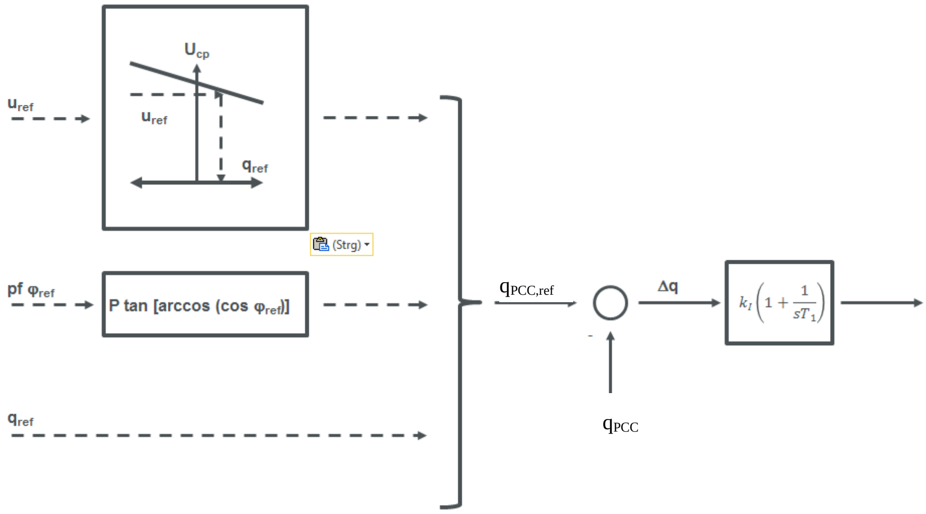

Figure 2: Reactive power control modes as input for PPM reactive power controller (see Figure 3)

Reactive power control for steady-state operation should be well combined with fast fault current contribution since both will support the voltage. In IGD Fault current contribution from PPMs & HVDC converters and Figure 3 the control scheme of a continuous dynamic grid support is presented. The block "PPM voltage controller" may contain each of the three reactive power control modes (see Figure 2) including adequate parameters to fulfil reactive power control requirements. For fault phases A and B alternative control arrangements may achieve higher speeds with less accuracy.

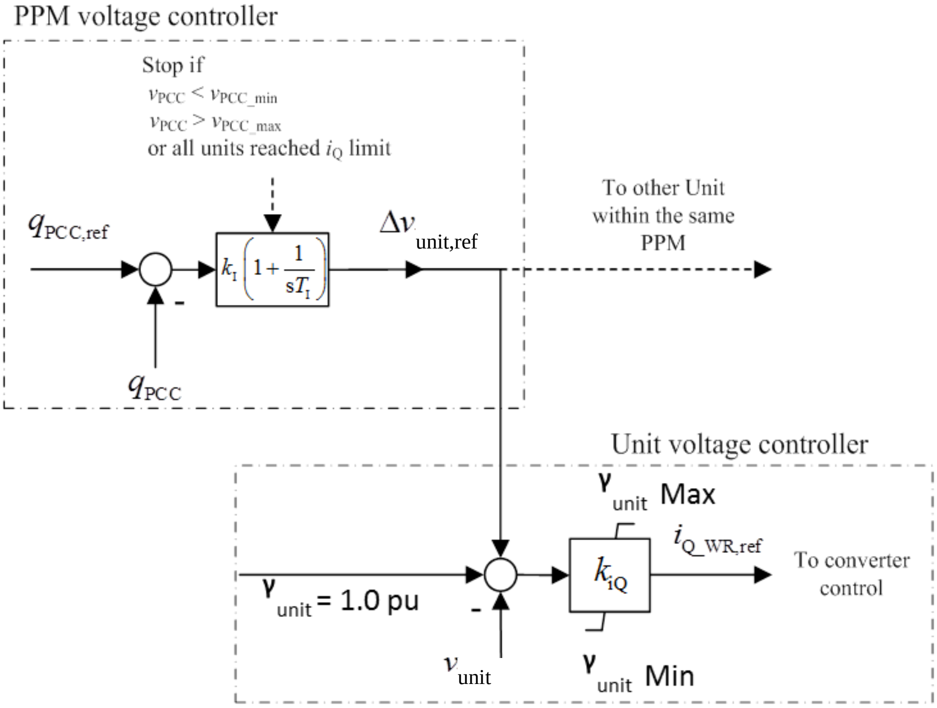

Figure 3: Principle of a continuous dynamic grid support