INCENTIVE SCHEME FOR EFFICIENT GRID UTILIZATION IN THE SWEDISH REVENUE CAP REGULATION FROM 2020

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ABSTRACT

The national regulatory authority (NRA) for energy in Sweden, the Swedish Energy Markets Inspectorate (Ei), determines a revenue cap for each distribution system operator (DSO) and for the transmission system operator (TSO) for a regulatory period of four years at a time. The revenue cap is adjusted based on e.g. the performance regarding efficient grid utilization and continuity of supply. Ei aims to continuously evaluate and improve the regulatory framework for DSOs and the TSO.

This paper describes the efficient grid utilization incentive scheme with extra focus on upcoming changes from next regulatory period 2020-2023. This incentive scheme is divided into two parts: 1) reducing network losses and 2) reducing load flow peaks in connections to other grids (load). The most significant change about the first part (losses) is the introduction of a benchmarking method when calculating norm values taking the DSO's individual objective conditions into consideration. The second part (load) has got a completely new structure, from comparing costs (that indirect partly depends on the load) to more directly comparing real achievements of the load. The indicator (average load factor) used to measure the load will remain the same but will evaluated further within the long-term development work at Ei.

INTRODUCTION

The Swedish electricity market underwent a major reform in 1996. Trading in and generation of electricity was exposed to competition, while the infrastructure operation remained as regulated monopolies (i.e. unbundling). The first version of current ex-ante revenue cap regulation was introduced in 2012 [1]. Since then, many new rules affecting the DSOs have however been introduced.

Sweden has approximately 170 DSOs (most local DSOs with the monopoly within an area up to a given voltage level, while the rest are referred to as regional DSOs) and one transmission system operator (TSO); all with different conditions regarding size, ownership and clime/terrain, making it a great challenge to develop an effective regulatory model. The national regulatory authority (NRA) for energy in Sweden, the Swedish Energy Markets Inspectorate (Ei), determines a revenue cap for each DSO and the TSO for regulatory periods (RP) of four years at a time since 2012. The revenue cap is adjusted based on continuity of supply (CoS) [2] and, as of 2016, also on efficient grid utilization [3]. Well-designed incentive schemes are becoming increasingly important to meet future ambitious climate goals in a time of large technique shifts. Ei aims to continuously evaluate and improve the regulatory framework.

According to Article 15(4) of the Energy Efficiency Directive, EU member states shall ensure that DSOs are incentivized to improve efficiency in infrastructure design and operation. In Sweden, Ei was mandated to define what is considered an efficient utilization of the grid and to design a new incentive scheme within the revenue cap regulation. The grid utilization incentive scheme is divided into two parts, incentives to: a) reduce network losses (both for the TSO and DSOs) and b) reducing load flow peaks in connections to other grids (only for DSOs). This relatively new incentive scheme has been evaluated and will undergo several changes until next RP 2020-2023.

The CoS incentive scheme will also undergo changes from the next RP 2020-2023, which is described in a parallel CIRED paper [4]. That paper also describes the common regulatory framework regarding maximum adjustment from this and the CoS incentive scheme and summarize some other changes in the revenue cap regulation.

SUMMARY OF CURRENT REGULATION

Overall revenue cap regulation

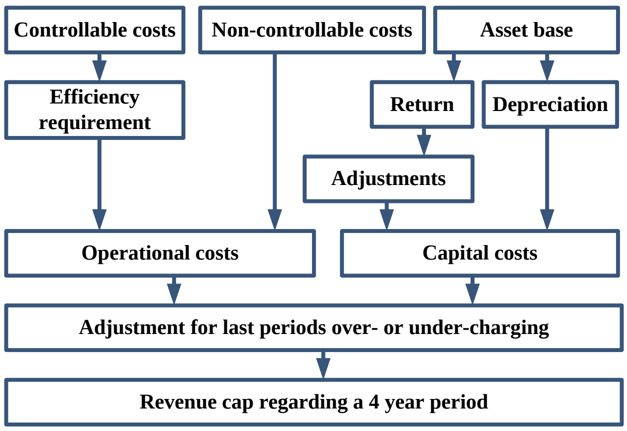

Figure 1 Overview of the Swedish revenue cap regulation

The current revenue cap regulation is illustrated in Figure 1 and described in more detail in a paper published by Ei in 2016 [5]. More details about current incentive schemes are provided in [2] (CoS) and [3] (efficient grid utilization).

Incentive scheme for efficient grid utilization

Overview of this incentive scheme

The first version of this incentive scheme was introduced from the second RP 2016-2019 and is divided into two parts: 1) reducing network losses and 2) reducing load flow peaks in connections to other grids (load). The outcome is calculated after each RP and gives an economic adjustment (positive or negative) to the regulated return return of the asset base (see Figure 1). The total adjustment, together with the adjustment regarding the CoS incentive scheme (see [2]), is however not allowed to exceed 5 % of the revenue cap or lead to a negative regulated return.

The network losses incentive

The cost of network losses is considered a non-controllable operational cost in the revenue cap regulation (see Figure 1). This means that the cost is handled as a pass-through cost carried 100 % by the customers. The reason for this is that this cost depends on electricity price and on energy consumption, which are difficult for the DSOs and the TSO to influence on a larger scale. This cost however also depends on the losses in percentage of the energy (which the DSOs and the TSO should be encouraged to minimize). Therefore, Ei choses to use the losses in percentage as an indicator that can adjust the regulated return, while the cost for losses is considered as a non-controllable cost.

The current incentive is calculated as in equation 1:

$$C_{NL} = 0.50 * (NL_{norm} - NL_{outcome}) * E_{out} * P_{NL} \quad (1)$$

Where:

- C_{NL} [kSEK] (thousands of Swedish kronor) = The value (positive or negative) that adjust the revenue cap.
- NL_{norm} [%] = Network losses during a four-year norm period that ends two years before the RP.
- $NL_{outcome}$ [%] = Network losses during the RP.
- E_{out} [MWh] = Distributed energy during the RP.
- P_{NL} [kSEK/MWh] = Price per megawatt hour for network losses calculated as an average price during the RP. All DSOs' costs for network losses are considered in the calculation.

All parameters in equation (1), except P_{NL}, are based on the individual data reported from each DSO and the TSO. Network losses ($NL_{norm}/NL_{outcome}$) is defined as the difference between measured energy that is fed into the grid from other grids and local producers (E_{in}) and the energy consumed (E_{out}) as percentage of E_{out}.

The load flow incentive

Unlike the incentive for network losses, the TSO is excluded from this part of the incentive scheme.

A reduced peak load flow (especially if it leads to lower maximum power) can have a positive economic impact. It can lead to postponed, reduced or even avoided grid investments. It can also lead to lower costs to superior grids (considered as a non-controllable cost in the revenue cap regulation, see Figure 1) and reduced network losses. However, the effects in the system varies a lot (from negligible to significant) and it is not obvious how to price the incentive and how to best evaluate the performance.

This part of the incentive scheme will be remodeled until next RP 2020-2023 (described later in this paper). Currently (2016-2019), this incentive, unlike rest of the incentives in the regulation, can only give a bonus to the DSO. The DSO get a bonus if the total costs for getting power to the own grid (mainly cost to superior grid), "feed-in costs" (normalized with the energy consumption) are reduced compared the corresponding costs during a norm period. If that is the case, the DSO keep a part of the total cost reduction which is equal to the cost reduction times the average load factor (Lf_a, defined in equation 2). The logic of connecting Lf_a with feed-in costs, is that a higher Lf_a can decrease that cost by e.g. lower peak power to superior grids. For more detail of current method, see [3].

$$Lf_a = \frac{\sum_{d=1}^{D} Lfday,d}{D} \quad (2)$$

Lf_a is the average of all daily load factors, where the daily load factors ($Lf_{day,\ d}$) is the average hourly power divided by the maximum hourly power during the actual day *d* and *D* is the number of days during a period (e.g. a year or a RP). The hourly power is calculated by summarizing the hourly power in all connections to other grids and if needed taking the absolute value (the load flow can be in two directions with a lot of local energy production).

CHANGES IN THE INCENTIVE SCHEME FOR EFFICIENT GRID UTILIZATION

Calculating the outcome for each year

A seemingly minor change is that the outcome from the incentive scheme will be calculated per year instead of comparing the outcome of the entire RP with the norm period. This will make it easier for the regulator to handle indexing of costs and changes within the RP (e.g. when DSOs merge). It also makes it possible to calculate the maximum adjustment per year.

Maximum adjustment

The maximum adjustment regarding the sum of this incentive scheme together with the CoS incentive is presented in the parallel CoS paper, see [4].

New method to calculate norm levels for losses

Evaluation of current regulation

Today, each DSO's individual historical losses are used as norm (Nf_{norm} in equation 1). There are sometimes however inexplicable, and seemingly unreasonable, variations between local DSOs with respect to reported network losses, also after considering that DSOs have very different conditions. A problem with today's norm method is that DSOs can continue having unmotivated high losses without any consequences.

Lower network losses mean long-term benefits for customers (lower costs) and for the climate. It is hence important with long-term incentives. A problem with today's norm method is that DSOs that invest in lower losses only receive a better outcome in the incentive scheme for six years (four-year RPs + a two-year gap between the RP and the norm period). At the same time, a typical investment has a 40-year long life time or more.

Developing a benchmarking norm level method

Ei has examined the possibility of using benchmarking instead of using each DSO's own historical losses to calculate individual norm levels (inspired by the current method of the CoS incentive scheme). It is not fair to use the same norm for every DSO. A substantial number of parameters have been evaluated to find what the norm method should compensate for [6].

The assessment of whether a parameter is suitable to consider in the norm function was done in several steps:

1. Parameters not too difficult to collect (preferably parameters that Ei already has access to).
2. It should be a sufficiently large dependency between the parameter and network losses. Was evaluated both by calculating the correlation and by visually study curves.
3. Assess whether it is a causal relationship. For example, there are a strong correlation between the share of underground cables and low network losses, but this is mostly explained by higher share of underground cables in cities with shorter distances between customers.
4. Assess whether it is an objective condition that should be considered. Examples of conditions that not fulfill this criterion are the average age or the choice of different techniques and solutions.
5. Assess whether the objective condition better can be captured by another available parameter.

The parameter which best meets the criteria (1-5) above is customer density (number of customer per km line + cable). The longer you must transport the energy, the higher losses. Another advantage is that this parameter already is used within the CoS incentive scheme (see [4]). It is hence best to use even if it exists parameters that capture the same condition (long distance between customers) in an analogous way. The initial approach was logically to use the same kind of function as within the CoS incentive (equation 2), where a-c is calculated by using the least square method.

$$Norm\ level = a + \frac{b}{[customer\ density]+c} \quad (3)$$

After concluding customer density as an essential parameter, the next step was to evaluate if there still are any other objective conditions reasonable to consider that explain remaining differences between norm and real values. This was done by repeating the same steps (1-5) looking for remining dependencies after having compensated for customer density. The result was that the norm function become more accurate by also consider the share of energy delivered to high voltage customers >1 kV (*SHV*). The more energy you do not have to transport at 0.4 kV, the lower network losses are reasonable. A factor hard to influence and hence reasonable to consider. Analyses also show that *SHV* can be added to the equation just by multiplying it with a new constant (in contrast to dependency customer density). Finally, no additional parameters were found that were significant enough to motivate a more complex function.

The new norm level method for local DSOs

The resulting norm function is hence:

$$Norm\ level = a + \frac{b}{[customer\ density]+c} + [SHV] * d \quad (4)$$

Where a-d are calculated by using the least square method. Even if *SHV* is included as a parameter which partly capture differences between local and regional DSO, the conditions still differ too much to use the same function. The TSO and the regional DSOs are hence excluded, and the norm method will be unchanged for them.

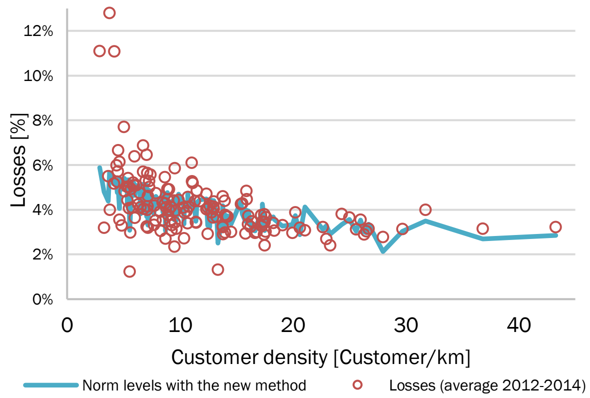

Figure 2 The new norm level method as a function of customer density and adjusted to SHV

Figure 2 shows how the resulting norm function (equation 4) looks like using data from 2012-2014, where the red circles are the reported average losses from different DSOs and the blue line is the norm values as a function of customer density. The line is irregular since it also considers different *SHV*. The norm values differ from about 2 % to about 6 % in terms of network losses.

Consequences

Everything the DSO does (investments and changes in the operation) will affect the outcome until the change does not influence the share of network losses any more (e.g. during an investment's entire life time). The average cost for customers will continuously decrease over time due to stronger incentives for DSOs with high losses.

Figure 3 shows the outcome (regarding network losses 2016) from this incentive using current method, compared with if the new norm function already had been in use. In both cases, the average outcome is close to 0. However, the variation between DSOs is larger with the new method. Note that this analysis only looks at this specific change. If the incentives are multiplied by 0.75 instead of 0.50 (as today), the outcomes will increase with 50 %.

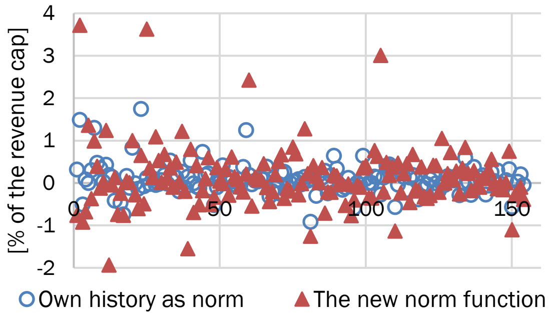

Figure 3 The Outcome from the network losses incentive, comparing the outcome using old or new norm method

Other changes of the network losses incentive

Besides a new method for calculating norm values for local DSOs, there are some other changes (which unlike the norm method also affect the TSO and regional DSOs).

0.75 instead of 0.50

By multiplying the incentive function with 0.50, the customer and the DSO/TSO equally share both lower and higher costs resulting from changes in the share of network losses. However, since Ei introduced this incentive, a common feed-back is that this incentive should be stronger. A straightforward way to do this is by increasing the multiplier. A stronger incentive means lower long-term costs for customers even if the customers will keep a lower part of the decreasing costs in a shorter perspective.

After analyzing scenarios of costumer costs over time with different multipliers, Ei conclude that 0.75 is a good compromise (with 1.00 it will take a very long time before customers in total got lower costs compared with 0.50 or 0.75). However, even if some stakeholders ask for stronger incentives regarding network losses, there is a natural limit. The cost of network losses only stands for about 3 % of the total revenue cap in average (differs between DSOs).

The definition of NL and using E_{in} instead of E_{out}

Today, NL_x is defined as $(E_{in} - E_{out})/\boldsymbol{E_{out}}$. That will be changed from the next RP to a more logical definition: $(E_{in} - E_{out})/\boldsymbol{E_{in}}$. Followed by the changed definition of NL_x, it is logical to replace E_{out} in the equation with E_{in}. For losses within a typical order of magnitude in power systems (often <10 %), the combination of these changes will almost have a negligible effect on the outcome.

The resulting, just slightly modified, incentive function

$$C_{NL} = 0.75 * (NL_{norm} - NL_{outcome}) * E_{in} * P_n \quad (5)$$

The new overall structure (equation 5) will remain almost the same as before (equation 1). The most notable change is the method to calculate NL_{norm} for local DSOs. The second most important is replacing 0.50 with 0.75 which makes the incentive 50 % stronger. When it comes to the other parts, P_n remain the same as before, while the rest undergo changes with negligible impact on the outcome.

Changed load flow incentive

Evaluation of current regulation

Already when Ei implemented this incentive in 2016, there were some known issues and a plan to continue the developing work until next RP 2020-2023. Hence, for prudential reasons, this incentive currently cannot result in any reduction of the revenue cap (only bonus if the outcome is better than the norm). This is of course problematic from a costumer perspective. From the DSOs' perspective, the incentive is problematic since it partly depends on parameters that are very difficult, if not impossible, for the DSOs to influence.

Today, both the pricing of the incentive and the way to indicate improvements are based on the difference in the total costs for getting power to the own grid (mainly cost to superior grid), "feed-in costs". These costs have an indirect connection to the load flow pattern but are only partly possible for the DSO to influence. The current parameter to more directly evaluate the peak load flow, Lf_a (see equation 2), only affects how much a DSO keep if the feed-in costs are reduced. A reason to not use Lf_a as the main indicator already in the current RP (2019-2019), was the lack of historical values to use.

Another issue is whether Lf_a is the best indicator to use. A drawback is that every day during the year contributes equally to the average Lf_a, while days with high peak power have more impact on the costs such as losses and investments needed. Another remark raised is the difficulty for DSOs to affect Lf_a.

From focus on cost to focus on performance

Instead of measuring how the cost has changed, Ei has decided to re-make the function as shown by equation 6. That will measure changes in the performance instead of costs and allow both positive and negative outcomes. This addresses most issues identified with this part of the incentive scheme and is a change all stakeholders (in reference groups etc.) agrees with.

$$([indicator]_{outcome} - [indicator]_{norm}) * C_{feed-in} \quad (6)$$

Best indicator to use

The next step was to decide the indicator in equation 6. Unlike when the first version of this incentive scheme was introduced, data on historic Lf_a is now available for calculating norm values. However, it is not obvious that Lf_a is the best indicator to use. Especially two other indicators have been identified as interesting, a weighted load factor (Lf_w as defined in equation 7) and a variant of utilization rate (η as defined in equation 8).

$$Lf_w = \sum_{i=1}^{D}\left(\frac{E_i^x}{\sum_{i=1}^{D} E_i^x} * Lf_i\right) \tag{7}$$

E_i is the delivered energy during day *i* and *D* is the number of days during the period (e.g. a year). The value of *x* can be adjusted to weight the load factor differently according to the energy. For example, x = 0 gives $Lf_w = Lf_a$; x = 1 gives a linear relation and if x is very high, only the days with the highest *E* matter. Lf_w was proposed in [7] and has since then been further analyzed. An obvious problem is the lack of historical data (unless Ei asks for data retrospectively). Another disadvantage is that it is a quite high initial administrative cost and risk if all ~170 DSOs had to learn and calculate a new complex indicator.

$$\eta = \frac{P_{average}}{P_{max}} \tag{8}$$

$P_{average}$ is the average power and P_{max} is the maximal power during a year. There is some flexibility in how to define details in the calculation, such as where the power should be measured and if the maximum power should be based on the highest hourly average or in another way. The indicator η has been identified as interesting and is the indicator proposed by the DSOs. It is relatively easy to calculate and understand and it focuses on the highest load. However, this indicator was proposed relatively late in the process. It must be evaluated more, both pros and cons of consequences compared with Lf_a.

The development work resulted in that Ei will continue to use Lf_a for the RP 2020-2023. Ei will however continue to evaluate which indicator that best fulfill the goal of the incentive until RP 2024-2027.

Description of implemented changes

The resulting incentive function is given in equation 9.

$$C_{Lf} = \left(Lf_{a\_outcome} - Lf_{a\_norm}\right) * C_{feed-in} \tag{9}$$

$C_{feed-in}$ is the feed-in costs, $Lf_{a\_outcome}$ is the outcome of Lf_a (see equation 2) during each year and Lf_{a_norm} is the norm value of Lf_a. There is no obvious way to create good benchmarking norms as for network losses or CoS, so the norm values of Lf_a will be based on each DSO's own historical outcomes.

Consequences

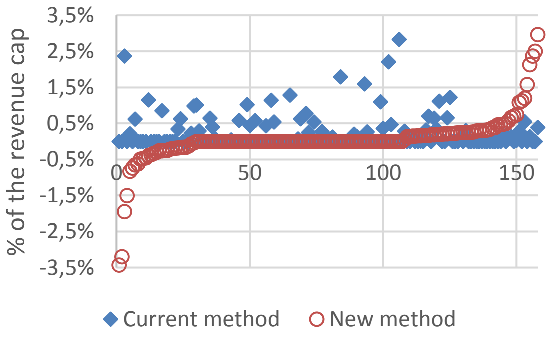

Figure 4 Analysis of outcome from the load flow incentive for one year comparing current and the new methods

The new load flow incentive has been compared with the current, which is illustrated in Figure 4. An obvious difference is that the current method only gives zero or positive (bonuses) outcomes (often below 1 %), while the new method is evenly distributed around zero (often ±0.5 %) Moreover, many of the larger outcomes from the new method probably depend on lack of quality in reported data during the first years of reporting Lf_a and many DSOs will report again before the implementation. The new incentive will initially, as show in Figure 4, be relatively weak which supports the claim that it is hard to affect Lf_a.

CLOSURE

The Swedish NRA determines revenue caps for the DSOs and the TSO. As a part of the revenue cap regulation, there is an incentive scheme for efficient grid utilization which may lead to bonus or penalty to the regulated return. This incentive scheme is divided into two parts: 1) reducing network losses and 2) reducing load flow peaks. The incentive has been developed and several changes will enter into force from 2020. The most innovative and important novelty is to calculate network losses norms for each local DSO by using a benchmarking norm function that consider different objective conditions. This will give a much stronger and more long-term incentive for reducing network losses which has been identified as an important goal, e.g. by EU. The load flow incentive will shift focus from reducing costs (with indirect connection to performance) to improving the DSOs' performance. This is a step in the right direction. There are however details that Ei has identified as interesting to investigate more in the long term-term development work.

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