Billing of reactive energy for passive recipients from 1 January 2011

Author: Martin Kurzidem

Table of contents

1 Introduction

This document describes the billing of reactive energy for passive recipients that was implemented as of 1 January 2010 in line with the 2011 voltage support concept. The so-called "cosine phi model" is used in accordance with the grid usage model for the Swiss transmission system (2007 edition).

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 in 2010. The amended 2011 model provides for an expansion of the cost-free range.

2 User-pays allocation

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.

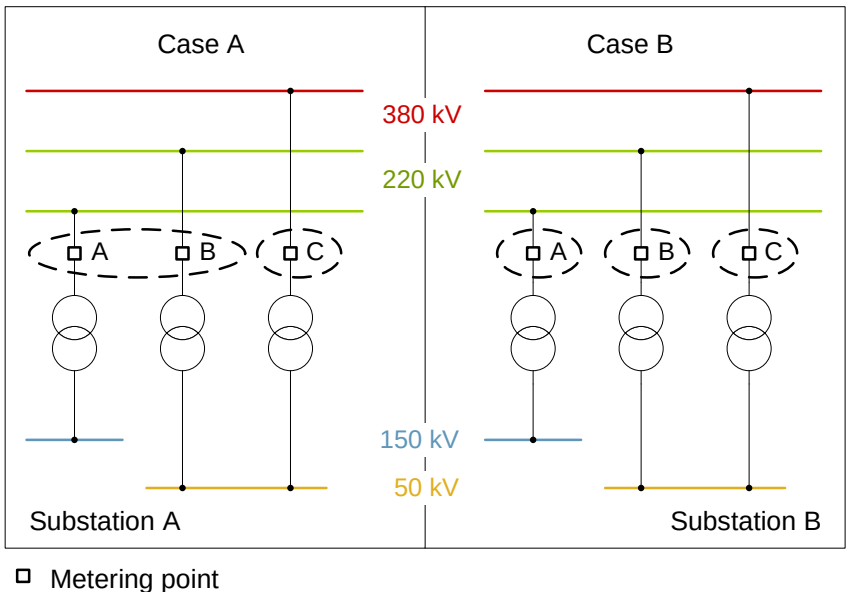

Figure 1: Case A: all transformers belong to the same grid user
Case B: all transformers belong to different grid users

Note

- Where grid connections are merged within a substation, no distinction is made between bus bars at a particular grid level. (See Case A: grid connections A and B are on different bus bars, but are combined.)
- Grid connections in different substations are always treated separately, even if the customer concerned operates an interconnected, at times high-transit grid that is directly subordinate to the transmission system.

3 Billing model

3.1 Billing principles

The billing model is based on the following principles:

- Reactive energy is only billed in Mvarh above a tolerance threshold of $W_{Q,lim}$. The tolerance threshold is increased by $\pm W_{Q,lim}$ on either side of the reactive energy base line and is symmetrical with regard to inductive and capacitive reactive energy, i.e. there is only one $W_{Q,lim}$. If this threshold is exceeded, the corresponding excess exchanged reactive energy is billed proportionately to its quantity. Within the tolerance range, nothing is billed.
- The cost-free range $\pm W_{Q,lim}$ on either side of the reactive energy base line 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 exchanged above the tolerance threshold («excess») is billed at the published reactive energy tariff («Individual AS tariff for reactive energy for passive participants»).
- The tolerance limit $W_{Q,lim}$ is determined for each 15-minute period as a function of the exchanged active energy.

End consumers connected directly to the transmission system and distribution systems connected directly to the transmission system are treated in the same way.

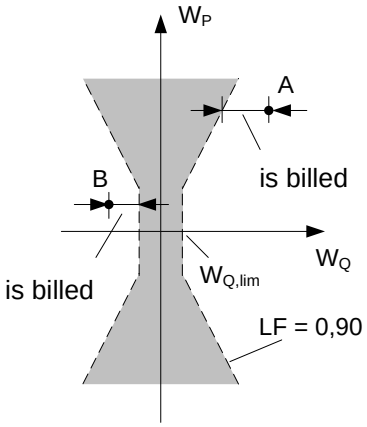

Figure 2: In the grey area, the exchange of reactive energy is free of charge. The quantity in excess of the grey area is billed.

3.2 Determining the billing amount

The tolerance threshold $W_{Q,lim}$ in Mvarh relates to the amount of reactive energy exchanged. The reactive energy exchanged beyond this tolerance threshold is billed to the grid user and can be represented by the following equations:

$$\text{IF } |W_Q| > W_{Q,lim} \text{ THEN } W_{Q,ver} = |W_Q| - W_{Q,lim}$$

$$\text{OTHERWISE } W_{Q,ver} = 0$$

where

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

$W_{Q,lim}$ is the blind energy limit in Mvarh (for both inductive and capacitive ranges)

$W_{Q,ver}$ is the excess exchanged reactive energy to be billed in Mvarh

In this document, net energy generally refers to the correctly signed sum of the two measured values for supply (usually negative) and purchase (usually positive) in the 15-minute meter interval in question, i.e. the net exchanged energy. Irrespective of the sign convention, the following formula can be used to determine the net energy W:

$$W = |W_{Purchase}| - |W_{Supply}|$$

The resulting amount to be billed is achieved by multiplying the 15-minute billing amount by the tariff:

$$VB_{Q,ver} = W_{Q,ver} \cdot T_{Q,ver}$$

where

$T_{Q,ver}$ is the tariff in CHF/Mvarh (as of 08.07.10: CHF 7.16 /MVarh)

$VB_{Q,ver}$ is the billing amount in CHF for the 15-minute period in question

The relative reactive energy limit $W_{Q,lim}$, also referred to as power factor or cosine-phi limit, is defined for each individual meter interval (15-minute period). It is calculated using the power factor and the active energy exchange. The power factor LF is defined as:

$$LF = \cos\left[\arctan\frac{W_Q}{W_P}\right]$$

where

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)

The relative reactive energy limit is defined using a minimal power factor LF_{lim}:

$LF_{lim} = 0.90$

Depending on the active energy, following equation can be used calculate the amount of reactive energy which can be exchanged free of charge:

$$\pm W_{Q,lim}^{LF} = \tan[\arccos\ 0{,}90] \cdot |W_P| = 0.4843 \cdot |W_P|$$

The power factor limit of 0.90 means, therefore, that in each meter interval, reactive energy in the amount of 48.43% of the exchanged active energy can be exchanged free of charge.

The relative reactive energy limit can be calculated by multiplying the active energy amount by 0.4843 for each meter interval (15-minute period).

The exchange of reactive energy within the reactive energy range on either side of the reactive energy base line is also free of charge. The reactive energy limit applicable to transformers is defined by (15-minute meter value):

$$\pm W_{Q,lim}^{Trafo} = \frac{u_k}{100} \cdot S_N \cdot 0.25h$$

where

u_k is the transformer's short-circuit voltage in %

S_N is the transformer's nominal apparent power in MW

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.

3.3 Contents

Figure 3 shows the data flow described in the previous section. The billing amount $VB_{Q,ver}$ is calculated for each 15-minute period from the measured values for active and reactive energy and the associated reactive energy tariff.

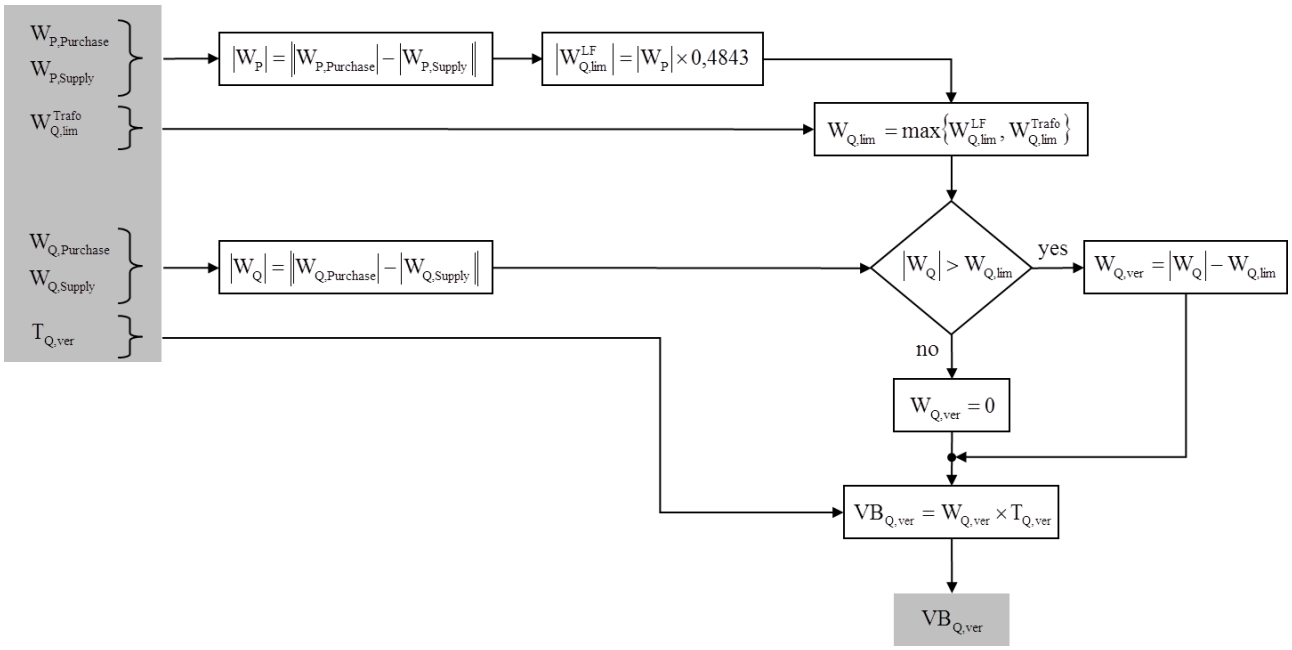

Figure 3: Data flow for determining the reactive energy amount to be billed

4 Sample calculation

Table 1 shows a simple example in which the reactive energy is calculated for three hours.

Input values						Interim values						Result	
Time hh:mm	$W_{P,Supply}$ kWh	$W_{P,Purchase}$ kWh	$W_{Q,Supply}$ kvarh	$W_{Q,Purchase}$ kvarh	$T_{Q,ver}$ CHF/Mvarh	$\|W_P\|$ kW	$\|W_Q\|$ kvarh	$\|W_{Q,lim,LF}\|$ kvarh	$\|W_{Q,lim,Trafo}\|$ kvarh	$\|W_{Q,lim}\|$ kvarh	$\|W_{Q,ver}\|$ kvarh	$VB_{Q,ver}$ CHF	LF
00:15	100'000	0	80'000	0	7.16	100'000	80'000	48'430	5'000	48'430	31'570	226.04	0.781
00:30	80'000	0	60'000	0	7.16	80'000	60'000	38'744	5'000	38'744	21'256	152.19	0.800
00:45	60'000	0	40'000	0	7.16	60'000	40'000	29'058	5'000	29'058	10'942	78.34	0.832
01:00	40'000	0	25'000	500	7.16	40'000	24'500	19'372	5'000	19'372	5'128	36.72	0.853
01:15	20'000	0	10'000	1000	7.16	20'000	9'000	9'686	5'000	9'686	0	0	0.912
01:30	10'000	2000	6000	1500	7.16	8'000	4'500	3'874	5'000	5'000	0	0	0.872
01:45	4000	8'000	1500	2500	7.16	4'000	1'000	1'937	5'000	5'000	0	0	0.970
02:00	0	12'000	200	4000	7.16	12'000	3'800	5'812	5'000	5'812	0	0	0.953
02:15	0	20'000	0	10'000	7.16	20'000	10'000	9'686	5'000	9'686	314	2.25	0.894
02:30	0	30'000	0	16'000	7.16	30'000	16'000	14'529	5'000	14'529	1'471	10.53	0.882
02:45	0	60'000	0	20'000	7.16	60'000	20'000	29'058	5'000	29'058	0	0	0.949
03:00	0	80'000	0	25'000	7.16	80'000	25'000	38'744	5'000	38'744	0	0	0.954

Table 1: Sample calculation for determining the reactive energy costs for an end consumer or distribution system operator directly connected to the transmission system

5 Adjustment of the limits of the cost-free reactive energy range

Swissgrid has determined that a direct application of the calculation formula to determine the cost-free reactive energy range (see section 0) in the first quarter of 2011 resulted in an unexpectedly sharp drop in the monthly chargeable reactive energy volume As the total costs that have to be covered by the reactive energy tariff remain unchanged, a sharp drop in the billing amount would have to result in a corresponding increase in the reactive energy tariff. Swissgrid does not consider a steep rise in the tariff to be desirable. As of 1 January 2012 the limits of the cost-free reactive energy range will therefore be defined as follows:

$$\pm W_{Q,lim}^{Trafo} = \left(\frac{u_k}{100} \cdot S_N \cdot 0.25h \right) \cdot 0{,}25$$

This should on the one hand counteract the undesirable incentive to switch off nearly idle transformers on cost grounds, which would jeopardise the security of supply and, on the other hand, minimise the effects of tariff-relevant reactive energy volumes on the individual AS tariff for passive participants.

The cost-free reactive energy range has been adjusted accordingly in the sample calculation in table 2.

Input values						Interim values						Result	
Time hh:mm	$W_{P,Supply}$ kWh	$W_{P,Purchase}$ kWh	$W_{Q,Supply}$ kvarh	$W_{Q,Purchase}$ kvarh	$T_{Q,ver}$ CHF/Mvarh	$\|W_P\|$ kW	$\|W_Q\|$ kvarh	$\|W_{Q,lim,\ LF}\|$ kvarh	$\|W_{Q,lim,Trafo}\|$ kvarh	$\|W_{Q,lim}\|$ kvarh	$\|W_{Q,ver}\|$ kvarh	$VB_{Q,ver}$ CHF	LF
00:15	100'000	0	80'000	0	7.16	100'000	80'000	48'430	1'250	48'430	31'570	226.04	0.781
00:30	80'000	0	60'000	0	7.16	80'000	60'000	38'744	1'250	38'744	21'256	152.19	0.800
00:45	60'000	0	40'000	0	7.16	60'000	40'000	29'058	1'250	29'058	10'942	78.34	0.832
01:00	40'000	0	25'000	500	7.16	40'000	24'500	19'372	1'250	19'372	5'128	36.72	0.853
01:15	20'000	0	10'000	1000	7.16	20'000	9'000	9'686	1'250	9'686	0	0	0.912
01:30	10'000	2000	6000	1500	7.16	8'000	4'500	3'874	1'250	3'874	626	4.48	0.872
01:45	4000	8'000	1500	2500	7.16	4'000	1'000	1'937	1'250	1'937	0	0	0.970
02:00	0	12'000	200	4000	7.16	12'000	3'800	5'812	1'250	5'812	0	0	0.953
02:15	0	20'000	0	10'000	7.16	20'000	10'000	9'686	1'250	9'686	314	2.25	0.894
02:30	0	30'000	0	16'000	7.16	30'000	16'000	14'529	1'250	14'529	1'471	10.53	0.882
02:45	0	60'000	0	20'000	7.16	60'000	20'000	29'058	1'250	29'058	0	0	0.949
03:00	0	80'000	0	25'000	7.16	80'000	25'000	38'744	1'250	38'744	0	0	0.954

Table 2: Sample calculation to determine the reactive energy costs for an end user or distribution system operator directly connected to the transmission system with adjusted limits for cost-free reactive energy costs.