Voltage support in 2011

Voltage support concept for the Swiss transmission system from 2011

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Summary

An expanded voltage support concept will be introduced on 1 January 2011. Together with stakeholders and experts from the sector, Swissgrid has served in an advisory capacity in discussions on the revision of the existing concept and, based on these, has drawn up the concept set out in this document and submitted it for consultation. The key changes compared to the 2009 and 2010 concepts can be summarised as follows:

- Beginning in 2011, the cost-free range of the reactive energy exchange above the power factor limit will be expanded by a fixed reactive power range for both distribution systems and end customers directly connected to the transmission system. The purpose of this is to counteract the undesirable incentive to switch off nearly idle transformers to save reactive energy costs, thus impairing the reliability of supply.
- From 2011 onwards, distribution systems and end customers directly connected to the transmission system should have the opportunity to take an active part in voltage support in the transmission system and receive financial compensation for this. Grid users will then be able to choose between an «active» and a «passive» role. Swissgrid's aim is to make additional reactive power resources available for voltage support in the transmission system.
- Active participants in voltage support in the transmission system (previously limited to power plants directly connected to the transmission system) will be compensated for the reactive energy delivered in compliance with the requirements. Beginning in 2011, active participants will also be invoiced for any non-compliant exchange of reactive energy. Swissgrid will enact this change in an effort to apply the user-pays principle more rigorously.
- The prerequisites regarding compliance for the reactive energy delivery of active participants in voltage support in the transmission system will be adapted. Beginning in 2011, compensation will only be paid for reactive energy delivered in compliance with the requirements if monthly compliance reaches at least 80 % (previously 70 %). When performing compliance tests, tolerances of ±2 and ±3 kV will be allowed for voltage measurements for the 220 and 380 kV levels, respectively (previously ±3 and ±5 kV). This change will increase the incentive to ensure and boost the quality of voltage support.

In future, the voltage schedule with setpoint voltage specifications for power plants at the infeed nodes will be displayed with a time resolution of 15 minutes. This means that when phase shifters are requisitioned it will also be possible to adjust the setpoint voltage during the hour at the corresponding infeed node. Setpoint voltages will continue to vary on an hourly basis.

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1 Introduction

1.1 Concept requirements

Various specifications limit the design freedom for a voltage support concept for the Swiss transmission system. The following sections are intended to provide an overview of the relevant concept development framework.

1.1.1 Legal and regulatory framework

The legal requirements for voltage support are set out in the Electricity Supply Act (StromVG) and the Electricity Supply Ordinance (StromVV) [1,2]:

- StromVG Art. 4 Para. 1g defines «voltage support (incl. proportion of reactive energy)» as an ancillary service.
- StromVG Art. 20 defines the responsibilities of the national grid company. Para. 2b: «It is responsible for balance management and guarantees the other ancillary services including provision of control energy. The power plant capacities required for this purpose must be procured using transparent and non-discriminatory processes». 2c: «In the event of a threat to stable grid operation, it shall order the necessary measures. It shall agree the details with the power plant operators, the grid operators and the other participants».
- StromVV Art. 22 Para. 1: «If it does not provide them itself, the national grid company shall procure the ancillary services by following a market-oriented, non-discriminatory and transparent process». Para. 2: «It sets the prices for ancillary services in such a way that costs are covered». Para. 6: «It reports annually to ElCom on the actual ancillary services provided and the allocation of costs».
- StromVV Art. 5 Para. 1: «The national grid company, grid operators, power generating companies and other parties involved shall initiate preparatory measures to ensure reliable grid operation. In doing so, they shall take international agreements, standards and recommendations from recognised specialist organisations into consideration, particularly the specifications issued by the Union for the Co-ordination of Transmission of Electricity (UCTE)».
- StromVV Art. 5 Para. 4: «In the event of a threat to stable grid operation, the national grid company must by rights take or order any measures that are necessary to ensure grid security (Article 20, Paragraph 2c StromVG). If an order from the national grid company is not followed, the national grid company may take an alternative measure at the expense of the recipient of the order».
- StromVV Art. 15, Para. 1 sets out how to charge costs incurred in connection with the transmission system: «The national grid operator individually bills: a. grid operators and end consumers directly connected to the transmission system for the costs of offsetting active power losses and delivering reactive energy based on the user-pays principle [...]».

The provisions set out in the Ordinance on High Voltage and Power Lines are not relevant here since this is a purely operational concept.

1.1.2 ENTSO-E specifications

Apart from the legal provisions, the rules set out in the ENTSO-E (UCTE[1]) Operation Handbook, Policy 3, Chapter B «Voltage Control and Reactive Power Management» must be observed [3]. The most important specifications contained in the Operation Handbook are:

[1] UCTE was integrated into ENTSO-E on 1 July 2009 and continues to exist under the name «Regional Group Continental Europe».

- B-D1: «The voltage is regulated in a range of values, which guarantees also in N-1 of elements (described in A1-D2.1):
  - the compatibility with the rating of the equipment,
  - the supply of customers within the contractual ranges of voltage,
  - the voltage stability of the power system, i.e. sufficient voltage stability margins for small and large disturbances in the short term and long term».
- B-S1.1: «Policies and procedures for voltage control have to be developed and implemented by each TSO in its respective responsibility area».
- B-S1.1.2: «TSOs are in charge of coordinating all needed operational actions with their adjacent TSOs and other stakeholders owning installations connected to the transmission network (Distribution System operators and related distribution networks, connected generating units, connected consumers)».
- B-S1.2.2: «TSOs have to keep available a sufficient number of other reactive power sources like generators, capacitors and reactors connected to the grid, which contribute to reactive power generation or absorption, in order to maintain or get back the voltage in normal ranges after any contingency».
- B-S1.2.3: «Each TSO must have information of the main reactive power resources available for use in the transmission network of its own responsibility area. TSOs shall be duly informed without delay about restriction of reactive power sources».

For a variety of reasons, yet primarily as a result of insufficient reactive power resources in the transmission system, Swissgrid is not entirely capable of meeting these requirements at present.

1.1.3 Objectives of voltage support in the transmission system and participants' responsibilities

Previously a vertically-integrated organisation of production, transmission and distribution, the unbundling of the transmission system creates new interfaces and responsibilities for the parties involved. Consequently, the interfaces for voltage support between power plants and the transmission system, on the one hand, as well as those between the transmission system, the distribution systems and the directly connected end customers, on the other, must be redefined. The changed role of the transmission system operator also entails new voltage support responsibilities and objectives.

1.1.3.1 Basic objectives

From a technical and scientific perspective, the following criteria should be met for the purpose of ensuring secure, reliable voltage support (see also [4]):

1. The voltage on all equipment in the system must be within the operational limits at all times.
2. It must be possible to guarantee voltage stability at all times. Sufficient reactive power resources are required for static stability. Moreover, reactive power reserves must also be available for use at short notice to ensure dynamic stability.
3. Reactive power flows (or node voltages) in the system should be optimised in order to reduce grid losses to a minimum.

1.1.3.2 Objectives of Swissgrid, the transmission system operator

In planning and operation, Swissgrid pursues the following three objectives with regard to voltage support (in order of decreasing priority).

- **Security and stability:** The primary objective of voltage support is to maintain the voltage within a secure, stable range. «Secure» is in reference to the threat to equipment and/or people. «Stable» relates to voltage stability; this is ensured by means of sufficient stability reserves. The secure, stable voltage range is defined by upper and lower voltage limits.
- **ENTSO-E (UCTE) compliance:** The aforementioned criteria set out in the ENTSO-E (UCTE) Operation Handbook must be met to the greatest extent possible. In particular, the availability of sufficient reactive power resources and reactive power reserves to cover domestic demand in Switzerland must be ensured.

- **Efficiency and cost minimisation:** Within the remaining room for manoeuvre, the voltage should be set in such a way as to minimise the cost of grid operation. This concerns both the cost of covering active power losses and the cost of reactive energy in compliance with the requirements.

1.1.3.3 Swissgrid's responsibilities

Swissgrid's main responsibility is to define the specifications that apply to the providers of the voltage support ancillary service in accordance with the above objectives and framework and to communicate these to them. In order to draw up these specifications, Swissgrid plans and coordinates the use of available resources in the Swiss control area. Swissgrid monitors the use of reactive power resources and settles the cost of the services provided and received with the providers and recipients in accordance with legal provisions. Through various regulations Swissgrid creates incentives for providers and recipients to act efficiently. Swissgrid also coordinates voltage support with neighbouring grid operators.

1.1.3.4 Responsibilities of the providers

On the instruction of Swissgrid, providers of the voltage support ancillary service are controllable or adjustable reactive power resources whose participation in voltage support is defined by contract. Providers are grid participants that are directly connected to the transmission system and capable of exchanging reactive energy with the transmission system in a controlled manner in compliance with the requirements. The providers' main responsibility is to implement Swissgrid's operating requirements. The providers also furnish Swissgrid with the data it requires to plan, monitor and bill for the services.

1.1.3.5 Responsibilities of the recipients/users

Recipients of the voltage support ancillary service (users responsible for the associated costs) are grid elements or grid participants that exchange reactive power with the transmission system and cannot be controlled or adjusted by Swissgrid. The recipients also furnish Swissgrid with the data it requires to monitor and bill for the services received.

1.2 2009 and 2010 concepts

The 2009 concept for voltage support in the Swiss transmission system is the result of the MUNCH project – Market Liberalisation of the Swiss Transmission Grid. This concept provides for mandatory participation by the power plants directly connected to the transmission system whereby the reactive energy exchanged in compliance with the requirements is compensated for at a flat rate (CHF/Mvarh). Supramandatory provision of reactive power (e.g. phase shifter) is governed by bilateral contracts and compensated for separately. The 2009 concept does not provide for the billing of costs to users (immediately downstream grids and directly connected end customers).

The 2010 concept is identical to the 2009 concept with the exception that it also includes user-pays billing for the reactive energy exchange to downstream grids or end customers directly connected to the transmission system in accordance with Art. 15 Para. 1a StromVV [2]. This is done at ElCom's [5] request. Billing is based on the grid usage model drawn up by the sector for the transmission system [6]. The portion of exchanged reactive energy that falls short of the 15-minute average power factor of 0.90 is invoiced at a fixed rate (CHF/Mvarh).

1.3 2011 concept

The 2011 concept differs greatly from the earlier 2009 and 2010 concepts on the following points:

- Beginning in 2011, the cost-free range of the reactive energy exchange above the power factor limit will be expanded by a fixed reactive power range for distribution systems and end customers directly connected to the transmission system. The purpose of this is to counteract the undesirable incentive to

switch off nearly idle transformers to save reactive energy costs, thus reducing redundancy and impairing the reliability of supply.

- Grids that are immediately downstream of the transmission system and directly connected end customers will be given the option of actively participating in voltage support in the transmission system.
- Participation will remain mandatory for any power plants connected directly to the transmission system. One new aspect of mandatory participation is that the power plant's reactive power capacity that is currently available at any given time and which can be provided without compromising the active power must be used to maintain the setpoint voltage[2].
- According to the 2009 and 2010 concepts, active voltage support participants (limited to power plants directly connected to the transmission system) are compensated for reactive energy exchanged in compliance with the requirements. Beginning in 2011, not only will power plants directly connected to the transmission system as well as other active participants (immediately downstream grids and directly connected end customers) be compensated for compliant reactive energy, they will also be invoiced for any non-compliant exchange of reactive energy.
- The monthly compliance limit for remuneration for compliant reactive energy will be increased from 70 % to 80 %.
- For settlement purposes, the voltage measurement tolerance applied to the reactive energy exchanged in compliance with the requirements will be reduced from 3 and 5 kV to 2 and 3 kV, respectively (220 kV and 380 kV levels).
- In future, the voltage schedule with setpoint voltage specifications for power plants at the infeed nodes will be displayed with a time resolution of 15 minutes. This means that when phase shifters are requisitioned, it will also be possible to adjust the setpoint voltage during the hour at the corresponding infeed node. Setpoint voltages will continue to vary on an hourly basis.

Table 1 summarises the changes in the billing methods.

Participant	**2009**	**2010**	**2011**
Power plants	Reactive energy in compliance with requirements	Reactive energy in compliance with requirements	Compliant and non-compliant reactive energy
Downstream grids and end customers	No billing	Billing outside the cost-free range (power factor below 0.90)	Freedom to choose between active and passive role
Active participants	(= Power plants)	(= Power plants)	Compliant and non-compliant reactive energy
Passive participants	(= Downstream grids and end customers)	(= Downstream grids and end customers)	Billing outside the cost-free range (extended)

Table 1: Overview of billing methods.

1.4 General principles, terminology and sign convention

1.4.1 Reactive power and reactive energy

The definition of reactive power can be found in specialist literature (e.g. IEC 60050 – International Electrotechnical Vocabulary, www.electropedia.org) and will not be discussed further in this document.

[2] In the past the concept prescribed that, regardless of the generators' operating status, the reactive power range that would be available at full active power must be used even if full active power was not being generated.

In accordance with IEC 60050 and IEC 60027-1, the unit used for reactive power is «var» and both «varh» and «Mvarh» are used for reactive energy.

From a purely physical point of view, reactive energy is always equivalent to zero because, by definition, the time integral of the reactive power is always equal to zero (if integrated over complete periods). Nevertheless, these terms are used in electrical engineering. Reactive energy is the product of reactive power and time. If 1 var is exchanged for 1 hour, we talk about 1 varh of reactive energy.

1.4.2 Sign convention

This document uses the consumer meter arrow system:

- **Q < 0, negative value:** delivery of inductive reactive power to the transmission system (hereinafter referred to as «delivery» for the sake of simplicity) leads to an increase in the voltage at the infeed node, behaviour like a capacitance.
- **Q > 0, positive value:** purchase of inductive reactive power from the transmission system (hereinafter referred to as «absorption») leads to a reduction in the voltage at the infeed node, behaviour like an inductance.

1.4.3 Power factor

The power factor refers to the quotient of active and apparent power. The average power factor can be calculated for each 15-minute metering period using the active and reactive energy meter values:

$$LF = \frac{|W_P|}{\sqrt{W_P^2 + W_Q^2}} \qquad (1.1)$$

Where

LF is the power factor (dimensionless);

W_Q is the net reactive energy exchanged in Mvarh (15-minute meter value);

W_P is the net active energy exchanged in MWh (15-minute meter value).

1.5 Contractual regulations

Today, remuneration for the reactive energy exchanged in compliance with the requirements is set out in the operating agreements with power plant operators. The billing of the individual ancillary service tariff for reactive energy to grids immediately downstream of the transmission system as well as end customers does not have an explicit contractual basis but is based rather on the General Conditions Governing Billing of Transmission System Costs [12].

For the supramandatory provision of reactive power, Swissgrid has concluded standard bilateral contracts with select power plants that contain a compensation mechanism for phase shifting operation of the plants.

2 2011 concept: «active/passive» model

2.1 Fundamental idea

The basic notion of the 2011 model is to give all power plants directly connected to the transmission system, grids immediately downstream of the transmission system and end customers directly connected to the transmission system, in Switzerland, the opportunity to actively participate in voltage support in the transmission system.

Participation in transmission system voltage support will remain mandatory for all power plants directly connected to the transmission system if they are in operation (this applies to production and pump mode)

As of 1 January 2011, downstream grids and end customers directly connected to the transmission system will be able to choose between «active» and «passive» participation in voltage support in the transmission system.

- **Active participation:** Delivery of compliant reactive energy according to Swissgrid's operating requirements, compensation for reactive energy exchanged in compliance with the requirements and billing of non-compliant exchange of reactive energy.
- **Passive participation:** Incentive to promote perturbation-free performance and to limit the exchange of reactive energy, billing of excess exchange of reactive energy outside the cost-free range.

2.2 Choice between active and passive role

The choice between active and passive participation in voltage support in the transmission system is made for each substation, voltage level in the transmission system and grid user. A distribution system operator whose distribution system is connected to the transmission system in several substations can thus choose between active and passive participation for each substation and each voltage level connected. Settlement in the passive model also works according to this principle (see Section 2.4.3).

Swissgrid offers this freedom of choice subject to the technical possibilities available. Swissgrid will review the technical feasibility of the choice as well as its impact on grid operations on a case-by-case basis and will reach an individual decision based on standard, transparent criteria. If required, Swissgrid can call for operational measurements and tests to be performed.

By default, Swissgrid treats all downstream grids and end customers directly connected to the transmission system as passive participants. If a participant desires to switch its status to active, that participant must submit a change request to Swissgrid. Participants can switch from active to passive (or vice versa) at the start of a new year subject to three months' notice. An informal written request to this effect must be received by Swissgrid by 1 October of the year prior to the change.

The first-time declaration of an active role for 2011 must be requested in writing by 30 July 2010 at the latest. Any feed-out points for which no explicit request for active status has been received by then will be treated as passive in 2011.

2.3 Mandatory and supramandatory participation in voltage support

2.3.1 Mandatory participation

As of 1 January 2011, active participation in voltage support for the transmission system will be mandatory for the following grid participants:

- All power plants directly connected to the transmission system which are in operation (production, pump mode or synchronous/phase shifting mode), within the scope of their available reactive power that can be exchanged with the transmission system without compromising the active power.
- Downstream grids and end customers directly connected to the transmission system that have declared their active participation, within the scope of their available reactive power that can be exchanged with the transmission system without compromising the active power. This obligation exists regardless of their operating status and is considered permanent.

Generally, a power plant is also considered to be directly connected to the transmission system if the machine voltage (generator bar) is transformed directly, in other words using just one single transformation stage, to the transmission system voltage and all power generated by the power plant is fed into the transmission system.

The tertiary side of 220/380 kV coupling transformers is considered part of the transmission system. Consequently, power plants that feed in power via the tertiary winding of 220/380 kV coupling transformers are considered to be directly connected to the transmission system.

There are power plants which, due to their technical design and potential, can be classified as «power plants in the transmission system» for voltage support purposes despite the fact that they do not fully satisfy the criteria specified above. This could be the case if a large power plant feeds into a grid which is downstream of the transmission system, for example. In cases such as these, the following exceptions to the rule described above have been defined. In addition to the criteria defined above, a power plant is also considered to be directly connected to the transmission system for voltage support purposes if one of the following applies:

- There is an electrical connection from the generator bar(s) to the transmission system (220/380 kV) which only passes over busbars, transformers and short, radial spur lines. The sole purpose of the spur lines is to transport power plant output.
- The connection to the transmission system is designed in such a way as to enable the power plant to supply its full rated power to the transmission system at any time, even if the distribution system connected to the power plant is not drawing any power (in other words, if the surrounding distribution system were «activated», the power plant could provide its full rated power to the transmission system via a remaining, direct path).
- Any direct connection to distribution systems or end consumers is not designed such that the power plant's full rated power could be fed into the distribution system or drawn by the end consumer.
- During operation, the power plant has a reactive power range which allows it to have a significant influence on the voltage at the transmission system's feed-in point.

This definition is not precise and leaves a certain discretionary latitude. At present, no precise definition is known which would make it possible define this term clearly and unambiguously without any exceptions.

2.3.2 Supramandatory participation

Power plants, distribution systems and end customers directly connected to the transmission system can conclude bilateral contracts with Swissgrid governing the provision of supramandatory reactive energy which exceed the obligations described above. Swissgrid will conclude a standard contract to this effect if there is a need for supramandatory reactive power in the vicinity of the infeed node.

2.4 Passive role

2.4.1 Responsibilities and obligations

Passive grid users do not take on any responsibilities or obligations with regard to active voltage support in the transmission system. In the event that they exceed the cost-free range, they are billed for the cost of the reactive energy.

2.4.2 Incentive to promote perturbation-free operation

The intention behind the incentive to limit the reactive energy exchange to a certain range is to promote perturbation-free behaviour from directly connected downstream grids and end customers in terms of voltage in the transmission system.

2.4.3 User-pays allocation and netting

The reactive energy volume that can be assigned to a user is defined as the reactive energy exchange per

- substation,
- voltage level in the transmission system, and
- grid user.

This principle is outlined in Figure 1 using two examples:

- In **Case A**, all three grid connections (A, B and C) belong to the same grid user. There is therefore only one grid user within the substation. However, a distinction must be made between the transmission system voltage levels in this substation – 220 and 380 kV. This is then used to settle the total for grid connections A and B. Point C is settled separately.
- In **Case B**, all three transformers (A, B and C) belong to different grid users. As a distinction is made between each grid user within the substation, all three grid connections are settled separately.

Notes:

- Where grid connections are merged within a substation, no distinction is made between busbars at a particular voltage level (see Case A: grid connections A and B are on different busbars, but are combined).
- Grid connections in different substations are always treated separately, even if the customer concerned operates an interconnected grid that is immediately downstream of the transmission system.

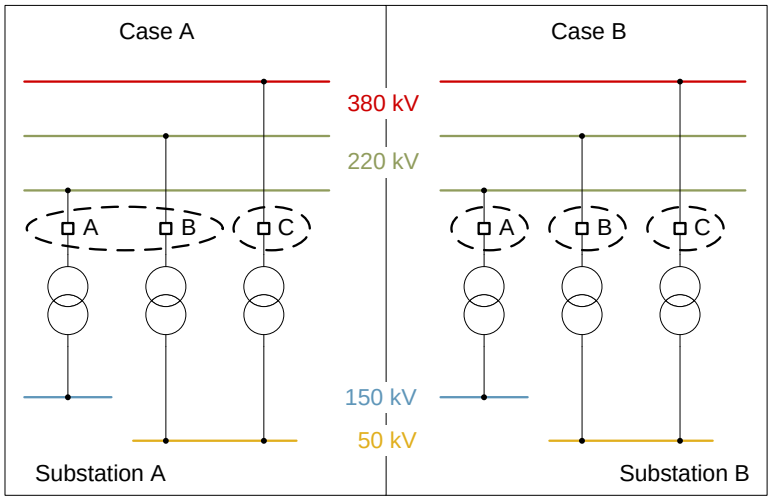

Figure 1. Case A: All transformers belong to the same grid user. Case B: All transformers belong to different grid users.

2.4.4 Settlement model

For settlement purposes, the treatment of «passive» end customers connected directly to the transmission system as well as immediately downstream grids is similar to that defined in the 2010 voltage concept. The amended 2011 model provides for an expansion of the cost-free range.

As in 2010 and in line with the user-pays principle, reactive energy is only billed once a certain tolerance threshold is exceeded. The tolerance threshold is symmetrical with regard to inductive and capacitive reactive energy. If this threshold is exceeded, the corresponding («excess» exchanged) reactive energy is billed. Within the tolerance range, nothing is billed or the tariff CHF 0/Mvarh applies.

With regard to the exchange of reactive energy, the cost-free range comprises the following:

- Power factor (LF) greater than or equal to 0.90: Reactive power of up to ±48.4 % of the active energy is free (as in the 2010 model).
- Cost-free reactive energy range: The exchange of reactive energy is free within a certain reactive energy range. This range is defined as $\pm W_{Q,lim}$ on either side of the reactive energy base line (see Figure 2). The

purpose of this expansion is to counteract the undesirable incentive to switch off nearly idle transformers during off-peak periods to save costs, thus possibly impairing the reliability of supply. The cost-free range $\pm W_{Q,lim}$ is determined individually for each feed-out point based on the installed nominal apparent power of the transformers and geared in size towards the capacitive load during rated operation (approximately: ± short circuit voltage x nominal apparent power).

The reactive energy units in excess of those within the cost-free reactive energy range will be invoiced. Net energy meter values are checked every 15 minutes; in the event that these values are in excess of the free range, settlement will be performed based on the amount by which these values are in excess.

Figure 2 provides a visual representation of this principle.

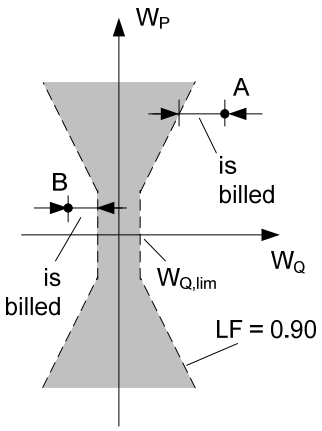

Figure 2: The reactive energy exchange within the grey area is free; the amount of reactive energy exchanged in excess of the grey area will be billed.

2.4.5 Invoicing

Invoicing is performed on a monthly basis.

2.4.6 Technical requirements

Active and reactive energy meter readings which distinguish between delivery and absorption will be needed every 15 minutes for those grid users declared as passive participants (four-quadrant metering). The net energy values (on a quarter-hourly basis) registered by the transmission system are relevant for the billing method described here. The Metering Code [7] and the energy metering requirements for the transmission system [8] apply.

2.5 Active role

2.5.1 Responsibilities and obligations

When necessary and without compromising the active power mode, active participants in voltage support in the transmission system are obligated to use the reactive power available to them for the purpose of voltage support in the transmission system. This necessity is deemed to exist for as long as the prescribed setpoint voltage value is not reached at the transmission system node.

To facilitate planning, active participants inform Swissgrid of the amount of reactive power available at their plants' connection nodes on the transmission system side. This planning basis is documented in a contract between the participant and Swissgrid (currently in the operating agreements). In the case of power plants directly connected to the transmission system, this is the reactive power that is available at the connection

node of the transmission system when the plant exchanges the maximum amount of active power. Here a distinction is made between pump and production mode at the power plant. In the case of grids immediately downstream of the transmission system and end customers directly connected to the transmission system, the available reactive power range is indicated in a daily profile with hourly intervals. Defining this range is the participant's responsibility. The starting point should be realistic minimum/maximum active power infeed amounts which take all technical and operational limitations into consideration (hydraulic/thermal, mechanical and electrical system). The planning range values always refer to the transmission system side and must be indicated using the consumer meter arrow system (see Section 1.4.2). Swissgrid will provide a guideline on how to calculate the planning range. In addition, the technique for indicating the planning range will also be defined in implementation together with the partners involved.

Additional details on the provision of reactive power are explained in Section 2.5.3.

Active participants in voltage support in the transmission system must be capable of receiving, acknowledging, processing and implementing a voltage schedule from Swissgrid at any time (24/7). Voltage schedules are transmitted and acknowledged via e-mail and/or the Internet. It must be possible to implement a newly-received voltage schedule immediately.

Active participants in voltage support in the transmission system must provide Swissgrid with a contact in operations who can be reached at any time (24/7) and can immediately check or intervene in the plants' reactive power exchange.

The voltage schedule must be implemented by means of continuous adjustments to the reactive power exchange between the plant and the transmission system. The plant operator is responsible for the concrete details of technical implementation; implementation can take place automatically or manually. The specifications of the Transmission Code [9] apply.

2.5.2 Prequalification

Successful prequalification is a condition for active participation in voltage support in the transmission system.

Power plants which are directly connected to the transmission system and which already participate in voltage support do not have to prequalify (again) for mandatory participation. These participants already provided information to Swissgrid and completed various series of tests before the 2009 model was introduced.

Distribution systems immediately downstream of the transmission system and directly connected end customers must prequalify in order to switch to an active role. Swissgrid will provide the requisite prequalification documents. At minimum, participants must provide their technical, operational and organisational data for prequalification. If required, Swissgrid can also call for operational measurements or tests to be performed.

Potential participants must submit a prequalification request to Swissgrid. Information regarding this process is or will be made available on the Swissgrid website.

2.5.3 Use of the available reactive power

Active/mandatory participation in voltage support does not require that reactive power is actually reserved. Participants are only required to use any freely available reactive power that can be exchanged without compromising the active power and without starting up additional equipment (machines). Figure 3 shows the freely available reactive power range for three fictitious operating points.

Active power generation is subject to constant fluctuations in machines used for primary and/or secondary control. In this case, it is not necessary to keep changing the reactive power in accordance with the active power limits shown in the generator diagram. Instead, the reactive power available over the longer term (measured in terms of hours) should be used in line with the voltage specifications.

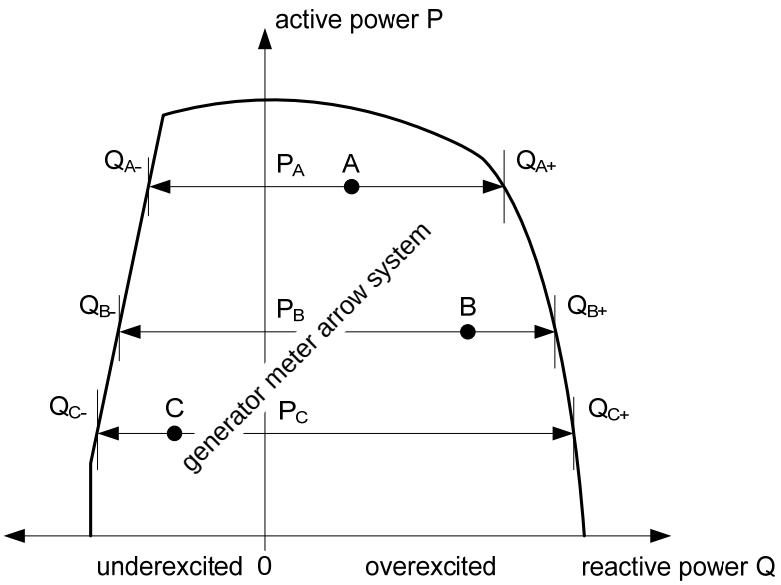

Figure 3: Use of available reactive power depicted in a generator operating diagram using three fictitious operating points (A, B and C). At operating point A, active power P_A is generated and the available reactive power range extends from Q_{A-} to Q_{A+}. At operating point B, active power P_B is generated and the available reactive power range extends from Q_{B-} to Q_{B+}. At operating point C, active power P_C is generated and the available reactive power range extends from Q_{C-} to Q_{C+}. The generator meter arrow system was chosen to illustrate this due to the fact that this is commonly used on the machine side.

Mandatory use does not result in any opportunity costs. Correspondingly, the provision of reactive power in the mandatory mode is not compensated for as power reserve-building. Within the scope of active/mandatory participation, compensation is only paid for the reactive energy actually exchanged in compliance with the requirements.

2.5.4 Connection

The units of active participants in voltage support in the transmission system are connected via

- the Internet and e-mail (voltage schedule receipt and acknowledgement);
- phone and fax (operational coordination, instructions);
- point-to-point connection (PIA, PIA2; delivery of measurement and monitoring data [10]).
- Four-quadrant metering data must be delivered to Swissgrid for reactive energy settlement. The specifications set out in the Metering Code [7] and the energy metering requirements concerning the transmission system [8] apply.

2.5.5 Requisition

Reactive power is always requisitioned based on the setpoint voltage specifications set out in the voltage schedule. The voltage schedule currently contains a node-specific setpoint voltage profile with a resolution of one hour (24 values per day) for each node of the transmission system where voltage is actively controlled. Beginning in 2011, the voltage schedule will be broken down into 15-minute intervals (96 values per day). This is not motivated by a desire to change the setpoint voltages every 15 minutes; generally, the same values will continue to apply for the entire hour. Sometimes, however, it might be necessary to adjust the setpoint voltage specification during the hour for a phase shifter requisition. This only concerns the relevant infeed node or the area in the vicinity of the phase shifter.

The setpoint voltage relates to all busbars at the relevant voltage level of a substation (the actual voltage of the relevant busbar is used for monitoring and settlement purposes).

The voltage schedule is drawn up and published every evening for the next day. If necessary, the voltage schedule can be adjusted over the course of the day and re-published. The voltage schedule recipients who actively participate in voltage support in the transmission system must be capable of immediately acknowledging and implementing a newly-received voltage schedule.

The freely available reactive power range must be used in accordance with the setpoint voltage specifications at all times. Where necessary, the freely available range must be delivered in full in order to bring the voltage as close as possible to the setpoint voltage.

2.5.6 Compliance

Active participants undertake to deliver reactive energy in compliance with the requirements. The exchange of reactive energy with the transmission system is deemed to be compliant if it contributes towards the attainment of the specified setpoint voltage. This is the case if

- the actual voltage is lower than the setpoint voltage and inductive reactive energy is fed into the transmission system (behaviour like a capacitance) or
- the actual voltage is higher than the setpoint voltage and inductive reactive energy is drawn out of the transmission system (behaviour like an inductance).

The relevant amount is the net reactive energy exchanged on the transmission system side during the 15-minute period. Voltage measurements are used to determine the actual voltage (currently transmitted via PIA). The actual 15-minute voltage used for settlement purposes is established by averaging the voltage measurements delivered 5, 10 and 15 minutes after the start of the relevant 15-minute period.

When determining the difference between the setpoint and the actual voltage, the settlement model makes allowances for deviations in voltage measurements in favour of the participant:

- ±2 kV in the 220 kV grid;
- ±3 kV in the 380 kV grid.

Figure 4 provides a visual representation of the compliance principle.

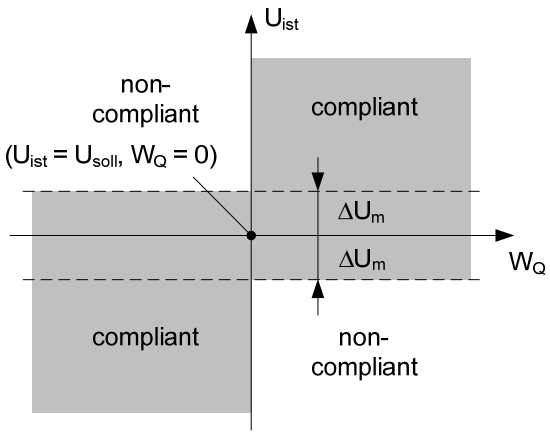

Figure 4: Compliance principle. U_{ist} is the actual voltage, U_{soll} is the setpoint voltage at the infeed node of the transmission system. ΔU_m is the deviation allowance for settlement (2 or 3 kV). W_Q is the net reactive energy exchange during the relevant 15-minute period. Left side: behaviour like a capacitance (delivery of reactive energy); right side: behaviour like an inductance (absorption of reactive energy).

The compliance of the reactive power exchange at any given moment is monitored by Swissgrid during ongoing operation. For settlement purposes, compliance is calculated every 15 minutes based on voltage measurements and energy meter values.

Monthly compliance is defined as the proportion of 15-minute periods in which the reactive energy exchange was compliant based on the total number of 15-minute periods in the month during which the power plant was online for generating active or reactive power (phase shifter operation) or for pumping.

Swissgrid currently uses active and reactive energy data to determine the 15-minute periods during which the power plant was online and uses a reconciliation report to confirm the result with its partners. This approach has proven to be impractical. Beginning in 2011, power plants will therefore be required to send a time series broken down into 15-minute intervals to Swissgrid in addition to the active energy, reactive energy and voltage measurement data; this time series will contain information regarding whether the power plant was online or not. This change will relieve Swissgrid of the task of verifying the conditions and will simplify what is currently a time-consuming reconciliation process.

With regard to compliance, the following points must also be taken into consideration:

- In addition to the compliance criterion, all the Transmission Code requirements concerning voltage-reactive power droop must also be met.
- In the event that Transmission Code specifications are violated or Swissgrid's operating instructions are not observed, the reactive energy exchange can be declared non-compliant.

2.5.7 Monitoring

Voltage measurement data is used to monitor compliance during operation. Swissgrid operates a monitoring system for this purpose. Swissgrid announces monitoring data delivery requirements in a separate document («Monitoring Data Requirements» [10]; the latest version will apply at any given time). Active participants in voltage support must provide the requested monitoring data in accordance with these requirements.

2.5.8 Compensation and billing

The reactive energy exchanged every 15 minutes is compensated for if

- the power plant is online and in production, pump or phase shifter mode during the relevant 15-minute period **and**
- the reactive energy exchange during the relevant 15-minute period is in compliance with the requirements **and**
- the exchange is compliant with the requirements during at least 80 % of the meter intervals during the month in question.

If the exchange is compliant in less than 80 % of the meter intervals, no remuneration will be paid for that month. In this case, Swissgrid reserves the right to review the active participation declaration and, if necessary, assign the participant a passive role. If the exchange is compliant in less than 70 % of the month's meter intervals during two consecutive months, the exchanged reactive energy will be billed in accordance with the passive model and prequalification for active participation will become invalid. The participant will be declared passive during the current (third) month and will need to repeat prequalification or submit a new declaration in order to return to the status of active participant (see Table 2).

Participants will always be billed for any reactive energy exchanged which is not in compliance with the requirements (see Table 2).

Monthly compliance CM	Compensation	Billing	Consequence
CM < 70 %	None	Reactive energy not in compliance with requirements After two consecutive months with CM < 70 % in accordance with the passive model retroactively from the first month	Passive role from the third month
70 % ≤ CM < 80 %	None	Reactive energy not in compliance with requirements	Declaration as a passive participant possible after Swissgrid review
80 % ≤ CM	Reactive energy in compliance with requirements	Reactive energy not in compliance with requirements	None

Table 2: 2011 compensation and billing model for active participants in voltage support in the transmission system.

2.5.9 Settlement

Settlement is performed on a monthly basis. Prior to the final credit note/invoice, participants receive a reconciliation report for confirmation.

2.6 Supramandatory provision of reactive power

All participants directly connected to the transmission system – in other words, all power plants, downstream grids and end customers – are offered the option of providing reactive power in excess of their mandatory obligation. This service is based on a bilateral contract concluded between the participant and Swissgrid.

2.6.1 Responsibilities and obligations

In the bilateral contract regarding supramandatory provision of reactive power, the participant undertakes to provide the contractually-defined reactive power capacities when requisitioned by Swissgrid to the best of its ability. The contract partner will provide the requested capacity for the requested time and will use this capacity in line with Swissgrid's operational requirements.

Generally speaking, the voltage schedule also applies during supramandatory operation. Instructions beyond this (e.g. «maximum absorption of reactive power») will be given priority over the voltage schedule. The reactive energy exchange within the supramandatory range is always considered compliant if Swissgrid's instructions are followed.

2.6.2 Prequalification

Prequalification is always necessary for the supramandatory provision of reactive power. At minimum, participants must provide their technical, operational and organisational data for prequalification. If required, Swissgrid can also call for operational measurements or tests to be performed. Potential participants must submit a prequalification request to Swissgrid. Information regarding this process is or will be made available on the Swissgrid website.

2.6.3 Reserve-building

The provision of supramandatory reactive power for voltage support does not require that reactive power is actually reserved. Reactive power is provided to the best of the participant's ability. Participants undertake to use the contractually-agreed machines for voltage support insofar as these are available for use and usage of such machines would not result in adjustments to the plant's active power mode. Participants do not incur any opportunity costs.

2.6.4 Connection

Connection is subject to the same terms as active/mandatory participation in voltage support (see Section 2.5.4).

2.6.5 Requisition

Details regarding the requisition of supramandatory capacities can be agreed individually in the bilateral contract. Swissgrid will procure information about the plant's capabilities by telephone prior to the actual requisition. The definitive requisition is made by phone, and an additional confirmation is sent to the participant by fax or e-mail.

2.6.6 Compliance

The voltage schedule and the compliance criterion explained in Section 2.5.6 will also apply with regard to supramandatory provision. In the event that Swissgrid issues instructions to the participant which deviate from the voltage schedule, these must always be followed. Regardless of the voltage schedule, the plant's reactive energy exchange during the relevant period of time will still be considered compliant as long as Swissgrid's instructions are followed. The compliance check for the period in question will be overridden by a corresponding bit in the settlement system.

2.6.7 Monitoring

Voltage measurement data is used to monitor compliance during operation. Swissgrid operates a monitoring system for this purpose. Swissgrid announces monitoring data delivery requirements in a separate document («Monitoring Data Requirements» [10]; the latest version will apply at any given time).

2.6.8 Compensation

The standard supramandatory reactive power provision contract provides for the following compensation components:

- remuneration of exchanged reactive energy equal to that in the mandatory range (tariff in CHF/Mvarh);
- additional remuneration for starting up a machine to provide reactive power at Swissgrid's request (CHF per start, individual for each machine);
- additional remuneration for every hour of operation commenced for a machine requested by Swissgrid (CHF per hour commenced, individual for each machine);

2.6.9 Settlement

Settlement is performed on a monthly basis. Prior to the final credit note/invoice, participants receive a reconciliation report for confirmation.

3 Operating processes

3.1 Scheduling at Swissgrid

Swissgrid schedules the use of available reactive power capacities for the purpose of voltage support in the transmission system and draws up at least one voltage schedule per day. If necessary, the voltage schedule can be adjusted over the course of the day and re-published. This schedule is published via e-mails sent to participants and on the Internet (SDL system).
Swissgrid also schedules the stepping of phase-regulated 220/380 kV coupling transformers in the transmission system and, if necessary, instructs the control centres in charge to step the transformers. These transformers are part of the transmission system and are subject to Swissgrid's operational management.

3.2 Usage

Active participants in voltage support use the exchangeable reactive power that is freely available in the current operating state, i.e. without compromising the active power mode, in a way that complies with the requirements.
Phase shifters are used as needed in accordance with Swissgrid's requirements.
The provisions of the Operation Handbook [11] apply.

3.3 Monitoring

Swissgrid monitors voltages in the transmission system, the use of reactive power and participants' compliance. If it observes any obvious misconduct, Swissgrid points this out to the participant and provides further instructions if needed.

3.4 Settlement

Settlement for reactive energy is performed on a monthly basis. The settlement process starts once all measurement and metering data required for settlement has been successfully submitted.

4 Tariffs

The tariffs are determined and published by Swissgrid in accordance with statutory and regulatory specifications. Beginning in 2011, the following tariff structure will apply for reactive energy (see Section 2.5.8):

- Tariff for reactive energy delivered in compliance with the requirements. This tariff is paid to active participants in voltage support for reactive energy delivered in compliance with the requirements.
- Tariff for reactive energy delivered that is not in compliance with the requirements (from 2011). This tariff is invoiced to active participants in voltage support for reactive energy delivered that is not in compliance with the requirements.
- Individual AS tariff for reactive energy. This tariff is invoiced to passive participants in voltage support in the transmission system for reactive energy exchange outside the power factor limits.

5 Steps for implementation

5.1 Consultation, decision and communication

The external consultation regarding this concept took place in November 2009. The concept was then revised based on the comments received. The revised concept was endorsed the Swissgrid Executive Board in March 2010 and then presented to the Swissgrid Board of Directors. The concept will be communicated in writing to the parties involved and stakeholders in early April and announced at an information event in May.

5.2 Implementation

The following is a summary of the most important steps for implementation:

- Amendment of and addition to relevant documents and contracts from March 2010
- Conclusion of new contracts and agreements from July 2010
- Process definition and introduction from April 2010
- Declaration of active participation by 30 July 2010
- Prequalification and testing for new active participants from July 2010
- System change on 1 January 2011

6 References

[1] **Federal Electricity Supply Act** (StromVG), 23 March 2007.

[2] **Electricity Supply Ordinance** (StromVV) of 14 March 2008.

[3] ENTSO-E Continental Europe, **UCTE Operation Handbook**, Policy 3, Version of 19 March 2009.

[4] Prabha Shankar Kundur, **Power System Stability and Control**. McGraw-Hill, 1994.

[5] Ruling by the Federal Electricity Commission ElCom, **Costs and tariffs for level 1 grid usage and ancillary services** of 6 March 2009, Section 4.3.3.4, pg. 56.

[6] **Grid usage model for the Swiss transmission system**, 2007 edition.

[7] **Swiss Metering Code**, 2008 edition.

[8] **Energy metering requirements regarding the transmission system**, Version 1.3 of 10 September 2009.

[9] swissgrid ltd, **Transmission Code (Switzerland)**, the current, valid version of which is published at www.swissgrid.ch and www.strom.ch.

[10] swissgrid ltd, **Monitoring Data Requirements**, the current, valid version of which is published at www.swissgrid.ch.

[11] **Operation Handbook for Grid Operation in Switzerland**, Version 2.99, Term 7.

[12] swissgrid ltd, **General Conditions Governing Billing of Transmission System Costs**, Version 1.0 of 3 October 2008, www.swissgrid.ch.