NTNU – Trondheim
Norwegian University of
Science and Technology

Flow Based Market Coupling

Birgit Jegleim

Master of Energy and Environmental Engineering
Submission date: June 2015
Supervisor: Gerard Doorman, ELKRAFT
Co-supervisor: Jan Hystad, Statnett

Norwegian University of Science and Technology
Department of Electric Power Engineering

NORGES TEKNISK-NATURVITENSKAPELIGE UNIVERSITET

Name of candidate: Birgit Jegleim

Program of study: Energi & Miljø

Norwegian title: **Flytbasert Markedskobling**

English title: **Flow Based Market Coupling**

Thesis description: Flow based market coupling gives a potential better utilization of the power grid because it to a greater extent accounts for the physical properties of the grid, which is in contrast to the current NTC method. There is also a great pressure from the regulatory authorities in EU (ACER) to use flow based market coupling, cf. the last draft of guidelines for Capacity Allocation and Congestion Management (CACM). Even though the flow based method in principle is well known, there are still many practical aspects of the method that needs to be studied before the method can be used actively. A central question is how the so-called Generation Shift Keys (GSK) should be determined, which are the coefficients that define how a change in an areas' net position influence the particular power plants. The goal of the thesis is to investigate the quality, or accuracy, of different strategies to calculate the GSKs.
The following sub-tasks are included:

- Describe the flow-based method and why it is preferred, and the status of the project in the Nordic region and in CWE.
- Perform a literature search of GSK and Flow Based in order to find relevant references.
- Describe the different GSK strategies that are considered to use in the Nordic flow-based project.
- Develop methods to compare the GSK strategies.
- Analyze the strategies. See if some strategies are generally better than others, if there are differences between high load and low load, type of production in the areas etc.
- Investigate if different GSK strategies should be used in different areas or for different network elements.

Executed at: Department of Electric Power Engineering

Submission: 10.06.2015

Supervisor: Gerard Doorman

Co-supervisor: Jan Hystad, Statnett

Preface

This master's thesis concludes my masters degree within Energy and Environment at NTNU in Trondheim. The thesis is written in co-operation with Statnett, as part of their current work regarding the introduction of flow-based market coupling in the Nordic power market. It is my hope that the work of this thesis will be a useful contribution.

Through the work of this thesis I have gained valuable knowledge about flow-based market coupling. It is with great gratitude that I would like to thank my supervisor Professor Gerard Doorman and co-supervisor Jan Hystad for the guidance throughout the work. They have been very helpful in answering my questions and sharing their knowledge.

Trondheim, June 2015

Birgit Jegleim

Summary

The current market coupling algorithm used in the Nordic power market is the Net Transfer Capacity (NTC) model. It maximizes social surplus according to the transfer capacities between bidding areas, which are provided by the TSOs. The model does not account for the actual physical power flow in the grid.

Flow based market coupling (FBMC) gives a potential better utilization of the power grid because it to a greater extent accounts for the physical properties of the grid. A simplified grid model is provided to the market. The grid model contains Power Transfer Distribution Factors (PTDFs), which describe how a power injection in a node influences the lines in the grid. Since the Nordic power market is divided into bidding areas, the PTDFs must be aggregated in order to reflect how an injection to an *area* influences the lines in the grid. A Generation Shift Key strategy is used for this aggregation. The GSK strategy defines how the node-to-line PTDFs should be weighted in order to obtain equivalent area-to-line PTDFs.

There is no straightforward, theoretical way of determining a GSK strategy. Consequently, several GSK strategies have been developed, giving rise to the question of how to find *good* GSK strategies. The task of this thesis is to develop a method that makes it possible to compare GSK strategies. Thereafter, the thesis seeks to investigate the different GSK strategies that are considered to use in the Nordic power market.

The method is based on the deviation that occurs between the predicted power flow and the actual power flow. The idea is to use data from the previous day to estimate the flow of the current day. The estimated flow is compared to the actual flow, resulting in a flow deviation. Small flow deviations indicate that the applied GSK strategy is good. For each GSK strategy, the flow deviation is calculated for each critical network element (CNE) in the Nordic grid.

The thesis also studies how detailed one should apply the GSK strategies. One can use one strategy for all CNEs in the Nordic power market, but one may also apply different GSK strategies in different areas or for different CNEs.

The results showed that applying the optimal strategy of each area lead to a decrease of the

global flow deviation. Similarly, using the optimal strategy for each CNE reduced the flow deviation of each area. Thus, using GSK strategies applicable for each area or CNE improves the results. Especially SE3 and SE4 experienced a large benefit using the optimal GSK strategy. Some GSK strategies were found to be generally better than others, where GSK 6 turned out as the best. GSK 7 and GSK 8 were not so good. NO1 and DK2 are examples of areas that are not sensitive to which strategy is applied. Some areas, like NO4 and NO5, experienced large flow deviations. This is due to certain CNEs where the flow is hard to predict.

The results of flow deviations were also divided into high load and low load. There were no major changes in the results compared to the results where all hours were included. The same strategies were best and worst. However, it was a trend that areas with large load were better predicted in high load hours.

Sammendrag

Dagens markedsalgoritme optimerer samfunnsøkonomisk overskudd basert på overføringskapasitetene mellom prisområdene i Norden, og kalles derfor Net Transfer Capacity (NTC). Modellen tar ikke hensyn til den faktiske kraftflyten i nettet.

Flytbasert markedskobling gir en potensielt bedre utnyttelse av kraftnettet fordi det i større grad tas hensyn til de fysiske parameterne i nettet. Markedsalgoritmen får tilgang til en forenklet nettmodell. Den inneholder parametere som beskriver hvordan en nettoinjeksjon i en node påvirker linjene i nettet. Disse parameterne kalles Power Transfer Distribution Factors (PTDFs). Siden det nordiske kraftmarkedet er delt inn i prisområder, må PTDFene aggregeres slik at de reflekterer hvordan en nettoinjeksjon i et *område* påvirker linjene i nettet. For å aggregere PTDFene brukes faktorer som beskriver hvordan en endring i områdeproduksjon fordeles over de enkelte enheter. Disse faktorene kalles Generation Shift Keys (GSK) og definerer hvordan node-PTDFene skal vektes for å oppnå en ekvivalent område-PTDF.

Det er ingen gitt metode for hvordan en GSK-strategi skal bestemmes. Derfor har det blitt utviklet flere forskjellige GSK-strategier, og spørsmålet om hvordan man finner *gode* GSK-strategier oppstår. Denne oppgaven skal utvikle en metode som gjør det mulig å sammenligne de ulike GSK-strategiene. Deretter kan man undersøke de ulike GSK-strategiene som vurderes i det nordiske flytbasert-prosjektet er, og finne ut hvor gode de er.

Metoden som er utviklet tar utgangspunkt i avviket som oppstår mellom den estimerte kraftflyten og den faktiske kraftflyten. Ideen er å estimere kraftflyten basert på tallmateriale fra dagen før. Den estimerte flyten blir sammenlignet med den faktiske flyten, og avviket mellom disse kan brukes til å se hvor gode GSK-strategiene er. Små flytavvik tilsier at GSK-strategien som er brukt er god. Flytavvikene er beregnet for alle kritiske nettelementer (Critical Network Elements (CNE)) i det nordiske kraftnettet for hver GSK-strategi. Oppgaven utforsker også hvor detaljert man bør bruke GSK-strategiene. Man kan bruke en strategi for hele Norden, men man kan også bruke ulike GSK-strategier i ulike prisområder eller for ulike nettelementer.

Resultatene viste at ved å bruke den optimale GSK-strategien i hvert område ble det totale flytavviket i Norden redusert. På samme måte ble flytavviket i Norden ytterligere redusert ved å

bruke den optimale GSK-strategien for hver CNE. Optimalisering av hver CNE reduserte også avviket i hvert prisområde. Særlig prisområdene SE3 og SE4 forbedret flytavvikene ved å bruke optimal GSK-strategi for hvert element. Noen GSK-strategier var generelt bedre enn andre. GSK 6 var den beste strategien, mens GSK 7 og GSK 8 var generelt dårlige. NO1 og DK2 er eksempler på robuste områder. De er ikke følsomme med tanke på hvilken strategi som ble brukt. Noen områder, som NO4 og NO5, hadde store flytavvik. Det er på grunn av enkelte linjer hvor det er vanskelig å estimere kraftflyten.

Flytavvikene ble også beregnet for høylasttimer og lavlasttimer. Det var ingen store endringer i resultatene sammenlignet med tidligere, og stort sett de samme strategiene ble best og verst for hvert område. Likevel var det en trend at områder med mye last ble bedre estimert i høylasttimene.

Contents

Abbreviations

CET – Central European Time

PX – Power Exchange

TSO – Transmission System Operator

ENTSO-E - European Network of Transmission System Operators for Electricity

NTC – Net Transfer Capacity

TTC - Total Transfer Capacity

TRM – Transmission Reliability Margin

ATC – Available Transfer Capacity

FBMC – Flow Based Market Coupling

NP - Net Position

CWE – Central Western Europe

PTDF – Power Transfer Distribution Factor

CNE - Critical Network Element

GSK - Generation Shift Key

RAM - Remaining Available Margin

FRM - Flow Reliability Margin

VBA - Visual Basic

Chapter 1

Introduction

1.1 Background

Statnett, in collaboration with the other Nordic transmission system operators, are currently investigating how to introduce flow-based market coupling in the Nordic power market. Flow-based market coupling provides a better solution than the current Net Transfer Capacity method, by including a simplified grid model to the market optimization problem. On May 20th 2015, five countries in Central Western Europe successfully launched flow-based market coupling in their power market, becoming the first power market to use this method.

1.2 Scope

There are several factors the Nordic flow-based project needs to investigate before introducing flow-based market coupling to the Nordic power market. One of them is the Generation Shift Keys (GSKs). Prior to the market clearing one doesn't know how a change in a bidding areas' net position will influence the different nodes within the particular area. A GSK is used as an estimation of how a change in an areas' net position will divide on the nodes within that area. Since there is no theoretical way of establishing a GSK strategy, several different GSK strategies have been developed.

The scope of this thesis is to develop a method that enables a comparison of the different GSK strategies. Thereafter, the thesis investigates how good the GSK strategies are. Different GSK strategies may be more suitable in some areas than in others, which makes it interesting to find strategies applicable for the different bidding areas in the Nordic region. It is also possible to use different GSK strategies on different power lines, or for different time stamps. The potential of applying GSK strategies at different levels of detail will be examined in this work.

1.3 Report structure

Chapter 2: Background gives an introduction to the Nordic power market, including, among other topics, the day-ahead market, the intraday market and congestion management. It also explains the current market clearing method.

Chapter 3: Flow based market coupling explains why this is the preferred market coupling method, before providing the theoretical foundation of the concept. Different flow-based parameters are elaborated, such as Power Transfer Distribution Factors, Generation Shift Keys and Flow Reliability Margins.

The Generation Shift Key (GSK) strategies are further explained in **Chapter 4: Generation Shift Key strategies**. The GSK strategies that are considered to use in the Nordic area are presented, before discussing the challenges of finding good GSK strategies.

The methodology developed in this thesis is presented in **Chapter 5: Method**. First, a general description of the data in the operational files is provided, followed by a stepwise explanation of how the flow deviation is calculated. Two different methods regarding how to aggregate the flow deviations are presented.

Chapter 6: Results and discussion presents and discusses the results of the flow calculations. The results are evaluated in order to see how good the different GSK strategies are. The results are provided for several levels of detail. At the end, simplifications and limitations are discussed.

In **Chapter 7: Conclusion** the results are summarized and conclusions are drawn, in addition to suggestions regarding future work.

Chapter 2

Background

2.1 History

Since the middle of the 1990s the electricity markets in the Nordic countries have undergone major changes. All countries have liberalized their electricity markets, introducing competition to both electricity trading and electricity production [1].

Before, electric entities were vertically integrated, meaning that generation, transmission and distribution of electricity were managed by one utility. This implied that the power market often was run by the state. Areas were self-supplied with power, which often led to over-production of power and inefficient utilization of electricity resources.

The 1990 Energy Act stated that electricity should be traded in a common market place, and that power producers were not allowed to own the transmission grid. Following the approval of the Energy Act, Norway was the first Nordic country to launch the liberalization process of its electricity market in 1991 [2]. The liberalization process is also referred to as deregulation; meaning that the state no longer runs the power market [3]. Electric entities with both grid and production were separated, which, among others, caused the splitting of "Statkraftverkene" into Statkraft and Statnett. Electricity resources, which had been directed towards local or national consumption, were now pooled together [4]. The intention of the liberalization was to improve conditions for competition, leading to better utilization of the production resources. Allowing free trade, the price would be determined by supply and demand, ensuring the utilization of the cheapest production unit regardless of where it was produced. This lowers the consumer costs, makes companies more effective, and results in a higher socio-economic surplus.

In 1996, after the Swedish market had opened up in 1995, Norway and Sweden established a common power market called Nord Pool ASA [2]. This was the first multinational exchange for electricity [5]. The Nordic electricity markets became fully integrated as Finland and Denmark joined in 1998 and 2000, respectively. The integration of the national electricity markets opened up for competition, and in addition border tariffs between the countries were abolished [6].

In 2002 Nord Pool organized their spot market activities in a separate company, and thus emerged Nord Pool Spot AS. In 2010 Nord Pool Spot opened a bidding area in Estonia, closely followed by bidding areas in Lithuania (2012) and Latvia (2014). With the inclusion of the Baltic power market, Nord Pool Spot is now the largest market place for trading power in Europe [7].

2.2 The Nordic power market

Supply and demand determines the power price, and must always be in balance. Before the deregulation, the local entities were responsible for keeping the production in balance with the consumption in its area. Today, the power exchange in the Baltic and Nordic markets, Nord Pool Spot, ensures that power production meet the demand for power. Power is traded on a daily basis, up to one hour before delivery hour. Nord Pool Spot is divided into two separate markets for power trade: Elspot and Elbas.

2.2.1 The day-ahead market and the intraday market

Elspot is the main arena for trading power in the Nordic and Baltic area, called the day-ahead market. Currently there are around 360 market members on Elspot [3]. These members are sellers and buyers, who each day submit bids (with specified price and volume) on production or consumption for every hour in the next day by 12.00 CET. Before placing the bids, the members need to plan what their production or consumption will be each hour of the following day. A seller must decide how much he can deliver and at what price, while a buyer needs to figure out the demand of the next day, and how much he is willing to pay for it. For each of the 24 hours the following day, advanced algorithms aggregate the bids into an equivalent demand and supply curve. The intersection of these curves determines the hourly system price. This is depicted in Figure 2.1.

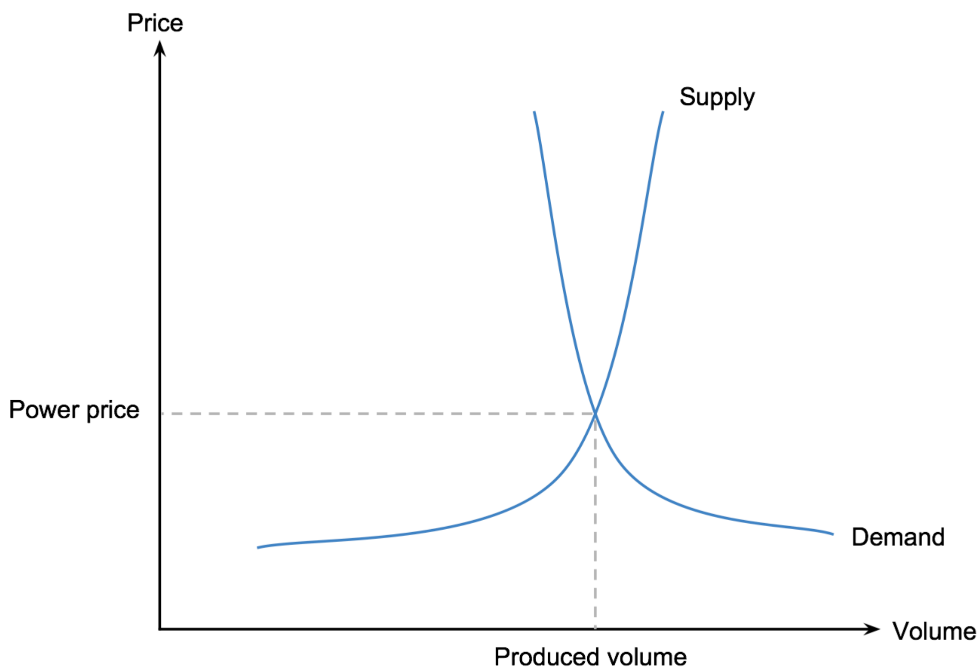

Figure 2.1: The system price is found at the intersection between the supply and demand curve.

The system price denotes the price without accounting for grid constraints, and would be the price the producers receive per unit generated power, and, correspondingly, the price the consumers have to pay for every unit of consumed power. The hourly prices for the next day are typically published by Nord Pool Spot between 12.30 and 13.00 CET [7], after which the trades are settled.

The transmission capacity on the interconnectors in the Nordic power grid is made available to the algorithm in addition to the bids from the market participants. There is no need for the participants to make separate (explicit) reservations of transmission capacity. The transmission capacity will be allocated to the producers and consumers according to the bids. In other words, the transmission capacity is implicitly reserved when trading. Therefore, this method is called implicit capacity auctioning [8].

The majority of power trade handled by Nord Pool Spot is done at the Elspot market. However, incidents may occur between the closing of Elspot at 12.00 CET and delivery the next day, which can change the planned production or consumption. A power plant might stop operating or strong winds may cause higher power production than anticipated. The intraday market, Elbas, enables buyers and sellers to trade power closer to real time. Thus, they can adjust the deviations between forecasted and actual supply and demand in order to bring the market back in balance. The available volumes at Elbas are published at 14.00 CET. Elbas is a continuous market, where trading can be done every day and every hour until one hour before delivery time. Currently, the share of wind power production in the Nordic power market is increasing. Future prospects also indicate that installed wind capacity will continue to grow. As more unpredictable power enters the grid, it will cause more imbalances between the produced power and the Elspot contracts. Thus, the intraday market will be increasingly important in the time to come. Additionally, having a market that is able to handle such imbalances, can be a key to increase the share of renewable energy [3].

2.2.2 Congestion handling

The system price is calculated for the whole Nordic market and assumes unlimited transfer capacity and no losses in the power system. In reality, however, there are several critical lines in the Nordic system which limits the total transferrable amount of power between regions. The available transmission capacity between Elspot areas may vary, and can therefore congest the power flow between areas. So-called bottlenecks occur when the market requests more capacity than is available. The transmission will in such cases be overloaded and leads to outages [9].

To relieve the congestion, the Nordic area is divided into different price areas [10], as seen in Figure 2.2. Norway consists of five price areas, Sweden of four, Denmark of two, while Finland, Lithuania, Latvia and Estonia constitute one price area each. In this thesis, the price areas will also be referred to as Elspot areas or bidding areas.

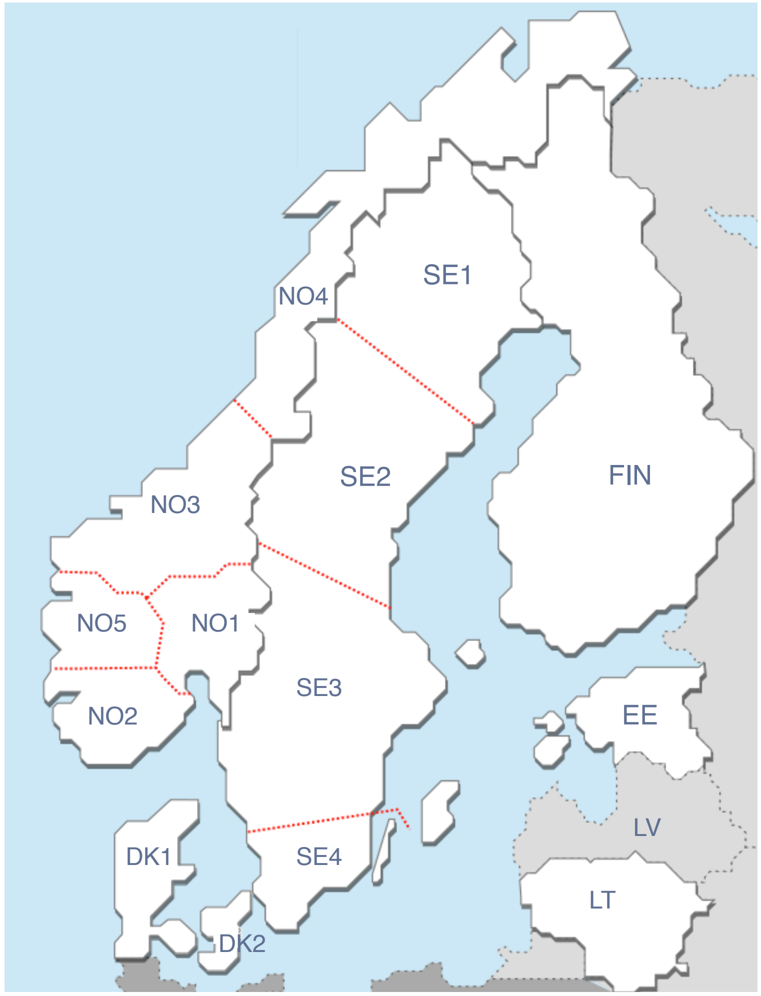

Figure 2.2: Price areas in the Nordic and Baltic power system. Note that the inclusion of Latvia in 2014 is not illustrated in this map. Source: Statnett SF.

Whenever there are grid congestions, the bids are aggregated within each area into individual supply and demand curves. A volume corresponding to the limiting lines' capacity is added as a price independent purchase in the surplus area and a price independent sale in the deficit area. This is done to ensure that the transfer capacity between areas is utilized to its maximum [10]. This leads to a parallel shift of the supply curve in the deficit area and parallel shift of the demand curve in the surplus area. Figure 2.3 shows the parallel shift of the curves.

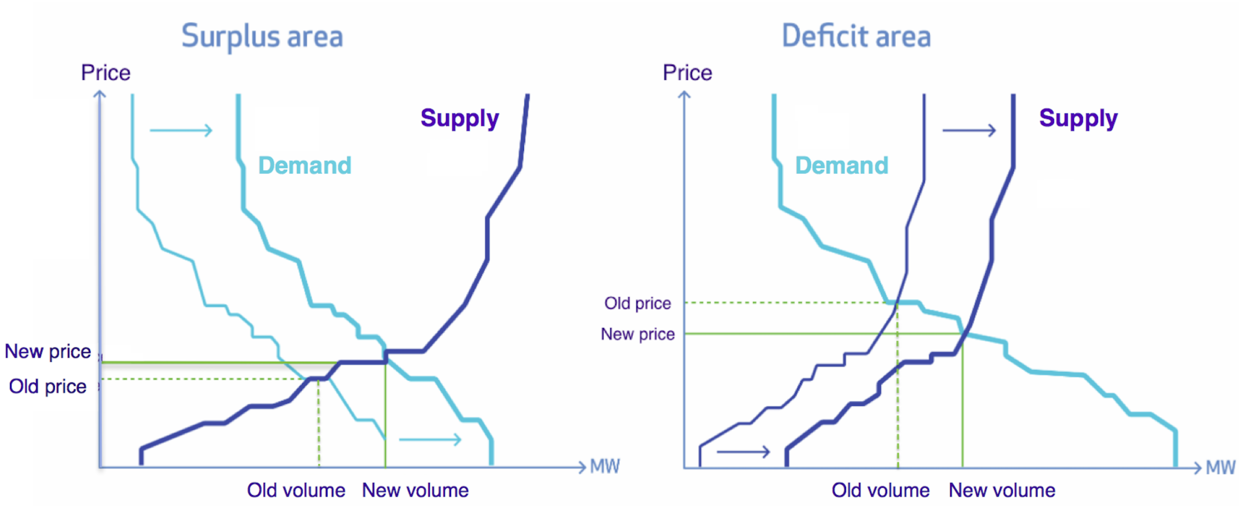

Figure 2.3: Shift of demand curve in surplus area and shift of supply curve in deficit area [10]

The area price in the surplus area and the deficit area is now found at the new intersections. As one can see in Figure 2.3, the area with a deficit of power will get a lower price than before. When the demand decreases, less power needs to be transported on the power connections, which helps to reduce the congestion. The surplus area will now experience a higher price than before.

When power is transferred from a low price area to a high price area, a trading surplus arises. This is called congestion rent and arises when the importing area pays more than the marginal cost of producing power in the exporting area [11]. The congestion rent equals the transfer capacity multiplied by the price difference between the two areas. The congestion rent (CR) is calculated as in Equation 2.1.

$$CR = F_{max} * (P_d - P_s) \tag{2.1}$$

P_s = price in surplus area

P_d = price in deficit area

F_{max} = power transmitted between surplus and deficit area

2.2.3 Transmission System Operators

The congestion rent usually goes to the system operator (SO), the Power Exchange (PX) or the grid owner. In the Nordic system it goes to the Nordic Transmission System Operators (TSO) as owners of the transmission grid [11]. Depending on the economic regulation in the country, there are different practices regarding the TSOs keeping the congestion rent or not. The revenue regulation in Norway ensures Statnett not to benefit from the congestion rent [5]. In the situation of congestion rents on power lines or interconnectors between countries, the involved TSOs share the income.

A system operator (SO) has to ensure power balance and sufficient capacity in the grid at all times, as well as keeping the frequency within acceptable limits (50 Hz). A transmission system operator (TSO), however, is a company that owns and maintains the transmission grid in a region, in addition to being a system operator. Therefore, the TSOs are responsible for both the high-voltage grid and the security of supply. Considering their market power, a TSO must be a neutral and non-commercial organization [12]. A TSO is not allowed to trade power in a commercial power exchange, in order to ensure equal terms for all market members. There are four national TSOs in the Nordic area, each responsible for the power systems of their country: Statnett in Norway, Svenska Kraftnät in Sweden, Fingrid in Finland and Energinet.dk in Denmark.

Nord Pool Spot is owned by the Nordic and Baltic TSOs. Nord Pool Spot, being a Norwegian registered company, has to operate according to Norwegian laws and regulations. The Norwegian Water Resources and Energy Directorate (NVE) ensures that these are followed [2]. In order to keep prices stable and at reasonable levels, NVE has imposed regulations that define levels of maximum profit. This is important, considering the TSOs being monopolists in certain geographical areas. The authorities also regulate Nord Pool Spot's income.

2.3 The current market model

The market model currently in use in the Nordic and Baltic region is the Net Transfer Capacity (NTC) model. The NTC values are transfer capacities between different Elspot areas determined by the TSOs. That is, the NTC values represent the maximum exchange of power between two areas taking into account uncertainties that may occur in the system as well as being compatible with security standards in the two areas [13]. The TSO calculates transfer capacities both within its own power system and for exchanges between countries. The transfer capacities are set for each hour the following day, and are provided to Nord Pool Spot ahead of the market clearing. The transfer capacities are thus acting as constraints in the market-clearing algorithm, which may cause price differences between areas as mentioned in the previous section.

The Nordic TSOs have agreed upon principles for determining the transfer capacities and margins through the System Operation Agreement [13]. The definitions of this agreement are in line with the definitions used in the European Network of Transmission System Operators for Electricity, ENTSO-E, which is an organization for system operators in Europe. The System Operation Agreement includes operational security standards, which are to be followed in order to ensure reliable operation of the power system [14].

The criteria for system security are based on the N-1 criterion. N-1 refers to a level of system security where the power system can handle the outage of any individual component, e.g. a transformer, a line or a production unit [13]. Loss of components that leads to the greatest impact of all fault events are called dimensioning faults. A dimensioning fault is often equal to the largest production unit in the system. When calculating the transfer capacities with respect to the N-1 criterion one must consider the following limiting factors: Thermal limitations, voltage limitations and rotor angle stability limitations. Through static and dynamic simulations performed on predefined transmission corridors, one can determine how much power can be transferred in any direction through the corridor before these limitations are reached due to a dimensioning fault. Breaking the limitations leads to thermal overloads, voltage collapse and/or instability. An arbitrary number of lines in different voltage levels can be included in the corridor (snitt in Norwegian) [13]. This capacity, which is found in accordance with the system security criteria, is called total transfer capacity (TTC). It is the maximum exchange of power between two areas within security limits (incorporated the N-1 criteria).

The TSOs calculate the transfer capacities in a three-step process. The NTC given to Nord Pool Spot is the total transfer capacity minus a transmission reliability margin (TRM), as depicted in

Equation 2.2.

$$NTC = TTC - FRM \tag{2.2}$$

The TRM is a security margin reflecting uncertainties in the predicted power flow, which may be due to changes in production and/or consumption in the two areas as well as inaccuracies caused by transit flows. The TRMs for each connection are agreed upon in the System Operation Agreement [13]. Thus, the NTC "is the maximum exchange program between two areas compatible with security standards applicable in both areas (N-1 criteria) and taking into account the technical uncertainties on future network conditions" [13].

One might wonder how to determine the initial transfer capacities. According to Goldstein [15], Statnett uses transfer capacities calculated up to one year in advance as a starting point when setting the capacities for the following day. "After the market clearing one can evaluate whether the capacities were set to a "correct level", considering the amount of special regulation. The trading capacities for the following 24 hours can then be adjusted accordingly." (Goldstein). The NTC values are a result of extensive load flow studies performed by the TSOs. According to Statnett, they run weekly power flow simulations in order to investigate the consequences of planned revisions or outages in the grid. When determining the NTC on an interconnection between two countries, the TSOs on each side calculates the capacity, using the lowest value of the two. Doing the NTC calculations, not only the constraints on connections between areas must be taken into account, but also the transmission constraints inside an area.

The term Available Transfer Capacity (ATC) is used in the continental Europe. This is the calculated NTC minus long-term nominations between countries. Long-term nominations are reservation of physical transfer capacity. In the Nordic power market, the total capacity between price areas is reserved for spot transfer, such that these long-term nominations are not allowed. Therefore, the transfer capacities given to the market are NTC [16].

Nord Pool Spot's market clearing algorithm finds the optimal solution for power exchange based on the given capacities and bids from market participants. The algorithm is a linear constrained optimization algorithm, with an objective function of maximizing the socio-economic surplus.

The constraints are the NTCs between the bidding areas supplied by the TSOs.

However, only the commercial exchanges between bidding areas are considered in the market-clearing algorithm, and it is assumed that the power will take the shortest path from production to consumption. In reality, the power distributes itself through the whole grid according to physical laws applied to the characteristics of the grid and the situation in the entire power system at any time [15] [17]. When transferring power between two nodes, flows occur on parallel paths also connecting the two nodes. The flows induced on the parallel paths are called loop flows. Figure 2.4 illustrates how a power transfer between northern Sweden and southern Norway not necessarily follows the shortest path. The loop flows, in addition to losses in the lines, are not accounted for by the market algorithm, and are therefore left to the TSOs to manage.

Figure 2.4: Illustration of how the power may flow from SE1 to NO2. [17]

Optimizing the socio-economic surplus without considering the actual power flow in the grid often creates deviations between real physical flows and market flows. The deviations create challenges to the TSOs, which are in charge of security of supply, and also are to provide the market with as much transfer capacity as possible. The deviation also creates disadvantages to the market players, because the congestions are not taken care of in an optimal way. The challenges related to the deviations between market flows and physical flows arise when there is uncertainty regarding how power will be distributed. Thus, expansion of the power grid will increase the challenges, due to more connections between areas. Additionally, increased transfer capacity on the connections to Europe and increased share of unregulated power in the system, makes it more challenging to predict the power flow of tomorrow [18].

The market optimization problem of both the NTC and the flow-based method can be formulated as follows, based on [19].

NTC formulation

Objective function:	Maximize socio-economic surplus
Subject to	$\sum$ NP = 0 NTC constraints

FB formulation

Objective function:	Maximize socio-economic surplus
Subject to	$\sum$ NP = 0 FB constraints

The net position (NP) is calculated by supply - demand. Both methods have the same objective function of maximizing the socio-economic surplus, but the constraints are different. Since the constraints are the only difference between the two methods, they are the key to understand why flow-based may provide a better solution than NTC. This will be further elaborated in the next chapter.

Chapter 3

Flow based market coupling

This chapter explains what flow based market coupling is. As an introduction, one explains why there is a need for a method like flow based market coupling, and the status of the method in the Nordic power market and in CWE. Section 3.2 describes how the flow-based method will provide a better solution to the market optimization problem. Section 3.3 introduce the flow-based parameter Power Transfer Distribution Factor, while section 3.4 regards aggregation of PTDFs using Generation Shift Keys (GSK). Section 3.5 and 3.6 is about Remaning Available Margins and Flow Reliability Margins, respectively. A short introduction to the steps performed in the market coupling process is provided in Section 3.7.

3.1 Introduction

The previous chapter described how the NTC method currently in use optimizes the power trade without accounting for the physical properties of the power grid. Consequently, it is desirable to include information about power flow in the market-clearing algorithm. This can be achieved by introducing a simplified grid model to the power market, which provides information about the physical properties of the grid. The introduction of the grid model is the basic idea behind flow-based market coupling (FBMC), separating it from the NTC method [19].

In order to find the optimal solution in terms of socio-economic surplus, a constrained optimization algorithm should be used. Through the grid model the physical properties can be incorporated into constraints. With the objective of maximizing the socio-economic surplus the optimal solution will then be found while still respecting the flow-limitations on the constraining lines or intersections of the power grid [15].

Thus, the market can manage congestions by prioritizing power flows that are most economically efficient, leading to a better utilization of the grid. This method is in contrast to the current NTC method where decisions regarding capacity allocations are made in advance of the market clearing [19].

The transition from NTC to flow-based (FB) does not involve great changes to the market participants. The price areas can remain the same, the bids can be delivered to Nord Pool Spot as before, and the market result will be published as before. The difference is that the participants will receive new information about the capacity in the power grid, including a simplified grid model [18].

In 2013 Sintef Energi in Trondheim performed simulations, using a flow-based model called Samnett, to investigate the possible advantages of this method compared to NTC. The results showed that Samnett had better utilization of the grid and lower price differences. Even though this was a simplified model, the results can be trusted. The conclusions were that Samnett provided a higher socio-economic surplus than the Samlast (NTC) model, facilitating a more efficient use of the transmission grid [20].

However, flow-based performs best in meshed grids and in congested systems. In radial grid systems, or in cases of no initial congestions, FB doesn't deviate much from the NTC method. With that said, FB is a better congestion management method than NTC, since it has no evident disadvantages and provides increased social welfare.

On May 20th 2015, the project partners of the Flow Based Market Coupling in Central Western Europe (CWE) successfully launched the flow-based methodology. They are the first to use the flow-based methodology in their power market. The project is a collaboration between the TSOs and the PXs in CWE, which have been working on this project since 2007 [21]. In their press release, they emphasize the importance of the flow-based method regarding the way towards the completion of the European Internal Energy Market. In addition, "the step to Flow Based Market Coupling is essential in order to be prepared for accurate and secure capacity calculation in a European energy sector where further growth in renewables is to be expected" [21]. Following the successful launch of FBMC in CWE, it is expected that the method will be used at a larger European scale in the future.

In the Nordic area, Statnett, in co-operation with the other Nordic TSOs, are in the phase of analyzing the effects of flow-based market coupling. Since they have a common power grid, it is natural to consider a common implementation of FBMC. The implementation is expected to take nearly 2 years, followed by a test period. This makes mid 2018 a realistic goal regarding operation of the flow-based method.

3.2 Solution domain

The solution domain of the market clearing is limited by the constraints in the optimization problem. The solution domain is often referred to as the security of supply domain, since the domain constitutes all the feasible solutions, withholding the transfer of capacities between bidding areas, as well as maintaining safe grid operation. The solution domain is a good way of illustrating why the flow-based method may provide a better solution than the NTC method. The following example, based on [19] and [22], is meant to illustrate some of the differences between the methods.

Figure 3.1 illustrates a simple three-node grid. Node C is a consumption node, while node A and B are generation nodes. The transfer capacity of each line is set to 1000 MW, and the lines' resistance are equal and set to 1 Ω for simplicity. This is what the TSOs face when determining how much capacity can be transferred. The task at hand is to determine how much power can be transferred to node C without violating the 1000 MW limit on any of the three lines.

Before the market clearing, one only knows that the node with the lowest production cost will produce. The TSO doesn't know which of A and B that will produce or how much each of them will produce. However, the physical characteristics of the grid are known. A 1 MW production

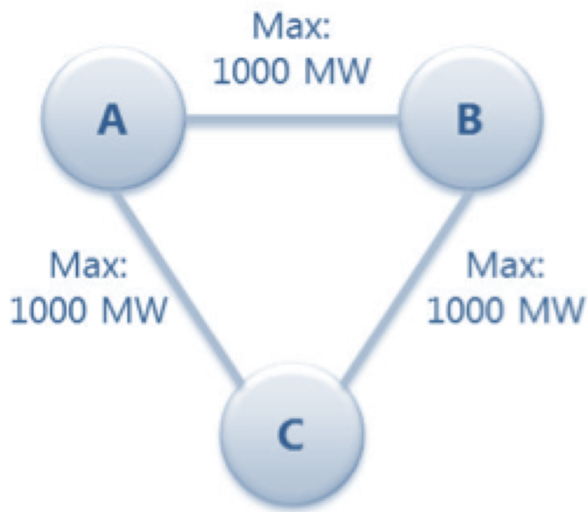

Figure 3.1: Three-node grid [19]

in node A will result in a $\frac{2}{3}$ MW flow on line A-C, while the flow on line A-B and B-C will be $\frac{1}{3}$ of the production. The same applies for a production in node B; loading line B-C by $\frac{2}{3}$, and A-B and A-C by -$\frac{1}{3}$ and $\frac{1}{3}$, respectively. Node C is the slack node (hub) of this system, absorbing the power injected to the grid. Injections in node C are also consumed by node C. Thus, node C has no influence on the power flows in the grid.

Consider a situation where the generation is 2000 MW in node A. This will result in a flow of 1333 MW on line A-C, which is 33 percent above the lines' capacity limit. To avoid such situations, the TSOs need to reduce the maximum transfer capacity. In this example, this means reducing the capacity of the lines to 1500 MW. Thus, even if all production is located at one node, the lines will not exceed their capacities ($\frac{2}{3}$*1500 = 1000 MW). The solution domain in Figure 3.2, which indicates the secure net positions of the three-node grid, illustrates this. If either A or B produce 1500 MW, the other cannot produce in order to stay within the solution domain. Another possible solution is that each node produces 750 MW.

Providing flow-based constraints to the market, the solution domain will change. The grey lines in Figure 3.2 represents the boundaries of the FB solution domain. Given the same level of operational security, the FB solution domain is always as large or larger than the NTC solution domain, meaning that the FB boundaries are located on or outside the boundaries of the NTC domain. Thus, if an optimal market solution is found within the NTC domain, both methods will

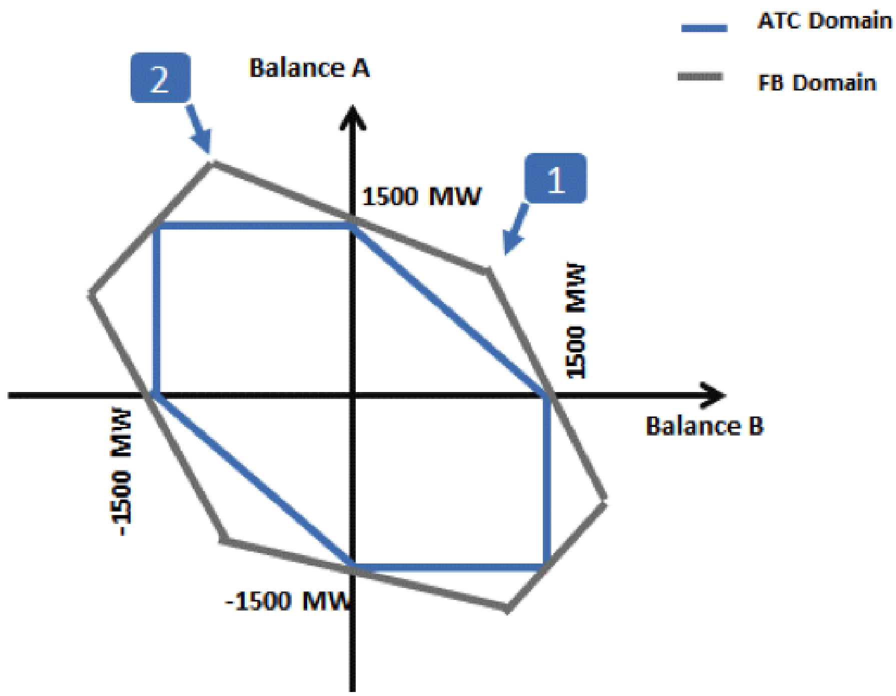

Figure 3.2: Solution domain of the three-node grid [19]

find this solution. However, not the other way around. The FB method might find an optimal solution outside the NTC domain [19].

By using the flow-based method on the three-node example grid, both node A and B can generate 1000 MW without violating the capacity limits of the lines. For example, the flow induced on line A-C is $1000 * \frac{2}{3} + 1000 * \frac{1}{3} = 1000$ MW. This solution, indicated by point 1 in Figure 3.2, is an example of a situation where the FB solution is better than the NTC solution. This solution is not possible with NTC due to the fact that the NTC method doesn't know the real physical flows between nodes or areas.

Even though all constraints provide information about the situation in the power system, not all are important to the market-clearing algorithm. Only the most limiting constraints must be respected. These are called non-redundant constraints [23]. The redundant constraints can be removed.

The reason why the FB solution domain is larger is because one can estimate the influence in the grid as the production dispatch changes during the market clearing. The calculated FB parameters indicate which net positions that can be facilitated during market clearing without risking grid security. Thus, the net positions are optimized through the market clearing "ensuring day-ahead market welfare is maximized while respecting the constraints provided by the TSOs" [23].

In other words, the flow-based method provides more trading opportunities with the same level of security of supply. Reports from simulations of the FB method in the CWE region confirmed this. According to [9], "FBMC results in higher welfare and better price convergence compared to the current ATC ones".

3.3 Power Transfer Distribution Factors

Power transfer distribution factors (PTDFs) are important parameters in the flow-based method. As mentioned before, the flow-based method accounts for the real physical flows in the power system by providing a grid model to the market. When a DC power flow model is used, there is a linear relationship between the total transferred quantity and the flow on a particular line. Thus, the grid model consists of linearized approximations of the induced flows in the power system. This linear relationship is the PTDF. The PTDFs are often also called sensitivities, describing how the flow on a transmission line change in response to a power exchange between two nodes in the system [24].

Consider again the three-node grid in the previous section. If node A increased its generation by 1 MW, we saw how $\frac{2}{3}$ of the generation (0,67 MW) would flow on line A-C. Thus, 0,67 is the PTDF between line A-C and node A. It reflects how the line is influenced by an increase in production in node A. Similarly the line will also be influenced by an increase in production in node B. The PTDF between line A-C and node B is 0,33 MW. Every node in the system has an individual influence on the lines. It is possible to calculate how a power injection in each node in the system affects all lines in the system, creating a PTDF matrix. This is shown in Table 3.1 below.

The left column contains the lines in the grid, while the other columns show the nodes with power injection. The numbers that constitutes the matrix are the PTDFs. For instance, the reader might recognize the PTDF of 0,67 between line A-C and node A, as mentioned before.

Table 3.1: PTDF matrix of the three-node grid in Figure 3.1

Line	*Inj. node A*	*Inj. node B*	*Inj. node C*
A to B	0.33	-0.33	0
A to C	0.67	0.33	0
B to C	0.33	0.67	0

67 percent of the power injection in node A flows on line A-C. Also note the PTDFs of node C, which are zero because of its' role as a slack node.

The PTDFs are calculated based on the physical characteristics of the lines in the power grid. This information is known to the TSOs, such that the PTDFs can be calculated ahead of the load flow analysis. As long as the line impedances and the grid topology remain unchanged, the PTDFs are constant. In order to solve the load flow equations one node must be defined as a slack node. In our three-node example, node C acted as a slack node. The choice of slack node is insignificant to the result, due to the fact that the pre-calculated PTDFs will give the correct loading on each single line in the grid [15].

The PTDFs are a useful tool considering how they can be used to establish a full description of the power flow in the whole grid. Equation 3.1 express the power flow on a line by the use of a PTDF [25].

$$P_{ij} = PTDF_{ij,mn} * P_{mn} \tag{3.1}$$

Here, PTDF$_{ij,mn}$ is the fraction of a transaction from node m to n that flows on the line connecting i and j. Whenever there is a new transaction in the grid, P$_{mn}$, the line flow, P$_{ij}$, will change accordingly.

3.4 Aggregating PTDFs

In the simplified three-node grid in the previous section, PTDFs were calculated on a nodal level. This is also how the PTDFs are computed from the base case. Using data from the previous day (D-2), an estimated base case can be created for the following day, D. The base case describes the expected grid topology, net positions, and power flows in each hour of operation on a nodal level for day D [19].

The nodal PTDFs describe how an injection in a specific node loads a specific line in the system. However, the flow-based method requires PTDFs describing the relationship between an *area* and a line, where the net positions of bidding areas give the flow on particular lines. This creates a need for aggregating the node-to-line PTDFs into equivalent area-to-line PTDFs. The resulting PTDF matrix will thus tell us how a power transaction from one area to another will influence the flow on the lines in the power system.

It is not interesting to consider all the lines in the system. The TSOs are required to monitor certain grid elements for potential overloads. These grid elements are called critical network elements (CNEs) [19] and can be a line, a transformer or a cross section of several lines (snitt in Norwegian). When calculating the area-to-line PTDFs, one only needs to know how a power transaction from one area to another influences the CNEs in the power system. Thus, the aggregated PTDFs come area-to-CNE PTDFs.

Figure 3.3 illustrates a power system with three bidding areas, A, B and C, each comprising five nodes. There are lines between the nodes within an area, as well as five CNEs connecting the areas. For example, if we want to investigate how a power injection in area A loads CNE 1, the five nodes in area A must be aggregated. However, each node within an area has an independent impact on each particular line or CNE in the system. In other words, the five nodes of area A have an individual impact on CNE 1. The question thus arises on how to weight each node in the aggregation. If one node gets too much or too little weight, the aggregated area-to-CNE PTDFs will be inaccurate. Thus, the PTDFs will be a poor estimation of the actual flows.

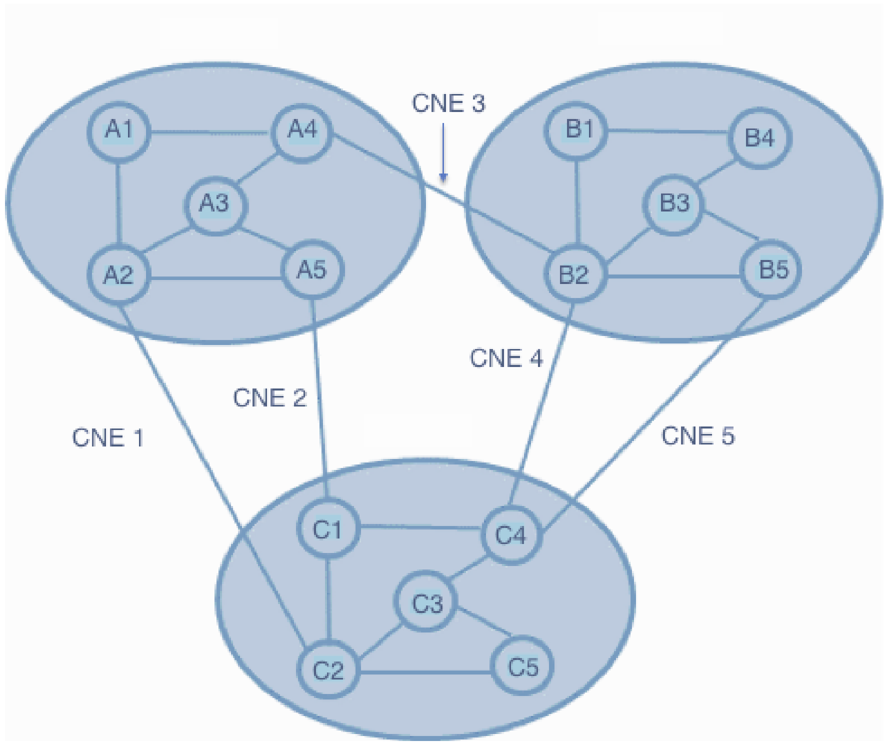

Figure 3.3: Example grid with three bidding areas.

A generation shift key (GSK) strategy is used to aggregate the node-to-line PTDFs into equivalent area-to-CNE PTDFs. A GSK defines how a change in an area's net position is divided on its nodes. In other words, it describes how a change in an area's net position will change the output from the generating and loading units inside the same area [26].

Equation 3.2 shows mathematically how the GSK is used in the aggregation from node-to-line PTDFs to area-to-CNE PTDFS.

$$PTDF_{ij}^{Area} = \sum_{\alpha} GSK^{\alpha} * PTDF_{ij}^{\alpha} \tag{3.2}$$

where

PTDF_{ij}^{Area} = Sensitivity of line ij to an injection in area *Area*

$\text{PTDF}_{ij}^{\alpha}$ = Sensitivity of line ij to an injection in node α

GSK^{α} = weight of node α

Again, considering the grid in Figure 3.3 and the problem aggregating the nodes in area A, a GSK can be applied to weight each of the five nodes. The GSK for an area has an important influence on the PTDF, as it translates the area-variation into an increase of generation in the specific nodes [26]. The simplest form of a GSK strategy is a flat strategy, where power production is divided equally on all nodes in an area. Applying a flat GSK strategy to area A, the aggregated areaA-to-CNE1 PTDF becomes

$$PTDF_{CNE1}^{AreaA} = \frac{1}{5} \times PTDF_{CNE1}^{A1} + \frac{1}{5} \times PTDF_{CNE1}^{A2} + \frac{1}{5} \times PTDF_{CNE1}^{A3} + \frac{1}{5} \times PTDF_{CNE1}^{A4} + \frac{1}{5} \times PTDF_{CNE1}^{A5} \tag{3.3}$$

Similarly, one can calculate the PTDF between area A and the other CNEs, and thereafter the same calculations for area B and C. This will result in a complete area-to-CNE PTDF matrix, which presents how a power injection in any area will load the lines of the grid when transferring power to the slack node. The aggregated PTDF matrix is shown in Equation 3.4, and is the matrix provided to the power market.

$$PTDF_{CNE}^{Area} = \begin{array}{cccc} & AreaA & AreaB & AreaC \\ CNE1 & PTDF_{CNE1}^{AreaA} & PTDF_{CNE1}^{AreaB} & PTDF_{CNE1}^{AreaC} \\ CNE2 & PTDF_{CNE2}^{AreaA} & PTDF_{CNE2}^{AreaB} & PTDF_{CNE2}^{AreaC} \\ CNE3 & PTDF_{CNE3}^{AreaA} & PTDF_{CNE3}^{AreaB} & PTDF_{CNE3}^{AreaC} \\ CNE4 & PTDF_{CNE4}^{AreaA} & PTDF_{CNE4}^{AreaB} & PTDF_{CNE4}^{AreaC} \\ CNE5 & PTDF_{CNE5}^{AreaA} & PTDF_{CNE5}^{AreaB} & PTDF_{CNE5}^{AreaC} \end{array} \tag{3.4}$$

However, it is not so interesting to see how a trade between a bidding area and the slack node impacts the lines in the system. The interesting part is to see how a power transaction between two areas influences the lines. This can be done by using a GSK strategy in both the exporting and importing area [22]. The GSK strategy of the two areas does not need to be the same. Equation 3.5 shows how the flow on a CNE is influenced by a power transfer between to bidding areas.

$$Flow_{CNE} = PTDF_{CNE}^{Exportarea} - PTDF_{CNE}^{Importarea} \tag{3.5}$$

In the previous section, it was said that as long as the line impedances and the grid topology remain unchanged, the PTDFs are constant. However, this only applies when considering node-to-line PTDFs. When the PTDFs are aggregated using a GSK strategy, the PTDFs will also depend on production and load in the system.

3.5 Remaining Available Margin

In flow-based market coupling there are two important parameters used when providing grid constraints to the market optimization at the PX. The first parameter is the PTDFs, which gives information about flows induced. The second parameter is the remaining available margin (RAM). The RAM is the free margin of every line, and reflects the capacity that can be used in the market clearing without endangering the grid security [26].

The definition of RAM is showed in Equation 3.6 [19].

$$RAM = F_{max} - FRM - FAV - Fref' \tag{3.6}$$

where

F$_{max}$ = Maximum allowable power flow on a CNE

FRM = Flow Reliability Margin

FAV = Final Adjustment Value

Fref' = Reference flow at zero net position when using the computed PTDFs

The reference flow is calculated as follows:

$$Fref' = Fref - PTDF * NP^{BC} \tag{3.7}$$

where

Fref = AC estimated loading of the CNEs in the base case given the net positions reflected in the base case

NP^{BC} = Net position of all bidding areas in the base case

The FRM is the margin that the TSOs must reserve in order to hedge against uncertainties. The next section explains the FRM more thoroughly. The final adjustment value accounts for remedial actions, operational skills and experience that cannot be introduced to the complex FB algorithm. Therefore, the final adjustment of the capacity is done manually by the TSOs [26]. Positive values of FAV reduce the available margin on a CNE. Due to system security reasons, the FAVs are often positive in order to reduce the risk of overloads [23].

The RAMs on the CNEs together with the PTDFs form the flow-based constraints used by the optimization algorithm at the power exchange:

$$PTDF * NP \leq RAM \tag{3.8}$$

Generally, the RAMs are positive, and the flows on the CNEs will be restricted by those values. However, the RAM can be negative if a CNE is congested before allocation. In such a situation, the reference flow, Fref', exceeds the other values on the right hand side of Equation 3.6, resulting in a negative RAM. Thus, Equation 3.8 becomes a constraint that enforces the flow on the particular CNE to be negative. The market-coupling algorithm will find the best way to relieve the congestion. It is also worth mentioning that the RAM of a CNE is only defined in one direction. If both directions are to be defined, there must be defined one CNE for each direction, resulting in two CNEs [19].

Figure 3.4 illustrates the relation between the net position, flow and RAM.

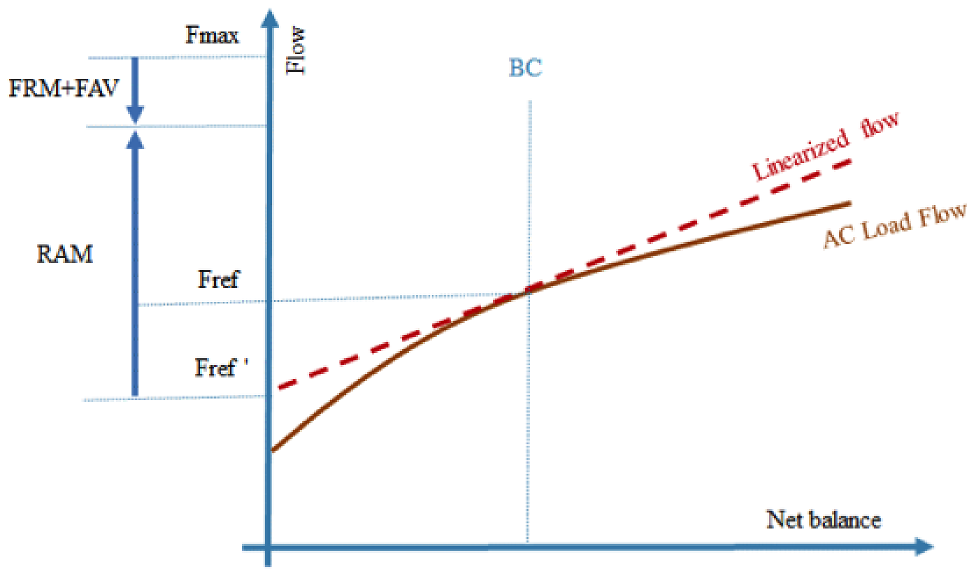

Figure 3.4: The relationship between RAM, net position and flow [19]

3.6 Flow Reliability Margin

The TSOs cannot know the exact power flow on the CNEs. The flow may be larger or smaller than anticipated, and larger flows may cause physical overloads on the CNEs. In order to manage uncertainty in the capacity calculations some of the capacity on each CNE will be retained from the market. This capacity is, in the flow-based method, called flow reliability margin (FRM). It is similar to the transmission reliability margin (TRM) of the NTC method.

The commission guideline on Capacity Allocation and Congestion Management (CACM) defines the flow reliability margin as follows: " 'Reliability margin' means the reduction of cross-zonal capacity to cover the uncertainties within capacity calculation" [27] (Definition per January 2015)

Each CNE has a unique FRM, expressed in MW, that reflects how the uncertainty affects the flow on that particular CNE. When using the flow-based procedure, the uncertainties due to transit flows are reduced, since the transit flows are calculated in the market clearing. However, there are other sources of uncertainty, in which two are specific to the flow-based procedure. These are the linearization of the grid model and the aggregation of PTDFs from node-to-line PTDFs to area-to-CNE PTDFs [19]. However, all uncertainties are reflected in the FRM. The FRM reduces the remaining available margin (RAM) because some of the physical capacity on the lines must be reserved to cope with these uncertainties [27]. The capacity provided to the market is thus the max capacity minus the FRM.

The size of the FRM is based on "statistical evaluation of the deviations between the flows estimated by the FB method and the actual flows observed" [19]. The CACM provides requirements regarding a methodology for determining the flow reliability margin. The Nordic FB project has interpreted the requirements from CACM in a proposed two step-process. The project is, however, in the middle of the process of designing FRMs. Thus, the following brief explanation of the determination of FRMs is based on [27], a preliminary draft regarding the design of FRMs.

The idea is to use historical snapshots of the grid to calculate the deviation between estimated power flow and actual power flow. The net position of an area is the basis for the estimated flow. Using a considerable amount of snapshots, one can create a probability distribution of the deviations for different hours. For each CNE and snapshot, this will be done both for an intact grid (N), as well as a N-1 situation, because the CNEs are monitored under both conditions. The FRM for a CNE will be derived from the probability distribution of the particular CNE, using a pre-defined percentile reflecting the risk level. After calculating the FRMs, the second step evaluates how the FRMs are influenced by the use of primary reserves. That is, if the FRMs can handle additional production in the system. Figure 3.5 illustrates the process of determining the FRM.

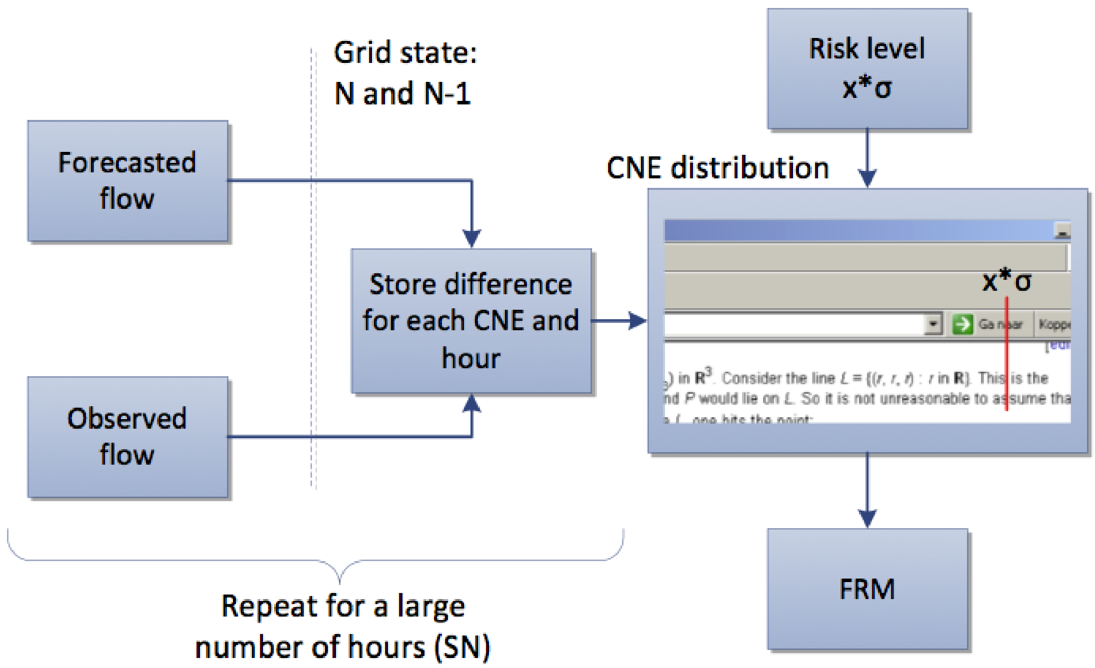

Figure 3.5: Simplified illustration of the FRM methodology [27]

The process is repeated regularly to keep the FRM updated as the system and market change. The very first FRMs must be based on simulations of snapshots, similar to the current NTC method. The calculation of the flow deviations will be further elaborated in Chapter 5.

3.7 The market coupling process

The market coupling process of the flow-based methodology can be divided into three phases: Pre-market coupling, market coupling and post-market coupling.

The pre-market coupling process is done by the TSOs, calculating capacities and the solution domain for the market. The first task at hand is to create the base case for each hour of operation. The base case describes the expected grid topology, net positions and the corresponding power flow in each hour of operation on a nodal level for day D. Following the base case, the TSO defines GSKs, CNEs and other parameters, in order to create PTDFs and capacities of the market. The parameters are then provided to the power exchange. This phase starts the evening on D-2 (two days before operation) and lasts until 10:00 on D-1 when the parameters are published on the PX website.

Market coupling is the actual solving of the market, performed by the PX (Nord Pool Spot in the Nordic area). The parameters calculated by the TSOs in the pre-market coupling phase are published to the market. Based on this information, the market players place bids to the PX. The bids are collected and form the basis of the calculation of the market equilibrium. Finally, the market result is published. The post-market coupling process is done by the TSOs. They verify the market results, share the congestion income and analyze the operational security [19].

Chapter 4

Generation Shift Key strategies

A generation shift key (GSK) strategy is used in the aggregation from node-to-line PTDFs to area-to-CNE PTDFs. The result of the aggregation is dependent on how the change in an areas' net position is divided on the nodes within that area. However, prior to the market clearing, this is not known. Therefore, one needs to develop methods to estimate/predict how the change in an areas' net position will influence the different nodes within the area. Consequently, there have been developed several different GSK strategies. At the time being there is no straightforward theoretical way on how the GSK strategies should be determined. In other words, there is no certain approach of estimating how the change in an areas net position will influence the areas' nodes. Thus, the GSK strategies can be one of the sources of inaccuracy in the flow based parameter calculation.

The question is how to find the optimal GSK strategy. The optimal GSK strategy is the one that provides the minimum deviation between estimated line flow and actual line flow. That is, the GSK strategy that is best at estimating how the change in an areas' net position will divide on its nodes, will have the smallest flow deviation. In order to estimate the flow, the flow based method uses a linear approximation of how the flow changes as a function of net position [19]. How to calculate this flow deviation will be elaborated in Chapter 5, while section 4.2 discusses how to find good GSK strategies.

4.1 GSK strategies in the Nordic area

This section describes the eight different GSK strategies that are considered to use in the Nordic power market following an implementation of flow based market coupling. The GSK strategies are presented in Table 4.1.

Table 4.1: GSK strategies in the Nordic power market

Nr of strategy	*Production*	*Load*
1	Max (P - P_{min})	0
2	Max (P_{max} - P)	0
3	Max P_{max}	0
4	1	0
5	P	0
6	P	Max (0 | P)
7	0	Max (0 | P)
8	0	1

For each strategy there is defined a certain weighting according to production and load. Before exploring each of them closer, a general division between production GSKs and load GSKs can be mentioned. GSK 1-5 weights according to production, while GSK 7 and 8 are load-GSKs. GSK 6 accounts for both.

GSK 4 is the same as the flat strategy used in the previous example of aggregating PTDFs. All production nodes are equally weighted. With this strategy, the constraints added to the market problem will not reflect the actual production in the solution that needs to be regulated. A drawback is that a node could get more generation than its maximum installed capacity, if there is sufficient net injection in the area. A flat strategy also treats every node as generating, although many nodes are not connected to a load or a generator [19]. Thus, this strategy can seem inaccurate. On the other hand, when the weighting is independent of the actual production, the PTDFs (both node-to-line and aggregated) only need to be calculated once. Therefore, a flat strategy is computationally efficient.

Instead of a flat strategy, the PTDFs can be weighted according to production at the single nodes. In this way, the constraints will contain aggregated PTDFs that reflect the production allocation of each solution. GSK 1, 2, 3 and 5 use this approach, with some variations. GSK 1 weights the nodes of the area according to the difference between actual production, P, and minimal production, P_{min}. The nodes with the largest difference are weighted most. Similarly with GSK 2, except the difference is between maximum production, P_{max}, and actual production, P. GSK 3 and GSK 5 weight only according to maximum production and actual production, respectively. Thus, the nodes with the highest maximum production, or actual production, will be weighted most. In other words, considering GSK 3, nodes with high maximum production will be most influenced by a change in the areas' net position.

GSK 6 is the only strategy that accounts for both production and load. It weights according to the net injection (production minus load) of each node, where the largest net injection is weighted most. Accounting for both production and load, it is likely that this strategy is a more correct approach, compared to the strategies only accounting for either production or load. Still, when the net position of the area is close to 0, this strategy can be unstable, i.e. when the area is balanced. This can be shown by Equation 4.1, which is an another way to express Equation 3.2.

$$PTDF_{ij}^{Area} = \frac{\sum_{\alpha} PTDF_{ij}^{\alpha} * w^{\alpha}}{\sum_{\alpha} w^{\alpha}} \tag{4.1}$$

where

$\mathrm{PTDF}_{ij}^{Area}$ = Sensitivity of line ij to an injection in area *Area*
$\mathrm{PTDF}_{ij}^{\alpha}$ = Sensitivity of line ij to an injection in node α
w^{α} = weight of node α

Equation 4.1 shows that if the sum of the net injections $\sum_{\alpha} w^{\alpha}$ to the nodes in an area is zero, the aggregated PTDF will be infinite [15].

GSK 7 and 8 are the only strategies where production is not evaluated. GSK 7 weights according to load in each node, while GSK 8 is a flat strategy weighting all nodes equally according to load. As with GSK 4, the same benefits and drawbacks applies for GSK 8.

4.2 How to find good GSK strategies

As previously mentioned, linear approximations of how the flow changes according to net position, is used to estimate the flow. Different linearization methods, or GSK strategies can be used, and the challenge is to find the best method. The following example is provided to illustrate two different linearization methods, or GSK strategies (based on [19]). The flow on a line is given by Equation 4.2, which actually is the same as Equation 3.7, only now solving for Fref.

$$Fref = Fref' + PTDF * NP^{BC} \tag{4.2}$$

The PTDF defines the slope of the linear relation between the flow on a CNE and the net position. This is illustrated in Figure 4.1. The brown line is the real flow on a CNE with a varying net position in "A". However, the real flow is nonlinear, so it has to be linearized. The vertical blue dotted line indicates the net position of the base case in area A. The intersection of the base case and the brown solid line, is the real flow.

The black and red dotted lines show the linearization of the flow using two different approximations. The black line shows the flow when using a flat strategy, while the red line assumes a marginal strategy. A marginal strategy is a strategy that distinguishes between generators that most likely will produce power and generators that there remain uncertainty about. The strategy assumes the marginal technology to represent the aggregated PTDFs. If the base case turns out to be the market solution, both strategies correctly estimate the flow on the line. If the market solution have a net position as in MS1, the marginal GSK strategy provides a more accurate estimation of the flow than the flat strategy. On the other hand, if the net position is given by the market solution in MS2, the flat strategy will provide a better estimation of the flow. Considering the different market solutions, one can expect that a marginal strategy is most accurate if the solution is close to the base case. A flat strategy is more robust, giving rather good estimations

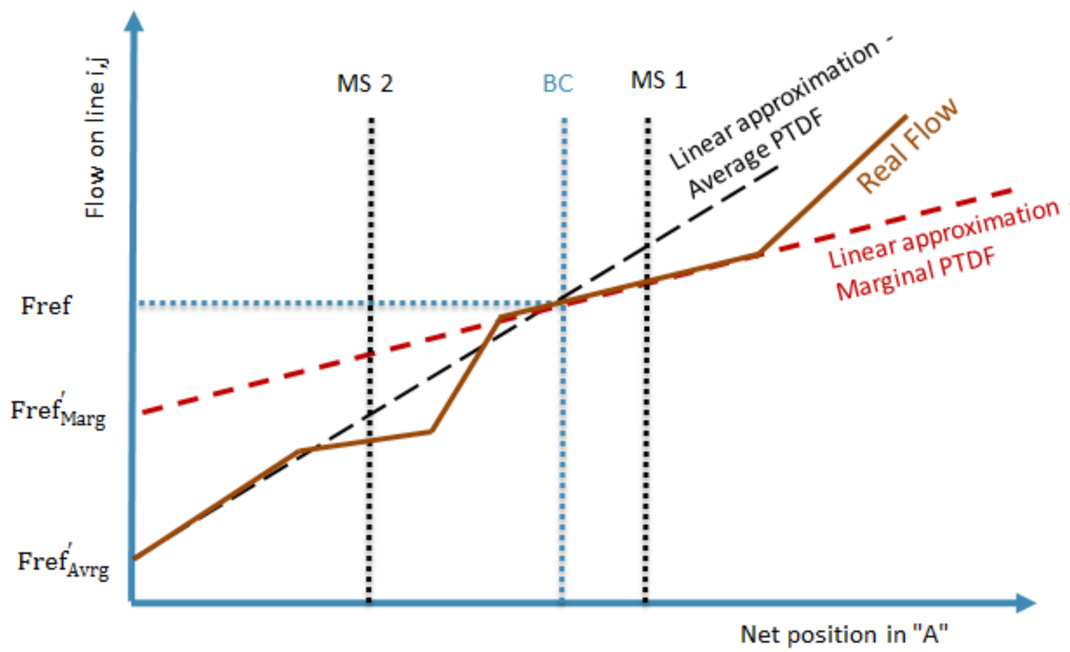

Figure 4.1: Linear approximations of flow [19]

even if the market solution is far from the base case. These two strategies serve as an illustration of the choice one may encounter when having several GSK strategies: More accuracy versus more robustness.

It is both technically and theoretically possible to use different strategies dependent on time and place. Whenever strategies seem optimal for one or more bidding areas, the different TSOs can apply different strategies. This is also possible if different strategies are optimal in different time periods. However, since the GSKs are used in the PTDF calculations before market clearing, the chosen GSK strategy will affect the final market solution. A bad GSK strategy can result in an incorrect solution space, either too small or too big. Therefore, it would be preferable to establish guidelines or rules "guiding how GSKs are defined in order to avoid potential obscure incentives and to insure transparency in the capacity calculation process" [19].

It should be noted that the GSK values can vary for every hour. They are recalculated for each day, resulting in a new solution to the market problem. The only exception is when a flat strategy is applied: When all nodes are weighted equally, the aggregated PTDFs will remain unchanged.

Why different GSK strategies may be optimal for different areas can be explained by variations in generation technology mixture between the areas or geographical distribution of generation. According to [23], “the GSK includes power plants that are market driven and that are flexible in changing the electrical power output.” This includes power plants of type gas/oil, hydro, pumped-storage and hard-coal. In addition, the TSOs can use other, less flexible units, like nuclear units, if they don’t have sufficient flexible generation to meet the required amount of power. While this applies in CWE, the power plants in the Nordic area are mainly hydro, wind and nuclear.

In CWE, the TSOs have different methods of using GSK strategies. For instance, the German TSO TransnetBW updates the GSK strategy every season, creating a seasonal dependence of power plant availability. Additionally, there is a differentiation between working days and weekends, as well as peak and off-peak hours. Amprion, also a German TSO, use monthly GSK strategies and updates according to new plants or block out of service. They also differ between base load and peak load. Basic load power plants, like nuclear and lignite, are considered as not being a relevant node to the GSK, while middle and peak load power plants are considered relevant. This is typically hard coal, gas and hydro plants [23].

Chapter 5

Method

As we have seen, the PTDFs are calculated based on an estimated base case. Applying GSK strategies translates the node-to-line PTDFs into area-to-CNE PTDFs provided to the market. Consequently, there is a desire of knowing how good a given GSK strategy is. This thesis aims at investigating the different GSK strategies and to develop methods to compare them. The Nordic TSOs are considering eight different GSK strategies, which all will be studied in this thesis.

One of the tasks of the TSOs is to correctly predict the flow on the lines in the Nordic grid. This is rather difficult, and one assumes some deviation between the estimated and the actual flow. Studying these flow deviations can be used as a method to see how the GSK strategies perform.

Operational files containing data for the previous day, D-1, is used as a base case. The data files are provided by Power World and contain net position of each area, flow on all lines, and the PTDF matrix of lines and areas. The idea is to use the results from the previous day to estimate the flow of the current day, D. The estimated flow is compared to the actual flow, given in the data file for day D, resulting in a flow deviation. The flow deviation tells us how good the estimations were. The flow deviations are calculated similarly to the FRM (section 3.6), but the FRM is the result of a statistical analysis. The FRMs are set to 0 MW in the data files, since they are not calculated today.

Doing this for several days and several GSK strategies, one can study which GSK strategy that gives the smallest flow deviation over time. Thus, this is a statistical approach. One advantage of this approach is that it only requires data files from two days of operation for each day being studied, which the TSOs can provide. Data for 10 days in January is the basis for the analysis in this thesis.

In the process of studying the GSK strategies three levels of detail is used. A global level where all the CNEs in the Nordic area are considered together using the same GSK strategy, an area level where the CNEs are sorted into areas, and one level considering each single CNE.

5.1 Description of data files

Each file from Power World contains operational data from one hour of operation. The 12 bidding areas of the Nordic area, as well as interconnectors between the areas, are listed along with their net position. The interconnectors are managed as virtual bidding areas, thus the number of bidding areas in the data files are 28. Further in the data files are data describing the CNEs of the Nordic grid: CNE number, CNE name, CNE capacity, flow on each CNE and a PTDF matrix. The number, name and capacity of the CNEs are constant for each strategy, while the flow on each CNE and the PTDF matrix change according to the GSK strategy applied. Thus, for every hour, there are 8 different PTDF matrices. The PTDF matrix presents the relation between all CNEs in the Nordic grid and the bidding areas. There are 1037 CNEs in the Nordic grid, such that the PTDF matrix has a size of 1037×28.

In order to manage the amount of data provided in the data files, a script has been developed in Visual Basic (VBA) in Excel. The task at hand is to extract the relevant data from the data files. This includes the net position of every bidding area, the flow and capacity of each CNE, as well as the PTDF matrices. When the necessary data is imported to the VBA script, one can calculate the flow deviations.

5.2 Calculation of flow deviations

Following are the steps performed when calculating the flow deviations. The calculations are managed by the script in VBA, and are done for each CNE in the Nordic grid and for all GSK strategies.

Step 1: Calculate the estimated flow

As seen in chapter 3, flow can be calculated by multiplying net position and PTDF. This relation is used in the following equation:

$$P\_est_{i,j,h,D} = P_{i,j,h,D-1} + \sum_{n \in N} (NP_{n,h,D} - NP_{n,h,D-1}) * PTDF_{i,j,n,h,D-1} \quad [MW] \tag{5.1}$$

where

Pest$_{i,j,h,D}$ = estimated flow on CNE i for GSK strategy j, hour h and day D

P$_{i,j,h,D-1}$ = flow on CNE i for GSK strategy j, hour h and previous day *D-1*

NP$_{n,h,D}$ = net position of area n for hour h and day D

NP$_{n,h,D-1}$ = net position of area n for hour h and day *D-1*

PTDF$_{i,j,n,h,D-1}$ = PTDF between CNE i and area n for GSK strategy j, hour h and day *D-1*

The term with the summation sign is the correction that is applied to the flow of the previous day, in order to get an estimated value for the CNE's flow on day D. The flow on the CNE is now given by the changed power injection in all areas, represented by their aggregated PTDFs. The flow has to be within the upper and lower bounds of the line, as shown in Equation 3.8 in section 3.5.

Step 2: Calculate the flow deviation

The estimated flow can then be compared to the actual flow, which is given in the data file for day D. The deviation is calculated using equation 5.2 below.

$$\Delta P_{i,j,h,D} = |P\_est_{i,j,h,D} - P_{i,j,h,D}| \quad [MW] \tag{5.2}$$

where

Δ $P_{i,j,h,D}$ = flow deviation on CNE i for GSK j, hour h and day D

$P_{i,j,h,D}$ = reference flow on CNE i for GSK j, hour h and day D

Small deviations indicate that the predictions were good. The flow deviations are calculated as absolute values. This is because two and two CNEs had the same flow, only with opposite signs. Thus, the flow deviation would be equal to zero when summing the flow deviation of all CNEs (see next step).

Step 3: Normalized flow deviation

In order to be able to compare the flow deviations of the different CNEs, the flow deviations should be normalized according to the capacity of the particular CNE. In this way, the deviations of the different CNEs can be compared. Note that this applies for day D; the index, D, is removed since we now only relate to the current day.

$$\Delta W_{i,j,h} = \frac{\Delta P_{i,j,h}}{\bar{C}_i} * 100 \quad [\%] \tag{5.3}$$

where

Δ $W_{i,j,h}$ = absolute deviation of CNE i for GSK j and hour h

Δ $P_{i,j,h}$ = deviation in flow on CNE i for GSK j and hour h

$\bar{C}_i$ = capacity of CNE i

Thus, we have obtained a final value of a CNEs' deviation that can be used in further analyses. However, it is often more interesting to see how a GSK strategy influences the flow in an entire area or country. In such situations, the deviations of each CNE within the area must be aggregated to an equivalent value describing the total flow deviation of the area. The step from one CNE to several CNEs must be considered in the aggregation process. In the work of this thesis, two different methods have been used when aggregating the CNEs for an area.

Method 1: Absolute deviation

In the first method, the flow deviations and capacities are summarized separately, before calculating a ratio that reflects the absolute flow deviation. This is shown in Equation 5.4.

$$\Delta W_{n,j,h} = \frac{\sum\limits_{i \in n} \Delta P_{i,j,h}}{\sum\limits_{i \in n} \bar{C}_i} * 100 \quad [\%] \tag{5.4}$$

where

Δ $W_{n,j,h}$ = absolute deviation of area n for GSK j and hour h

$\sum\limits_{i \in n} \Delta P_{i,j,h}$ = sum of flow deviation of CNE i in area n for GSK j and hour h

$\sum\limits_{i \in n} \bar{C}_i$ = sum of capacity of the CNEs in area n

In this way, the flow deviation is weighted according to the capacity of the CNEs in question. The summation regards all CNEs within the area. Summarizing deviation and capacity separately results in an absolute deviation that can be compared regardless of considering one CNE, all CNEs in an area or all CNEs in the Nordic grid.

Method 2: Relative deviation

Method 2 uses another approach to the aggregation problem. As seen before, Equation 5.3 provides the flow deviation of a single CNE. In this method, the flow deviation of each CNE within an area is summarized, before dividing by the number of CNEs in the area. Since Δ $W_{i,j,h}$ already is given in percent, there is no need to multiply by 100. Equation 5.5 shows how this is achieved.

$$\Delta W_{n,j,h} = \frac{\sum\limits_{i \in n} \Delta W_{i,j,h}}{N_n} \quad [\%] \tag{5.5}$$

where

Δ $W_{n,j,h}$ = relative deviation of area n for GSK j and hour h

$\sum_{i \in n} \Delta W_{i,j,h}$ = sum of the relative deviation of each CNE i in area n for GSK strategy j and hour h

N_n = number of CNEs in area n

This method enables a comparison between CNEs with large capacity and CNEs with small capacity. Additionally, one can compare the deviation of each area regardless of the number of CNEs within each area. The summation regards all CNEs within the area in question. The same equation can therefore be applied for larger regions or countries. There is no mathematical difference in the calculations; it is only a question of which CNEs that is included.

Step 4: Aggregating for several hours

Another dimension to the method is the time scope. The previous steps are done for each hour, but in order to get more robust results the flow deviations must be evaluated for a greater amount of hours. The flow deviation derived in the previous step, regardless of which method is used, reflects the deviation of one hour. When looking at several hours, or days, the flow deviations of each hour must be aggregated into one value reflecting the whole time period in question. The aggregation of absolute deviation for an area for several hours is done according to Equation 5.6, while the aggregation of relative deviation for several hours is shown with Equation 5.7.

$$\Delta W_{n,j,T} = \frac{\sum_{t=1}^{T} \sum_{i \in n} \Delta P_{i,j,t}}{\sum_{t=1}^{T} \sum_{i \in n} \bar{C}_{i,t}} * 100 \quad [\%] \tag{5.6}$$

where

T = total number of hours

Δ $W_{n,j,T}$ = absolute deviation of CNEs in area n for GSK j and total number of hours, T

$\sum_{i \in n} \Delta P_{i,j,t}$ = sum of deviation of CNEs i in area n for GSK strategy j and hour t

$\sum_{i \in n} \bar{C}_{i,t}$ = sum of capacity of the CNEs in area n for hour t

$$\Delta W_{n,j,T} = \frac{\sum_{t=1}^{T} \sum_{i \in n} \Delta W_{i,j,t}}{T * N_n} \quad [\%] \tag{5.7}$$

where

T = total number of hours

Δ $W_{n,j,T}$ = relative deviation of CNEs in area n for GSK j and total number of hours, T

$\sum_{i \in n} \Delta$ $W_{i,j,t}$ = sum of the hourly relative deviation of each CNE i in area n for GSK j and hour t

N_n = number of CNEs in area n

For both methods, the flow deviation of a particular CNE for a given GSK strategy for one hour is summarized with the corresponding flow deviation of the next hour. In Equation 5.6, the capacity for each CNE is summarized for each hour, before calculating the resulting absolute deviation. In Equation 5.7 the number of CNEs is increasing in step with the flow deviation, multiplying by the number of hours in question. The same aggregation methods are used when aggregating the deviation of single CNEs for several hours.

Chapter 6

Results and discussion

This chapter presents and discusses the results of the analysis of different GSK strategies. The first section presents the main results of the analysis, while section 6.2 and 6.3 further elaborates the underlying data of the global level and the area level, respectively. Descriptions of the different bidding areas can be found in Section 6.4, before studying individual CNEs in Section 6.5. At the end, simplifications and limitations will be discussed in Section 6.7.

The following studies are based on ten days of data from 2015: 1st - 10th of January. Each day is estimated using data from the previous day. Weekdays are estimated using the closest previous weekday, and the same applies for days in the weekends.

Due to 1^{st} of January being a holiday, estimating Friday 2^{nd} based on this would be wrong, since Friday is a weekday. Thus, January 2^{nd} is skipped in order to get the analyses correct considering weekdays and weekend days. Therefore, the first day of the analysis is Saturday January 3^{rd} using January 1^{st} as previous day. Sunday 4^{th} is based on Saturday 3^{rd}, Monday 5^{th} is based on Friday 2^{nd} and so on until Saturday 10^{th} of January, which is based on Sunday 4^{th}, and is the last day in scope. Note that the choice of skipping Friday January 2^{nd} in the analysis decreases the time horizon to 9 days. Still, this would be the most correct way in order to ensure no mix up between weekdays and weekend days.

The analysis has been divided into three levels of detail. A global level where all CNEs in the Nordic grid are considered together for each GSK strategy. An area level, where the CNEs are sorted into their respective areas. The last level is even more detailed, studying each single CNE of each area.

It should also be mentioned that due to lack of good indications of P_{min} in the data files provided, P_{min} is close or equal to zero. Remembering that GSK 1 weights according to $P - P_{min}$ (see Table 4.1 in chapter 4), this means that GSK 1 actually will be weighting according to P, only. In other words, GSK 1 will become equal to GSK 5, and the results will be the same. Therefore, GSK 1 will not focused on in the discussion of the results, but the discussions regarding GSK 5 applies to the results of GSK 1 as well.

6.1 Main results

Table 6.1 contains the main results using method 1 with absolute deviation, while Table 6.2 provides the main results of method 2 with relative deviation.

	Global		
	Minimum	Opt. GSK each area	Improvement
All CNEs	4,70 %	4,43 %	5,74 %

	Area		
	Minimum	Opt. GSK each CNE	Improvement
NO1	2,42 %	2,31 %	4,55 %
NO2	5,73 %	5,61 %	2,09 %
NO3	2,47 %	2,31 %	6,48 %
NO4	7,97 %	7,37 %	7,53 %
NO5	7,98 %	7,75 %	2,88 %
SE1	6,74 %	6,40 %	5,04 %
SE2	4,03 %	3,67 %	8,93 %
SE3	3,69 %	2,97 %	19,51 %
SE4	2,53 %	2,23 %	11,86 %
DK2	4,01 %	3,94 %	1,75 %
FIN	4,30 %	4,30 %	0,00 %
DK1	6,03 %	5,51 %	8,62 %
All CNEs	4,70 %	4,07 %	13,40 %

Table 6.1: Main results - relative deviation (method 1)

	Global		
	Minimum	Opt. GSK each area	Improvement
All CNEs	6,46 %	6,09 %	5,73 %

	Area		
	Minimum	Opt. GSK each CNE	Improvement
NO1	2,51 %	2,34 %	6,77 %
NO2	6,05 %	5,93 %	1,98 %
NO3	2,94 %	2,77 %	5,78 %
NO4	11,20 %	10,36 %	7,50 %
NO5	8,45 %	8,22 %	2,72 %
SE1	7,03 %	6,58 %	6,40 %
SE2	4,94 %	4,56 %	7,69 %
SE3	4,17 %	3,41 %	18,23 %
SE4	2,44 %	2,12 %	13,11 %
DK2	6,23 %	6,13 %	1,61 %
FIN	3,74 %	3,74 %	0,00 %
DK1	6,76 %	6,12 %	9,47 %
All CNEs	6,46 %	5,67 %	12,23 %

Table 6.2: Main results - absolute deviation (method 2)

The upper section is the results for the global level, when all CNEs are considered together, while the larger, lower section is the results of the area level. The cell of the column called "Minimum" and the row labeled “All CNEs”, contains the value of the GSK strategy that resulted in the smallest deviation for all CNEs together. The value is extracted from Table 6.3 in the next section.

Considering the area level, the CNEs are sorted into their respective areas, and the minimum values reflect the GSK strategy giving the smallest deviation for each area. These values are extracted from Table 6.5 in Section 6.3.

Instead of using the same GSK strategy for all CNEs in the Nordic region, one may apply different GSK strategies in different areas. The idea is that by applying GSK strategies on a more detailed level, one might find strategies that are more suitable for the area in question. This will, theoretically at least, improve the overall flow deviation of the Nordic region. When applying the optimal strategy for each area, that is, the strategy resulting in the minimum deviation of each area, the global flow deviation will decrease. This value is showed under “Opt. GSK each area” for the global level. Optimizing the GSK strategy of each area, the global flow deviation decreases from 4,70 % to 4,43 % with method 1, which is an improvement of 5,74 %. A decrease in the global flow deviation is also obtained with method 2. The improvement achieved by the two methods is almost identical. Based on these values, it is beneficial to use the optimal strategy for each area. Still, the improvement is not as substantial as one might had expected.

Similarly, one may optimize the area deviations as well. By analyzing each single CNE within an area, one can find the optimal strategy for each CNE. Using the optimal strategy for each CNE will decrease the total deviation of the area. These values are presented in the column called “Opt. GSK each CNE”. Consider for instance the results of method 2. Applying the optimal GSK strategy for each CNE in SE3 reduces the total deviation of SE3 from 4,17 % to 3,41 %, which is an improvement of 18,23 %. Regardless of method, SE3 is the area experiencing the largest benefit of optimizing the strategy for each CNE. Still, all areas benefit from optimizing each CNE, with one exception. Finland doesn’t improve at all. In other words, in this area it is not necessary to optimize each CNE. This behavior is due to Finland being a radial (will be further explained in section 6.3). Areas like NO2 and DK2 have small improvements by optimizing each single CNE. In such cases, one may consider if optimizing each CNE is “worth” the work. The CNEs in these areas are not very sensitive to which GSK strategy that is applied.

As seen, using the optimal strategy of each area improved the global deviation of the Nordic region from 4,70 % to 4,43 % with method 1, and from 6,46 % to 6,09 % with method 2. It is also seen that by applying the optimal strategy of each CNE, the deviation of each area decreases. Thus, the global deviation will also decrease. Applying the optimal strategy on each CNE, the global deviation is further decreased to 4,07 % with method 1 and to 5,67 % with method 2. This is displayed in the bottom line of Table 6.1 and Table 6.2. The improvement from 4,70 % to 4,07 % in method 1 is 13,40 %. For method 2, the improvement from 6,46 % to 5,67 % is 12,23 %.

The improvements presented in Table 6.1 and Table 6.2 are based on a comparison with the best strategy. However, one doesn’t always apply the best strategy. Thus, if another strategy is used, the improvement will be larger.

Looking at the results provided in Table 6.1 and Table 6.2, it is interesting to investigate the underlying results. Section 6.2 - 6.5 further elaborate the results of the different levels

6.1.1 Evaluation of methods

Until now, the results of both methods have been discussed. In the following, only the results of one method will be presented and discussed. The methods are different regarding how they weight the flow deviation of each CNE when calculating the total flow deviation of an area. Method 1 weights the total flow deviation of an area according to the total capacity of the CNEs in question, resulting in an absolute deviation. However, the absolute deviation doesn't properly account for the number of CNEs within each area. In other words, areas with many CNEs will dominate, and areas with few CNEs will be weighted less. The same applies for the transfer capacity of the transmission lines; lines with large capacity will dominate lines with little capacity. For instance, consider a small CNE that considerably reduces its flow deviation when the optimal GSK strategy is applied. This improvement might not be reflected in the areas' flow deviation if there are many large CNEs in the same area. With method 1, the improvements of small CNEs may disappear among the larger CNEs, even though it might be just as important to optimize a small CNE if it is limiting.

The relative deviation found by method 2, accounts for the number of CNEs within each area. In this way, small and large CNEs will be treated equally, and areas will be treated equally regardless of how many CNEs each area consists of. However, with this method, the small CNEs, and areas with few CNEs, will perhaps get too large impact.

It was decided to use the relative deviation in the further discussion of the results, thinking that it would provide a slightly better representation of all the CNEs in the grid. It should, however, be emphasized that both methods provide a good solution to the aggregation problem. Looking at the results provided in Table 6.1 and Table 6.2, one can observe that there are only minor differences between the results of the two methods. The results of method 1 and method 2 are, in general, showing the same trends and patterns. The results of the absolute flow deviations calculated with method 1 are provided in Appendix A.

6.2 Global results

Table 6.3 shows the result when all CNEs are considered together and applied the same GSK strategy.

	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8
All CNEs	6,78 %	6,80 %	6,46 %	6,54 %	6,78 %	6,68 %	7,23 %	6,46 %

Table 6.3: The relative flow deviation of all CNEs for each GSK strategy.

These values are an average of the flow deviations of all CNEs in the Nordic grid. The largest deviation occurs using GSK 7, while GSK 3 and GSK 8 turn out to be the best strategies with a deviation of 6,46 %. It is this minimum value of 6,46 % that can be seen for the global level in Table 6.2.

GSK 7 is the worst strategy with 7,23 %. It is also quite evident, considering that the deviation of the second worst strategy is 6,80 %. Thus, dividing the change of net position according to load only, is not a very good strategy for the whole Nordic area combined. However, GSK 8, which also weights according to load, is the best strategy. Thus, one may assume that a flat strategy is a good approach. This can also be verified looking at GSK 4, the other flat strategy in this analysis, which has the second lowest flow deviation. In addition to GSK 8, also GSK 3 is best, weighting according to maximum production of the nodes.

Still, there are small differences between the different strategies. Even though GSK 7 stands out as the worst, the difference between GSK 7 at 7,23 % and GSK 3 or 8 at 6,46 % is not substantial.

Counting the amount of hours each strategy is best or worst, helps to verify the flow deviation results. Table 3 and Table 4 in Appendix B show the amount of hours each strategy is best or worst, respectively. Note that the tables only show when the strategies are best and worst, and not whenever they are second best or second worst. Still, they are useful giving an indication of how the different strategies perform. For instance, one can observe that GSK 7 has the highest share of hours being the worst strategy, and, correspondingly, almost never the best strategy. This confirms the result in Table 6.3.

Table 4 shows that GSK 3 is never the worst strategy, which verifies that GSK 3 is a good strategy. Also, GSK 6 has no hours where it is the worst strategy, while GSK 8 is only worst for 4 hours. Since GSK 6 has no hours where it is the worst strategy, one may ask why it doesn't turn out better in the results presented in Table 6.3. Compared to GSK 8, it is because GSK 8 is the best strategy for *more* hours than GSK 6. However, according to Table 3, GSK 6 should be better than GSK 3, having more hours where it's the best strategy. An explanation is that when counting only the best and worst, one can't see how the strategies perform when they are somewhere in between. Thus, one can assume that GSK 3 is better than GSK 6 in general, even though these numbers indicate the opposite. Additionally, some of the explanation of these global results will be hidden due to lack of detail at this level.

Studying the amount of hours that each GSK strategy is best and worst, reveal some information regarding GSK 5 that can't be seen in Table 6.3. It is the strategy that is best for most hours. However, it also has many hours as the worst strategy, which explains why the resulting deviation of Table 6.3 is neither best nor worst.

Due to GSK 5 appearing both best and worst for many hours, one might think that the flow deviation is varying a lot between the hours. However, the standard deviation of the flow deviations of GSK 5 is 2,64 %, which actually is the lowest standard deviation of the GSK strategies. The standard deviation reflects the spread between the data points in consideration. A small spread, or variation, between the data points reflects that the final average value is good. With a large variation, the final result is not as consistent as with a small variation. The standard deviations are presented in Table 6.4.

	GSK 1	**GSK 2**	**GSK 3**	**GSK 4**	**GSK 5**	**GSK 6**	**GSK 7**	**GSK 8**
All CNEs	2,64 %	3,19 %	2,71 %	2,84 %	2,64 %	2,74 %	3,36 %	2,75 %

Table 6.4: Standard deviation of all CNEs for each GSK strategy

To a certain extent, it seems that the standard deviation is better for the good strategies. GSK 7 has the highest standard deviation, while the standard deviation of GSK 3 and 8 are rather low, although not the lowest. GSK 5 has the lowest standard deviation of 2,64 %. Figure 6.1 presents the distribution of the flow deviations for GSK 5 and GSK 7, which are the strategies with lowest and highest standard deviation, respectively. It shows how many hours the flow deviation is within certain intervals. As one can see, the flow deviations of GSK 5 is varying between 2 % and 14 %, but mostly the deviation is between 4 and 10 %. This coincides with the average deviation of 6,78 % in Table 6.3.

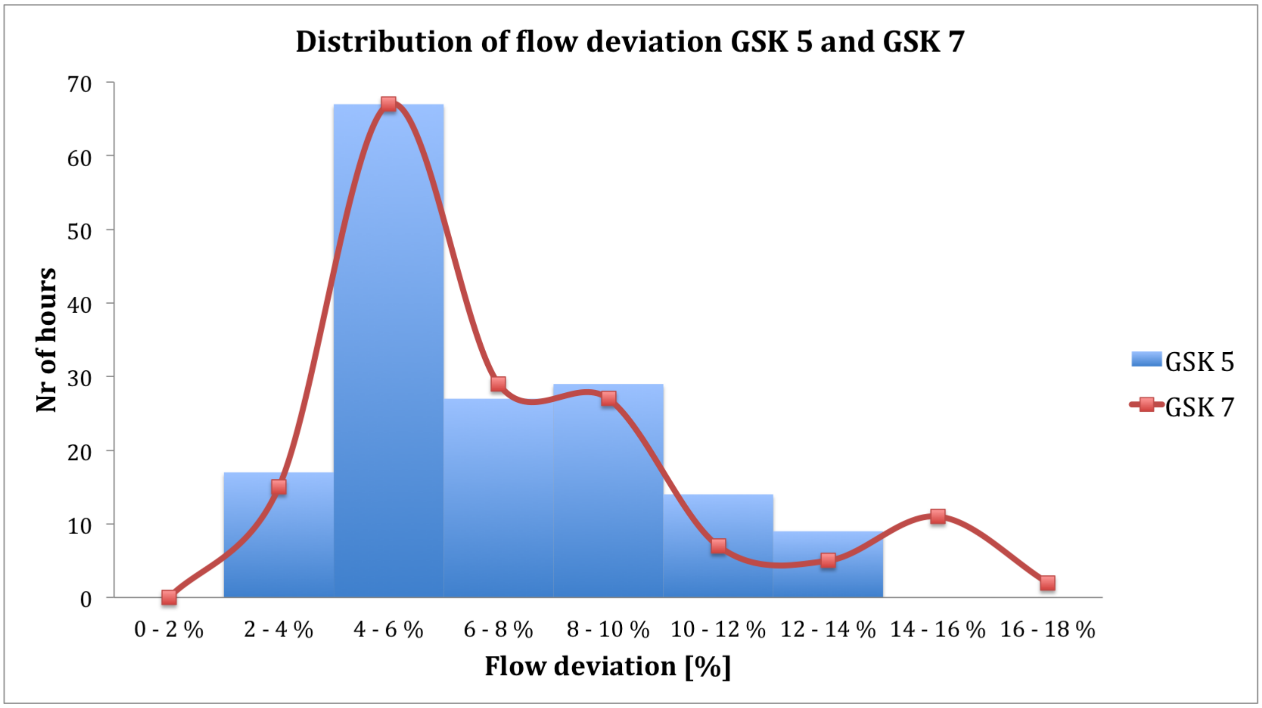

Figure 6.1: Distribution of flow deviation for GSK 5 and GSK 7.

One can observe that the values of GSK 7 varies more than the values of GSK 5, with some hours having flow deviations between 16 and 18 %. The distribution of the flow deviation of GSK 5 is more concentrated. However, the differences are not considerably large.

6.3 Area results

Considering all CNEs together gives an overall indication of the influence by the different GSK strategies, but the global results may conceal variations within the areas. The results for the different bidding areas can be seen in Table 6.5.

Area	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8
NO1	2,70 %	2,51 %	2,61 %	2,78 %	2,70 %	2,51 %	2,63 %	2,86 %
NO2	6,05 %	6,67 %	6,14 %	7,78 %	6,05 %	6,66 %	7,87 %	7,77 %
NO3	3,24 %	3,47 %	3,24 %	3,26 %	3,24 %	2,94 %	3,10 %	3,30 %
NO4	11,20 %	12,03 %	11,22 %	11,81 %	11,20 %	11,41 %	13,35 %	15,23 %
NO5	8,45 %	10,18 %	8,60 %	9,90 %	8,45 %	9,28 %	13,06 %	11,70 %
SE1	7,13 %	7,28 %	7,03 %	7,52 %	7,13 %	7,04 %	7,66 %	8,32 %
SE2	5,22 %	6,40 %	5,17 %	5,60 %	5,22 %	4,94 %	5,19 %	5,71 %
SE3	4,77 %	5,60 %	4,56 %	4,52 %	4,77 %	4,17 %	4,45 %	4,26 %
SE4	2,77 %	3,09 %	2,80 %	3,26 %	2,77 %	2,44 %	2,46 %	2,62 %
DK2	8,16 %	6,97 %	7,04 %	6,23 %	8,16 %	7,79 %	7,81 %	6,43 %
FIN	3,74 %	3,93 %	3,84 %	4,07 %	3,74 %	3,82 %	3,98 %	4,17 %
DK1	6,76 %	7,34 %	6,90 %	7,50 %	6,76 %	6,93 %	7,90 %	6,99 %

Table 6.5: Relative flow deviation for each area and each GSK strategy

Considering the flow deviations on an area level provides more details to the results, and reveals new and interesting information. GSK 8, which was one of the best strategies in the results of the global level, is now the worst strategy. In the previous section, it was mentioned why the result of GSK 6 wasn't better. The area results show that GSK 6, in fact, is the best strategy. It is best in 5 out of 12 areas, and it's never the worst strategy. Additionally, when other GSK strategies are better, GSK 6 is not far from the best.

GSK 3 is still a good strategy, although not as evident as on the global level. It is never the worst strategy, and best in SE1. SE1 is an area with much production, thus it is reasonable that a strategy weighting according to maximum production is a good strategy for this area. Table 6 in Appendix B clearly shows that GSK 3 and GSK 6 are standing out as almost never being the worst strategies in any area.

Studying the deviations on an area level, one can see that also GSK 5 is quite good. In fact, it seems better than expected based on the global level results. Except being the worst strategy for DK2, it is the best strategy for five areas. Still, GSK 5 is not as stable as GSK 6 or GSK 3. Where GSK 6 almost never is the worst strategy, GSK 5 is worst for many hours (see Table 6 in Appendix B). However, GSK 5 is actually better for more hours than GSK 6. This is the same trend as mentioned when considering all CNEs together in the previous section: The average performance of the strategy is good, even if it is the worst strategy for many hours.

GSK 7 and GSK 8 stand out as bad strategies. They are never best, and worst for several areas. Also, when they're not the worst strategy, they are not far from it. When the results were evaluated on a global level, GSK 7 was pointed out as a bad strategy, which still is the case. Interestingly, GSK 8, which was best on a global level, is now the worst strategy. It is worst for NO1, NO4, SE1 and FIN. SE1, and partly NO4, have much production, which makes it reasonable that GSK 8 provides a poor estimation. NO1 is considered a consumption area, while FIN is mixed, but leaning towards consumption. With this in mind, it is strange that GSK 8 turns out so bad in NO1 and FIN. Still, GSK 8 is a generally bad strategy, independent of the area being consumption or production area. As an exception, GSK 8 is rather good for SE3 and DK2.

GSK 7 is worst for three areas: NO2, NO5 and DK1. These are all areas with a high share of production, thus it is logical that a strategy weighting according to load will be a poor estimation. Oppositely, it is the second best strategy for SE4. Since SE4 is an area with much load, this seems reasonable.

GSK 2 is not very good either. It is the worst strategy for NO3, SE2 and SE3 and the best strategy for NO1, but generally the strategy turns out poorly. NO1 is an area with much load, so it is somewhat strange that a production strategy turns out best. However, NO1 is a robust area, and not very sensitive to which GSK strategy that is applied. One may also ask questions as to why GSK 2 is bad for both areas like SE3 and SE2, which have much production, and for NO3, which is considered a consumption area.

GSK 2 is weighting the nodes according to P_{max}-P, while GSK 3 weights according to P_{max} only. Both based in P_{max}, it is interesting that GSK 3 performs better than GSK 2. As an example, consider an area where half of the nodes are producing close to their max capacity and the other half runs with a good margin to the capacity limit. The nodes producing close to the capacity limit will have a small influence with GSK 2, since the difference between maximum capacity and actual production will be small. The other half will correspondingly influence more. In other words, GSK 2 is weighting the nodes according to who has most available capacity. Using GSK 3, the production units with largest installed capacity will be weighted most. Thus, large power plants will influence more. GSK 3 is the best strategy in NO5, and also good in areas like NO2 and SE1, which are areas that have large power plants. Since GSK 3 seems to be a better strategy than GSK 2, one may conclude that weighting according to available capacity (as with GSK 2) is not the most essential approach. Especially, this seems to be the case in NO3, SE2 and SE3, where GSK 2 is the worst strategy.

GSK 4 doesn't stand out either way, and is a strategy somewhat on the average. It is worst for SE4, and best for DK2. Looking at DK2, most of the GSK strategies give poor estimates of the flow in this area, except GSK 4 and GSK 8. The flow deviation in DK2 can be seen in Figure 6.2.

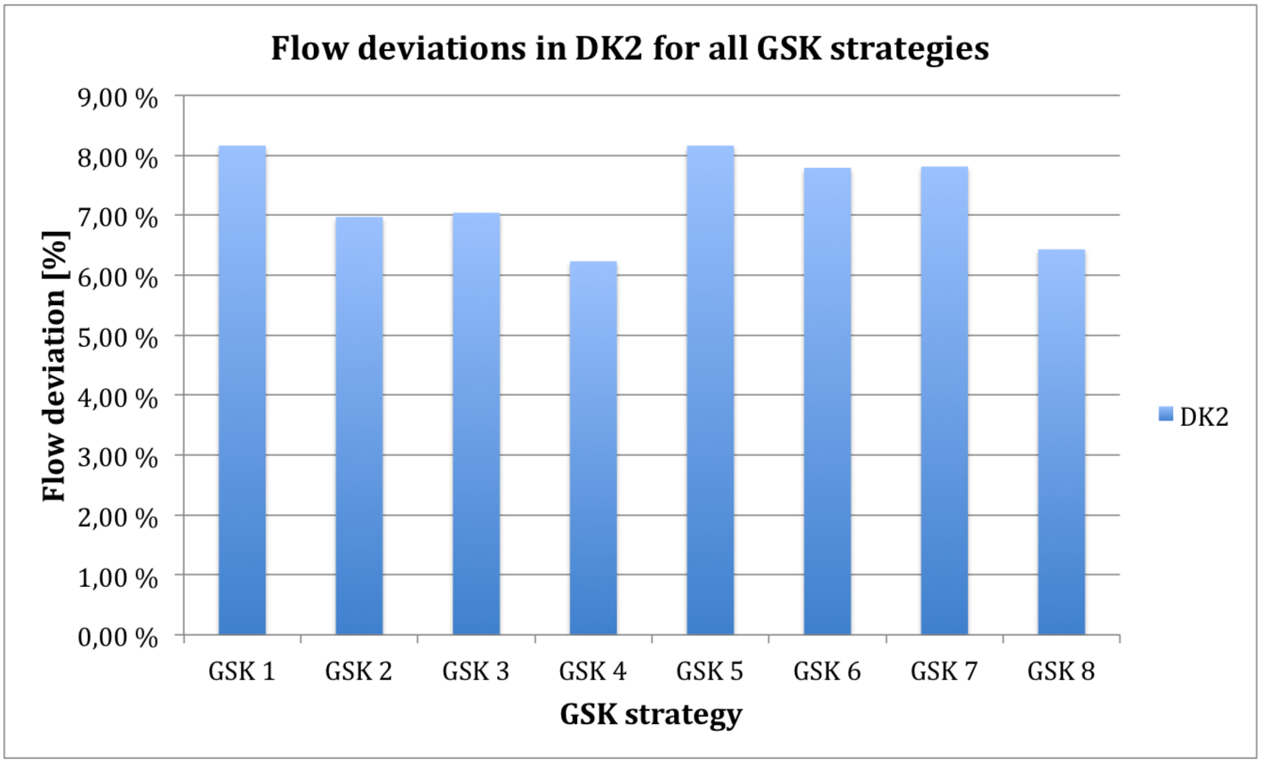

Figure 6.2: Flow deviation in DK2

These are both strategies with a flat weighting, so one can assume that a flat strategy is suitable in DK2. Considering that DK2 has few large production units (but many small production units), it is reasonable that a flat strategy is good. If there had been many large production units, the contribution from these units would not have been properly accounted for with a flat strategy. DK2 has a large production and a large load, which explains why both GSK 4 and 8 performs well in this area.

Even though some strategies evidently perform better than others, the differences are not always substantial. Consider Figure 6.3, which presents the flow deviations of area NO1 and NO4 for all

GSK strategies. The best strategy in NO1 is GSK 2 and GSK 6, while the worst is GSK 8. However, looking at the columns of NO1 in the figure, the differences between the strategies are not very large. The flow deviations are only varying by 0,35 percent points. NO1 is a robust area and not very sensitive to which GSK strategy that is applied. Area NO4 on the other hand, is more sensitive to the strategy applied. In this area, GSK 5 is best and GSK 8 is worst, with a difference of 4,03 percent points. Thus, the choice of GSK strategy in NO4 will have a greater influence on the results.

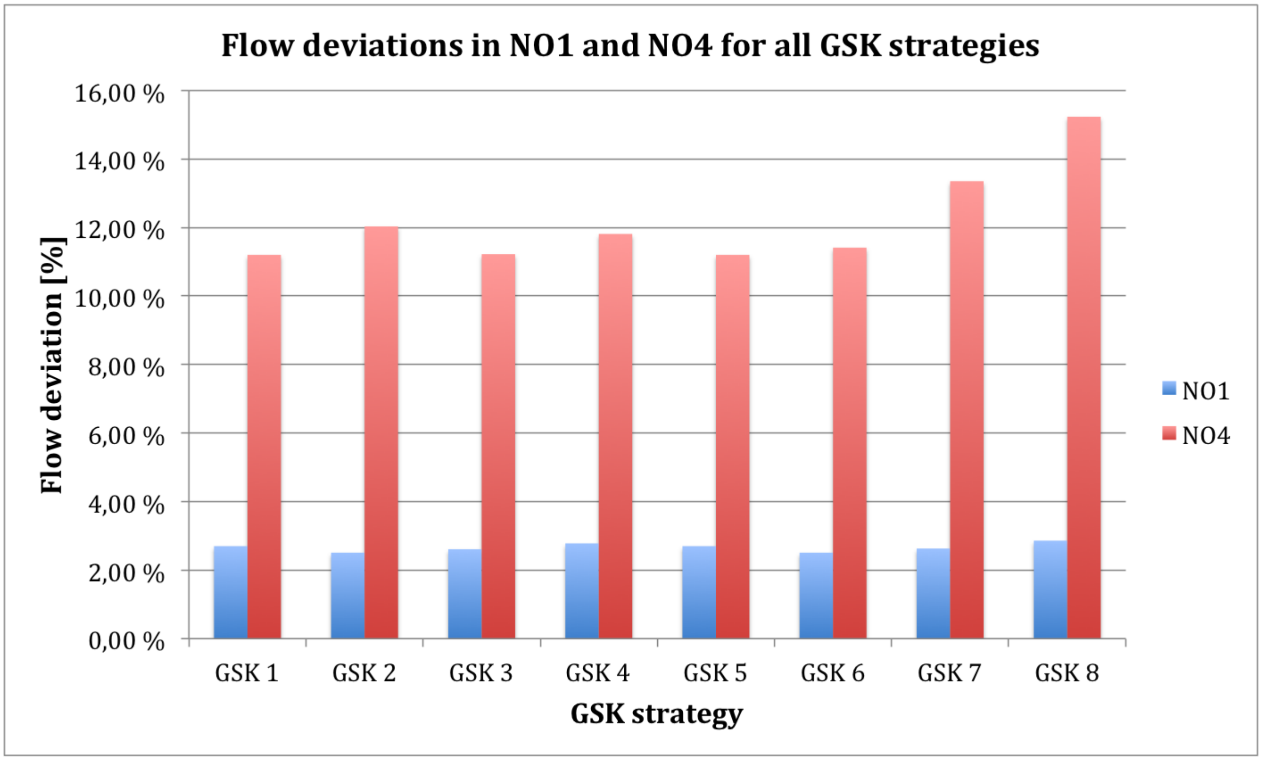

Figure 6.3: Flow deviation in NO1 and NO4

Figure 6.3 also illustrates another interesting aspect. Some areas experience much higher flow deviations than others (see Table 6.5). Areas like NO1 and SE4 have small deviations, while NO4 is the area with the highest deviation. NO5 and SE1 also experience large deviations. In order to find out why some areas have larger flow deviations, one may study the flow deviation of each CNE within the area. This will be further elaborated in Section 6.5.

Table 6.6 contains the standard deviation of the flow deviation of all hours.

Each cell represents the standard deviation of the flow deviation of the particular area and GSK

Area	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8
NO1	1,86 %	1,72 %	1,81 %	1,95 %	1,86 %	1,75 %	1,82 %	2,03 %
NO2	4,36 %	5,00 %	4,42 %	6,25 %	4,36 %	5,05 %	6,31 %	6,18 %
NO3	1,33 %	2,23 %	1,63 %	1,87 %	1,33 %	1,63 %	1,80 %	2,03 %
NO4	7,67 %	8,65 %	7,67 %	8,42 %	7,67 %	8,24 %	9,75 %	12,22 %
NO5	5,63 %	8,55 %	5,93 %	6,98 %	5,63 %	6,40 %	9,93 %	8,72 %
SE1	4,83 %	3,78 %	4,16 %	5,00 %	4,83 %	4,46 %	4,56 %	5,36 %
SE2	2,38 %	3,76 %	2,52 %	3,36 %	2,38 %	2,27 %	2,47 %	3,22 %
SE3	2,17 %	3,04 %	2,08 %	2,75 %	2,17 %	2,04 %	2,47 %	2,58 %
SE4	1,25 %	1,46 %	1,21 %	2,70 %	1,25 %	1,58 %	1,57 %	1,94 %
DK2	5,06 %	4,38 %	4,34 %	3,68 %	5,06 %	4,83 %	5,02 %	3,84 %
FIN	2,61 %	2,72 %	2,65 %	2,75 %	2,61 %	2,72 %	2,85 %	2,94 %
DK1	2,38 %	3,41 %	2,70 %	3,11 %	2,38 %	2,60 %	3,46 %	2,78 %

Table 6.6: Standard deviation for all areas and all GSK strategies

strategy for all hours. Generally, it seems that high standard deviation occurs where the flow deviation is high. GSK 7 and GSK 8 have high standard deviation, while GSK 3, 5 and 6 have low standard deviations. NO4 has the largest standard deviation, followed by NO5. As seen before, these are also the areas with the highest flow deviation. The good strategies seems to have small standard deviations, which verify the results in Table **??**. Similarly, the poor strategies seem to have higher standard deviations.

6.4 Area descriptions

This section elaborates more about the characteristics of each bidding area. In Norway, both NO1 and NO3 are areas with small deviations, with average flow deviations around 2 -3 % (see Table 6.5). Both NO1 and NO3 have more load than generation, and can be considered as consumption areas. In NO1 most of the CNEs are at Hasle, and it's not too difficult to estimate the flows here. As earlier mentioned, these areas are robust and not sensitive to which strategy that is applied.

In the other three Norwegian bidding areas, the deviations are larger. NO2, NO4 and NO5 are all areas with much production. The production units in NO2 are spread within the area, while the CNEs are connecting NO2 to NO1 and NO5. In NO2 the differences between the strategies are not large, but the deviations are generally higher than they were in NO1 and NO2.

NO4 and NO5 are the areas with the highest flow deviation in the Nordic region. NO4 is somewhat special, with a division between load and production within the area. The southern part of NO4 has much production. One often talks about a distinction between north and south of Ofoten. In the northern parts of NO4, in Finnmark, there is more load than production. However, the production in Finnmark increases in summer due to river hydro plants. The flow on the lines in NO4 is dependent on where the production is located. The grid in NO4 is also little developed, which can be a contributing factor to the large flow deviations in this area.

NO5 has generally much production, but also this area has some internal divisions. The western part, with both production and load, can deviate from large surplus to large deficits. The eastern part, including Hallingdal and Aurland, consists of production from large reservoir hydro plants. In this area, the GSK strategies weighting according to production is the best strategies, while the load strategies are bad.

In Sweden, the northern part of the country (SE1 and SE2) is characterized by much production and little load, while the southern part (SE4) has less production and more load. SE3 is somewhere in between, with both large production and large load. It is reasonable that GSK 6 is the best strategy in this SE3. SE3 also comprises some large nuclear power plants, which gives another production dispatch than many of the other areas in the Nordic. These plants will always run, and SE3 will often behave different than areas dominated by hydropower production. GSK 2 is clearly the worst strategy in SE3, which may be due to the nuclear power plants running and utilizing much of their installed capacity. SE4 has low flow deviations, and seems rather robust.

Finland is, most often, a consumption area. Considering the flow deviations, the area seems robust when it comes to the strategy applied. The results of the single CNEs verify this (see Table 16 in Appendix D). There is not much to benefit from using the optimal strategy, which is clearly indicated in Table 6.2. The improvement was actually 0 %. This is probably because the grid in Finland is radial, which means that the grid is attached to the rest of the Nordic grid. Thus, the grid here is not highly meshed and loop flows occur rarely, such that the flow-based method may not provide a better solution than the NTC method in this area.

The bidding areas in Denmark have a lot of CNEs compared to the other areas in the Nordic. While the other Nordic bidding areas have between 6 and 83 CNEs, DK1 and DK2 have 436 and 334 CNEs, respectively. The production in Denmark is dominated by wind power. Wind is a source that cannot be controlled, making the production planning challenging. Consequently, the flow deviations are likely to increase, since the estimates might not be correct at all times. Both DK1 and DK2 have rather high flow deviations, with a maximum around 8 %. As mentioned before, the flat strategies seem to be good in DK2. DK1 is best with GSK strategy 5, and worst with GSK 7. DK1 has much production, and most of the time the production is larger than the load. This makes it reasonable that weighting according to actual production is the best strategy.

6.5 Individual CNEs

When predicting the flow on CNEs, some are harder to predict than others. In order to see any relation to why some areas have higher flow deviations, it is useful to investigate each CNE within the area. Characteristics of the bidding areas and knowledge of the Nordic power grid is important in order to evaluate the behavior of single CNEs. The results of the individual CNEs of all bidding areas can be found in Appendix D. This section discusses a few chosen CNEs with large flow deviations. These are presented in Table 6.7.

CNE nr	Area	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8
60850	NO4	34,48 %	34,90 %	34,51 %	38,23 %	34,48 %	33,38 %	32,77 %	49,89 %
31550	NO4	13,05 %	12,04 %	11,91 %	11,84 %	13,05 %	14,53 %	21,28 %	18,32 %
60400	NO5	11,58 %	16,33 %	12,65 %	16,34 %	11,58 %	14,24 %	22,03 %	18,70 %
40701	SE1	12,28 %	14,12 %	12,94 %	12,78 %	12,28 %	11,56 %	11,14 %	12,99 %
31801	SE1	6,05 %	7,08 %	6,25 %	9,03 %	6,05 %	7,67 %	11,76 %	13,59 %
30150	SE3	3,24 %	14,02 %	3,89 %	7,16 %	3,24 %	4,14 %	5,58 %	5,57 %

Table 6.7: Flow deviation for some chosen CNEs for each GSK strategy

The flow deviation of the individual CNEs in NO1, NO2 and NO3 is in general rather good (see Appendix D). However, looking at the individual CNEs of NO4 and NO5, it is evident that some CNEs are causing the large deviations seen in these areas. In NO4, CNE 60850 stands out with a maximum flow deviation of 49,89 %. This is the largest flow deviation seen in the analysis. The minimum flow deviation of the same CNE is 32,77 %. This CNE is a cut between NO4 and FIN. In this area there is only a weak 132 kV grid. In cases of large surplus or deficits one is concerned that one might loose the whole area in case of a single fault. Therefore, instead of having a loop from Finland through Northern Norway to Sweden, the area is often separated into two radially connected areas. The GSK strategies cannot predict these grid separations, which will increase the flow deviation. When the net position of FIN changes, it should be seen at the slack node in SE3. In the case of grid separation, there will be no transit flow through NO4 and down to the node in SE3. Thus, the influence from FIN on this CNE will be zero. Looking at the PTDF matrix (in the operational files) for this CNE reveals that the PTDF between this CNE and FIN often is zero. This verifies the theory of grid separations. Still, if one applies the optimal GSK strategy on CNE 60850, the flow deviation will still be large. It seems that this CNE is not easy to predict with the flow-based method.

There are also six other CNEs in NO4 with quite large deviations, varying from approximately 11 % to 21 %. These are CNEs 31550 to 31555, and are all cuts between Sildvik and Tornehamn. As they have the same flow deviation, only CNE 31550 is presented in Table 6.7. The high flow deviation is probably caused by the geographical location of the CNE, which is approximately in the middle of NO4. Production is dominating south of the line, while there is much load north of the line. The results show that the generation strategies are good, while the two load strategies, GSK 7 and GSK 8, are bad. The reason is probably that the production units respond most to a change in the areas' net position.

NO5 only consists of six CNEs. Two of them stand out with high flow deviations varying from 11 % to 22 %. This is a cut between Fardal and Aurland, and is shown with CNE 60400 in Table 6.7. The location in the middle of NO5 makes it challenging to predict the flow on this line. The line connects two, at times, very different profiles. Production dominates east of the CNE, while the western part can vary between surplus and large deficit. The production strategies provide the best results for this CNE, which can be explained similarly to CNE 31550: It is the production units that will change most due to a change in the net position.

The CNEs in the Swedish areas are not as hard to predict as some of the Norwegian CNEs. Only a few CNEs in each area stand out with large flow deviations. The maximum flow deviation of the worst CNE is approximately 14 %. This is CNE 40701 in SE1, which is a cut between SE2 and NO4 called Røssåga. There is no evident cause why this CNE is bad, but it is a weak connection (220 kV) in an area of 420 kV lines and several 300 kV lines.

In general, the Swedish areas experience high benefits from applying the optimal GSK strategy on each CNE. Consider for instance CNE 30801 in SE1, which improves from 13,59 % to 6,05 % by using the optimal strategy. Also SE3 has some bad CNEs where the choice of GSK strategy is especially important. As seen in Table 6.2, SE3 is the area that improves most by using the optimal GSK strategy of each CNE. In other words, SE3 is sensitive to the GSK strategy that is applied. For instance, the worst CNE in SE3 is CNE 30150 with the highest flow deviation at 14,02 %. If one applies the optimal strategy, the flow deviation decreases to 3,24 %. The best strategy for this CNE is GSK 5 weighting according to actual production. GSK 2 stands out as the definite worst strategy. There is no evident reason why GSK 2 performs so bad for this CNE. It could be caused by the line being located close to a power plant, such that it is affected by the plants' behavior. However, this should be studied further to be able to say this for certain.

Finland is a rather good area, considering the flow deviation of each CNE. The bidding areas in Denmark experience more variations, which reflects the somewhat large flow deviation at the area level, see Table 6.5. Generally, the flow deviations of the CNEs in Denmark are fine, but there are also several bad CNEs. Sufficient information about the grid in Denmark was not available, which made it hard to explain the underlying causes of the results. The complete results for the individual CNEs are provided in Appendix D.

The standard deviation for the CNEs discussed in this section is presented in Table 6.8.

CNEnr	Area	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8
60850	NO4	38,70 %	37,38 %	37,64 %	41,49 %	38,70 %	36,51 %	34,99 %	56,35 %
31550	NO4	11,57 %	9,87 %	10,24 %	10,36 %	11,57 %	13,64 %	20,11 %	17,25 %
60400	NO5	9,73 %	15,33 %	10,12 %	13,58 %	9,73 %	11,56 %	19,28 %	16,17 %
40701	SE1	8,20 %	11,70 %	9,20 %	9,89 %	8,20 %	7,94 %	8,56 %	10,60 %
31801	SE1	5,41 %	7,02 %	5,74 %	8,73 %	5,41 %	7,23 %	10,68 %	12,75 %
30150	SE3	2,27 %	10,30 %	2,56 %	5,00 %	2,27 %	2,95 %	4,11 %	3,87 %

Table 6.8: Standard deviation of some CNEs for each GSK strategy

The standard deviation helps to verify the results in Table 6.7. CNE 60850 has a large standard deviation, which means that the flow deviation of this CNE varies a lot from hour to hour. Regardless of the strategy, the standard deviation is large. The standard deviation of CNE 31550 is smallest for GSK 2, even though the best strategy for this CNE is GSK 4. The same can be seen for CNE 40701. The difference is however minimal. In general, the GSK strategies providing the largest flow deviations are also the ones with the most varying results. Correspondingly, the good strategies experience small standard deviations.

6.6 High load and low load

In addition to the three levels of detail, another approach has been evaluated. So far, all hours have been considered. However, there might be differences throughout a day, which can influence the performance of the GSK strategies. Therefore, the day has been divided into high load hours and low load hours. Data from Nord Pool Spot was used to create a consumption profile for the Nordic area. Based on this consumption profile, the high load hours for weekdays were chosen from 07.00-17.00, while the high load hours in the weekend were defined from 10.00-19.00. In general, the operation of the power system deviates between high load and low load. There is more export during the day and less export, or even import, at night. However, in this period in January there was much water, leading to generally large export both day and night.

Table 6.9 shows the final results including the results for the high load and low load hours. The values are extracted from Table 7 and Table 8 in Appendix C. The upper section contains the results of the global level. The minimum flow deviation is 6,37 % for the high load hours. Compared to the deviation of all hours (6,46 %), the improvement is 1,39 %. The low load hours have a minimum flow deviation of 6,52 %, which is 0,93 % worse than for all hours.

	Global						
	All hours			High load		Low load	
	Minimum	Opt. GSK each area	Improvement	Minimum	Improvement	Minimum	Improvement
All CNEs	6,46 %	6,09 %	5,73 %	6,37 %	1,39 %	6,52 %	-0,93 %

	Area						
	All hours			High load		Low load	
	Minimum	Opt. GSK each CNE	Improvement	Minimum	Improvement	Minimum	Improvement
NO1	2,51 %	2,34 %	6,77 %	2,42 %	3,59 %	2,58 %	-2,79 %
NO2	6,05 %	5,93 %	1,98 %	6,14 %	-1,49 %	5,98 %	1,16 %
NO3	2,94 %	2,77 %	5,78 %	2,80 %	4,76 %	3,06 %	-4,08 %
NO4	11,20 %	10,36 %	7,50 %	11,34 %	-1,25 %	11,06 %	1,25 %
NO5	8,45 %	8,22 %	2,72 %	8,19 %	3,08 %	8,66 %	-2,49 %
SE1	7,03 %	6,58 %	6,40 %	7,71 %	-9,67 %	6,40 %	8,96 %
SE2	4,94 %	4,56 %	7,69 %	5,00 %	-1,21 %	4,88 %	1,21 %
SE3	4,17 %	3,41 %	18,23 %	4,25 %	-1,92 %	4,08 %	2,16 %
SE4	2,44 %	2,12 %	13,11 %	2,24 %	8,20 %	2,59 %	-6,15 %
DK2	6,23 %	6,13 %	1,61 %	6,08 %	2,41 %	6,36 %	-2,09 %
FIN	3,74 %	3,74 %	0,00 %	3,90 %	-4,28 %	3,61 %	3,48 %
DK1	6,76 %	6,12 %	9,47 %	6,81 %	-0,74 %	6,72 %	0,59 %
All CNEs	6,46 %	5,67 %	12,23 %				

Table 6.9: Final results for all hours, high load hours and low load hours

The same is done for the area level. The minimum flow deviation of each area is listed in the "Minimum" columns, and compared to the minimum flow deviation of all hours. For both low load hours and high load hours, there are variations in whether the areas improve or not. In fact, if an area improves its minimum flow deviation using the high load hours, the area will correspondingly worsen the flow deviation using the load low hours. Areas with improved flow deviation in high load hours are NO1, NO3, NO5, SE4 and DK2. SE4 improves most with 8,20 %. All of these areas can be considered as consumption areas, with one exception. NO5 has much production, but can, at times, experience much load in the western part of the area. However, with the possible exception of NO5, it seems that areas with much load are better predicted in high load hours. They are, correspondingly, not improving in the low load hours. The other areas - NO2, NO4, SE1, SE2, SE3, FIN and DK1 – behave oppositely. They experience reduced flow deviations in low load hours, and higher flow deviations in high load hours.

Generally, the flow deviations of high load hours are a notch higher than the flow deviations of low load hours. The net position one tries to estimate is probably further away in high load hours than low load hours. In other words, the low load hours are more similar to each other, than the high load hours.

SE1 is the area experiencing the largest change, with -9,67 % for high load hours, and 8,96 % for low load hours. SE1 is, as mentioned, an area with many large hydropower plants. DK1 and DK2 don't seem to change much either way. One explanation can be the large amount of wind power in the areas, which will produce regardless of when the consumption is peaking.

Comparing Table 6.5 with the results from the high and low load hours in Table 7 and Table 8 in Appendix C, one can observe that there are small differences regarding which GSK strategy that is best and worst. There are some deviations, but the same overall conclusions apply with the high and low load results as with all hours. GSK 6 is the best, followed by GSK 3, while GSK 7 and 8 are the worst. GSK 4 has changed slightly. It performs better in high load hours, and worse in low load hours.

7 of 12 areas have the same best and worst strategy for high load and low load hours, as they previously had for all hours. Of the ones changing strategy, NO4, SE1 and SE3 change only the strategy that is best, while FIN changes the worst strategy. SE4 is the area that changes most due to high and low load hours. Previously, GSK 6 was the best strategy in SE4 and GSK 4 was the worst. In high load hours the worst strategy is changed to GSK 2. In low load hours the best strategy is changed to GSK 7.

Although some of the areas change the best and/or worst strategies when looking at high load and low load hours, the differences in the flow deviations are minimal. Using the optimal strategies previously seen for all hours would not be bad strategies for high load hours or low load hours, either.

6.7 Simplifications and limitations

The goal of this thesis was to develop a method that enabled a comparison of the different GSK strategies considered for the Nordic power market. Although this has been done through the work of this thesis, it serves as an initial attempt of developing a method. With this in mind, there will most certainly be ways of improving the method. However, the work of this thesis can serve as a starting point for developing a solid and general method to compare GSK strategies.

The fact that the analysis is based on only ten days of data naturally limits the validity of any conclusion drawn. Seasonal variations will probably influence the results. In order to draw general conclusions a larger number of hours should be used. Simulations of a year will provide more solid conclusions. At the time of this study, operational data for these ten days in January was the ones available. Still, the work of this thesis provides an indication of the behavior of the GSK strategies, and can serve as a starting point for analyzing a larger amount of hours.

When running the scripts in VBA, one experienced that the ten days provided were somewhat unfortunate, due to 1st of January being a holiday. During the work, it was also discovered that GSK 1 was not correct, which limited the analysis.

There are also some limitations regarding the files with the operational data. In the operational files from PowerWorld there are some hours that just don't exist. In such situations, the VBA script skips those hours. Out of the ten days of data used in this thesis, there are 16 hours that don't exist. Additionally, the operational files are from an early stage. It has recently been discovered some weaknesses in the files regarding the definitions of some of the CNEs. Due to lack of time before due date of this thesis, it was decided not to rerun the calculations.

In the data files, there are several CNEs that are unnecessary to include in the calculations. These are removed by the VBA-script in advance of the flow calculations. This regards the following CNEs.

- CNEs with CNE number below 10000 are not limiting. They are automatically generated between areas for monitoring.
- CNE 89182 and 89213. They belong to area 95, which is a fictive area.
- CNEs with capacity equal to 9999 MW. For these CNEs, the flow is only relevant in one direction. This is automatically handled in the Power World files by setting the capacity artificially high when a direction is not relevant. Thus, it will never be constraining.

Chapter 7

Conclusion and further work

Flow based market coupling provides a better solution to the market optimization problem than the current NTC method. By including a grid model in the market clearing, it accounts for the real physical flows in the power system. FBMC is a better congestion management method than NTC, since it has no evident disadvantages and provides increased social welfare.

One of the flow-based parameters, the Power Transfer Distribution Factors (PTDFs), describes how a power transfer between two nodes in the system influences the flow on a line. In order to use the PTDFs in an area based power market, they have to be aggregated from node-to-line PTDFs into equivalent area-to-CNE PTDFs. This can be achieved by applying a generation shift key (GSK) strategy. A GSK defines how a change in an areas' net position is divided on the nodes within that area.

Prior to the market clearing it is not known how the change in an areas' net position will divide on the nodes within the area. A GSK attempts to estimate how the change in net position will influence the nodes. At the time being, there is no straightforward way on how to do this. Thus, there have been developed several different GSK strategies, and the question is how to find the optimal GSK strategy. The optimal GSK strategy is the one that most correctly estimates how the change in net position will influence the nodes in the area, resulting in the smallest flow deviation. In order to estimate the flow, one has used a linear approximation of how the flow changes as a function of net position.

The goal of this thesis has been to develop a method that enables us to compare the different GSK strategies. The estimated power flow is compared to the real power flow, resulting in a flow deviation. The method in this thesis is based on an analysis of the flow deviations of the different GSK strategies. The calculations were done for ten days in January 2015.

7.1 Summary of results

The results showed that it is beneficial to use the optimal strategy of each area, rather than the same GSK strategy in the whole Nordic region. This reduced the flow deviations. Similarly, the flow deviation was further reduced when applying the optimal strategy of each CNE within the areas. The improvement of using the optimal strategies was found to be 12,23 %. Thus, one may conclude that **it is beneficial to apply different GSK strategies for each area and for each CNE.** SE3 and SE4 were the areas that benefited most when optimizing the strategy of each CNE, with an improvement of 18,23 % and 13,11 %, respectively.

Applying the same GSK strategy on all CNEs showed that GSK 3 and 8 were the best strategies, while GSK 7 was the worst strategy. Sorting the CNEs into areas changed the results; GSK 6 turned out to be the best strategy, followed by GSK 3 and GSK 5. GSK 6 is the only strategy weighting according to both load and production, thus it is reasonable that this strategy will provide a good estimation of the flow deviation in many areas. GSK 7 and GSK 8, the strategies weighting according to load, were generally bad. Some areas experienced larger flow deviations than others, which likely is caused by certain CNEs within the area that are challenging to predict. Investigation of each CNE revealed that some CNEs had very large deviations.

Another approach was to divide the hours into high load hours and low load hours. The results showed that there were only minor differences as to how the GSK strategies performed. The best and worst strategies for all hours were the best and worst strategies when considering high load hours or low load hours, with a few exceptions. It was a tendency that areas with much load were better predicted in the high load hours, i.e. the flow deviation was reduced. Correspondingly, the flow deviation of these areas increased in low load hours.

Although the results of this thesis might not have been as evident as one hoped, they clearly indicate that applying GSK strategies for each area or each CNE is beneficial. Additionally, the analysis enables us to get an idea of the behavior of the different GSK strategies. The work of this thesis can serve as a starting point for developing a solid and general method to compare GSK strategies.

7.2 Further work

As this study is based on ten days of operational data, it is evident that this limits the validity of the conclusions drawn. For future work, it is recommended to perform similar calculations using a greater amount of hours. Further development of the model is possible, and one of the tasks can be to include GSK 1 in a proper way. It would also be interesting to further investigate the use of GSK strategies according to high load and low load.

Bibliography

[1] "An overview of the Nordic electricity market." http://www.nordicenergyregulators.org/about-nordreg/an-overview-of-the-nordic-electricity-market/. April 2015.

[2] http://www.nordpoolspot.com/About-us/History/. March 2015.

[3] http://www.nordpoolspot.com/How-does-it-work/. March 2015.

[4] S. I. Angell and O. A. Brekke in *Frå kraft versus natur til miljøvenleg energi? Norsk vasskraftpolitikk i eit hundreårsperspektiv*, 2011.

[5] I. Wangensteen, *Power System Economics - the Nordic Electricity Market*. Tapir Academic Press, 2nd ed., 2012.

[6] L. Bergman in *The Nordic electricity market*, 2002.

[7] E. C. Stavseth in *The Nordic-Baltic Power Market - why, how and where?*, Nord Pool Spot, presented at the seminar "Market Operations in the Nordic Power Market", 2014.

[8] Nord Pool Spot in *How does it work? Explicit and implicit capacity auction.* March 2015.

[9] P. Noury and P. Schavemaker in *CWE Flow-Based Market Coupling: on the Eve of Implementation*, 2012.

[10] http://www.nordpoolspot.com/TAS/Day-ahead-market-Elspot/Price-calculation. April 2015.

[11] Nord Pool Spot in *How to calculate the congestion rent.* April 2015.

[12] Nord Pool Spot in *The Nordic electricity exchange and the Nordic model for a liberalized electricity market.* April 2015.

[13] ENTSO-E in *Principles for determining the transfer capacities in the Nordic power market*, 2015.

[14] ENTSO-E in *System Operation Agreement*, 2014.

[15] H. S. Goldstein, “Flow Based Market Clearing in a Nordic context,” Master’s thesis, NTNU, 2012.

[16] I. Wangensteen, A. Botterud, and N. Flatabø in *Power System Planning and Operation in International Markets—Perspectives From the Nordic Region and Europe*, 2005.

[17] N. Ræder in *Hva er, hvorfor vil vi ha, og hvordan kan vi innføre flytbasert markedskobling i Norden?*, "Faglunsj med Ung i Statnett", 2013.

[18] Statnett SF in *Økt handel og bedre nettutnyttelse - Bidrag til norsk verdiskaping*, 2013.

[19] EnerginetDK, Svenska Kraftnät, Fingrid and Statnett SF in *Methodology and concepts for the Nordic Flow-Based Market Coupling Approach*, 2014.

[20] A. Helseth in *Flow-based vs ATC market coupling in the Nordic Power Market, Method and Simulation results*, Sintef Energi, 2013.

[21] http://www.epexspot.com/en/press-media/press/details/press/FLOW-BASED_METHODOLOGY_FOR_CWE_MARKET_COUPLING_SUCCESSFULLY_LAUNCHED. May 2015.

[22] Daniel Stølsbotn, “Flow Based Market Coupling,” Master’s thesis, NTNU, 2015.

[23] TSOs in CWE in *Documentation of the CWE FB MC solution - As basis for the formal approval-request*, 2013.

[24] http://www.powerworld.com/WebHelp/Content/html/Power_Transfer_Distribution_Factors.htm. May 2015.

[25] Handouts from supervisor. *Power flow and Power Transfer Distribution Factors.*

[26] P. Schavemaker in *Annex 16.2, Educational example: "How does Flow Based capacity calculation work?"*, 2014.

[27] Johan Setréus, Svenska Kraftnät in *Flow Reliability Margin design*, Draft from Feb 2nd, 2015, 2015.

Appendix

A Results from method 1

This appendix contains the results obtained when using Method 1 (as explained in Chapter 5).

A.1 Global level

	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8
All CNEs	4,84 %	5,07 %	4,70 %	4,84 %	4,84 %	4,70 %	5,10 %	4,77 %

Table 1: Absolute flow deviation of all CNEs for each GSK strategy

A.2 Area level

Area	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8
NO1	2,54 %	2,43 %	2,47 %	2,61 %	2,54 %	2,42 %	2,51 %	2,65 %
NO2	5,73 %	6,31 %	5,81 %	7,53 %	5,73 %	6,34 %	7,52 %	7,44 %
NO3	2,78 %	2,97 %	2,79 %	2,88 %	2,78 %	2,47 %	2,55 %	2,88 %
NO4	7,97 %	9,54 %	8,35 %	8,85 %	7,97 %	8,06 %	8,97 %	10,51 %
NO5	7,98 %	8,84 %	7,98 %	8,65 %	7,98 %	8,35 %	10,41 %	9,61 %
SE1	6,89 %	6,93 %	6,74 %	7,34 %	6,89 %	6,89 %	7,61 %	8,21 %
SE2	4,29 %	5,52 %	4,22 %	4,64 %	4,29 %	4,03 %	4,25 %	4,77 %
SE3	4,37 %	4,85 %	4,14 %	3,99 %	4,37 %	3,69 %	3,91 %	3,74 %
SE4	2,75 %	3,14 %	2,78 %	3,42 %	2,75 %	2,53 %	2,59 %	2,81 %
DK2	5,07 %	4,45 %	4,48 %	4,01 %	5,07 %	4,91 %	5,01 %	4,13 %
FIN	4,30 %	4,52 %	4,41 %	4,67 %	4,30 %	4,38 %	4,54 %	4,70 %
DK1	6,03 %	6,61 %	6,19 %	6,65 %	6,03 %	6,19 %	7,06 %	6,26 %

Table 2: Absolute flow deviation of each area and GSK strategy

B Best and worst strategy

Appendix B contains the results from counting the number of hours each strategy is best or worst.

B.1 Global level

	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8
All CNEs	40	11	15	33	40	24	3	37

Table 3: Number of hours each strategy is best

	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8
All CNEs	37	16	0	29	37	0	77	4

Table 4: Number of hours each strategy is worst

B.2 Area level

Area	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8
NO1	5	52	9	22	5	35	26	14
NO2	83	38	8	8	83	0	19	7
NO3	33	17	12	11	33	22	50	18
NO4	40	31	8	12	40	20	40	12
NO5	48	61	13	5	48	8	17	11
SE1	45	31	8	30	45	9	31	9
SE2	27	12	12	29	27	35	25	23
SE3	22	7	17	14	22	34	26	43
SE4	21	30	12	42	21	7	20	31
DK2	15	5	3	103	15	3	24	10
FIN	19	28	7	41	19	20	42	6
DK1	64	39	4	8	64	8	14	26

Table 5: Number of hours each strategy is best

Area	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8
NO1	32	16	3	45	32	1	14	52
NO2	38	16	0	30	38	0	69	10
NO3	65	40	1	6	65	1	29	21
NO4	32	22	0	2	32	0	38	69
NO5	28	13	1	0	28	0	118	3
SE1	18	52	0	12	18	1	19	61
SE2	26	79	1	11	26	0	13	33
SE3	43	89	5	9	43	0	14	3
SE4	13	68	1	66	13	0	7	8
DK2	58	0	0	38	58	0	67	0
FIN	2	8	0	60	2	1	47	45
DK1	26	27	1	21	26	0	82	6

Table 6: Number of hours each strategy is worst

C High and low load hours

This appendix shows the results when using high load hours and low load hours.

C.1 High load hours

	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8
All CNEs	6,71 %	6,73 %	6,39 %	6,41 %	6,71 %	6,58 %	7,06 %	6,37 %

Area	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8
NO1	2,61 %	2,42 %	2,53 %	2,62 %	2,61 %	2,44 %	2,55 %	2,71 %
NO2	6,14 %	6,62 %	6,20 %	7,79 %	6,14 %	6,73 %	7,97 %	7,78 %
NO3	3,24 %	3,35 %	3,19 %	3,09 %	3,24 %	2,80 %	2,94 %	3,16 %
NO4	11,34 %	12,05 %	11,42 %	11,92 %	11,34 %	11,70 %	14,08 %	15,49 %
NO5	8,19 %	9,55 %	8,23 %	9,27 %	8,19 %	8,65 %	12,37 %	11,32 %
SE1	7,78 %	8,14 %	7,78 %	8,05 %	7,78 %	7,71 %	8,52 %	9,05 %
SE2	5,29 %	6,55 %	5,28 %	5,47 %	5,29 %	5,00 %	5,06 %	5,34 %
SE3	4,83 %	6,11 %	4,64 %	4,55 %	4,83 %	4,28 %	4,54 %	4,25 %
SE4	2,73 %	3,21 %	2,77 %	2,86 %	2,73 %	2,24 %	2,30 %	2,37 %
DK2	7,80 %	6,78 %	6,86 %	6,08 %	7,80 %	7,50 %	7,49 %	6,28 %
FIN	3,90 %	3,98 %	3,93 %	4,09 %	3,90 %	4,03 %	4,27 %	4,42 %
DK1	6,81 %	7,18 %	6,81 %	7,33 %	6,81 %	6,88 %	7,68 %	6,90 %

Table 7: Relative flow deviation for all CNEs and areas for high load hours

C.2 Low load hours

	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8
All CNEs	6,85 %	6,85 %	6,52 %	6,65 %	6,85 %	6,76 %	7,36 %	6,54 %

Area	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8
NO1	2,77 %	2,58 %	2,68 %	2,91 %	2,77 %	2,58 %	2,70 %	2,98 %
NO2	5,98 %	6,70 %	6,09 %	7,77 %	5,98 %	6,61 %	7,80 %	7,75 %
NO3	3,24 %	3,56 %	3,27 %	3,40 %	3,24 %	3,06 %	3,22 %	3,42 %
NO4	11,09 %	12,00 %	11,06 %	11,73 %	11,09 %	11,17 %	12,74 %	15,02 %
NO5	8,66 %	10,71 %	8,90 %	10,42 %	8,66 %	9,80 %	13,64 %	12,02 %
SE1	6,60 %	6,57 %	6,40 %	7,09 %	6,60 %	6,49 %	6,94 %	7,72 %
SE2	5,16 %	6,27 %	5,08 %	5,72 %	5,16 %	4,88 %	5,29 %	6,02 %
SE3	4,72 %	5,17 %	4,49 %	4,50 %	4,72 %	4,08 %	4,37 %	4,28 %
SE4	2,81 %	2,99 %	2,81 %	3,60 %	2,81 %	2,61 %	2,59 %	2,83 %
DK2	8,46 %	7,13 %	7,19 %	6,36 %	8,46 %	8,04 %	8,07 %	6,56 %
FIN	3,61 %	3,88 %	3,76 %	4,06 %	3,61 %	3,64 %	3,75 %	3,96 %
DK1	6,72 %	7,48 %	6,97 %	7,64 %	6,72 %	6,97 %	8,08 %	7,06 %

Table 8: Relative flow deviation for all CNEs and areas for low load hours

D Results of individual CNEs

This appendix contains the results of each CNE within the bidding areas in the Nordic area. The tables provide the relative flow deviation of each CNE for all GSK strategies. The column to the right displays the maximum flow deviation of each CNE. Note that the tables of DK1 and DK2 don't contain all the CNEs of the areas. However, the CNEs that are listed reflect the behavior of several CNEs with the same behavior, that is, same flow deviation and same capacity. Still, when calculating how the optimal strategy of the Danish CNEs improves the deviation on the area level and the global level, all CNEs are accounted for.

D.1 Norwegian bidding areas

CNEnr	CNE name	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8	Max
50001	NO1 CB:420 Tegneby - 420 Sylling CO: 420 Hasle - 420 Evje: RD	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %
50003	NO1 CB:420 Tegneby - 420 Sylling CO: 420 Frogner - 420 ≈dal: RD	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %
50050	NO1 CB:420 Hasle - 420 Tegneby CO:420 Hasle - 420 Evje: FD	0,94 %	0,99 %	0,94 %	0,92 %	0,94 %	1,05 %	1,14 %	1,12 %	1,14 %
50051	NO1 CB:420 Hasle - 420 Tegneby CO: 420 Hasle - 420 Evje: RD	0,94 %	0,99 %	0,94 %	0,92 %	0,94 %	1,05 %	1,14 %	1,12 %	1,14 %
50100	NO1 CB:420 Hasle - 420 Evje CO:420 Hasle - 420 Tegneby: FD	0,96 %	0,89 %	0,92 %	1,16 %	0,96 %	0,86 %	0,83 %	0,94 %	1,16 %
50101	NO1 CB:420 Hasle - 420 Evje CO: 420 Hasle - 420 Tegneby: RD	0,96 %	0,89 %	0,92 %	1,16 %	0,96 %	0,86 %	0,83 %	0,94 %	1,16 %
50102	NO1 CB:420 Hasle - 420 Evje CO:420 Rjukan - 420 Sylling: FD	0,96 %	0,89 %	0,92 %	1,16 %	0,96 %	0,86 %	0,83 %	0,94 %	1,16 %
50103	NO1 CB:420 Hasle - 420 Evje CO: 420 Rjukan - 420 Sylling: RD	0,96 %	0,89 %	0,92 %	1,16 %	0,96 %	0,86 %	0,83 %	0,94 %	1,16 %
50104	NO1 CB:420 Hasle - 420 Evje CO:420 Tegneby - 420 Sylling: FD	0,96 %	0,89 %	0,92 %	1,16 %	0,96 %	0,86 %	0,83 %	0,94 %	1,16 %
50105	NO1 CB:420 Hasle - 420 Evje CO: 420 Tegneby - 420 Sylling: RD	0,96 %	0,89 %	0,92 %	1,16 %	0,96 %	0,86 %	0,83 %	0,94 %	1,16 %
50150	NO1 CB:300 ÿ. Vinstra - 300 FÂberg CO:420 Nea - 420 HˆgÂsen: FD	3,86 %	3,59 %	3,82 %	2,97 %	3,86 %	2,93 %	2,82 %	3,33 %	3,86 %
50400	NO1 CB:300 Flesaker - 300 Sylling CO:420 Hasle - 420 Tegneby: FD	3,49 %	3,06 %	3,35 %	3,85 %	3,49 %	3,77 %	4,22 %	5,19 %	5,19 %
50401	NO1 CB:300 Flesaker - 300 Sylling CO: 420 Hasle - 420 Tegneby: RD	3,49 %	3,06 %	3,35 %	3,85 %	3,49 %	3,77 %	4,22 %	5,19 %	5,19 %
50450	NO1 CB:300 Flesaker - 300 Sylling CO:300 Flesaker - 300 Tegneby: FD	2,97 %	2,25 %	2,76 %	2,67 %	2,97 %	2,91 %	2,98 %	3,84 %	3,84 %
50451	NO1 CB:300 Flesaker - 300 Sylling CO: 300 Flesaker - 300 Tegneby: RD	2,97 %	2,25 %	2,76 %	2,67 %	2,97 %	2,91 %	2,98 %	3,84 %	3,84 %
50500	NO1 CB:300 Flesaker - 300 Tegneby CO:300 Flesaker - 300 Sylling: FD	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %
50550	NO1 CB:300 Flesaker - 300 Tegneby CO:420 Hasle - 420 Evje: FD	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %
50700	NO1 CB:300 Hamang - 300 BÊrum CO:420 Tegneby - 420 Sylling: FD	1,30 %	1,17 %	1,20 %	1,64 %	1,30 %	0,91 %	0,71 %	0,76 %	1,64 %
50701	NO1 CB:300 Hamang - 300 BÊrum CO: 420 Tegneby - 420 Sylling: RD	1,30 %	1,17 %	1,20 %	1,64 %	1,30 %	0,91 %	0,71 %	0,76 %	1,64 %
50750	NO1 CB:300 Hamang - 300 BÊrum CO:420 Frogner - 420 ≈dal: FD	6,36 %	6,34 %	6,31 %	6,58 %	6,36 %	6,06 %	5,98 %	6,05 %	6,58 %
50751	NO1 CB:300 Hamang - 300 BÊrum CO: 420 Frogner - 420 ≈dal: RD	6,36 %	6,34 %	6,31 %	6,58 %	6,36 %	6,06 %	5,98 %	6,05 %	6,58 %
50801	NO1 CB:420 Frogner - 420 ≈dal CO: 420 Tegneby - 420 Sylling: RD	12,24 %	12,31 %	12,21 %	12,22 %	12,24 %	12,18 %	12,17 %	12,14 %	12,31 %
50850	NO1 CB:300 Hasle - 420 Hasle CO:420 Hasle - 420 Tegneby: FD	2,03 %	2,48 %	2,02 %	3,32 %	2,03 %	2,47 %	3,44 %	3,65 %	3,65 %
50900	NO1 CB:300 Flesaker - 300 Hof CO:420 Hasle - 420 Evje: FD	2,57 %	2,09 %	2,42 %	3,60 %	2,57 %	2,81 %	5,88 %	8,37 %	8,37 %
51401	NO1 CB:300 Flesaker - 300 Tokke CO: 300 Flesaker - 300 Vemork: RD	4,12 %	2,77 %	3,83 %	2,53 %	4,12 %	2,84 %	2,91 %	3,52 %	4,12 %
60000	NO1 Cut Hasle A: FD	0,99 %	1,01 %	0,96 %	2,00 %	0,99 %	1,01 %	1,59 %	1,94 %	2,00 %
60100	NO1 Cut Hasle C: FD	3,49 %	3,37 %	3,44 %	3,41 %	3,49 %	3,36 %	3,32 %	3,30 %	3,49 %
60150	NO1 Cut Hasle D: FD	3,76 %	3,72 %	3,74 %	3,73 %	3,76 %	3,71 %	3,67 %	3,66 %	3,76 %
60201	NO1 Cut Flesaker A: RD	1,44 %	1,76 %	1,32 %	1,68 %	1,44 %	1,35 %	1,61 %	1,68 %	1,76 %
60250	NO1 Cut Flesaker B: FD	1,31 %	1,26 %	1,18 %	1,47 %	1,31 %	1,17 %	1,38 %	1,68 %	1,68 %
61000	NO1 Cut NO3-NO1 A: FD	4,15 %	4,42 %	4,09 %	4,39 %	4,15 %	3,84 %	3,82 %	3,74 %	4,42 %
61001	NO1 Cut NO3-NO1 A: RD	4,15 %	4,42 %	4,09 %	4,39 %	4,15 %	3,84 %	3,82 %	3,74 %	4,42 %
61050	NO1 Cut NO3-NO1 B: FD	6,71 %	5,74 %	6,54 %	6,78 %	6,71 %	5,91 %	5,65 %	5,56 %	6,78 %
61051	NO1 Cut NO3-NO1 B: RD	6,71 %	5,74 %	6,54 %	6,78 %	6,71 %	5,91 %	5,65 %	5,56 %	6,78 %
61150	NO1 Cut NO1-SE3: FD	2,33 %	1,41 %	2,02 %	1,92 %	2,33 %	1,55 %	1,21 %	1,24 %	2,33 %
61151	NO1 Cut NO1-SE3: RD	1,82 %	1,10 %	1,58 %	1,50 %	1,82 %	1,21 %	0,95 %	0,97 %	1,82 %
61200	NO1 Cut NO5-NO1: FD	4,30 %	4,31 %	4,27 %	4,20 %	4,30 %	4,23 %	4,30 %	4,24 %	4,31 %
61201	NO1 Cut NO5-NO1: RD	4,30 %	4,31 %	4,27 %	4,20 %	4,30 %	4,23 %	4,30 %	4,24 %	4,31 %
61250	NO1 Cut NO1-NO2: FD	0,84 %	0,81 %	0,75 %	0,93 %	0,84 %	0,74 %	0,88 %	1,06 %	1,06 %
61251	NO1 Cut NO1-NO2: RD	0,84 %	0,81 %	0,75 %	0,93 %	0,84 %	0,74 %	0,88 %	1,06 %	1,06 %

Table 9: Relative flow deviation of the CNEs in NO1

CNEnr	CNE name	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8	Max
50600	NO2 CB:300 T_Sundsbarm - 300 R¯d CO:420 R¯d - 420 Holen: FD	2,71 %	2,26 %	2,57 %	3,50 %	2,71 %	2,72 %	4,38 %	4,92 %	4,92 %
50602	NO2 CB:300 T_Sundsbarm - 300 R¯d CO:300 Flesaker - 300 Tokke: FD	2,71 %	2,26 %	2,57 %	3,50 %	2,71 %	2,72 %	4,38 %	4,92 %	4,92 %
50650	NO2 CB:300 T_Sundsbarm - 300 R¯d CO:300 Flesaker - 300 Vemork: FD	3,79 %	2,67 %	3,51 %	3,01 %	3,79 %	2,87 %	3,77 %	4,29 %	4,29 %
50950	NO2 CB:300 T_Tj¯rhom - 300 Lyse CO:420 Arendal - 420 Bamble: FD	6,39 %	7,40 %	6,57 %	7,73 %	6,39 %	6,85 %	7,49 %	7,34 %	7,73 %
51000	NO2 CB:300 Lyse - 300 Duge CO:420 Kristiansand - 420 Brokke: FD	5,25 %	5,76 %	5,35 %	6,41 %	5,25 %	5,59 %	6,03 %	6,12 %	6,41 %
51002	NO2 CB:300 Lyse - 300 Duge CO:420 Holen - 420 Brokke: FD	5,25 %	5,76 %	5,35 %	6,41 %	5,25 %	5,59 %	6,03 %	6,12 %	6,41 %
51004	NO2 CB:300 Lyse - 300 Duge CO:300 Tonstad - 300 T_Tj¯rhom: FD	5,25 %	5,76 %	5,35 %	6,41 %	5,25 %	5,59 %	6,03 %	6,12 %	6,41 %
51051	NO2 CB:300 Tonstad - 300 T_Tj¯rhom CO: 420 Holen - 420 Brokke: RD	9,34 %	10,89 %	9,60 %	11,46 %	9,34 %	10,19 %	11,40 %	11,19 %	11,46 %
51053	NO2 CB:300 Tonstad - 300 T_Tj¯rhom CO: 300 Solhom - 300 Tonstad: RD	9,34 %	10,89 %	9,60 %	11,46 %	9,34 %	10,19 %	11,40 %	11,19 %	11,46 %
51101	NO2 CB:300 Tonstad - 300 T_Tj¯rhom CO: 420 Kristiansand - 420 Brokke: RD	9,27 %	10,46 %	9,46 %	11,30 %	9,27 %	10,17 %	11,47 %	11,20 %	11,47 %
51103	NO2 CB:300 Tonstad - 300 T_Tj¯rhom CO: 300 Kvinen - 300 Solhom: RD	9,27 %	10,46 %	9,46 %	11,30 %	9,27 %	10,17 %	11,47 %	11,20 %	11,47 %
51150	NO2 CB:300 R¯d - 300 Porsgrunn CO:420 R¯d - 420 Grenland: FD	2,41 %	3,20 %	2,51 %	6,24 %	2,41 %	3,63 %	5,62 %	4,98 %	6,24 %
51200	NO2 CB:300 Kvinen - 300 Solhom CO:300 Tonstad - 300 T_Tj¯rhom: FD	7,39 %	8,45 %	7,58 %	9,16 %	7,39 %	8,25 %	9,39 %	9,41 %	9,41 %
51250	NO2 CB:300 Solhom - 300 Tonstad CO:300 Tonstad - 300 T_Tj¯rhom: FD	13,10 %	14,96 %	13,43 %	14,00 %	13,10 %	13,86 %	15,13 %	14,30 %	15,13 %
51300	NO2 CB:300 Tonstad - 300 Feda (2) CO:300 Tonstad - 300 Feda: FD	3,16 %	3,16 %	3,10 %	6,30 %	3,16 %	4,55 %	6,60 %	6,02 %	6,60 %
51350	NO2 CB:300 Tonstad - 300 Feda CO:300 Tonstad - 300 Feda (2): FD	3,65 %	3,64 %	3,58 %	7,30 %	3,65 %	5,26 %	7,64 %	6,96 %	7,64 %
60350	NO2 Cut S¯rlandet: FD	4,63 %	5,36 %	4,75 %	6,77 %	4,63 %	5,06 %	5,65 %	5,75 %	6,77 %

CNEnr	CNE name	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8	Max
50300	NO3 CB:300 Verdal - 300 Tunnsj¯dal CO:300 Namsos - 300 Tunnsj¯dal: FD	2,71 %	2,83 %	2,60 %	2,50 %	2,71 %	2,36 %	2,21 %	2,77 %	2,83 %
50301	NO3 CB:300 Verdal - 300 Tunnsj¯dal CO: 300 Namsos - 300 Tunnsj¯dal: RD	2,71 %	2,83 %	2,60 %	2,50 %	2,71 %	2,36 %	2,21 %	2,77 %	2,83 %
60450	NO3 Cut Midt A: FD	5,97 %	7,35 %	6,45 %	6,49 %	5,97 %	5,62 %	5,83 %	6,50 %	7,35 %
60500	NO3 Cut Midt B: FD	2,90 %	2,91 %	2,78 %	2,61 %	2,90 %	2,54 %	2,83 %	3,16 %	3,16 %
60550	NO3 Cut Midt C: FD	4,73 %	4,34 %	4,34 %	4,21 %	4,73 %	4,57 %	5,38 %	4,05 %	5,38 %
60551	NO3 Cut Midt C: RD	2,76 %	2,53 %	2,53 %	2,46 %	2,76 %	2,66 %	3,14 %	2,36 %	3,14 %
61100	NO3 Cut NO3-SE2: FD	2,07 %	2,46 %	2,29 %	2,66 %	2,07 %	1,71 %	1,59 %	2,39 %	2,66 %
61101	NO3 Cut NO3-SE2: RD	2,07 %	2,46 %	2,29 %	2,66 %	2,07 %	1,71 %	1,59 %	2,39 %	2,66 %

Table 10: Relative flow deviation of the CNEs in NO2 and NO3

CNEnr	CNE name	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8	Max
31550	NO4 CB:135 SILD - 135 PT95 CO:400 PK1 - 400 PK52: FD	13,05 %	12,04 %	11,91 %	11,84 %	13,05 %	14,53 %	21,28 %	18,32 %	21,28 %
31551	NO4 CB:135 SILD - 135 PT95 CO: 400 PK1 - 400 PK52: RD	12,91 %	11,91 %	11,79 %	11,72 %	12,91 %	14,38 %	21,05 %	18,13 %	21,05 %
31552	NO4 CB:135 SILD - 135 PT95 CO:400 PK51 - 400 PK52: FD	13,05 %	12,04 %	11,91 %	11,84 %	13,05 %	14,53 %	21,28 %	18,32 %	21,28 %
31553	NO4 CB:135 SILD - 135 PT95 CO: 400 PK51 - 400 PK52: RD	12,91 %	11,91 %	11,79 %	11,72 %	12,91 %	14,38 %	21,05 %	18,13 %	21,05 %
31554	NO4 CB:135 SILD - 135 PT95 CO:400 PK51 - 400 OFOTEN: FD	13,05 %	12,04 %	11,91 %	11,84 %	13,05 %	14,53 %	21,28 %	18,32 %	21,28 %
31555	NO4 CB:135 SILD - 135 PT95 CO: 400 PK51 - 400 OFOTEN: RD	12,91 %	11,91 %	11,79 %	11,72 %	12,91 %	14,38 %	21,05 %	18,13 %	21,05 %
50200	NO4 CB:220 N. R¨ssÂga - 220 GeimÂn CO:420 Kobbelv - 420 Ofoten: FD	11,46 %	16,17 %	13,12 %	15,01 %	11,46 %	11,79 %	12,49 %	17,11 %	17,11 %
50250	NO4 CB:220 N. R¨ssÂga - 220 GeimÂn CO:420 Nea - 420 HˆgÂsen: FD	6,77 %	8,26 %	7,40 %	7,49 %	6,77 %	6,26 %	5,99 %	7,43 %	8,26 %
50251	NO4 CB:220 N. R¨ssÂga - 220 GeimÂn CO: 420 Nea - 420 HˆgÂsen: RD	7,53 %	9,18 %	8,22 %	8,33 %	7,53 %	6,95 %	6,66 %	8,25 %	9,18 %
50252	NO4 CB:220 N. R¨ssÂga - 220 GeimÂn CO:420 N.R¨ssoga - 420 Rana: FD	6,77 %	8,26 %	7,40 %	7,49 %	6,77 %	6,26 %	5,99 %	7,43 %	8,26 %
50253	NO4 CB:220 N. R¨ssÂga - 220 GeimÂn CO: 420 N.R¨ssoga - 420 Rana: RD	7,53 %	9,18 %	8,22 %	8,33 %	7,53 %	6,95 %	6,66 %	8,25 %	9,18 %
60600	NO4 Cut Nord A: FD	2,85 %	3,02 %	2,89 %	3,13 %	2,85 %	2,95 %	3,02 %	4,55 %	4,55 %
60650	NO4 Cut Nord B: FD	9,06 %	7,76 %	8,10 %	8,31 %	9,06 %	9,17 %	10,15 %	8,96 %	10,15 %
60700	NO4 Cut Nord C: FD	10,53 %	16,86 %	12,84 %	15,29 %	10,53 %	11,77 %	13,16 %	18,48 %	18,48 %
60750	NO4 Cut Nord D: FD	9,52 %	15,53 %	11,53 %	12,11 %	9,52 %	9,47 %	9,85 %	12,77 %	15,53 %
60800	NO4 Cut NO4-SE1: FD	4,77 %	4,61 %	4,60 %	4,51 %	4,77 %	4,28 %	4,11 %	5,03 %	5,03 %
60801	NO4 Cut NO4-SE1: RD	5,30 %	5,12 %	5,11 %	5,01 %	5,30 %	4,75 %	4,57 %	5,59 %	5,59 %
60850	NO4 Cut NO4-FIN: FD	34,48 %	34,90 %	34,51 %	38,23 %	34,48 %	33,38 %	32,77 %	49,89 %	49,89 %
60851	NO4 Cut NO4-FIN: RD	34,48 %	34,90 %	34,51 %	38,23 %	34,48 %	33,38 %	32,77 %	49,89 %	49,89 %
60900	NO4 Cut NO4-NO3: FD	3,14 %	3,50 %	3,06 %	2,99 %	3,14 %	2,77 %	2,61 %	3,47 %	3,50 %
60901	NO4 Cut NO4-NO3: RD	3,14 %	3,50 %	3,06 %	2,99 %	3,14 %	2,77 %	2,61 %	3,47 %	3,50 %

CNEnr	CNE name	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8	Max
60300	NO5 Cut Hallingdal: FD	7,45 %	7,31 %	7,28 %	7,22 %	7,45 %	7,29 %	7,38 %	7,22 %	7,45 %
60301	NO5 Cut Hallingdal: RD	7,45 %	7,31 %	7,28 %	7,22 %	7,45 %	7,29 %	7,38 %	7,22 %	7,45 %
60400	NO5 Cut FarAur: FD	11,58 %	16,33 %	12,65 %	16,34 %	11,58 %	14,24 %	22,03 %	18,70 %	22,03 %
60401	NO5 Cut FarAur: RD	11,58 %	16,33 %	12,65 %	16,34 %	11,58 %	14,24 %	22,03 %	18,70 %	22,03 %
60950	NO5 Cut NO2-NO5: FD	6,32 %	6,91 %	5,85 %	6,12 %	6,32 %	6,31 %	9,78 %	9,19 %	9,78 %
60951	NO5 Cut NO2-NO5: RD	6,32 %	6,91 %	5,85 %	6,12 %	6,32 %	6,31 %	9,78 %	9,19 %	9,78 %

Table 11: Relative flow deviation of the CNEs in NO4 and NO5

D.2 Swedish bidding areas

CNEnr	CNE name	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8	Max
31750	SE1 CB:400 PK2 - 400 PK1 CO:400 PK1 - 400 NK6: FD	5,32 %	6,18 %	5,28 %	5,83 %	5,32 %	5,12 %	5,59 %	4,96 %	6,18 %
31751	SE1 CB:400 PK2 - 400 PK1 CO: 400 PK1 - 400 NK6: RD	5,32 %	6,18 %	5,28 %	5,83 %	5,32 %	5,12 %	5,59 %	4,96 %	6,18 %
31800	SE1 CB:400 PK46 - 400 UT82 CO:400 PK4 - 400 UT42: FD	4,54 %	5,31 %	4,69 %	6,77 %	4,54 %	5,75 %	8,82 %	10,20 %	10,20 %
31801	SE1 CB:400 PK46 - 400 UT82 CO: 400 PK4 - 400 UT42: RD	6,05 %	7,08 %	6,25 %	9,03 %	6,05 %	7,67 %	11,76 %	13,59 %	13,59 %
31850	SE1 CB:400 PK2 - 400 PK46 CO:400 PK3 - 400 PK4: FD	8,54 %	8,08 %	8,21 %	8,85 %	8,54 %	8,46 %	9,11 %	9,89 %	9,89 %
31851	SE1 CB:400 PK2 - 400 PK46 CO: 400 PK3 - 400 PK4: RD	8,54 %	8,08 %	8,21 %	8,85 %	8,54 %	8,46 %	9,11 %	9,89 %	9,89 %
31852	SE1 CB:400 PK2 - 400 PK46 CO:400 PK3 - 400 NK25: FD	8,54 %	8,08 %	8,21 %	8,85 %	8,54 %	8,46 %	9,11 %	9,89 %	9,89 %
31853	SE1 CB:400 PK2 - 400 PK46 CO: 400 PK3 - 400 NK25: RD	8,54 %	8,08 %	8,21 %	8,85 %	8,54 %	8,46 %	9,11 %	9,89 %	9,89 %
31900	SE1 CB:400 PK3 - 400 PK4 CO:400 PK2 - 400 PK46: FD	9,51 %	8,88 %	9,12 %	9,87 %	9,51 %	9,47 %	10,38 %	11,21 %	11,21 %
31901	SE1 CB:400 PK3 - 400 PK4 CO: 400 PK2 - 400 PK46: RD	9,51 %	8,88 %	9,12 %	9,87 %	9,51 %	9,47 %	10,38 %	11,21 %	11,21 %
31902	SE1 CB:400 PK3 - 400 PK4 CO:400 PK3 - 400 NK25: FD	9,51 %	8,88 %	9,12 %	9,87 %	9,51 %	9,47 %	10,38 %	11,21 %	11,21 %
31903	SE1 CB:400 PK3 - 400 PK4 CO: 400 PK3 - 400 NK25: RD	9,51 %	8,88 %	9,12 %	9,87 %	9,51 %	9,47 %	10,38 %	11,21 %	11,21 %
31950	SE1 CB:400 PK3 - 400 NK25 CO:400 PK3 - 400 PK4: FD	5,89 %	6,17 %	5,83 %	5,77 %	5,89 %	5,59 %	5,14 %	5,27 %	6,17 %
31951	SE1 CB:400 PK3 - 400 NK25 CO: 400 PK3 - 400 PK4: RD	5,89 %	6,17 %	5,83 %	5,77 %	5,89 %	5,59 %	5,14 %	5,27 %	6,17 %
31952	SE1 CB:400 PK3 - 400 NK25 CO:400 PK2 - 400 PK46: FD	5,89 %	6,17 %	5,83 %	5,77 %	5,89 %	5,59 %	5,14 %	5,27 %	6,17 %
31953	SE1 CB:400 PK3 - 400 NK25 CO: 400 PK2 - 400 PK46: RD	5,89 %	6,17 %	5,83 %	5,77 %	5,89 %	5,59 %	5,14 %	5,27 %	6,17 %
40700	SE1 Cut RˆssÂga (SE2>NO4): FD	10,24 %	11,77 %	10,78 %	10,65 %	10,24 %	9,63 %	9,28 %	10,82 %	11,77 %
40701	SE1 Cut RˆssÂga (SE2>NO4): RD	12,28 %	14,12 %	12,94 %	12,78 %	12,28 %	11,56 %	11,14 %	12,99 %	14,12 %
40750	SE1 Cut Ritsem (SE1>NO4): FD	5,72 %	5,46 %	5,32 %	4,78 %	5,72 %	4,65 %	4,83 %	4,89 %	5,72 %
40751	SE1 Cut Ritsem (SE1>NO4): RD	4,90 %	4,68 %	4,56 %	4,10 %	4,90 %	3,99 %	4,14 %	4,19 %	4,90 %
40800	SE1 Cut Finland Norra (SE1>FI): FD	2,88 %	2,94 %	2,90 %	3,31 %	2,88 %	3,10 %	3,73 %	4,65 %	4,65 %
40801	SE1 Cut Finland Norra (SE1>FI): RD	3,93 %	4,02 %	3,95 %	4,52 %	3,93 %	4,22 %	5,08 %	6,34 %	6,34 %

Table 12: Relative flow deviation of the CNEs in SE1

CNEnr	CNE name	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8	Max
30000	SE2 CB:400 IK2 - 400 CT13 CO:400 IK2 - 400 CT72: FD	3,26 %	3,48 %	3,16 %	2,67 %	3,26 %	3,21 %	3,23 %	2,73 %	3,48 %
30001	SE2 CB:400 IK2 - 400 CT13 CO: 400 IK2 - 400 CT72: RD	3,26 %	3,48 %	3,16 %	2,67 %	3,26 %	3,21 %	3,23 %	2,73 %	3,48 %
30002	SE2 CB:400 IK2 - 400 CT13 CO:400 CT72 - 400 RT15: FD	3,26 %	3,48 %	3,16 %	2,67 %	3,26 %	3,21 %	3,23 %	2,73 %	3,48 %
30003	SE2 CB:400 IK2 - 400 CT13 CO: 400 CT72 - 400 RT15: RD	3,26 %	3,48 %	3,16 %	2,67 %	3,26 %	3,21 %	3,23 %	2,73 %	3,48 %
30200	SE2 CB:400 CT269 - 400 CT261 CO:400 IK2 - 400 CT13: FD	3,66 %	4,84 %	3,89 %	5,37 %	3,66 %	3,84 %	3,97 %	4,77 %	5,37 %
30201	SE2 CB:400 CT269 - 400 CT261 CO: 400 IK2 - 400 CT13: RD	3,66 %	4,84 %	3,89 %	5,37 %	3,66 %	3,84 %	3,97 %	4,77 %	5,37 %
30202	SE2 CB:400 CT269 - 400 CT261 CO:400 CT14 - 400 CT13: F	3,66 %	4,84 %	3,89 %	5,37 %	3,66 %	3,84 %	3,97 %	4,77 %	5,37 %
30203	SE2 CB:400 CT269 - 400 CT261 CO: 400 CT14 - 400 CT13:	3,66 %	4,84 %	3,89 %	5,37 %	3,66 %	3,84 %	3,97 %	4,77 %	5,37 %
30450	SE2 CB:400 UT67 - 400 CT22 CO:400 RT16 - 400 OT12: FD	5,00 %	5,96 %	4,85 %	4,67 %	5,00 %	4,64 %	4,54 %	3,61 %	5,96 %
30451	SE2 CB:400 UT67 - 400 CT22 CO: 400 RT16 - 400 OT12: RD	5,00 %	5,96 %	4,85 %	4,67 %	5,00 %	4,64 %	4,54 %	3,61 %	5,96 %
30650	SE2 CB:400 IK2 - 400 CT72 CO:400 UT67 - 400 CT22: FD	3,57 %	3,55 %	2,86 %	2,65 %	3,57 %	2,78 %	2,55 %	1,63 %	3,57 %
30651	SE2 CB:400 IK2 - 400 CT72 CO: 400 UT67 - 400 CT22: RD	3,57 %	3,55 %	2,86 %	2,65 %	3,57 %	2,78 %	2,55 %	1,63 %	3,57 %
30652	SE2 CB:400 IK2 - 400 CT72 CO:400 CT23 - 400 CT22: FD	3,57 %	3,55 %	2,86 %	2,65 %	3,57 %	2,78 %	2,55 %	1,63 %	3,57 %
30653	SE2 CB:400 IK2 - 400 CT72 CO: 400 CT23 - 400 CT22: RD	3,57 %	3,55 %	2,86 %	2,65 %	3,57 %	2,78 %	2,55 %	1,63 %	3,57 %
31450	SE2 CB:400 IK2 - 400 CT91 CO:400 CT90 - 400 IK2_P: FD	6,01 %	7,89 %	5,90 %	6,55 %	6,01 %	5,78 %	6,19 %	7,51 %	7,89 %
31451	SE2 CB:400 IK2 - 400 CT91 CO: 400 CT90 - 400 IK2_P: RD	6,01 %	7,89 %	5,90 %	6,55 %	6,01 %	5,78 %	6,19 %	7,51 %	7,89 %
31452	SE2 CB:400 IK2 - 400 CT91 CO:400 IK2_P - 400 CT269: FD	6,01 %	7,89 %	5,90 %	6,55 %	6,01 %	5,78 %	6,19 %	7,51 %	7,89 %
31453	SE2 CB:400 IK2 - 400 CT91 CO: 400 IK2_P - 400 CT269: RD	6,01 %	7,89 %	5,90 %	6,55 %	6,01 %	5,78 %	6,19 %	7,51 %	7,89 %
31600	SE2 CB:220 NK53_P - 220 N.R÷SS CO:400 PK1 - 400 PK52:	7,40 %	8,16 %	7,60 %	7,90 %	7,40 %	7,10 %	7,05 %	8,33 %	8,33 %
31601	SE2 CB:220 NK53_P - 220 N.R÷SS CO: 400 PK1 - 400 PK52:	7,40 %	8,16 %	7,60 %	7,90 %	7,40 %	7,10 %	7,05 %	8,33 %	8,33 %
31602	SE2 CB:220 NK53_P - 220 N.R÷SS CO:400 PK51 - 400 PK52	7,40 %	8,16 %	7,60 %	7,90 %	7,40 %	7,10 %	7,05 %	8,33 %	8,33 %
31603	SE2 CB:220 NK53_P - 220 N.R÷SS CO: 400 PK51 - 400 PK5	7,40 %	8,16 %	7,60 %	7,90 %	7,40 %	7,10 %	7,05 %	8,33 %	8,33 %
31604	SE2 CB:220 NK53_P - 220 N.R÷SS CO:400 PK51 - 400 OFO	7,40 %	8,16 %	7,60 %	7,90 %	7,40 %	7,10 %	7,05 %	8,33 %	8,33 %
31605	SE2 CB:220 NK53_P - 220 N.R÷SS CO: 400 PK51 - 400 OFO	7,40 %	8,16 %	7,60 %	7,90 %	7,40 %	7,10 %	7,05 %	8,33 %	8,33 %
31700	SE2 CB:400 IK33 - 400 CT91 CO:400 PK1 - 400 NK6: FD	5,34 %	9,43 %	5,14 %	6,37 %	5,34 %	4,94 %	6,37 %	8,49 %	9,43 %
31701	SE2 CB:400 IK33 - 400 CT91 CO: 400 PK1 - 400 NK6: RD	5,34 %	9,43 %	5,14 %	6,37 %	5,34 %	4,94 %	6,37 %	8,49 %	9,43 %
31702	SE2 CB:400 IK33 - 400 CT91 CO:400 UT67 - 400 CT22: FD	5,34 %	9,43 %	5,14 %	6,37 %	5,34 %	4,94 %	6,37 %	8,49 %	9,43 %
31703	SE2 CB:400 IK33 - 400 CT91 CO: 400 UT67 - 400 CT22: RD	5,34 %	9,43 %	5,14 %	6,37 %	5,34 %	4,94 %	6,37 %	8,49 %	9,43 %
32150	SE2 CB:220 IK1 - 220 AT41 CO:220 AT58 - 220 IK1: FD	10,70 %	11,10 %	10,38 %	10,62 %	10,70 %	10,80 %	12,05 %	9,62 %	12,05 %
32151	SE2 CB:220 IK1 - 220 AT41 CO: 220 AT58 - 220 IK1: RD	10,70 %	11,10 %	10,38 %	10,62 %	10,70 %	10,80 %	12,05 %	9,62 %	12,05 %
40100	SE2 Cut SN1 (SE1>SE2): FD	1,55 %	2,30 %	1,82 %	1,98 %	1,55 %	1,52 %	1,52 %	2,18 %	2,30 %
40101	SE2 Cut SN1 (SE1>SE2): RD	1,41 %	2,09 %	1,65 %	1,80 %	1,41 %	1,38 %	1,39 %	1,98 %	2,09 %
40650	SE2 Cut Nea (SE2>NO3): FD	4,22 %	4,99 %	4,65 %	5,40 %	4,22 %	3,49 %	3,25 %	4,84 %	5,40 %
40651	SE2 Cut Nea (SE2>NO3): RD	7,03 %	8,31 %	7,74 %	9,00 %	7,03 %	5,82 %	5,41 %	8,06 %	9,00 %

Table 13: Relative flow deviation of the CNEs in SE2

CNEnr	CNE name	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8	Max
30050	SE3 CB:400 CT14 - 400 CT13 CO:400 IK2 - 400 CT72: FD	3,24 %	3,46 %	3,15 %	2,69 %	3,24 %	3,19 %	3,20 %	2,74 %	3,46 %
30051	SE3 CB:400 CT14 - 400 CT13 CO: 400 IK2 - 400 CT72: RD	3,24 %	3,46 %	3,15 %	2,69 %	3,24 %	3,19 %	3,20 %	2,74 %	3,46 %
30052	SE3 CB:400 CT14 - 400 CT13 CO:400 CT72 - 400 RT15: FD	3,24 %	3,46 %	3,15 %	2,69 %	3,24 %	3,19 %	3,20 %	2,74 %	3,46 %
30053	SE3 CB:400 CT14 - 400 CT13 CO: 400 CT72 - 400 RT15: RD	3,24 %	3,46 %	3,15 %	2,69 %	3,24 %	3,19 %	3,20 %	2,74 %	3,46 %
30100	SE3 CB:400 CT14 - 400 CT15 CO:400 CT14 - 400 CT267: FD	2,50 %	2,44 %	2,39 %	3,67 %	2,50 %	2,01 %	2,90 %	3,47 %	3,67 %
30101	SE3 CB:400 CT14 - 400 CT15 CO: 400 CT14 - 400 CT267: RD	2,50 %	2,44 %	2,39 %	3,67 %	2,50 %	2,01 %	2,90 %	3,47 %	3,67 %
30150	SE3 CB:400 RT16 - 400 OT12 CO:400 UT67 - 400 CT22: FD	3,24 %	14,02 %	3,89 %	7,16 %	3,24 %	4,14 %	5,58 %	5,57 %	14,02 %
30151	SE3 CB:400 RT16 - 400 OT12 CO: 400 UT67 - 400 CT22: RD	3,24 %	14,02 %	3,89 %	7,16 %	3,24 %	4,14 %	5,58 %	5,57 %	14,02 %
30152	SE3 CB:400 RT16 - 400 OT12 CO:400 CT23 - 400 CT22: FD	3,24 %	14,02 %	3,89 %	7,16 %	3,24 %	4,14 %	5,58 %	5,57 %	14,02 %
30153	SE3 CB:400 RT16 - 400 OT12 CO: 400 CT23 - 400 CT22: RD	3,24 %	14,02 %	3,89 %	7,16 %	3,24 %	4,14 %	5,58 %	5,57 %	14,02 %
30154	SE3 CB:400 RT16 - 400 OT12 CO:400 CT23 - 400 OT12: FD	3,24 %	14,02 %	3,89 %	7,16 %	3,24 %	4,14 %	5,58 %	5,57 %	14,02 %
30155	SE3 CB:400 RT16 - 400 OT12 CO: 400 CT23 - 400 OT12: RD	3,24 %	14,02 %	3,89 %	7,16 %	3,24 %	4,14 %	5,58 %	5,57 %	14,02 %
30250	SE3 CB:400 CT14 - 400 CT261 CO:400 IK2 - 400 CT13: FD	3,73 %	4,85 %	3,95 %	5,49 %	3,73 %	3,91 %	4,02 %	4,86 %	5,49 %
30251	SE3 CB:400 CT14 - 400 CT261 CO: 400 IK2 - 400 CT13: RD	3,73 %	4,85 %	3,95 %	5,49 %	3,73 %	3,91 %	4,02 %	4,86 %	5,49 %
30252	SE3 CB:400 CT14 - 400 CT261 CO:400 CT14 - 400 CT13: FD	3,73 %	4,85 %	3,95 %	5,49 %	3,73 %	3,91 %	4,02 %	4,86 %	5,49 %
30253	SE3 CB:400 CT14 - 400 CT261 CO: 400 CT14 - 400 CT13: RD	3,73 %	4,85 %	3,95 %	5,49 %	3,73 %	3,91 %	4,02 %	4,86 %	5,49 %
30300	SE3 CB:400 CT36 - 400 CT38 CO:400 FT61 - 400 FT63: FD	4,79 %	5,82 %	3,86 %	2,59 %	4,79 %	4,24 %	3,63 %	3,53 %	5,82 %
30301	SE3 CB:400 CT36 - 400 CT38 CO: 400 FT61 - 400 FT63: RD	4,79 %	5,82 %	3,86 %	2,59 %	4,79 %	4,24 %	3,63 %	3,53 %	5,82 %
30302	SE3 CB:400 CT36 - 400 CT38 CO:400 FT64 - 400 FT63: FD	4,79 %	5,82 %	3,86 %	2,59 %	4,79 %	4,24 %	3,63 %	3,53 %	5,82 %
30303	SE3 CB:400 CT36 - 400 CT38 CO: 400 FT64 - 400 FT63: RD	4,79 %	5,82 %	3,86 %	2,59 %	4,79 %	4,24 %	3,63 %	3,53 %	5,82 %
30350	SE3 CB:400 CT35 - 400 CT30 CO:400 CT36 - 400 CT38: FD	3,78 %	6,19 %	3,57 %	3,18 %	3,78 %	3,49 %	3,25 %	3,11 %	6,19 %
30351	SE3 CB:400 CT35 - 400 CT30 CO: 400 CT36 - 400 CT38: RD	3,78 %	6,19 %	3,57 %	3,18 %	3,78 %	3,49 %	3,25 %	3,11 %	6,19 %
30352	SE3 CB:400 CT35 - 400 CT30 CO:400 CT35 - 400 CT38 (9): FD	3,78 %	6,19 %	3,57 %	3,18 %	3,78 %	3,49 %	3,25 %	3,11 %	6,19 %
30353	SE3 CB:400 CT35 - 400 CT30 CO: 400 CT35 - 400 CT38 (9): RD	3,78 %	6,19 %	3,57 %	3,18 %	3,78 %	3,49 %	3,25 %	3,11 %	6,19 %
30400	SE3 CB:400 CT267 - 400 FT58 CO:400 FT11 - 400 FT182: FD	6,93 %	3,09 %	5,94 %	2,81 %	6,93 %	2,88 %	2,99 %	3,22 %	6,93 %
30401	SE3 CB:400 CT267 - 400 FT58 CO: 400 FT11 - 400 FT182: RD	6,93 %	3,09 %	5,94 %	2,81 %	6,93 %	2,88 %	2,99 %	3,22 %	6,93 %
30500	SE3 CB:400 CT23 - 400 CT22 CO:400 RT16 - 400 OT12: FD	5,98 %	7,14 %	5,79 %	5,59 %	5,98 %	5,55 %	5,43 %	4,33 %	7,14 %
30501	SE3 CB:400 CT23 - 400 CT22 CO: 400 RT16 - 400 OT12: RD	5,98 %	7,14 %	5,79 %	5,59 %	5,98 %	5,55 %	5,43 %	4,33 %	7,14 %
30550	SE3 CB:400 OT12 - 400 CT36 CO:400 FT81 - 400 CT35: FD	5,86 %	8,55 %	5,94 %	8,90 %	5,86 %	6,90 %	8,24 %	8,79 %	8,90 %
30551	SE3 CB:400 OT12 - 400 CT36 CO: 400 FT81 - 400 CT35: RD	5,86 %	8,55 %	5,94 %	8,90 %	5,86 %	6,90 %	8,24 %	8,79 %	8,90 %
30600	SE3 CB:400 CT55 - 400 CT53 CO:400 FT47 - 400 CT68: FD	2,29 %	3,91 %	2,66 %	2,61 %	2,29 %	3,75 %	5,42 %	3,14 %	5,42 %
30601	SE3 CB:400 CT55 - 400 CT53 CO: 400 FT47 - 400 CT68: RD	2,29 %	3,91 %	2,66 %	2,61 %	2,29 %	3,75 %	5,42 %	3,14 %	5,42 %
30700	SE3 CB:400 RT16 - 400 RT15 CO:400 UT67 - 400 CT22: FD	2,37 %	4,46 %	1,91 %	1,71 %	2,37 %	2,09 %	2,12 %	2,09 %	4,46 %
30701	SE3 CB:400 RT16 - 400 RT15 CO: 400 UT67 - 400 CT22: RD	2,37 %	4,46 %	1,91 %	1,71 %	2,37 %	2,09 %	2,12 %	2,09 %	4,46 %
30702	SE3 CB:400 RT16 - 400 RT15 CO:400 CT23 - 400 CT22: FD	2,37 %	4,46 %	1,91 %	1,71 %	2,37 %	2,09 %	2,12 %	2,09 %	4,46 %
30703	SE3 CB:400 RT16 - 400 RT15 CO: 400 CT23 - 400 CT22: RD	2,37 %	4,46 %	1,91 %	1,71 %	2,37 %	2,09 %	2,12 %	2,09 %	4,46 %
30750	SE3 CB:400 FT61 - 400 CT38 CO:400 FT188 - 400 FT93: FD	4,28 %	6,51 %	4,42 %	5,32 %	4,28 %	5,34 %	6,95 %	6,23 %	6,95 %
30751	SE3 CB:400 FT61 - 400 CT38 CO: 400 FT188 - 400 FT93: RD	4,28 %	6,51 %	4,42 %	5,32 %	4,28 %	5,34 %	6,95 %	6,23 %	6,95 %
30752	SE3 CB:400 FT61 - 400 CT38 CO:400 FT188 - 400 FT15: FD	4,28 %	6,51 %	4,42 %	5,32 %	4,28 %	5,34 %	6,95 %	6,23 %	6,95 %
30753	SE3 CB:400 FT61 - 400 CT38 CO: 400 FT188 - 400 FT15: RD	4,28 %	6,51 %	4,42 %	5,32 %	4,28 %	5,34 %	6,95 %	6,23 %	6,95 %
30754	SE3 CB:400 FT61 - 400 CT38 CO:400 FT58 - 400 FT189_P: FD	4,28 %	6,51 %	4,42 %	5,32 %	4,28 %	5,34 %	6,95 %	6,23 %	6,95 %
30755	SE3 CB:400 FT61 - 400 CT38 CO: 400 FT58 - 400 FT189_P: RD	4,28 %	6,51 %	4,42 %	5,32 %	4,28 %	5,34 %	6,95 %	6,23 %	6,95 %
30756	SE3 CB:400 FT61 - 400 CT38 CO:400 FT188 - 400 FT189_P: FD	4,28 %	6,51 %	4,42 %	5,32 %	4,28 %	5,34 %	6,95 %	6,23 %	6,95 %
30757	SE3 CB:400 FT61 - 400 CT38 CO: 400 FT188 - 400 FT189_P: RD	4,28 %	6,51 %	4,42 %	5,32 %	4,28 %	5,34 %	6,95 %	6,23 %	6,95 %
30850	SE3 CB:400 FT58 - 400 FT122 CO:400 FT58 - 400 FT182: FD	1,67 %	0,89 %	1,51 %	2,15 %	1,67 %	1,33 %	1,14 %	1,17 %	2,15 %
30851	SE3 CB:400 FT58 - 400 FT122 CO: 400 FT58 - 400 FT182: RD	1,67 %	0,89 %	1,51 %	2,15 %	1,67 %	1,33 %	1,14 %	1,17 %	2,15 %
30852	SE3 CB:400 FT58 - 400 FT122 CO:400 FT58 - 400 FT72: FD	1,67 %	0,89 %	1,51 %	2,15 %	1,67 %	1,33 %	1,14 %	1,17 %	2,15 %
30853	SE3 CB:400 FT58 - 400 FT122 CO: 400 FT58 - 400 FT72: RD	1,67 %	0,89 %	1,51 %	2,15 %	1,67 %	1,33 %	1,14 %	1,17 %	2,15 %
30950	SE3 CB:400 FT58 - 400 FT72 CO:400 FT58 - 400 FT122: FD	3,39 %	2,47 %	3,17 %	4,07 %	3,39 %	3,11 %	3,02 %	3,07 %	4,07 %
30951	SE3 CB:400 FT58 - 400 FT72 CO: 400 FT58 - 400 FT122: RD	3,39 %	2,47 %	3,17 %	4,07 %	3,39 %	3,11 %	3,02 %	3,07 %	4,07 %
31000	SE3 CB:400 FT11 - 400 FT24 CO:400 FT11 - 400 FT182: FD	12,58 %	6,67 %	11,24 %	5,28 %	12,58 %	7,52 %	5,45 %	5,64 %	12,58 %
31001	SE3 CB:400 FT11 - 400 FT24 CO: 400 FT11 - 400 FT182: RD	12,58 %	6,67 %	11,24 %	5,28 %	12,58 %	7,52 %	5,45 %	5,64 %	12,58 %
31050	SE3 CB:400 FT188 - 400 FT189_P CO:400 FT58 - 400 FT122: FD	10,10 %	7,21 %	9,71 %	11,86 %	10,10 %	8,49 %	7,67 %	8,17 %	11,86 %
31051	SE3 CB:400 FT188 - 400 FT189_P CO: 400 FT58 - 400 FT122: RD	10,10 %	7,21 %	9,71 %	11,86 %	10,10 %	8,49 %	7,67 %	8,17 %	11,86 %
31100	SE3 CB:400 FT24 - 400 FT182 CO:400 FT11 - 400 FT182: FD	9,35 %	4,32 %	8,40 %	3,73 %	9,35 %	4,71 %	5,13 %	5,24 %	9,35 %
31101	SE3 CB:400 FT24 - 400 FT182 CO: 400 FT11 - 400 FT182: RD	9,35 %	4,32 %	8,40 %	3,73 %	9,35 %	4,71 %	5,13 %	5,24 %	9,35 %
31150	SE3 CB:400 OT12 - 400 FT52 CO:400 FT92 - 400 CT38: FD	4,16 %	6,58 %	4,29 %	4,90 %	4,16 %	4,31 %	4,64 %	4,49 %	6,58 %
31151	SE3 CB:400 OT12 - 400 FT52 CO: 400 FT92 - 400 CT38: RD	4,16 %	6,58 %	4,29 %	4,90 %	4,16 %	4,31 %	4,64 %	4,49 %	6,58 %
31152	SE3 CB:400 OT12 - 400 FT52 CO:400 FT92 - 400 FT93: FD	4,16 %	6,58 %	4,29 %	4,90 %	4,16 %	4,31 %	4,64 %	4,49 %	6,58 %
31153	SE3 CB:400 OT12 - 400 FT52 CO: 400 FT92 - 400 FT93: RD	4,16 %	6,58 %	4,29 %	4,90 %	4,16 %	4,31 %	4,64 %	4,49 %	6,58 %
31200	SE3 CB:400 CT267 - 400 FT11 CO:400 CT267 - 400 FT58: FD	12,61 %	9,38 %	10,68 %	10,21 %	12,61 %	6,28 %	6,54 %	7,04 %	12,61 %
31201	SE3 CB:400 CT267 - 400 FT11 CO: 400 CT267 - 400 FT58: RD	12,61 %	9,38 %	10,68 %	10,21 %	12,61 %	6,28 %	6,54 %	7,04 %	12,61 %
31350	SE3 CB:400 FT81 - 400 CT35 CO:400 RT16 - 400 OT12: FD	6,73 %	8,94 %	5,94 %	5,66 %	6,73 %	6,67 %	6,49 %	5,34 %	8,94 %
31351	SE3 CB:400 FT81 - 400 CT35 CO: 400 RT16 - 400 OT12: RD	6,73 %	8,94 %	5,94 %	5,66 %	6,73 %	6,67 %	6,49 %	5,34 %	8,94 %
31400	SE3 CB:400 FT92 - 400 CT38 CO:400 FT61 - 400 CT38: FD	2,81 %	5,67 %	3,21 %	3,10 %	2,81 %	3,72 %	4,56 %	3,06 %	5,67 %
31401	SE3 CB:400 FT92 - 400 CT38 CO: 400 FT61 - 400 CT38: RD	2,81 %	5,67 %	3,21 %	3,10 %	2,81 %	3,72 %	4,56 %	3,06 %	5,67 %
31500	SE3 CB:400 CT15 - 400 CT267 CO:400 CT14 - 400 CT267: FD	9,28 %	3,34 %	8,50 %	5,09 %	9,28 %	5,28 %	3,58 %	3,87 %	9,28 %
31501	SE3 CB:400 CT15 - 400 CT267 CO: 400 CT14 - 400 CT267: RD	9,28 %	3,34 %	8,50 %	5,09 %	9,28 %	5,28 %	3,58 %	3,87 %	9,28 %
32050	SE3 CB:400 CT55 - 400 UT75 CO:400 FT47 - 400 CT68: FD	3,05 %	5,22 %	3,55 %	3,46 %	3,05 %	5,01 %	7,23 %	4,18 %	7,23 %
32051	SE3 CB:400 CT55 - 400 UT75 CO: 400 FT47 - 400 CT68: RD	3,05 %	5,22 %	3,55 %	3,46 %	3,05 %	5,01 %	7,23 %	4,18 %	7,23 %
32200	SE3 CB:400 CT14 - 400 CT267 COn 2: FD	7,07 %	2,61 %	6,48 %	3,00 %	7,07 %	3,92 %	3,24 %	3,77 %	7,07 %
32201	SE3 CB:400 CT14 - 400 CT267 COn 2: RD	7,07 %	2,61 %	6,48 %	3,00 %	7,07 %	3,92 %	3,24 %	3,77 %	7,07 %
32250	SE3 CB:400 CT14 - 400 CT267 COn 3: FD	5,21 %	3,59 %	4,82 %	5,19 %	5,21 %	3,41 %	3,98 %	4,82 %	5,21 %
32251	SE3 CB:400 CT14 - 400 CT267 COn 3: RD	5,21 %	3,59 %	4,82 %	5,19 %	5,21 %	3,41 %	3,98 %	4,82 %	5,21 %
40001	SE3 Cut VK Sˆdra: RD	10,83 %	6,98 %	9,56 %	5,84 %	10,83 %	6,55 %	5,20 %	5,41 %	10,83 %
40150	SE3 Cut SN2 (SE2>SE3): FD	0,52 %	0,52 %	0,50 %	0,52 %	0,52 %	0,45 %	0,49 %	0,49 %	0,52 %
40151	SE3 Cut SN2 (SE2>SE3): RD	0,46 %	0,46 %	0,44 %	0,46 %	0,46 %	0,40 %	0,43 %	0,43 %	0,46 %
40600	SE3 Cut Hasle (SE3>NO1): FD	2,74 %	1,71 %	2,41 %	2,34 %	2,74 %	1,90 %	1,52 %	1,54 %	2,74 %
40601	SE3 Cut Hasle (SE3>NO1): RD	2,07 %	1,25 %	1,82 %	1,78 %	2,07 %	1,42 %	1,12 %	1,15 %	2,07 %
40850	SE3 Cut Jylland (DK1>SE3): FD	9,80 %	9,80 %	9,80 %	9,80 %	9,80 %	9,80 %	9,80 %	9,80 %	9,80 %
40851	SE3 Cut Jylland (DK1>SE3): RD	9,58 %	9,58 %	9,58 %	9,58 %	9,58 %	9,58 %	9,58 %	9,58 %	9,58 %
40900	SE3 Cut Finland Sˆdra (FI>SE3): FD	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %
40901	SE3 Cut Finland Sˆdra (FI>SE3): RD	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %

Table 14: Relative flow deviation of the CNEs in SE3

CNEnr	CNE name	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8	Max
30800	SE4 CB:400 FT15 - 400 FT64 CO:400 FT61 - 400 FT63: FD	1,71 %	1,34 %	1,64 %	1,86 %	1,71 %	1,64 %	1,60 %	1,79 %	1,86 %
30801	SE4 CB:400 FT15 - 400 FT64 CO: 400 FT61 - 400 FT63: RD	1,71 %	1,34 %	1,64 %	1,86 %	1,71 %	1,64 %	1,60 %	1,79 %	1,86 %
30802	SE4 CB:400 FT15 - 400 FT64 CO:400 FT64 - 400 FT63: FD	1,71 %	1,34 %	1,64 %	1,86 %	1,71 %	1,64 %	1,60 %	1,79 %	1,86 %
30803	SE4 CB:400 FT15 - 400 FT64 CO: 400 FT64 - 400 FT63: RD	1,71 %	1,34 %	1,64 %	1,86 %	1,71 %	1,64 %	1,60 %	1,79 %	1,86 %
30900	SE4 CB:400 FT12 - 400 FT122 CO:400 FT12 - 400 FT72: FD	2,75 %	3,64 %	2,90 %	4,00 %	2,75 %	2,76 %	2,93 %	3,18 %	4,00 %
30901	SE4 CB:400 FT12 - 400 FT122 CO: 400 FT12 - 400 FT72: RD	2,75 %	3,64 %	2,90 %	4,00 %	2,75 %	2,76 %	2,93 %	3,18 %	4,00 %
30902	SE4 CB:400 FT12 - 400 FT122 CO:400 FT58 - 400 FT72: FD	2,75 %	3,64 %	2,90 %	4,00 %	2,75 %	2,76 %	2,93 %	3,18 %	4,00 %
30903	SE4 CB:400 FT12 - 400 FT122 CO: 400 FT58 - 400 FT72: RD	2,75 %	3,64 %	2,90 %	4,00 %	2,75 %	2,76 %	2,93 %	3,18 %	4,00 %
30904	SE4 CB:400 FT12 - 400 FT122 CO:400 FT58 - 400 FT182: FD	2,75 %	3,64 %	2,90 %	4,00 %	2,75 %	2,76 %	2,93 %	3,18 %	4,00 %
30905	SE4 CB:400 FT12 - 400 FT122 CO: 400 FT58 - 400 FT182: RD	2,75 %	3,64 %	2,90 %	4,00 %	2,75 %	2,76 %	2,93 %	3,18 %	4,00 %
31250	SE4 CB:400 FT12 - 400 FT72 CO:400 FT58 - 400 FT72: FD	2,08 %	2,35 %	2,19 %	1,97 %	2,08 %	1,34 %	1,18 %	1,10 %	2,35 %
31251	SE4 CB:400 FT12 - 400 FT72 CO: 400 FT58 - 400 FT72: RD	2,08 %	2,35 %	2,19 %	1,97 %	2,08 %	1,34 %	1,18 %	1,10 %	2,35 %
31300	SE4 CB:400 FT76 - 400 FT12 CO:400 FT58 - 400 FT189_P: FD	5,83 %	6,90 %	5,68 %	9,63 %	5,83 %	6,80 %	6,88 %	7,35 %	9,63 %
31301	SE4 CB:400 FT76 - 400 FT12 CO: 400 FT58 - 400 FT189_P: RD	5,83 %	6,90 %	5,68 %	9,63 %	5,83 %	6,80 %	6,88 %	7,35 %	9,63 %
31302	SE4 CB:400 FT76 - 400 FT12 CO:400 FT188 - 400 FT189_P: FD	5,83 %	6,90 %	5,68 %	9,63 %	5,83 %	6,80 %	6,88 %	7,35 %	9,63 %
31303	SE4 CB:400 FT76 - 400 FT12 CO: 400 FT188 - 400 FT189_P: RD	5,83 %	6,90 %	5,68 %	9,63 %	5,83 %	6,80 %	6,88 %	7,35 %	9,63 %
32000	SE4 CB:400 FT242 - 400 FT13 CO:400 FT76 - 400 FT12: FD	9,49 %	9,15 %	9,62 %	3,98 %	9,49 %	3,83 %	3,23 %	2,95 %	9,62 %
32001	SE4 CB:400 FT242 - 400 FT13 CO: 400 FT76 - 400 FT12: RD	9,49 %	9,15 %	9,62 %	3,98 %	9,49 %	3,83 %	3,23 %	2,95 %	9,62 %
40200	SE4 Cut SN4 (SE3>SE4): FD	0,38 %	0,40 %	0,37 %	0,51 %	0,38 %	0,44 %	0,63 %	0,93 %	0,93 %
40201	SE4 Cut SN4 (SE3>SE4): RD	0,92 %	0,99 %	0,91 %	1,26 %	0,92 %	1,08 %	1,57 %	2,34 %	2,34 %
40350	SE4 Cut Baltic Cable (DE>SE4): FD	0,03 %	0,03 %	0,03 %	0,03 %	0,03 %	0,03 %	0,03 %	0,03 %	0,03 %
40351	SE4 Cut Baltic Cable (DE>SE4): RD	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %
40400	SE4 Cut SwePol (PL>SE4): FD	0,01 %	0,01 %	0,01 %	0,01 %	0,01 %	0,01 %	0,01 %	0,01 %	0,01 %
40401	SE4 Cut SwePol (PL>SE4): RD	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %
40450	SE4 Cut Sj%olland (DK2>SE4): FD	0,49 %	0,53 %	0,52 %	0,57 %	0,49 %	0,59 %	0,66 %	0,54 %	0,66 %
40451	SE4 Cut Sj%olland (DK2>SE4): RD	0,56 %	0,60 %	0,58 %	0,64 %	0,56 %	0,67 %	0,74 %	0,62 %	0,74 %

Table 15: Relative flow deviation of the CNEs in SE4

D.3 Bidding areas in Finland and Denmark

CNEnr	CNE name	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8	Max
20000	FIN Cut P1 North: FD	5,29 %	5,57 %	5,44 %	5,56 %	5,29 %	5,36 %	5,42 %	5,37 %	5,57 %
20001	FIN Cut P1 North: RD	8,12 %	8,54 %	8,34 %	8,52 %	8,12 %	8,22 %	8,31 %	8,24 %	8,54 %
20050	FIN Cut P1: FD	6,18 %	6,59 %	6,41 %	6,87 %	6,18 %	6,24 %	6,29 %	6,27 %	6,87 %
20051	FIN Cut P1: RD	9,48 %	10,11 %	9,83 %	10,53 %	9,48 %	9,57 %	9,64 %	9,61 %	10,53 %
20100	FIN Cut RAC: FD	2,60 %	2,65 %	2,61 %	2,99 %	2,60 %	2,80 %	3,40 %	4,25 %	4,25 %
20101	FIN Cut RAC: RD	3,46 %	3,54 %	3,48 %	3,99 %	3,46 %	3,73 %	4,53 %	5,67 %	5,67 %
20150	FIN Cut FS FIN: FD	0,51 %	0,51 %	0,51 %	0,51 %	0,51 %	0,51 %	0,51 %	0,51 %	0,51 %
20151	FIN Cut FS FIN: RD	0,51 %	0,51 %	0,51 %	0,51 %	0,51 %	0,51 %	0,51 %	0,51 %	0,51 %
20200	FIN Cut EL: FD	0,62 %	0,62 %	0,62 %	0,62 %	0,62 %	0,62 %	0,62 %	0,62 %	0,62 %
20201	FIN Cut EL: RD	0,62 %	0,62 %	0,62 %	0,62 %	0,62 %	0,62 %	0,62 %	0,62 %	0,62 %

Table 16: Relative flow deviation of the CNEs in FIN

CNEnr	CNE name	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8	Max
80000	DK1 CB:KAS_150 - MAG_150 CO:KAS_400 - LAG_400: FD	3,45 %	3,74 %	3,41 %	3,68 %	3,45 %	3,72 %	5,68 %	4,04 %	5,68 %
80025	DK1 CB:AND_150 - MAG_150 CO:KAS_400 - LAG_400: FD	4,96 %	6,16 %	5,49 %	6,64 %	4,96 %	6,02 %	8,16 %	4,77 %	8,16 %
80050	DK1 CB:AND_150 - BDR_150 CO:KAS_400 - LAG_400: FD	5,63 %	6,76 %	6,14 %	6,16 %	5,63 %	6,07 %	7,02 %	4,59 %	7,02 %
80075	DK1 CB:BDR_150 - LAG_150 CO:KAS_400 - LAG_400: FD	5,14 %	6,47 %	5,74 %	5,38 %	5,14 %	4,39 %	3,75 %	4,26 %	6,47 %
80100	DK1 CB:KAS_400 - LAG_400 CO:KAS_400 - REV_400: FD	3,48 %	4,14 %	3,75 %	3,89 %	3,48 %	3,60 %	3,92 %	3,14 %	4,14 %
80125	DK1 CB:ABS_150 - SÿN_150 CO:KAS_400 - LAG_400: FD	14,51 %	16,87 %	15,48 %	20,64 %	14,51 %	15,66 %	18,25 %	11,25 %	20,64 %
80150	DK1 CB:SHE_150 - SÿN_150 CO:KAS_400 - LAG_400: FD	7,22 %	11,95 %	9,63 %	13,26 %	7,22 %	8,88 %	12,10 %	8,83 %	13,26 %
80175	DK1 CB:KNA_150 - LAG_150 CO:LAG_400 - MAL_400: FD	8,82 %	10,82 %	9,80 %	10,04 %	8,82 %	7,99 %	7,20 %	8,96 %	10,82 %
80200	DK1 CB:KNA_150 - THY_150 CO:LAG_400 - MAL_400: FD	2,98 %	4,40 %	3,74 %	4,52 %	2,98 %	4,46 %	6,88 %	4,99 %	6,88 %
80225	DK1 CB:ASR_150 - THY_150 CO:LAG_400 - MAL_400: FD	3,14 %	2,94 %	3,02 %	2,94 %	3,14 %	3,31 %	5,59 %	3,06 %	5,59 %
80250	DK1 CB:ASR_400 - ASR_150 CO:LAG_400 - MAL_400: FD	3,30 %	3,09 %	3,18 %	3,08 %	3,30 %	3,47 %	5,86 %	3,20 %	5,86 %
80275	DK1 CB:HAT_150 - KNA_150 CO:LAG_400 - MAL_400: FD	4,91 %	5,49 %	5,16 %	5,21 %	4,91 %	4,68 %	4,55 %	5,75 %	5,75 %
80300	DK1 CB:HAT_150 - MAL_150 CO:LAG_400 - MAL_400: FD	3,96 %	4,74 %	4,28 %	4,67 %	3,96 %	4,55 %	6,08 %	5,00 %	6,08 %
80325	DK1 CB:HNB_150 - TRI_150 CO:FER_400 - TRI_400: FD	10,09 %	7,28 %	8,14 %	6,95 %	10,09 %	10,22 %	10,69 %	6,76 %	10,69 %
80350	DK1 CB:HNB_150 - KAG_150 CO:FER_400 - TRI_400: FD	4,64 %	3,64 %	3,87 %	3,81 %	4,64 %	4,77 %	5,08 %	3,29 %	5,08 %
80375	DK1 CB:KAG_150 - THÿ_150 CO:FER_400 - TRI_400: FD	5,43 %	7,02 %	6,18 %	6,54 %	5,43 %	5,29 %	5,28 %	6,34 %	7,02 %
80400	DK1 CB:FER_150 - THÿ_150 CO:FER_400 - TRI_400: FD	5,87 %	7,45 %	6,52 %	7,21 %	5,87 %	5,69 %	6,11 %	5,69 %	7,45 %
80425	DK1 CB:TAN_150 - TJE_150 CO:FER_400 - TRI_400: FD	6,91 %	6,65 %	6,64 %	7,74 %	6,91 %	8,22 %	10,70 %	6,90 %	10,70 %
80450	DK1 CB:EDR_400 - EDR_150 CO:KAS_400 - REV_400: FD	9,43 %	9,25 %	8,85 %	9,53 %	9,43 %	9,21 %	9,75 %	8,88 %	9,75 %
80475	DK1 CB:EDR_400 - EDR_001 CO:KAS_400 - REV_400: FD	8,31 %	8,32 %	8,14 %	8,21 %	8,31 %	7,95 %	7,94 %	8,09 %	8,32 %
80500	DK1 CB:EDR_150 - LYK_150 CO:KAS_400 - REV_400: FD	8,13 %	7,99 %	7,94 %	7,57 %	8,13 %	7,61 %	7,40 %	7,40 %	8,13 %
80550	DK1 CB:LYK_150 - RIB_150 CO:KAS_400 - REV_400: FD	7,60 %	7,39 %	7,37 %	8,28 %	7,60 %	7,22 %	7,59 %	7,24 %	8,28 %
80575	DK1 CB:KAS_150 - RIB_150 CO:KAS_400 - REV_400: FD	6,66 %	7,03 %	6,66 %	6,82 %	6,66 %	6,72 %	8,00 %	7,52 %	8,00 %
80600	DK1 CB:BBR_150 - LYK_150 CO:KAS_400 - REV_400: FD	7,63 %	7,59 %	7,51 %	7,47 %	7,63 %	7,26 %	8,02 %	7,29 %	8,02 %
80625	DK1 CB:BBR_150 - KAS_150 CO:KAS_400 - REV_400: FD	6,82 %	7,95 %	7,15 %	8,13 %	6,82 %	7,11 %	8,25 %	9,97 %	9,97 %
80650	DK1 CB:BIL_150 - STR_150 CO:IDU_400 - TJE_400: FD	13,50 %	13,51 %	13,33 %	15,91 %	13,50 %	14,59 %	17,07 %	14,54 %	17,07 %
80675	DK1 CB:BIL_150 - LOL_150 CO:IDU_400 - TJE_400: FD	12,40 %	13,84 %	12,97 %	14,26 %	12,40 %	13,76 %	16,57 %	15,80 %	16,57 %
80700	DK1 CB:LOL_150 - TJE_150 CO:IDU_400 - TJE_400: FD	13,65 %	13,85 %	13,58 %	14,83 %	13,65 %	14,80 %	17,20 %	17,58 %	17,58 %
80725	DK1 CB:HER_150 - STR_150 CO:FER_400 - TJE_400: FD	11,06 %	11,41 %	11,08 %	10,36 %	11,06 %	11,12 %	11,60 %	9,51 %	11,60 %
80750	DK1 CB:HER_150 - SFE_150 CO:FER_400 - TJE_400: FD	6,87 %	6,53 %	6,38 %	6,80 %	6,87 %	6,42 %	6,11 %	8,46 %	8,46 %
80775	DK1 CB:KAE_150 - SFE_150 (2) CO:FER_400 - TJE_400: FD	6,67 %	6,52 %	5,94 %	5,97 %	6,67 %	6,21 %	6,00 %	6,73 %	6,73 %
80800	DK1 CB:NVV_150 - ≈Bÿ_150 CO:FER_400 - VHA_400: FD	5,49 %	5,07 %	5,08 %	3,92 %	5,49 %	5,82 %	6,50 %	6,34 %	6,50 %
80825	DK1 CB:NVV_150 - SBA_150 CO:FER_400 - VHA_400: FD	2,59 %	3,16 %	2,80 %	6,44 %	2,59 %	2,79 %	3,54 %	2,81 %	6,44 %
80850	DK1 CB:VHA_150 - ≈Bÿ_150 CO:FER_400 - VHA_400: FD	7,47 %	5,07 %	5,84 %	4,76 %	7,47 %	5,52 %	3,93 %	4,98 %	7,47 %
80875	DK1 CB:HASV150 - MAL_150 CO:MAL_400 - TRI_400: FD	5,05 %	6,61 %	5,79 %	6,49 %	5,05 %	5,90 %	7,70 %	6,64 %	7,70 %
80925	DK1 CB:TRI_400 - TRI_150 CO:FER_400 - TRI_400: FD	6,51 %	6,53 %	6,28 %	7,01 %	6,51 %	6,57 %	7,31 %	6,69 %	7,31 %

Table 17: Relative flow deviation of the CNEs in DK1

CNEnr	CNE name	GSK 1	GSK 2	GSK 3	GSK 4	GSK 5	GSK 6	GSK 7	GSK 8	Max
70000	DK2 CB:KAM_132 - SPA_132 CO:ASV_400 - BJS_400: FD	10,29 %	11,31 %	11,08 %	9,16 %	10,29 %	12,05 %	14,07 %	9,57 %	14,07 %
70025	DK2 CB:BJS_400 - BJS_132 CO:ASV_400 - BJS_400: FD	4,68 %	4,59 %	4,58 %	3,81 %	4,68 %	5,11 %	5,55 %	4,03 %	5,55 %
70050	DK2 CB:JER_132 - SPA_132 CO:BJS_400 - ISH_400: FD	9,04 %	8,74 %	8,74 %	7,55 %	9,04 %	9,83 %	10,65 %	7,91 %	10,65 %
70075	DK2 CB:JER_132 - KRL_132 CO:BJS_400 - ISH_400: FD	11,20 %	9,71 %	9,85 %	8,14 %	11,20 %	11,57 %	12,11 %	8,81 %	12,11 %
70100	DK2 CB:KRL_132 - MOSÿ132 CO:BJS_400 - ISH_400: FD	11,23 %	9,74 %	9,89 %	7,92 %	11,23 %	11,52 %	11,97 %	8,63 %	11,97 %
70125	DK2 CB:FLA_132 - MOSÿ132 CO:BJS_400 - ISH_400: FD	14,91 %	12,97 %	13,16 %	10,53 %	14,91 %	14,87 %	15,11 %	11,19 %	15,11 %
70150	DK2 CB:FLA_132 - ISH_132 CO:BJS_400 - ISH_400: FD	10,22 %	8,34 %	8,54 %	7,16 %	10,22 %	9,67 %	9,40 %	7,42 %	10,22 %
70200	DK2 CB:ISH_400 - ISH_132 CO:BJS_400 - ISH_400: FD	2,49 %	2,35 %	2,34 %	2,28 %	2,49 %	2,50 %	2,66 %	2,28 %	2,66 %
70225	DK2 CB:AVV_400 - AVV_132 CO:AVV_400 - ISH_400: FD	13,51 %	11,42 %	11,50 %	10,32 %	13,51 %	12,33 %	11,61 %	10,55 %	13,51 %
70250	DK2 CB:BRY_132 - ISH_132 CO:AVV_400 - ISH_400: FD	15,20 %	10,38 %	10,93 %	9,03 %	15,20 %	12,68 %	11,02 %	9,26 %	15,20 %
70300	DK2 CB:AVV_132 - BRY_132 CO:AVV_400 - ISH_400: FD	16,41 %	10,33 %	10,91 %	9,47 %	16,41 %	12,55 %	10,21 %	9,55 %	16,41 %
70325	DK2 CB:AVV_132 - BRY_132 (2) CO:AVV_400 - ISH_400: FD	16,44 %	10,35 %	10,92 %	9,49 %	16,44 %	12,57 %	10,23 %	9,57 %	16,44 %
70350	DK2 CB:AVV_132 - BRY_132 (3) CO:AVV_400 - ISH_400: FD	16,19 %	10,19 %	10,76 %	9,34 %	16,19 %	12,37 %	10,07 %	9,42 %	16,19 %
70375	DK2 CB:ASV_132 - SOS_132 CO:ASV_400 - BJS_400: FD	9,17 %	8,39 %	8,46 %	7,37 %	9,17 %	9,45 %	9,86 %	7,49 %	9,86 %
70400	DK2 CB:NYR_132 - SOS_132 CO:ASV_400 - BJS_400: FD	7,54 %	7,82 %	7,73 %	6,58 %	7,54 %	8,15 %	8,90 %	6,95 %	8,90 %
70425	DK2 CB:NYR_132 - OST_132 CO:ASV_400 - BJS_400: FD	6,76 %	5,90 %	5,98 %	4,87 %	6,76 %	7,35 %	7,99 %	5,31 %	7,99 %
70450	DK2 CB:FLA_132 - OST_132 CO:ASV_400 - BJS_400: FD	7,20 %	6,33 %	6,42 %	5,23 %	7,20 %	7,65 %	8,15 %	5,41 %	8,15 %
70475	DK2 CB:FLA_132 - KAM_132 CO:ASV_400 - BJS_400: FD	5,57 %	4,48 %	4,50 %	4,49 %	5,57 %	4,67 %	4,48 %	4,53 %	5,57 %
70500	DK2 CB:KAM_132 - KSV_132 CO:ASV_400 - BJS_400: FD	3,20 %	4,03 %	3,87 %	4,07 %	3,20 %	3,46 %	3,85 %	3,87 %	4,07 %
70525	DK2 CB:GLN_132 - STA_132 CO:GLN_400 - GLN001A: FD	8,75 %	8,80 %	8,40 %	8,87 %	8,75 %	8,18 %	8,81 %	9,18 %	9,18 %
70550	DK2 CB:GÿR_400 - GÿR_132 CO:GÿR_400 - HVE_400: FD	5,34 %	6,01 %	5,89 %	5,79 %	5,34 %	5,95 %	6,49 %	5,83 %	6,49 %
70575	DK2 CB:BOR_132 - HVE_132 CO:GÿR_400 - HVE_400: FD	2,70 %	2,61 %	2,61 %	2,61 %	2,70 %	2,53 %	2,73 %	2,60 %	2,73 %
70600	DK2 CB:EBY_132 - LIN_132 CO:AVV_400 - ISH_400: FD	17,46 %	15,85 %	15,82 %	16,14 %	17,46 %	16,66 %	16,43 %	15,82 %	17,46 %
70625	DK2 CB:STA_132 - TEG_132 (2) CO:HVE_400 - S≈N_400: FD	1,43 %	1,55 %	1,49 %	1,62 %	1,43 %	1,76 %	1,98 %	1,93 %	1,98 %
70650	DK2 CB:HVE_400 - S≈N_400 CO:GÿR_400 - S≈N_400: FD	0,49 %	0,53 %	0,52 %	0,57 %	0,49 %	0,59 %	0,67 %	0,55 %	0,67 %
70675	DK2 CB:GÿR_400 - S≈N_400 CO:HVE_400 - S≈N_400: FD	0,61 %	0,65 %	0,64 %	0,69 %	0,61 %	0,73 %	0,80 %	0,68 %	0,80 %
70700	DK2 CB:TEG_132 - MRP_132 CO:HVE_400 - S≈N_400: FD	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %
70725	DK2 CB:TEG_132 - MRP_132 (2) CO:HVE_400 - S≈N_400: FD	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %	0,00 %
70750	DK2 CB:BJS_400 - HVE_400 CO:BJS_400 - ISH_400: FD	1,71 %	1,58 %	1,59 %	1,41 %	1,71 %	1,84 %	1,98 %	1,46 %	1,98 %
70800	DK2 CB:BJS_400 - ISH_400 CO:BJS_400 - HVE_400: FD	1,75 %	1,59 %	1,60 %	1,42 %	1,75 %	1,85 %	1,97 %	1,46 %	1,97 %
70825	DK2 CB:HVE_400 - ISH_400 CO:BJS_400 - HVE_400: FD	1,73 %	2,03 %	1,96 %	1,91 %	1,73 %	2,08 %	2,64 %	1,95 %	2,64 %
70850	DK2 CB:ASV_400 - BJS_400 CO:BJS_400 - HKS_400: FD	1,15 %	1,12 %	1,11 %	1,11 %	1,15 %	1,20 %	1,25 %	1,11 %	1,25 %
70900	DK2 CB:ASV_400 - HKS_400 CO:BJS_400 - HKS_400: FD	0,02 %	0,02 %	0,02 %	0,02 %	0,02 %	0,02 %	0,02 %	0,02 %	0,02 %
70925	DK2 CB:AVV_400 - ISH_400 CO:AVV_400 - HCV_400: FD	5,02 %	4,05 %	4,08 %	4,02 %	5,02 %	4,14 %	4,07 %	4,02 %	5,02 %
70950	DK2 CB:AVV_400 - HCV_400 CO:AVV_400 - ISH_400: FD	2,41 %	2,03 %	2,03 %	2,01 %	2,41 %	2,05 %	2,08 %	2,01 %	2,41 %
70975	DK2 CB:HCV_400 - HCV_132 CO:AVV_400 - ISH_400: FD	10,59 %	8,91 %	8,95 %	8,84 %	10,59 %	9,02 %	9,14 %	8,84 %	10,59 %
71000	DK2 CB:GÿR_400 - HVE_400 CO:HVE_400 - S≈N_400: FD	1,36 %	1,56 %	1,52 %	1,54 %	1,36 %	1,54 %	1,75 %	1,52 %	1,75 %
71025	DK2 CB:STA_132 - TEG_132 CO:HVE_400 - S≈N_400: FD	1,47 %	1,61 %	1,55 %	1,68 %	1,47 %	1,84 %	2,06 %	2,00 %	2,06 %
79000	DK2 Cut ÿresund (DK2-SE4): FD	0,46 %	0,49 %	0,48 %	0,53 %	0,46 %	0,55 %	0,62 %	0,50 %	0,62 %
79001	DK2 Cut ÿresund (DK2-SE4): RD	0,56 %	0,60 %	0,58 %	0,64 %	0,56 %	0,67 %	0,74 %	0,62 %	0,74 %
79050	DK2 Cut StorebÊlt (DK2-DK1): FD	0,01 %	0,01 %	0,01 %	0,01 %	0,01 %	0,01 %	0,01 %	0,01 %	0,01 %
79100	DK2 Cut Kontek (DK2-DE): FD	0,01 %	0,01 %	0,01 %	0,01 %	0,01 %	0,01 %	0,01 %	0,01 %	0,01 %
79101	DK2 Cut Kontek (DK2-DE): RD	0,01 %	0,01 %	0,01 %	0,01 %	0,01 %	0,01 %	0,01 %	0,01 %	0,01 %

Table 18: Relative flow deviation of the CNEs in DK2