INCENTIVE SCHEME FOR CONTINUITY OF SUPPLY 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 continuity of supply (CoS). Ei aims to continuously evaluate and improve the regulatory framework for DSOs and the TSO.

This paper describes the CoS incentive scheme with extra focus on upcoming changes from next regulatory period 2020-2023. There are two more significant changes, new interruption cost parameters based on a recently published study and changed CoS indicators to consider the specific size of each customer (power weighted indicators). Furthermore, the legislation regarding interruptions ≥12 hours has been changed. The impact of all changes combined will be stronger incentives (higher rewards and penalties, while he average outcome still will be close to zero) and that the estimation of energy and power not supplied will be less approximative.

Finally, the way of calculating the max reward or penalty allowed from this incentive scheme together with the incentive scheme for efficient utilization (described in a parallel CIRED paper) will also be changed.

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). Performance based regulation of distribution system operators (DSOs) was first introduced in 2003, while the first version of current ex-ante revenue cap regulation was introduced in 2012 [1]. Since then, new rules affecting the DSOs have been introduced, e.g. improved incentives for continuity of supply (CoS) [2] and a new incentive scheme for efficient grid utilization [3] from 2016.

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 and efficient grid utilization. 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.

During the first RP (2012-2015), the CoS of local DSOs were assessed using the indicators SAIDI (indicators mentioned in this paper are defined in Table 1) and SAIFI (ENS and PNS for regional DSOs). The outcome for each DSO was compared to their own historical CoS levels and priced using average power and customer interruption cost parameters. For the second RP (2016-2019), major updates were implemented to the incentive scheme for local DSOs [2]. A new benchmarking method to calculate norm levels based on customer density was introduced, SAIDI and SAIFI was differentiated between different customer groups and the indicator CEMI4 was introduced. For regional DSOs, the norm levels where still only based on their own historical performance. The TSO was subject to similar incentive scheme as the regional DSOs from 2016.

Table 1 Definitions

AIF	Average Interruption Frequency (power weighed interruption frequency), defined as PNS divided by average power.
AIT	Average Interruption Time (power weighed interruption time), defined as ENS divided by average power.
$CEMI_4$	The share of customers with four or more interruptions during a year. This indicator can only lower the reward or the penalty.
ENS	Energy not supplied [kWh].
PNS	Power not supplied [kW].
SAIDI	System Average Interruption Duration Index (consumer weighed interruption time), the average interruption time per customer and year.
SAIFI	System Average Interruption Frequency Index (consumer weighed interruption frequency), the average number of interruptions per customer and year.

SUMMARY OF CURRENT REGULATION

Overview of the revenue cap regulation

The current regulatory model is illustrated in Figure 1 and described in more detail in a paper published by Ei in 2016 [4]. More details about current incentive schemes are provided in [2] (CoS) and [3] (efficient utilization). The current CoS incentive scheme is also briefly summarized

in this paper. Background information regarding the regulatory model is provided in [1].

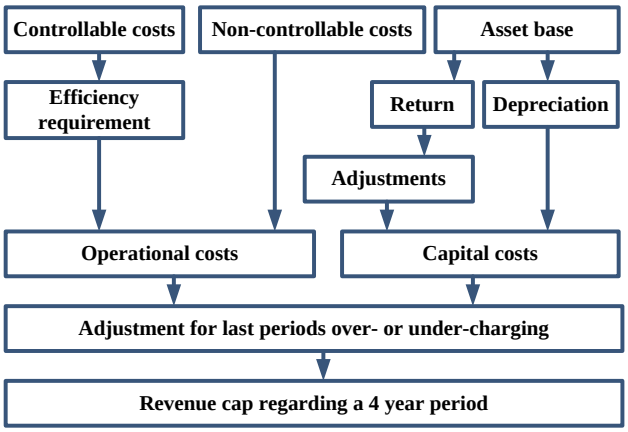

Figure 1 Overview of the Swedish revenue cap regulation

Incentive scheme for continue of supply

Introduction and overview

Various incentives schemes regarding CoS has been included in Swedish revenue regulations since the early 2000s [1]. The first version of current incentive scheme was introduced in 2012, and further improved from 2016.

The year before each RP of four years, individual norm levels for 20-24 CoS indicators are calculated for each DSO (SAIFI/PNS and SAIDI/ENS for each 5-6 customer categories and separated into notified and unnotified interruptions) based on a four-year norm period that ends two years before the RP starts. The outcome for each indicator is compared with its norm level every year during the RP and priced by cost parameters (see Table 2) and the average power per customer category. SAIFI/SAIDI are used for local DSOs, while PNS/ENS are used for regional DSOs and the TSO.

Calculating norm levels

For each local DSO, individual norm levels are calculated based on a mix-method using a combination of bench-marking and each DSOs' own historical CoS levels. A benchmarking function Y(T) is calculated for each indicator based on all local DSOs historical outcomes and customer densities (T [km/ customers]) using the least squares method to calculate the constants (α, β and γ) as in equation 1:

$$Y(T) = \alpha + \frac{\beta}{T+\gamma} \quad (1)$$

An example of such function is shown in Figure 2. The norm levels for SAIFI/SAIDI is determined as the own historical outcome (Z) provided that this is better than the outcome from the benchmarking function (Y) using the individual T. Else the norm level is set to N_i = Y + ((Z – Y) / 4)×(4 – i) where N_i is the norm level during year i in the RP (i = 1,2,3,4). Norm levels for CEMI4 (used for local DSOs) and PNS/ENS (used for regional DSOs and the TSO) are calculated based on the own historical outcome.

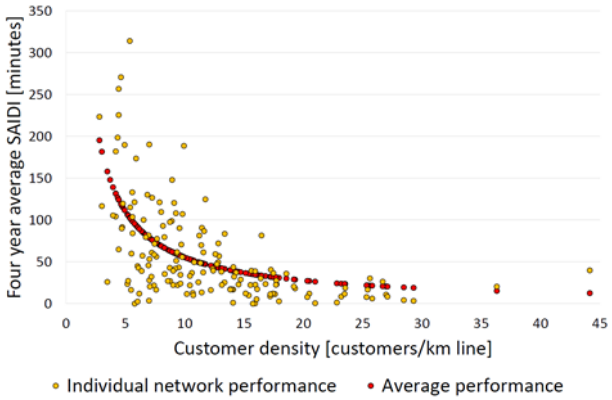

Figure 2 Example of a benchmarking function

Calculating adjustments on the regulated return

For each year during the RP, the total economic adjustment is calculated as shown in equation 2:

$$Q_y = \sum_{k=1}^{5\ or\ 6} \sum_{j=1}^{2} \left((SAIDI_{n,j,k} - SAIDI_{o,j,k}) K_{E,j,k} + (SAIFI_{n,jk} - SAIFI_{o,jk}) K_{P,j,k} \right) P_{av,k} \quad (2)$$

$SAIDI_{n,j,k}/SAIFI_{n,j,k}$ are norm levels and $SAIDI_{o,j,k}/SAIFI_{o,jk}$ the annual outcomes (replaced by PNS/ENS for regional DSOs and the TSO). The equation summarizes per customer category (k) and per interruption category (j, notified and unnotified interruptions). The difference between norm and outcome is multiplied by a cost parameter ($K_{E,j,k}$ or , $K_{P,j,k}$ see Table 2) and the average power for the customer category ($P_{av,k}$).

For local DSO, the annual reward or penalty Q_y (equation 2) can be reduced based on the indicator CEMI4 (see [2]). Finally, the outcome for all four years of the RP is summarized to a total adjustment for CoS. The maximum adjustment on the regulated return, together with the adjustment regarding efficient utilization incentive scheme (see [3]), is 5 % of the total revenue cap (see Figure 1).

INCENTIVE SCHEME FOR COS 2020-2023

Parts that will remain the same

The upcoming changes of the CoS incentive scheme should be regarded rather as a development of the current regulatory method than something completely new. New CoS indicators are introduced, but the overall structure of how to calculate norm levels and how to calculate annual economic adjustment of the revenue cap are the same. The use of CEMI4 and the definition of customer categories are also unchanged.

Maximum adjustment

Evaluation of current regulation

The reasons for having a maximum adjustment (increased or decreased revenue cap) are to protect DSOs or their customers from extreme outcomes and to ensure that the regulated return of the asset base (see Figure 1) isn't negative (the latter defined by the law).

The maximum adjustment is today defined as a percentage of the total revenue cap, while the incentives only adjust the regulated return (see Figure 1). The consequence of this is that the maximum adjustment in percentage of the regulated return differ between DSOs and that the NRA must manually check that the regulated return never becomes negative.

Defining a maximum adjustment regarding the entire RP instead of each year makes the consequence of extreme outcomes during a single year higher.

Description of implemented changes
Instead of having a limit of 5 % of the total revenue cap regarding the entire RP of four years, the limit will instead be 1/3 of the regulated return per year.

Consequences
In average, 1/3 of the regulated return is about 5 % of the total revenue cap, i.e. in average the same limits as before (but with variations between DSOs).

DSOs seldom reach the maximum adjustment. This will probably not change during the next RP 2020-2023 even if the incentives (sum of all changes described in this paper and in [5]) will be stronger. In conclusion, the changes will lower the risk for the DSOs and make it more compatible with the rest of the regulation.

Power weighted CoS indicators

Evaluation of current regulation
Ideally, the CoS incentive scheme should be priced based on what the customers are willing to pay for avoiding an interruption. When choosing between using power weighed indicators or not, the relation between customer size (average power) and interruption cost is crucial. What is the better approximation? a) that all customers within same category, regardless of size, have the same interruption cost (captured by e.g. using SAIFI/SAIDI) or b) that the interruption costs are linear dependent with the size (captured by e.g. PNS/ENS)? Most likely b), even if the truth probably is somewhere in between.

When calculating SAIDI and SAIFI, all customers in the same customer category have the same impact on the outcome regardless of their yearly energy consumption (used to calculate average power). The cost is instead based on the average customer in each category. It is however less approximative to instead base the cost on more detailed information on an individual customer level regarding both interruptions and each customer's energy consumption; data that Ei already collects today.

For regional DSOs and for the TSO, the CoS indicators used (ENS and PNS) today are based on more detailed information than the indicators currently used for the local DSOs (SAIDI and SAIFI). Changing indicators for local DSOs would thus make the incentive scheme more similar across different net levels.

Are ENS and PNS the best indicators to use?
An alternative to using SAIFI and SAIFI, would be to use ENS and PNS as indictors also for local DSOs. These indicators are however not normalized, which is a problem when using the benchmarking functions for local DSOs to calculate norm levels. Another issue with having non-normalized indicators is that differences between norm levels and outcome may depend on differences between annual energy consumption, not only the performance.

Description of implemented changes
Taking this into account, Ei has decided to use the normalized indicators Average Interruption Time (AIT) and Average Interruption Frequency (AIF) for all DSOs and the TSO. AIT and AIF are closely related to ENS and PNS (see equation 3-4). The units are the same as for SAIDI and SAIFI, but power weighed.

$$AIT = \frac{ENS}{average\ power} \quad (3)$$

$$AIF = \frac{PNS}{average\ power} \quad (4)$$

Consequences
Figure 3 shows the outcome of the CoS incentive scheme for local DSOs for 2016 using SAIFI and SAIDI or using AIF and AIT. For most DSOs, the difference is small, and the average outcome is close to zero in both cases. For reginal DSOs and the TSO, the change from ENS/PNS to AIT/AIF is almost negligible.

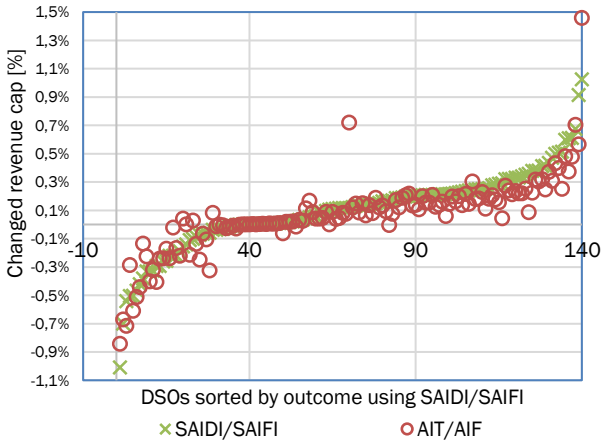

Figure 3 Hypothetical outcome from the CoS incentive scheme comparing SAIDI/SAIFI with AIT/AIF as indicators for all DSOs (using data from 2016)

The DSOs that have participated in reference groups are positive to changing to power weighed indicators regardless of the DSO's net level. The new way of calculating indicators, gives incentives closer to how DSOs currently prioritize and operate their systems. It is also give a more accurate pricing of the incentive. The change will not impose any additional administrative costs

for the DSOs as the NRA already collects the required data on customer level.

Updated interruption costs parameters

Evaluation of current regulation

Today, the incentive is priced based on an interruption cost survey from the early 2000s [6], indexed with inflation every year. The cost parameters are differentiated by notified and unnotified interruptions and divided in cost per kW and cost per kWh. As of RP 2016-2019, they are also divided by 5-6 customer categories:

1. Agriculture
2. Industry
3. Commercial service
4. Public service
5. Household
6. Border points (weighted average)

Since the dependency of electricity probably had changed over the past 15 years, a new interruption cost study was initiated [7]. Results from this study, that will be used in the incentive scheme, was published in December 2018.

Description of implemented changes

All cost parameters from the new study [7] are provided in Table 2 with the corresponding old ones in parentheses. All parameters, both from the new and the old study, are presentation in 2017 prices to give a fair comparison.

Table 2 New interruption cost parameters in (old in parentheses), both new and old in 2017 prices

*	Unnotified interruptions		Notified interruptions	
	[SEK[1]/KW][2]	[SEK[1]/KWh][3]	[SEK[1]/KW][2]	[SEK[1]/KWh][3]
1	9.78 (8.2)	34.35 (45.1)	1.72 (3.1)	14.10 (26.7)
2	70.75 (23.6)	159.96 (72.8)	20.71 (22.6)	76.00 (71.8)
3	17.78 (63.6)	175.06 (151.8)	5.94 (42.1)	79.31 (138.5)
4	7.65 (5.1)	96.97 (40.0))	0.92 (4.1)	43.70 (24.6)
5	1.95 (1.0)	5.84 (2.1)	1.85 (0.0)	4.98 (2.1)
6	22.18 (24.6)	96.01 (67.7)	7.08 (18.5)	45.16 (62.6)
*Customer category, [1]SEK = Swedish krona, 10 SEK ≈ €1 (EUR) [2]Cost for power not supplied, [3]Cost for energy not supplied				

Consequences

Table 3 Costs (based on new parameters compared with old) based on Swedish interruption statistics regarding 2007

Customer Category[1]	Share of all customers	Share of total interruption cost	Changed cost new compared with old
1	0.73 %	1.7 % (2.6 %)	-22.3%
2	1.96 %	42.1 % (26.6 %)	+90.6%
3	8.66 %	43.3 % (64.1 %)	-18.8%
4	2.57 %	7.9 % (4.3 %)	+121.5%
5	86.09 %	5.0 % (2.3 %)	+158.8%
Sum:	**100 %**	**100 %**	**+20.4%**
[1]Border points excluded (costs instead calculated in underlying grid)			

Table 3 give some statistics from 2017 regarding interruption and customer data [8], with the last column comparing interruption cost outcomes between the old and the new study. Most customers (~86 %) are households, while industry and commensal service stand for the major part of the interruption costs (they are larger, and they value interruptions higher per kW and kWh).

Customers are, in average, willing to pay more to avoid an interruption today than ~15 years ago. However, for some of the cost parameters and customer groups, the cost seems to have decreased over time. The consequence for the incentive scheme is that the incentive becomes over 20 % stronger in average. That means higher rewards and penalties, but the average outcome will still be close to zero. Most important is that the pricing of the incentives will be closer to the intention of the legislation.

Interruptions ≥12 hours

Evaluation of current regulation

Today (RP 2016-2019), interruptions ≥12 hours are excluded by law from the incentive scheme. The reason for this is that such long interruptions give individual customer compensation (more information in [4]) that traditionally gives a higher economic consequence for the DSO than the incentive scheme. This is however not true for all customer categories. In some cases, an interruption just below 12 hours can be more expensive for the DSO than a longer interruptions.

Description of implemented changes

The Swedish government recently changed the law that allows Ei to include interruptions from 12 hours in the incentive scheme.

Consequences

Including interruptions from 12 hours will increase both the norm levels and the outcomes, so the average outcome will still be close to zero. DSOs with relatively few interruptions ≥12 hours (compared with DSOs with similar customer density) will get a better outcome in the revenue cap regulation, and the opposite for DSOs with relatively many such interruptions.

The incentive will however become a little stronger since the gap between norm level and outcome (sometimes positive and sometimes negative) will increase. The incentives will in average be about 13 % stronger.

Combined effects

Figure 4 shows the differences in outcome for local DSOs (percentage points) between current method and if the change to AIT/AIF and including interruptions ≥12 hours already had been in place in 2016. The combined effects of these two changes is in average only +0.01 percentage points (a result above zero can be explained by fever interruptions ≥12 hours during 2016 compared with the norm period) and for individual DSOs seldom larger than 0.5 percentage points. As stated before, including interruptions ≥12 hours and implementing new interruption cost parameters will give stronger incentives. The effect of these changes is independent from each other

and the combined effect will be about 36 % stronger incentives than today (1.204*1.130 ≈ 1.36).

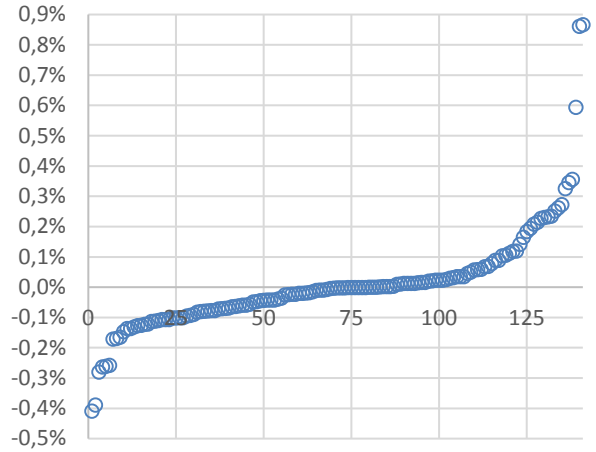

Figure 4 Difference in outcome in percentage point between current method and upcoming modifications

OTHER CHANGES IN THE REVENUE CAP REGULATION FROM RP 2020-20203

Changes in the inventive scheme regarding efficient utilization (net losses and load pattern) are summarized in [5]. There will also be other changes from the next RP 2020-2023 even if the overall structure as shown in Figure 1 is the same. The two most significant other changes are linked to the calculation of capital costs: 1) the way of calculating WACC has been more specified and 2) the depreciation periods have been more differentiated [9].

WACC: The discount rate used in the revenue cap should give a reasonable return for the DSOs. Today, Ei is relatively free to decide the WACC, but that often leads to long and complex court proceedings. The government have specified more in detailed how various parts of the WACC calculation should be calculated in the future.

Depreciation periods: Currently there are two depreciation periods, 40 years for all power components except for meters/IT that instead have a depreciation period of 10 years. Ei has however identified that this is too approximative; 40 years can be too long for certain types of new power system equipment, while too short for other (e.g. risk of decreasing incentives for maintenance).

Therefore, there will be six different depreciation periods from 2020: 10 years (IT/meters), 15 years (control and monitoring equipment), 30 years (cable cabinets), 40 years (a lot of different component, e.g. sub stations), 50 years (a lot of different component, e.g. transformers) and 60 years (transmission overhead lines). Overhead lines and cables have different depreciation periods depending on the net level (the higher voltage levels, the higher depreciation time for overhead lines, while cables however have higher depreciation time on lower voltage levels).

CLOSURE

The Swedish NRA determines revenue caps for the DSOs and the TSO for a regulatory period of four years at a time. As a part of the revenue cap regulation, there is an incentive scheme for CoS which may lead to reward or penalty to the regulated return. This incentive scheme should be priced after the customers' willingness to pay. Ei aims to continuously evaluate and improve the regulatory framework for DSOs.

This paper focuses on changes in this incentive scheme that will soon enter into force. The two most significant changes are the introduction of power weighed indictors instead of SAIDI and SAIFI for local DSOs and updated interruption cost parameters. The outcome will not be radically changed, and the average outcome will still be close to zero even if the incentives becomes about 36 % stronger than today (higher variance in the outcome). The maximum outcome will be ±1/3 of the regulated return.

The administrative costs will not increase because of the changes, even if the method will be less approximative for local DSOs than today. The NRA will not collect more data, but instead better utilize data already collected.

REFERENCES

[1] C. J. Wallnerström, L. Bertling, 2010, "Laws and Regulations of Swedish Power Distribution Systems 1996-2012: learning from novel approaches such as less good experiences". *CIRED Workshop*

[2] E. Grahn et al., 2016, "Incentivizing CoS in Sweden", *the 13th International Conference on the European Energy Market (EEM)*

[3] G. Wigenborg et al., 2016, " Incentive Scheme for Utilization of Electricity Network in Sweden", *the 13th International Conference on the European Energy Market (EEM)*

[4] C. J. Wallnerström et al., 2016, "The regulation of electricity network tariffs in Sweden from 2016", *Swedish Association for Energy Economics Conference 2016 (SAEE2016)*

[5] C. J. Wallnerström et al., 2019, "Incentive scheme for efficient grid utilization in the Swedish revenue cap regulation from 2020". *CIRED2019*

[6] H. Vefsnmo and G. Kjølle, 2015, *Estimation of Costs of Electricity Interruptions in Sweden – Interruption cost parameters based on the survey conducted by University of Gothenburg from 2005*, SINTEF

[7] Fredrik Carlsson et al., 2018, "Kostnader av elavbrott för svenska elkunder", University of Gothenburg

[8] Ei, 2018, "Leveranssäkerhet i Sveriges elnät 2017" (report with statistics regarding continue of supply in Swedish power systems during 2017), Ei R2018:16

[9] SFS 2018:1520, 2018, *Förordning om intäktsram för elnätsverksamhet*, (legislation from the Swedish government, only in Swedish)