A COMPARATIVE STUDY OF REGULATION POLICIES FOR INTERRUPTION OF SUPPLY OF ELECTRICAL DISTRIBUTION SYSTEMS IN SWEDEN AND UK

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ABSTRACT

This paper presents a comparative study of regulating policies for interruption of supply in Sweden and UK. The two regulating regimes have been applied for a case study with a real rural electrical distribution system in Sweden, Flymen. The Swedish and UK regulations state that the distribution system operators (DSO) should restore power delivery to customers within 12 and 18 hours respectively for normal weather conditions. If this could not be fulfilled the DSOs are opposed to different predetermined penalty payments to the customers.

In a comparative case study of Flymen the Swedish model (GL) gives a 68% higher compensation to customers than the UK model (GS) for a 30 hours interruption of supply during normal weather conditions. Historical interruption data for the same system gives a 75% higher compensation with the Swedish model (GL) than the UK model (GS).

The main conclusion from the comparative study is that the Swedish GL model provides a higher compensation for interruptions of supply to customers than the UK GS model.

INTRODUCTION

The deregulation of the electrical distribution system throughout the world has raised a need of regulation with respect to the reliability of supply and the tariffs to the customers. The regulators in the different countries have developed various types of regulating regimes. Generally these are based on the average performance of the system reliability in terms of *System Average Interruption Frequency Index* (SAIFI) [1] and *System Average Interruption Duration Index* (SAIDI) [1], and give the DSOs incentives to increase efficiency. Improvements of the system reliability indices, however, do not necessarily lead to an improvement of reliability of supply for individual customers. Since these regulation policies are based on average values, all customers receive the same compensation for all interruptions that occur in the system, and there is also normally a maximum level for compensation. To handle this situation, complementary regulations have been developed in e.g. Sweden and UK. These have been adapted to give incentives for the DSOs in the handling and prevention of large blackouts in extreme situations (caused by e.g. storms, unexpected large failures etc) and by introducing compensation payments that increases with the length of the outage. In Sweden the construction of the regulation were accentuated after the severe storm Gudrun that struck the southern part of Sweden 8-9 January 2005 and caused the interruption of supply for approximately 450 000 customers [2]. For this reason the regulation policy, handling unplanned interruptions of supply lasting longer than 12 hours, were referred to as the *Gudrun law* (GL). If a DSO does not restore an interruption of supply within the specified time, it must compensate the affected customer with a predefined payment that depends on the customer's energy consumption and the length of the interruption [2]. The UK regulation model for restoration of supply, specified in the *Guaranteed Standards* (GS) *of performance* [3][4], is in its construction similar to the GL regulation. GS states that an interruption of supply for a customer must be restored within a predefined time that depends on the weather condition classified in four groups in the standard. Given normal weather condition the DSO must restore the interruption within 18 hours to avoid a compensation payment to the affected customer.

This paper compares the Swedish and the UK regulation policies GL and GS for interruptions of supply with a case study for a real electrical distribution system named Flymen.

TWO REGULATION POLICIES FOR INTERRUPTION OF SUPPLY

The Regulation in Sweden, GL

The regulation of interruptions of supply in Sweden was introduced by changes in the Swedish law (1997:857) [5], applied since 1 January 2006 and in this paper referred to as the *Gudrun law* (GL) [2]. GL regulates unplanned customer outages longer than 12 hours and work parallel with the existing regulation of quality of supply, the Network Performance Assessment Model (NPAM) [6][7], which handle outages longer than 3 minutes. In this paper, the consequences of the NPAM are not taken into consideration in the study. This simplification is justified since the consequences of the two regulation models normally do not overlap for the DSOs.

Table 1 summarizes the compensation levels within the GL regulation. A customer suffering an interruption longer than 12 hours receives an individual payment from the DSO, depending on the customer's annual network tariff, α, and the length of the interruption [2]. A minimum value of the compensation is defined as a percentage of the Swedish base amount β, in 2007 set by the government to 41 100 SEK (€4567, €1 = 9 SEK) [5].

Table 1. Compensation levels to the customers defined by the Swedish Gudrun law (GL) [2].

Length of interruption, T	Compensation to customer	Minimum * compensation
12≤T<24 hours	12,5 % of tariff α	2 % of β
24≤T<48 hours	+ 25% of tariff α	4 % of β
48≤T<72 hours	+ 25% of tariff α	6 % of β
Following 24 hour periods	+ 25% of tariff α	+ 2% of β

α = { Individual customer's annual network tariff }
β = { Yearly set base amount } = €4567
* Is always set to even 100 SEK values, rounded up

According to Table 1 the lowest compensation for a 12 hour interruption is thereby 900 SEK (€100). The maximum value of the compensation is set to three times the annual network tariff α for the customer [2]. These limits are per interruption; multiple interruptions in a year may result in a total compensation above three times the tariff. The GL regulation has exceptions for compensation in case of extreme situation (act of God) such as war, sabotages, terror actions etc [2]. Weather disasters that are exceptional may be included in this category.

The regulation in UK, GS

In UK the DSOs is subject to *Guaranteed Standards* (GS) *of Performance* which contains a number of requirements that has to be met by the DSOs [4]. The GS regulation works in parallel with the existing program *Information and Incentives Project* (IIP) which handles interruptions longer than 3 minutes [8]. IIP includes an incentive scheme linking the DSOs rewards and penalties to annual quality of supply. This creates incentives for the DSOs to improve the annual number of interruptions and annual duration of interruptions for the system, but not the individual customer. The consequences of IIP have not been considered in this paper as the focus is on the GS regulation.

The GS regulation sets a number of requirements on the supply reliability that must be met by the DSO to avoid a compensation payment defined in [3]. Within the GS regulation there are four policies that regulate the restoration of supply; GS2, GS11A, GS11B and GS11C [4]. The applied policy depends on the weather condition that caused the interruption. GS2 handles normal weather conditions and GS11A-GS11C severe weather conditions categorized by its impact with category 1-3, where 3 is the most severe [3]. The present weather condition is determined by predefined multiples of the daily mean faults for the system and the number of interrupted customers in the system. The thresholds levels and intervals for the weather conditions are defined in [3] for each designated DSO and system in UK.

Table 2 summarizes the compensation levels to the customers for different length of interruption and for the present weather condition. The GS2 standard for normal weather conditions states that DSOs should restore unplanned interruptions of supply to its customers within 18 hours. Shortcoming to do so will result in a compensation payment for the DSOs of £50 (€75, 1£= €1.5) for each domestic customer and £100 (€150) for each non-domestic customer. Each following 12 hour periods will lead to an extra compensation of £25 (€37.5) for both customer types. For weather category 3 the intervals for compensation in GS11C starts after an interruption length that depends on the specific UK system and the number of interrupted customer [3]. For this reason GS11C only is applicable in UK and therefore not considered in this paper. The compensation level in GS11C is always lower than GS11B.

Table 2. Compensation levels to the customers defined by the UK Guaranteed Standard (GS) [3].

Weather condition	Length of interruption, T	Domestic costumer	Non-domestic
Normal (GS2)	18≤T<30 hours	€75.0	€150.0
	Following 12 hour periods	+ €37.5	+ €37.5
Category 1 (GS11A)	24≤T<36 hours	+ €37.5	+ €37.5
	Following 12 hour periods	+ €37.5 , max €300	+ €37.5 , max €300
Category 2 (GS11B)	48≤T<60 hours	€37.5	€37.5
	Following 12 hour periods	+ €37.5 , max €300	+ €37.5 , Max €300
Category 3 (GS11C)	Intervals for compensation are dependent on the number of customers interrupted and the specific system in UK.		

Comparison of the two regulation models

The Swedish GL regulation has chosen to compensate the customers independent of type and instead base the compensation on the customer's annual network tariff. The UK GS regulation for restoration of supply, on the other hand, separates the customers in domestic and non-domestic customers, but is independent of customer demand. The GS regulation also has different policies and compensation levels for different weather conditions, which the GL does not have. During normal weather conditions the GS regulation does not have a maximum level of compensation, which the GL has.

COMPARATIVE CASE STUDY

Approach in the comparative study

The comparative case study has been performed by comparing the resulting compensations of the two regulations in a real electrical distribution system named Flymen for two cases. The first case compares the compensation levels for eight typical customers of different size. A composition of these customers is then used to study the scenario of a 30 hour interruption in the entire system. The second case compares the regulations by the use of historical interruption data recorded during April 2004 to November 2006 for the same system.

Main characteristics of the studied system Flymen

The Flymen network is a 10 kV rural electrical distribution system located in Blekinge in southern Sweden. This system has been assessed in previous work involving the RCAM methodology [9][10][11]. The Flymen system includes just over 900 customers, fed radial from a main transformer, mainly by overhead lines. Approximately 99 % of the customers are of domestic type [9].

Flymen case study of a 30 hour interruption

The two regulating policies have been compared by the selection of eight typical customers with different size defined in Table 3. The selection and classifications is based on the median values of 2006 from the central government authority for official statistics in Sweden, SCB and the report in [12]. In the scenario these customers suffer a 30 hour interruption of supply during different weather conditions. Table 4 shows the compensation to each customer type from the two regulating policies. The result shows that the compensation is higher in each single case with the GL policy compared to GS. The difference increases with the size of the studied customer.

Compensation for a 30 hour interruption in Flymen

The proportion of the typical customers in Flymen has been estimated with the customer's energy consumption in reference [9]. This includes half of the system's customers. With this approximation there are 238 apartments, 664 residential (a), 28 residential (b) and 12 agriculture customers. The total compensation that the DSO for Flymen has to pay with the two regulations if all customers suffer a 30 hour interruption can be calculated with the assumed customer proportion and the result in Table 4. Table 5 presents the result of this calculation. The result from the studied scenario shows that the compensation in GL is higher than GS in all weather conditions. Given normal weather conditions GL compensate the customers 68% higher than GS in this scenario of Flymen.

Table 3. Eight selected typical customers in Sweden with different energy demand. Source: [12]

Customer type	Load level	Energy, MWh/yr	Network Tariff, €/yr
Apartment	16 A	2	105
Residential (a)	16 A	5	222
Residential (b)	20 A	20	501
Agriculture	35 A	30	796
Industry (a)	50 A	100	1877
Industry (b)	160 A	350	6 494
Industry (c)	1 MW	5 000	77 222
Industry (d)	20 MW	140 000	964 444

Table 4. Compensation to the eight typical customers, suffering a 30 hour interruption of supply.

Compensation for a 30 hour interruption:	GL, Sweden	GS, UK Weather condition:		
		Normal	Cat .1	Cat. 2
Apartment	€189	€112.5	€37.5	0
Resident. (a)	€189	€112.5	€37.5	0
Resident. (b)	€225	€112.5	€37.5	0
Agriculture	€299	€187.5	€37.5	0
Industry (a)	€703	€187.5	€37.5	0
Industry (b)	€2 435	€187.5	€37.5	0
Industry (c)	€21 458	€187.5	€37.5	0
Industry (d)	€361 667	€187.5	€37.5	0

Table 5. Compensations in the Swedish GL and UK GS regulation for a 30 hour interruption in Flymen.

Regulation	GL, Sweden	GS, UK Weather condition		
		Normal	Cat.1	Cat.2
Total compensation	€180 000	€107 000	€35 000	€0
Average comp./customer	€191	€113	€38	€0

Flymen case study with historical data

Analyzed interruption data

The studied data includes the date and duration of the interruption, the number of customers affected and an *energy not supplied* (ENS) [1] approximation (kWh/interruption). Figure 1 and Figure 2 presents the number of customer interruptions in the studied data for each compensation interval in the GL and GS2 regulation.

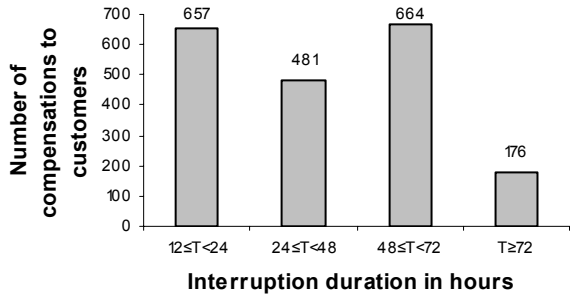

Figure 1. The number of customer compensations within the GL regulation intervals. (Each interruption is represented by its affected number of customers.)

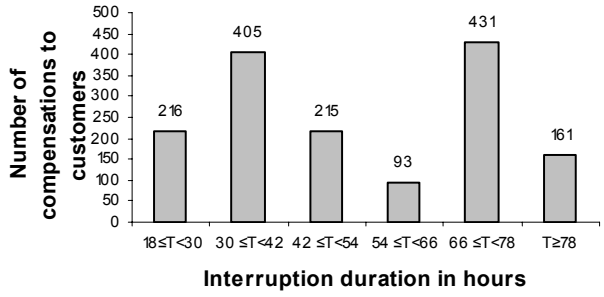

Figure 2. The number of customer compensations within the intervals of the GS2 regulation for normal weather conditions. (Each interruption is represented by its affected number of customers.)

The Flymen system is situated in a part of Sweden that was struck by Gudrun in 2005. Figure 3 shows the lengths of the interruptions during the studied period for Flymen and the peak of the duration for the interruptions during Gudrun can be seen clearly in the figure. Approximately 38 % of the interruptions and 93 % of the total outage duration during the overall studied period arise from this storm.

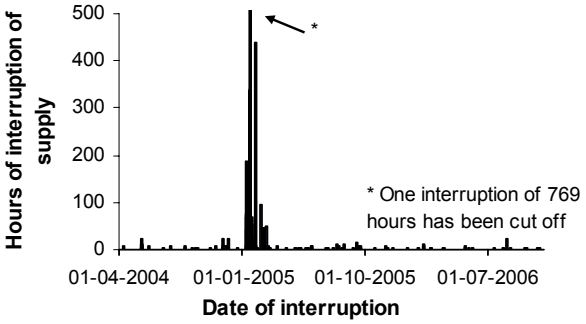

Figure 3. The interruptions and their length in hours during the studied period in Flymen.

Customer type and size in Flymen

The studied interruption data did not include the interrupted customer's yearly tariffs. As the GL regulation is highly dependent on the customer tariff, an approximate tariff has been estimated for each interruption and customer. This calculation has been performed by adding the fixed part of the tariff of a typical customer in the system to the part that depends on the yearly energy consumption, estimated from the ENS value and the duration of interruption. In the GS regulation it has been approximated that all customers are of domestic type. The weather conditions for the studied period's interruptions have not been determined. Instead all conditions are carried out separately for the period.

Compensation with the GL and GS regulations

Table 6 presents the result from the analysis of the historical data with GL and GS. The result shows that GL result in a 75% higher compensation than GS if the weather condition in the studied period is assumed to be normal. If the weather condition is assumed to be in category 1 or 2, the differences between the regulations become even larger as the Swedish regulation treats all weather condition the same. The true compensation for GS is probably somewhere between the result of the three weather conditions, as the actual weather during the period is a mixture of these. The average compensation per customer for the DSO is relatively high due to the reason that Flymen is a rural distribution system (not mixed with urban parts), and also is one of the systems where Gudrun had a severe impact.

Table 6. Compensation to the customers with the GL and GS regulations during the studied period. The period includes the severe storm Gudrun, which stands for the majority of the total compensation.

Regulation	GL, Sweden	GS, UK Weather condition		
		Normal	Cat.1	Cat.2
Compensation (Gudrun part of the comp. in %)	€477000 (99.3%)	€273000 (99.4%)	€172000 (100%)	€76000 (100%)
Comp./customer	€506	€290	€183	€81

CONCLUSIONS

This paper has presented a comparative study of two regulating regimes for interruption of supply in Sweden and UK, referred to as GL and GS respectively.

In the comparative case study of Flymen the Swedish model (GL) gives a 68% higher compensation to customers than the UK model (GS) for a 30 hours interruption of supply during normal weather conditions. Historical interruption data for the same system gives a 75% higher compensation with the Swedish model (GL) than the UK model (GS).

The main conclusion from the comparative study is that the Swedish GL model provides a higher compensation for interruptions of supply to customers than the UK GS model.

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