

Report

Treatment of regenerative braking for metered operators on the dc network - CP5 proposal

Network Rail consultation
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1. Introduction

Train operators who use on-train metering on the Network Rail dc electrification network pay their traction electricity charges on the basis of metered consumption. Currently, regenerated energy is subtracted from the gross energy consumption and then the losses mark-up (currently 27%) is applied to this net energy consumption. This consumption is then multiplied by the electricity price to calculate the metered traction electricity charge.

The losses mark-up, applied to consumption, takes account of the electrical losses which consist of a combination of fixed and variable losses. The fixed losses are a constant and occur all the time the network is energised. Variable losses occur when current is flowing, predominantly as a result of trains drawing traction energy, this electric current for traction is known as EC4T.

The purpose of this document is to consult the industry on the effectiveness of the way in which metered regenerated dc energy is allowed for in metered traction electricity charges in CP5. We are also seeking views on a suitable application during CP6 and beyond.

These views will be used to formulate our conclusions on a proposal to the industry regarding the treatment of metered dc regenerated energy during CP5. Views from this consultation will be concluded on at the same time as we conclude on all other EC4T related issues, early in 2013.

2. Scope

The scope of the document is limited to the consideration of electrical losses solely in relation to dc regenerated energy. Total dc losses are also being consulted on alongside this report.

3. Background

Modern electric trains are commonly equipped with two types of braking system; conventional mechanical disc brakes and electric regenerative braking. The use of regenerative braking reduces the net energy consumed, and represents a cost saving for the train operators which use it.

For non-metered operators this cost saving is recognised through a regenerative braking discount, which is applied as a discount to the modelled traction electricity consumption. A dc regenerative braking discount of 15% has been available to all dc Train Operating Companies (TOC) in CP4. We recently consulted on the option to retain this discount for CP5, we will be concluding on this early in 2013.

Currently, all metered train operators pay for net consumption after taking in to account the regenerated energy. This means that all regenerated energy is subtracted from the gross energy consumption and then the losses mark-up is applied to this net energy consumption to calculate the EC4T charge.

To understand the reasons for regenerative braking, and how it works, it is useful to compare a train to a bicycle. In both cases considerable effort is required when starting off and then, when up to the desired speed on level ground, little effort is required to maintain speed. When accelerating or climbing a gradient, further energy is required. On downhill sections, negligible or zero energy is required and in fact it may be necessary to apply the brakes to avoid excessive speed. Applying the brakes reduces speed by creating friction and dissipating (wasting) the surplus energy as heat.

Many bicycles are equipped with dynamo lighting where a small generator is powered through the wheels to create electricity. Using the dynamo creates an extra load which requires extra energy to avoid the cycle slowing down. There are parallels in a train equipped with regenerative braking. When the train needs to reduce its speed, it is possible to reverse the operation of the electric motors so that instead of using power, they generate power similar to the bicycle dynamo. The power exported from the train reduces the momentum of the train to such an extent that it will bring the train to a halt.

A measure of the effectiveness of regenerative braking is that, in slippery conditions, it is capable of causing the wheels to skid in the same way that over application of a mechanical brake will cause the wheels to lock and slide.

Where regenerative braking is used, the electrical power exported from the train feeds back into the electricity traction network. Here it will be:

- used by another train nearby that is drawing power;
- dissipated through network losses; or
- fed back into the national grid system (in the case of the ac network).

It is important to note that surplus regenerated power on the dc system can technically only be returned to the national grid by using inversion equipment. Inversion equipment can be costly and may not represent 'value for money'. An technically feasible alternative, although also fairly costly, is to store some of this surplus energy either on board the train or line-side in batteries or fly wheels.

3.1 Factors affecting regeneration

Trains have a low rolling resistance which is an advantage when moving at speed, but a disadvantage when trying to stop a high-speed train. Rail adhesion is a key factor in braking performance. For this reason, regenerative braking can be overridden to avoid sliding in poor conditions such as ice or leaves. This manual intervention may result in a lower than expected use of regenerative braking.

The level of deceleration and hence regeneration varies according to train design, and the blending of mechanical braking with regenerative braking. Some train designs operate friction and electric braking in parallel; others only use friction to supplement the electric braking when the driver calls for increased retardation.

Table 1 details factors which affect regeneration. We have found that these issues often result in a few days where no regenerative energy is being produced, and many days when the output is not maximised.

Table 1: Factors affecting regeneration

| Factors affecting regeneration | Influencing factors |
|--|---|
| The degree of timetable optimisation | A timetable that is optimised to reduce energy consumption by enabling trains to operate at a steady average speed with few signal stops will use less energy and also reduce regenerated brake energy. |
| Robustness of train operating service Passenger Performance Measures (PPM) | To maintain PPM a TOC may have to maintain a high average speed achievable only by aggressive driving. This will consume more energy but also due to reduced coasting create greater regenerative energy. |
| Number of electrically braked axles | The amount of regenerated power that a train can generate is partly dependent on the number of braked axles; the power that can be generated per axle is limited due to the wheel adhesion per axle. |
| Rail Adhesion / Weather | In poor conditions (leaves, ice) then regenerated power is reduced, possibly to zero. |
| Coasting policy | A coasting train is using no energy and is gradually reducing speed, braking and regenerated power only when required to stop. |
| Train braking control logic | The braking of modern trains is determined by their software. The balance between mechanical and regenerative braking varying |

Table 1: Factors affecting regeneration

| Factors affecting regeneration | Influencing factors |
|--------------------------------|--|
| | according to train class. |
| Driving style | An economical driving style avoids harsh braking and reduces regeneration energy. |
| Type of service | As indicated by the current range of regeneration discounts the type of service influences the amount of regenerated energy. |
| Line design | A line with gradients, curves and junctions will require the train to brake and accelerate thereby increasing both the power consumption and power regeneration. |

While we are keen for operators to gain the full savings that can be made through regenerative braking, it is important that it is fair.

4. The regenerative braking discount (modelled dc usage)

During the decades of relatively cheap energy there was little financial incentive to invest in regenerative braking. As energy prices have increased and environmental issues have taken on greater importance, the need to be more energy efficient has improved the viability of regenerative braking.

It was, however, still expensive for TOCs to install regenerative braking on new trains. To reward the installation of regenerative braking, TOCs were incentivised by a regenerative braking discount in the modelled traction electricity charges for trains equipped with regenerative braking in CP2. The ac and dc regenerative braking discounts vary according to route type assuming that as local commuter trains stop more frequently they would use their regenerative braking more than inter-city trains and hence return more power to the network. A 15% discount has been available on all dc networks during CP4. We recently consulted on the option to retain this discount for CP5, we will be concluding on this early in 2013¹.

The regenerative braking discounts were based on a number of assumptions which did not take account of the impact of the different variables which affect the amount of power regenerated. Historically this was not a major concern, as any imbalance due to these assumptions between the modelled and actual consumption was resolved through the annual volume wash-up.

As more operators fit meters to their trains, it becomes even more important to revisit the way we incentivise the use of regenerative braking so that operators are fairly rewarded for regenerating energy. As discussed in our Sep 2012 consultation document, a very small sample of metered data from Southern Trains shows that the average regenerated energy, as an average percentage of the gross consumption the regenerated energy, was between 16% and 20%. However we do not feel that this data is sufficiently robust to draw conclusions from.

The key point to note is that the data analysed reflects situations where regenerative braking is fully functional. However, this may not always be the case due to reduced levels of rail adhesion during leaf fall and icy conditions.

We will be concluding on the responses to our Sep 2012 consultation which included a proposal on the dc regenerative braking discount for CP5, early in 2013.

¹ Network Rail (Sep 2012), 'Periodic Review 2013: Network Rail consultation on traction electricity & electrification asset usage charges in CP5'. Accessible here: <http://www.networkrail.co.uk/WorkArea/DownloadAsset.aspx?id=30064783482>

(A) Do you have any further views on our Sep 2012 proposal to retain the 15% regenerative braking discount for modelled dc usage?

5. Regenerative braking and effect on losses (metered dc usage)

Currently on-train meters measure regenerated energy as well as the gross energy consumption. Therefore, operators which use on-train metering are charged based on metered energy consumption net of any regenerated power returned to the rail network. This net consumption is then uplifted to take account of losses. This means that a metered train does not pay for losses incurred on the energy imported to the train equivalent to that later regenerated. We set out some detail below on what we consider to be the interaction between losses and regenerated energy on the dc network.

If train A regenerates energy, when there is another motoring train B nearby, train B will consume the regenerated power. Due to the short distance, the transfer of power will have little associated losses and in all probability much less loss than had train B been supplied by the normal feed.

Conversely, if train A regenerates energy and there is no other train to consume this energy nearby, the regenerated energy is lost through leakage and heat loss. This is because the surplus dc energy cannot be returned to the National Grid through the normal grid supply point without the installation of considerably expensive inversion equipment. Under the current billing process, the train operator in this scenario will not incur the cost of losses in supply and return for the regenerated energy. As a result, the cost of these losses will pass through to the volume wash-up and be shared by all parties to the volume wash-up in that ESTA (i.e. modelled operators).

Regenerative braking will always reduce overall energy consumption. However, it will increase the current flowing in the electrification system, and therefore increase electrification variable losses, albeit that it will supply a proportion of the leakage loss. Given the scenarios described above, it is apparent that losses differ between gross energy consumption and energy regenerated though this effect is not currently fully understood. We discuss some options, on how to reflect this in the way metered dc usage is billed, below.

6. Options

This section discusses the options for reflecting the interaction between regenerative braking and losses in the way metered dc usage is billed.

As discussed above, some of the energy regenerated on the dc network is used and paid for by other trains while the remainder is lost either as heat or in reducing leakage losses. Under the current metered billing process these losses are not captured, this is because regenerated energy is deducted from the gross consumption before the losses mark-up is applied. Therefore, the current approach, may be under-estimating actual consumption, this could result in the under-recovered amount being transferred to the volume wash-up. This is because TOCs are credited with the full value of the power regenerated at the point where it leaves the train without taking into account any losses between the train location and the location where the regenerated energy is reused.

The current approach was introduced around the time that the first operators moved to metered billing as a pragmatic way forward. Given that we now have more understanding about this issue, we consider that it should be addressed. We consider there are a number of options for reflecting regenerated energy in metered charges, they are:

- (a) To retain the current approach – which is to apply a total losses mark-up to net energy consumption (i.e. gross consumption minus regenerated energy);
- (b) to apply the losses mark-up to gross energy consumption only – and then net off the regenerated energy; or
- (c) to apply separate loss factors to gross consumption and regenerated energy to reflect the different losses on both

While we consider option (c) to be the most accurate approach, we are conscious that this

would require a substantial amount of further work. Quantifying the losses factor for regenerated energy is a significant task and it is unlikely that we would be able to carry out this work robustly in time for the start of CP5. For this reason we recommend that further consideration of option (c) is carried out during CP5, and any such implementation of this option is deferred to CP6.

On this basis, we consider that the current approach (a) is still the most appropriate option for CP5.

(B) Do you agree with our proposal to continue using the current approach to reflecting regenerated energy in metered dc charges? (i.e. apply total losses mark-up to net energy consumption)

We recognise the need to improve our understanding of the actual regenerated energy being exported from trains to the traction electricity network. In reality, this can only be achieved by full on-train metering. For this reason, we strongly support the installation of metering and regenerative braking to provide more information about how the industry can reduce overall electricity consumption.

(C) Do you have any views on the consideration of a separate losses factor for metered regenerated energy in CP6?

(D) Do you have any other views our approach to reflecting regenerated energy in metered dc charges?

7. Conclusions

In conclusion, we are proposing the following:

- to retain the current approach to reflecting regenerated energy in metered traction electricity charges on the dc network. This approach applies a total losses mark-up to net energy consumption (this is gross consumption minus regenerated energy); and
- to consider the feasibility of applying a separate losses factor to regenerated energy on the dc network during CP5, for possible implementation in CP6.

We are keen to hear your views on these proposals.

In Sep 2012, we consulted on the proposal to retain the 15% regenerative braking discount applied to modeled dc energy usage. We will be concluding on this consultation, and our earlier consultation in Sep 2012, in early 2013.

Appendix A - Definitions and abbreviations

| | |
|------|---|
| ac | Alternating current |
| CP5 | Control period 5 (1 April 2014 – 31 March 2019) |
| CP6 | Control period 6 (1 April 2019 – 21 March 2014) |
| dc | Direct current |
| EC4T | Electric current for traction |
| NR | Network Rail |
| ORR | Office of Rail Regulation |
| TOC | Train operating company |