Wheeling and dealing: Connecting electricity suppliers and customers

The emergence of independent power producers and distributed generation has resulted in the need for transporting electricity between producer and consumer over a network owned by a third party. These arrangements can be simple or complex, depending on the network, and require well developed rules and regulations to operate properly.

The general definition of wheeling is the transport of electricity from one entity to another using the transport network of a third entity. Entities may be generating companies, electricity retailers, distributors or aggregators as well as large consumers of electricity. In networks where there are multiple generators, retailers and distributors as well as a separate network operator, wheeling forms the basis for operation of the network. An example of this is the New Zealand electricity network which has five major generating companies, seven retailers and 29 distributors, and a separate transmission company, a state owned entity, which provides the power transport network [1]. Day to day operation of the network is handled by a state appointed system operator, which is responsible to coordinate supply and demand resources to maintain real-time security of supply.

In South Africa, a single utility, Eskom, owns the majority of generating plant and the transmission network, as well as being the single buyer of electricity (and seller of electricity to both large customers and distributors). Wheeling of electricity in this case means transport of electricity via the Eskom grid from a private, non-Eskom generator (NEG) to a private customer. Although there are isolated instances of power purchase agreements (PPAs) between independent power producers (IPPs) and distributors [2], which use the grid for wheeling power, in most cases wheeling involves a single private customer. Wheeling may also be used for transport of electricity from a generating plant owned by a private company to its own sites remote from the generating plant, via either the transmission or the distribution network.

Wheeling overview
The idea of wheeling generally implies that electricity generated at one site will find its way to the site of the receiving customer, as illustrated in Fig. 1, which shows a simple connection of generator and consumer on a line which has no other connections. However, once other consumers and generators are connected to the network the flow of electricity becomes far more complicated, and as the generation mix changes and the load profile of the network varies, it is very difficult to determine the flow of power in the network from the generator to the intended load, or where power for a contracted load will come from (Fig 2). In reality the generator supplies power to the grid and the customer draws power from the grid, and there is no fixed power flow between them. For instance it is unlikely that power generated by an IPP in Mpumalanga will find its way to a customer in the Western Cape. In simple terms, the generator decreases the load on the grid in its vicinity, and the customer increases the load on the grid, and the connection is more contractual than physical.

The two main challenges with wheeling power are balancing generation and consumption, and determining the cost of wheeling and appropriate charges, and these form the basis of most of the rules and regulations related to wheeling.

Balancing generation and consumption
In any network, there must exist a balance between the electricity generated and the electricity consumed. In the simple case of one generator and one load, this balance is simple, as the load cannot consume more than what is generated. In a more complex network, a net balance between generation and consumption also exists, but the customer load can draw power from any source and the generator can supply power to any load, and the problem is one of balancing the output of a specific generator with the consumption of a specific load on the network.

Complex networks rely on accurate real-time metering at both the generation and consumption points, and communication between load and generator. Few generators are capable of instantaneous response to load changes, however, and there will always be an imbalance between energy supplied by the generator and energy consumed by the load. The purpose of balancing is to reduce this imbalance as much as economically possible. There are several ways of doing this, technically and contractually.

Balancing where generation is less than the load
This simple situation where the generator always provides less than the load, i.e. the customer only purchases portion of the requirement from the private generator, and balancing consists of the generator controlling output to a set level. Irrespective of how much the customer draws the generator will always know how much was contributed, using metered information.

Balancing and reconciliation
Other than the simple situation above, many cases involve the customer drawing the full load from one generator, and the problem of balancing exists.

Two situations can exist:
- The generator supplies more than the load consumes and some of the output is consumed by other loads on the network.
The generator supplies less than the load consumes and some of the consumption is supplied from other generating sources. Many systems make use of a periodic (hourly/daily) reconciliation and balancing system where the generation and consumption are balanced by contractual adjustments of performance to achieve a net balance over the operating period. This requires real time accurate metering and communication between the generator, the consumer and the other entities involved. Over-generation will result in a credit for the next period, both of which must be balanced the next operating period. Imbalance over a longer period is resolved by billing for the difference, either a debit or credit to account for variations in generating costs from period to period.

Wheeling costs and charges

Determining the detailed cost of wheeling is a complex issue, which will depend on several issues:

- The amount of energy being transferred
- The extent of the network being utilised (distance between load and generator)
- Connection and metering requirements
- Variations in technical losses incurred
- Lost capacity to network operator
- Loading of the network

The fact that there is no energy connection between generator and customer makes determination of the extent of the network used very difficult. In a network with uniformly distributed generating plant this may not be a problem, as a load increase in one sector of the network is offset by a decrease in another, without any mutual affect on the interconnections. (Fig. 2), but in networks with a non-uniform distribution, distance becomes significant. For example, a customer in the Western Cape may well draw power from a power station in Mpumalanga. The reason for including a distance component is based on increased losses as well as the loss of capacity available to the transport network operator.

Costing models in most cases include a connection cost as well as a network usage cost, which may depend on the distance between the generator and consumer. The location of the supplier and customer may also determine the usage costs, as location of either or both in a distribution network complicates the allocation of costs, which will include both transmission use-of-system (UOS) costs and distribution UOS costs. Several variations are possible including:

- Generator and consumer are in the same distribution network. This is the simplest model as there is only one supply, namely the grid, and it will be easy to determine the charging and balancing parameters.
- Generator and consumer are in different remote distribution networks. This is a complex situation as both distribution networks and the grid will be involved.
- Generator on the grid and customer in the distribution network. Involves grid and distribution charges and balancing
- Generator and customer both on the grid. Grid balancing and charges only

The wheeling-charge structure may consist of the following components:

- Use-of-system charges
- Connection charges
- Service charges
- Subsidy charges

The South African situation

The Electricity Regulation Act (Act No. 40 of 2006) requires that the transmission or distribution function shall provide non-discriminatory network access to all users of the transmission or distribution system. Wheeling of power using Eskom or a distributor’s network is thus allowed in South Africa, subject to the necessary regulatory approvals, and Nersa has drawn up guidelines and regulations covering the technical and charging aspects involved, namely “Rules on network charges for third party transportation of energy” [3].

Wheeling rules and regulations

The main points of the Nersa regulations are summarised in the following sections:

General requirements and provisions
- Any load customer shall be free to go into bilateral arrangements with any third-party generator, i.e. non-municipal and non-Eskom generator
- Balancing is not covered and is left to a future decision by the ISMO. A limit of 300 MW has been imposed until such as mechanism is in place. Wheeling is only permitted at 11 kV and above

General use-of-system charge principles
The regulations make a distinction between transmission use-of-system charges (TUOS) and distribution use-of-service charges (DUOS). UOS charges recover the costs associated with making capacity available

<table>
<thead>
<tr>
<th>Transmission distance from Johannesburg</th>
<th>Zone (Fig. 3)</th>
<th>% Price differential or surcharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 300 km</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>301 – 600 km</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>601 – 900 km</td>
<td>2</td>
<td>2%</td>
</tr>
<tr>
<td>&gt; 900 km</td>
<td>3</td>
<td>3%</td>
</tr>
</tbody>
</table>

Table 1: Geographical differentiation for transmission load customers.
on the network, and are independent of the commercial trading arrangements.

The costs for recovery of transmission losses and procurement of ancillary services are charged to loads and generators using the TUOS charge. Distribution service providers (DSP) recover the costs of losses using the DUOS charge, which reflects the marginal cost of network usage through distribution loss factors. The DSP charges for each of the connection points used and retailers recover the DUOS charges through their retail tariffs.

Generators are required to pay the regulated UOS charges and may recover the charges from the buyer through supplemental pass-through payments. UOS charges do not recover connection charges, which are charged for separately.

Geographic differentiation

All UOS charges are designed with geographic and voltage differentiation unique to the network provider. The six-zone geographical differentiation outlined in Fig. 1 is used for transmission connected generators.

The transmission network costs for loads shall be allocated to each customer segment based on a 0 to 3% price differential as illustrated in Table 1.

Transmission network charges

The charging structure for transmission networks is designed to split the charges equally between the generator and the load.

Transmission network charge for loads

Transmission network charges (TNC) for loads are charged in R/kVA per month, based on the customer’s maximum demand with a surcharge differentiated into four zones based on the distance of the load in kilometres from Johannesburg as shown in Table 1. The TNC for loads shall be calculated such that 50% of the network cost of the transmission network service provider is recovered.

Transmission network charge for generators

The TNC charge for generators is charged in R/MW per month, based on the installed sent out capacity, to recover the remaining 50% of the cost of the transmission network. The TNC for generators shall be differentiated into six tariff zones based on the concentration of power generation in South Africa as shown in Fig. 1. All generators in zones with negative network charges (i.e. zones where connection of generators decreases network losses) shall have their network charge rates set to zero.

Transmission loss charges

All loads or generators connected directly to the transmission network are charged for losses according to the Wholesale Electricity Pricing System (WEPS) energy rate. The cost of losses is based on calculated average loss factors for all loads and generators. The transmission loss factors for loads are calculated for the 0 to 3% geographic differentiation and the loss factors for generators are calculated for the six generator zones (Fig. 3).

Cost of TUOS losses is calculated as follows:

\[
\text{Cost of TUOS Losses} = \sum_{i=1}^{n} (\text{Delivered energy, } x \text{ (Transmission loss factor } - 1)) \times P_i,
\]

where

- \( t \) = the appropriate metering period and
- \( P_i \) = WEPS energy rate.

The cost of losses is incorporated in the energy charge levied by Eskom in the South African case, and is subtracted from the energy charge used to calculate the customer credit.

Transmission connection charges

Transmission connection charges are once-off charges based on customer (load or generator) specific costs, i.e. dedicated costs incurred for the benefit of the customer. Upstream reinforcement costs shall not be raised from wheeling generators but an early termination benefit of losses. The network charge for HV connected generators is a fixed amount based on the maximum generator export capacity and not split into an access and a demand charge.

Distribution network charges

Distribution network charges for loads

The network charges are differentiated according to the distributor’s voltage and topographical (rural/urban) categories. The charge is based on the cost per kVA demand determined using notified annual maximum demand (NMD). The charge for loads shall be split into network access and network demand charges. The network access charge in R/kVA is based on the highest utilised capacity.

Distribution network charges for generators

Generators connected at medium voltage level (11 to 33 kV) are assumed to be embedded in demand-dominated nodes and are exempted from paying network charges. Generators connected at high voltage (66 to 132 kV) pay a network charge calculated as for loads and converted to a R/kVA charge less a network charge rebate based on the benefit of losses. The network charge for HV connected generators is a fixed amount based on the maximum generator export capacity and not split into an access and a demand charge.

Distribution network loss charges

The cost of electrical losses is recovered as a function of the appropriate loss factors for the relevant voltage level and the distributor’s cost of energy purchases on a time-of-use basis. The distributor is responsible for all losses flowing through its system and recovers these costs from all loads connected to its system as part of the commercial trading arrangements.
of the DUOS charge. Losses are priced at the wholesale electricity purchase price that the distributor is charged for losses incurred.

Cost of DUOS losses is calculated as follows:

\[ \text{Cost of DUOS losses} = \sum \text{delivered energy } t \times (\text{distribution loss factor} \times \text{transmission loss factor} - 1) \times P_t \]

where

- \( t \) = the appropriate metering period
- \( P_t \) = energy purchase price

**Distribution loss charges for generators**

The charges for an embedded generator take into account the generator’s impact on the distribution losses. In the case of co-generators which are both importers and exporters of energy, the network charges applicable to loads apply to the net load imposed on the distribution network.

**Distribution connection charges for generators**

Connection charges for distribution connected generators apply as for loads where there is exported onto the network. All actual upstream shared costs are recovered in the base rate, but an early termination guarantee for shared assets, i.e. upstream reinforcements, is applied.

**Other charges**

**Reliability service charge**

All loads and generators will be charged for reliability services based on the total energy exported or consumed into/from the network.

**Service and administration charge**

Service and administration charges are independent of network operations or installed capacity and will be applied to both loads and generators to recover billing, meter reading and customer support costs.

**Subsidy contributions**

Users of the network from a load perspective pay only the electrification and rural component of the subsidy. Generators are exempted from paying the electrification and rural subsidy.

**Eskom wheeling arrangements, regulations and charges [5,6]**

The Eskom contract treats the generator and the customer as if they were unconnected entities, i.e. the customers is billed as a normal Eskom customer and the generator is treated like a normal supplier to the Eskom network, with the only difference being that the customer receives a credit for energy supplied by the NEG, and will be billed by the NEG.

Both generator and customer pay charges according the Nersa regulations, and at rates approved by Nersa.

The Eskom billing system is based on the assumption that the customer uses more energy than that supplied by the generator and draws the balance from Eskom. The customer is billed by Eskom for the total energy supplied and receives a credit (less network-loss charges) for the energy supplied by the generator. There is thus no need to balance or reconcile supply and consumption as the customer pays for the actual energy delivered by the generator. Both customer and generator are metered. There is at this moment no balancing system between the NEG and Eskom, but this should be reconciled once the ISMO is in place. The possibility of the generator supplying more energy than that consumed by the customer will not occur as long as the customer’s load exceeds the generator’s capacity, and it is up to the generator to ensure that power supplied to the network remains within the bounds of the supply agreement. The Eskom system does allow customers which generate electricity for their own use and which infrequently exceed their requirements to “bank” surplus energy on the grid, which will be offset against the following metering periods consumption. This may also apply to wheeling arrangements with third parties who purchase surplus power from the NEG, and where the generation surplus exceeds the load requirement of the third party [6].

Fig. 4 illustrates the charges incurred by the parties to a power wheeling agreement using the Eskom network.

**References**


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