

Distribution Working Group

Reactive Power charging for Generators

A Briefing Note for the DWG by Renewable Generators' Representative

Introduction

The attached Technical Note "Reactive Power Charging for Generators" has been brought together with assistance and input from DWG members, generators, DNOs, the ENA and Econnect. It describes the technical commercial and regulatory background and state of play of reactive power charging for generators. It sets out the general principles supported by the DWG.

Background

The report was an initiative arising from various disputes over reactive power charges that came to the attention of the DWG and the renewable generator representatives.

Conclusions of the document

- Generators (or suppliers responsible for their import) should be charged for use of the distribution system on the same basis as other customers, i.e. when generators are acting as demand customers they should be treated as demand customers.
- Generators' import capacities should be calculated only using metered reactive import or metered reactive export (if this methodology is also applied to other demand customers) data during periods of real power import (and not confused with reactive data during periods of real power export).
- That the power factor range of distributed generators could actually be used to help support the voltage profile of distribution networks and may obviate the need for asset replacement, were the commercial signals and the ancillary services contracts in place for DNO's to actively manage reactive power flows. That this could in future be considered under the remit of licence condition five as an efficient network development on a site-specific basis.
- That generators could in theory agree an abnormal power factor range with the DNO where this obviated the need for network reinforcement as part of their connection agreement and hence achieve a cheaper connection, although under the current charging methodologies such a generator would still be liable for excess reactive charges especially if connected under the tariff systems at LV and HV, although there is more remit for flexibility in the use of system charges levied for EHV connections.
- Generators should only be charged for reactive capacity or reactive energy consumed during periods of real power exports if these charges are cost reflective of the impact of the reactive energy on the network, and if the reactive energy requirement exceeds the reactive capacity agreed and paid for under the connection charging arrangements.
- That the BSC Metering Codes of Practice should be amended so that reactive flow metered data is related to the relevant periods of real power import and export and hence allocated to the appropriate MPAN (and appropriate supplier) for a half hour period. The data should also be sampled to remove those half hour periods where a changeover occurs between real power import and export.

Way Forward

The DWG agrees that this document should be promoted to be accepted and adopted in all relevant industry forums (e.g. the ISG) and used to guide and promote the changes needed in the industry needed to create a more cost reflective and balanced approach to reactive power metering, charging and billing for generators in particular.



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TECHNICAL NOTE

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Reactive Power Charging For Generators

DRAFT for DWG Review

This draft is for DWG review, comment and ultimate endorsement. The endorsed document can go forward to the relevant groups with appropriate authority to resolve the issues raised.

GENERATOR OPERATION

The normal operating regime of a generation site is to export real power (P, measured in kW), in most cases the power generated will greatly outweigh the onsite electrical power demand i.e. power for generator ancillary equipment, load for office facilities, building heating and lighting etc. However, when the generation equipment is out of service for maintenance and/or repair, or in the case of wind power, during periods of no wind, the site will invariably import real power.

These two modes of operation (importing and exporting) are shown below in Figure 1. The figure also shows reactive power (Q, measured in kVAr) and the apparent power (S, measured in kVA). When not generating, the real and reactive power vectors are shown in red, when generating the real and reactive power vectors are shown in blue. The numbers in square brackets [] are for reference purposes.

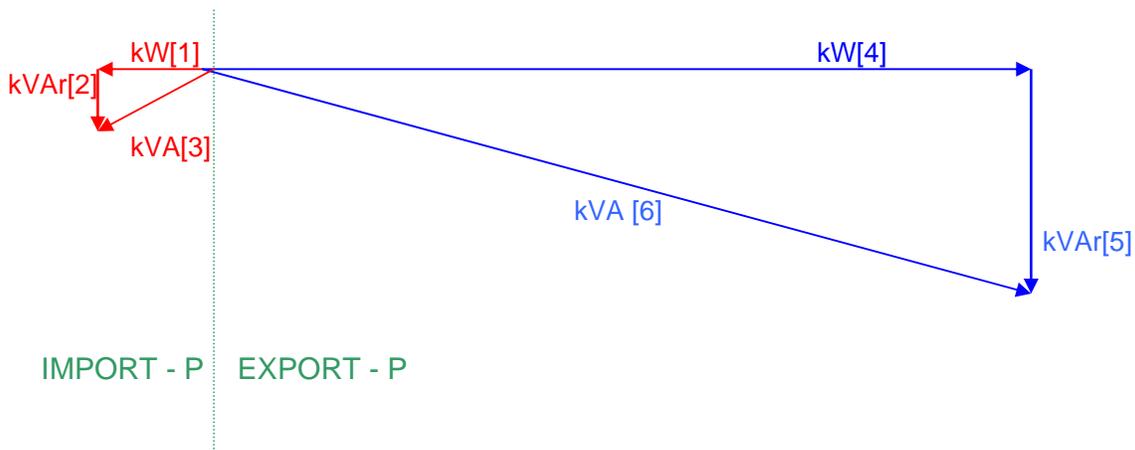


Figure 1: Electrical phasor diagram showing difference in kVA and kVAr between Import of Real Power (kW[1]) and Export of Real Power (kW[4])(not to scale)

Most embedded generators commonly operate in the mode where they export real power (P), but import reactive power (Q) to a greater or lesser extent. Importing reactive power is often necessary to stabilise the distribution network voltage. However, generators may also export reactive power, especially when there are no distribution network voltage constraints or due to Grid Code requirements. These two modes of operation are shown in Figure 2 below, importing reactive power shown in blue, exporting reactive power shown in orange.

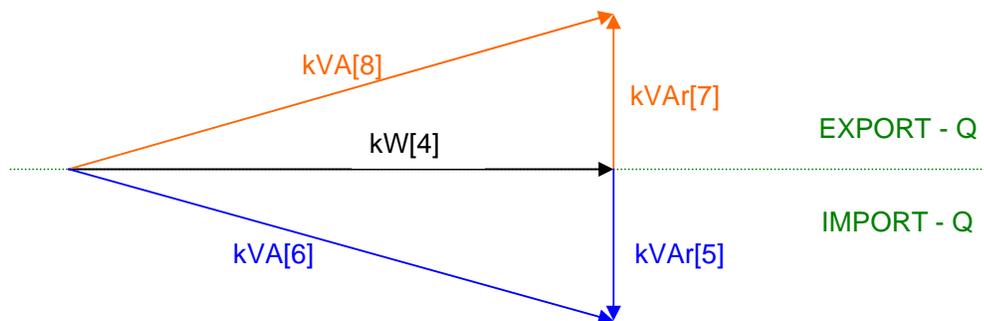


Figure 2: Electrical phasor diagram showing difference in kVA and kVAr between Import of Reactive Power (kW) and Export of Reactive Power (not to scale)

A generator may also export reactive power while importing real power, for example due to the inherent capacitance of a wind farm's array cable network whilst it is not generating.

Also, generators are incentivised to operate at or close to unity power factor as this reduces the losses between the generator and the meter and reduces the rating and cost of equipment required in the generator's installation. Generators with induction machines (such as wind turbines) are generally power factor corrected to operate close to unity throughout the full range of operation. Without power factor correction induction generators and motors import significant amounts of reactive power. It is acknowledged that in future the permitted power factor range is likely to become more site specific depending on specific network requirements.

CHARGING DEMAND LOADS FOR REACTIVE POWER

Loads that have a poor power factor¹ (i.e. import a lot of reactive power relative to the amount of real power) increase the electric current flowing in the local distribution network to which they are connected and this increases losses and the ratings required for distribution assets which deliver useful real power from the transmission system to that load. Reactive power charges are therefore justified where they are associated with a demand load (i.e. import of real power). Distribution Network Operators (DNOs) levy charges to recover the costs associated with loads operating at poor power factors, e.g.:

- *Reactive Energy Charge*: per kVAh delivered to the site (it should be noted that not every DNO levies a reactive energy charge although most DNOs levy an excess charge when certain reactive energy thresholds are exceeded).
- *Availability Charge*: levied per kVA of import capacity² to recover the costs of network assets the site uses.

The levying of these use of system charges (kVA/kVAh), which reflect reactive power consumed during periods of real power import is acceptable in principle, in so far as such charging is cost reflective.

The DNO often imports reactive power from the transmission system and no charge is currently levied for this by the Transmission Owner or System Operator, although in future there may be a need for the DNO's to manage this reactive power import. Reactive power may also be generated or consumed by assets in the DNO network. The costs that the DNO currently recovers therefore are related entirely to the cost of the assets necessary to distribute electricity plus additional losses and not to the purchase of reactive energy in the first place. Recovering the cost of losses is generally accounted for in the loss adjustments factors (LAFs) and care must be taken not to double charge for losses through these LAFs, as well as through reactive charges.

¹ Power Factor of a system is defined as the ratio of the real power (P) to the apparent power (S). Apparent power is defined as the product of RMS phase voltage and RMS phase current summed over all phases, and is related to real and reactive power (Q) by the rule $S^2 = P^2 + Q^2$. When power factor is 1 the power flow is purely real, while if the power factor is 0 the power flow is purely reactive.

² kVA is a function of kW (real power) and kVAh (reactive power), see Figure 1.

REACTIVE POWER CHARGING AND GENERATORS

When generators are importing real power they are behaving in an identical manner to a pure demand customer with an intermittent load and should be charged on the same basis for real and reactive power.

Reactive power used by generators during periods of generating (exporting real power) has a different impact on network assets and losses compared to the reactive component of demand.

The export of real power into the distribution network usually reduces the current flows as the real current from the embedded generation opposes the current flowing for demand. Even when the generator power factor is less than unity the currents are still generally reduced.

In the unusual circumstance where there was an increase in currents in the DNO network due to the generator being connected, this increase may or may not result in a requirement to reinforce or strengthen the network assets. If reinforcement were required, generators will incur charges as a result, and the costs are recovered through these charges³. If no reinforcement were required there are no additional asset costs to the DNO and therefore additional charges are not justified.

For the DNO the costs of reactive power are primarily related to increased asset requirements. For generators, the costs of these assets are recovered from connection and UoS charges. Therefore there is no justification for making specific separate charges for reactive capacity or reactive energy to generators, unless the generator is exceeding the reactive range specified in its connection agreement. Indeed in such a scenario the excess reactive power could lead to the agreed kVA capacity being exceeded leading to an increase in UoS charges. Should this poor power factor be sustained, it is likely that the connection agreements would be reopened, especially if work was required to reinforce the network, or where safety was a concern.

There will probably be a difference in losses between a generator operating at unity power factor and some other power factor. However, such differences also occur for demand. For large generators connected at 33kV a site specific LAF can be applied to reflect the benefit or cost of losses taking into account the operating power factor(s). For other generators the difference in the quantity of losses for the different power factors used in practise by different generators is not significant enough to warrant individual or special treatment.

³ If assets or new voltage control schemes were required as a result of the increased or varying currents due to a poor power factor, the cost of these upgrades would be recovered through the generator's connection and use of system charges (assuming that augmentation of network voltage control schemes were allowed into the regulated asset base and hence recoverable through GDUoS). When connecting to the distribution network, generators are charged for the assets required to provide the required capacity to generate over the site's full power factor range. Prior to 1st April 2005 generators were charged for all network reinforcements required to provide this capacity in their connection charge. Post 1st April 2005 the charge is split between a connection charge and a Generator Distribution Use of System (GDUoS) charge.

ERRONEOUS CALCULATION OF IMPORT CAPACITY

As shown in Figure 1 import capacity (kVA[3]) is derived from real and reactive power import during periods of real power import (kW[1]). This is the capacity upon which a site's import availability charge should be based.

In the past some DNOs have calculated the import capacity upon which they base their *import* available capacity charge, according to reactive power imports during periods of real power *export*. As shown in Figure 3 this produces an incorrect capacity (kVA[9] purple dashed line), which is usually far greater than the true import capacity.

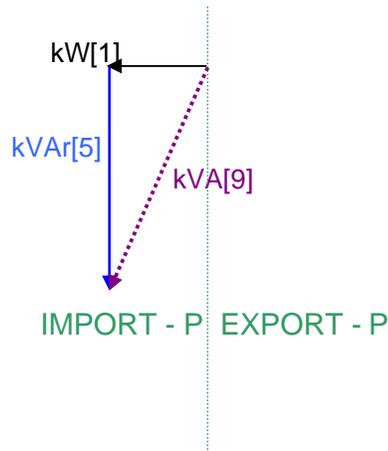


Figure 3: Electrical phasor diagram showing incorrect calculation of import capacity (not to scale)

When import capacity is calculated in this manner, it often results in a chargeable capacity greatly in excess of the actual import capacity and leads to punitive charges being levied on the distributed generator. Especially since the *export* capacity (kVA[6] or kVA[8] in figure 2) that the generator utilises has been, or is already being paid for through connection and/or Generator Distribution Use of System (GDUoS) charges.

In addition, different DNO's use diverse formula's to calculate a site's supply capacity (see below for examples). Each formula utilises the metered reactive energy element differently, which can be both to the advantage and disadvantage of sites with distributed generation.

$$\text{Supply Capacity} = 2 \sqrt{(kWh)^2 + (kVAh \text{ lead} + kVAh \text{ lag})^2} \dots\dots\dots(1)$$

$$\text{Supply Capacity} = 2 \sqrt{(kWh \text{ reading})^2 + (kVAh \text{ reading})^2} \dots\dots\dots(2)$$

$$\text{Supply Capacity} = 2 \sqrt{(\text{Active Import (kWh)})^2 + (\text{Reactive Import (kVAh)} - \text{Reactive Export (kVAh)})^2} \dots\dots\dots(3)$$

For example, using formula (1) to summate the reactive lead and lag metered values, could result in a wind farm (with high reactive import and export values) paying for a supply capacity far in excess of its actual network requirement because although no site can import and export reactive power at the same instant, wind farms can go from high reactive import to high reactive export within a half hour period.

Efforts should be made to ensure that distributed generators are charged for the correct import capacity which is based on their requirement for active and reactive power flows through the network assets during periods of real (active) power import only.

It is acknowledged that standardising the formula for the calculation of Supply Capacity for demand as well as generation customers is still being actively progressed by the DNO's with a paper on this issue due to be put forward by the Capacity Charging sub-group to the Imbalance Settlement Group (one of the Balancing & Settlement Panel Committees).

CONTRACTUAL RELATIONSHIPS BETWEEN SUPPLIERS, GENERATORS AND DNO's

A generation site connected to the distribution network will incur Use of System charges, which are levied by the DNO on the supplier, who generally passes them through to the generator⁴.

The power a generator exports is sold to a supplier, while the power it imports is purchased from a supplier. Although the generator will often seek to contract with the same supplier for both imports and exports, in some cases this may not be the most economic solution and in other cases it is outside the generator's control.

For example, NFFO/SRO⁵ contracts are administered through the NFPA⁶ who auction export contracts to the highest bidder, and therefore the export supplier is not determined by the generator. The generator however, must still arrange a contract with a supplier for imports to the site and the export supplier is not obliged to offer such a contract.

The collection and pass through of data from the meter via the Data Collector, Data Aggregator, DNO or either supplier may cause difficulty in the calculation of the correct import capacity.

IMPACT OF METERING CODES OF PRACTICE

(Extracts courtesy of Matthew Hays-Stimson EDF Energy Networks)⁷

Indeed the current Balancing & Settlement (BSC) Code Metering Codes of Practice may hinder the calculation of the correct import capacity for generators especially where there may be two suppliers (one import and one export) providing two sources of metering data. This is because at the time the metering codes of practice were written, electromechanical metering of kWh and KVAh were predominant and the capability was not available to relate real time instances of reactive power flows to the real time coincident flow of real power. Also there was little need for such a requirement as there was only limited generation connected to the distribution system. Hence the codes of practice and settlement arrangements were based on a four-register approach (as shown in Figure 4)⁸.

Present Four Register Approach	
Power Component	Allocated to
AE – active export	Export MPAN
RE – reactive export	
AI – active import	Import MPAN
RI – reactive import	

Figure 4 Four-Register Metering

⁴ This depends on the contract between the Supplier and Generator. Although it is understood that there may be potential for DNO's to charge Generators directly under the proposed Distribution Connection Use of System Code.

⁵ Non Fossil Fuel Obligation (NFFO) and Scottish Renewables Order (SRO) contract arrangements were put in place as the means of contracting renewables before the Renewable Obligation came into force and these arrangements continue in a slightly modified form under the Renewables Obligation.

⁶ Non Fossil Purchasing Agency (NFPA) www.nfpa.co.uk

⁷ Response to paper DWG 27/05 Matthew Hays-Stimson, Connection relationships Manager (EDF energy networks) 01/11/05

⁸ In practice some meters also have the RE- reactive export power component allocated to the Import MPAN

The upshot of this four-register system is that the reactive import metered flow must be allocated to the import MPAN even if that flow occurs at a time of real power export. Similarly reactive export metered flow must be allocated to the export MPAN even when the flow occurs at a time of real power import.

Two different data collector agents would then potentially collect this metered data, and the charges levied accordingly by the relevant DNO.

Developments in electronic metering now mean that new metering systems are available which operate on a six-register basis, having import and export reactive channels associated to both import and export MPANs (as shown in Figure 5). This six-register system would allow the reactive power flows to be correctly linked to the direction of real power flow and hence allocated to the correct MPAN.

Proposed future Six Register Approach	
Power Component	Allocated to
IAE – Import active export	Import MPAN
IRE – Import reactive export	
IRI – Import reactive import	
EAI – Export active import	Export MPAN
ERE – Export Reactive export	
ERI – Export reactive import)	

Figure 5 Six register metering

Were an embedded generator to configure their metering systems on a six register basis and were the six registers to correctly allocate reactive power flows to the import and export MPAN and were the data to be correctly received from the half hourly data collector and processed by the DNO this would remove this metering anomaly brought about by the metering codes of practice, and remove one of the obstacles to correctly setting and charging for a generators import capacity.

SUPPLIER VOLUME ALLOCATION GROUP (SVG) PAPERS ON THIS ISSUE

John Lucas of the ELEXON design authority put forward a paper to the SVG⁹ investigating whether the BSC would allow reactive power at a site with generating plant to be allocated as in figure 5. Currently in the view of ELEXON's legal advisers, Section K of the BSC does not allow responsibility for Reactive Power flows to be allocated in the manner outlined in SVG62/08 (and figure 5) and that as a result any party wishing to progress this method of allocation would need to raise a BSC modification proposal¹⁰. This issue is currently undergoing further debate at the SVG.

⁹ SVG62/08 Clarification of responsibility for reactive power flows at sites with exemptable generating plant (22nd March 2006) John Lucas ELEXON

¹⁰ SVG64/07 Further update on responsibility for reactive power flows at sites with exemptable generating plant (21st April 2006) John Lucas ELEXON

CONCLUSIONS

- Generators (or suppliers responsible for their import) should be charged for use of the distribution system on the same basis as other customers, i.e. when generators are acting as demand customers they should be treated as demand customers.
- Generators' import capacities should be calculated only using metered reactive import or metered reactive export (if this methodology is also applied to other demand customers) data during periods of real power import (and not confused with reactive data during periods of real power export).
- That the power factor range of distributed generators could actually be used to help support the voltage profile of distribution networks and may obviate the need for asset replacement, were the commercial signals and the ancillary services contracts in place for DNO's to actively manage reactive power flows. That this could in future be considered under the remit of licence condition five as an efficient network development on a site-specific basis.
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