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# Demand Response as a resource for the adequacy and operational reliability of the power systems

## Explanatory Note

## 1 Introduction

1.1 Generally, in a commodity market the price of the product is an outcome of the sellers' willingness to sell and the buyers' willingness to pay in the prevailing situation. Thus, the price more or less reflects the balance between supply and demand in the foreseeable future. The buyers optimize their procurements based on their needs and the market outlook.

1.2 Electricity is more a necessity for the end-users than many other commodities. The flexibility in using electricity is smaller. However, the use of electricity can be optimised to some extent. Utilisation of the price elasticity will contribute to a market-oriented equilibrium between supply and demand and mitigation of market power. Without price elasticity the price of electricity will reflect only the costs of electricity supply.

1.3 As electricity is a commodity that cannot be stored the price follows the instantaneous physical balance especially in the power systems dominated by the thermal power stations. The higher the price the more strained the power balance is. High price spikes indicate possible critical periods for the adequacy of the power system.

1.4 The end-users of electricity can ask themselves whether they really need to be 100 % supplied in all situations and how much they are willing to pay for electricity at each moment. If this consideration results in a voluntary adjustment in the demand, that reaction is called demand response (DR). When reducing their demand the end-users contribute to the balance between supply and demand and thus also to the market price of electricity and the security of supply. The end-user benefits from lower procurement costs.

1.5 Demand reductions are also used as contracted resources e.g. power system reserves for real-time balancing purposes, disturbance reserves or peak load resources. In these cases the driving force for their activation is the frequency of the power system, a disturbance on a power system or the forecasted physical balance between supply and demand, not directly the market price. As disturbance reserves or peak load resources, the availability of DR resources will positively contribute to the security of supply and lower the risk of forced load shedding. As a resource for balancing purposes, DR will primarily contribute to the efficiency and economy of the balancing arrangement. When utilising DR in order to affect the load flows in the networks, the location of the DR is decisive.

1.6 Utilisation of demand response as a power resource is a complex issue. The objective of this explanatory note is to contribute to the discussion and common understanding of DR as a resource by presenting the TSOs' experiences and views on the DR potential, pre-requisites and obstacles in activating demand resources.

## 2 Definition of Demand Response

2.1 Demand response (DR) is a voluntary temporary adjustment of power demand taken by the end-user as a response to a price signal (market price or tariffs) or taken by a counter-party based on an agreement with the end-user. DR during a short-term time (hours) has an impact on the system power balance and can be seen as economical optimisation of the electricity demand rather than energy saving. DR during a longer period will also affect the energy balance in the power system and may also result in saving of energy.

2.2 The price signal may come from all market places that indicate a price for capacity or energy (spot market, intra-day market, regulating power market or balancing market, market for ancillary services). DR resources will be activated if their bid price is lower than the market clearing price. DR participation in any of the markets will reduce the chance of a market failure. The price signal may also be based on tariffs for electricity or transmission and distribution services.

2.3 The driving force for DR may not only be the absolute price level, but also the price difference between high price and low price periods like for example in the traditional time-of-use tariffs. The price difference may give rise to investments in technical solutions that enable shifting of the demand from a high price period to a low price period, for example from the day time to night time. However, this kind of DR cannot be utilised as a resource in real time operation.

2.4 Adjustment of the demand can be both a reduction of demand due to a high price or an increase of demand due to a low price. The adjustment is economically justified when the benefit from using or not-using electricity exceeds the electricity price. Increase of demand can be relevant in the power systems where the share of must-take generation (like for example wind power in some regulatory regimes) is substantial and the electricity price sometimes can be very low.

2.5 An adjustment of demand can also be taken by a counter-party manually or automatically on a contractual basis. The counter-party can be a seller or balance responsible party, an aggregator (managing several small DR resources as one big resource), a TSO or distributor. In the two latter cases the reason for contracting DR resources is connected with the balancing or security of the power system. In these cases, the activation signal is based on the power system balance or heavy load flows. The price is the second criteria while activating the resources in merit order.

2.6 Forced load shedding as a last resort to maintain the security of supply and to prevent black-outs is not considered to be demand response.

2.7 Distributed local generation like small back-up generation is often also considered as a DR as well. This is because the effects on the grid level do not make any difference between changes in the local generation or demand and the activation of the small generation units during the system peak hours may require similar actions like activation of demand response.

## 3 Potential of demand response

3.1 In order to evaluate the realistic potential of DR as a resource for the adequacy and operational reliability of the power system a thorough analysis has to be made. Very often, the indicated DR potential reflects a technical or theoretical potential evaluated without taking into account the pre-requisites for the activation of the potential. Such estimates indicate an upper limit for the practical potential.

3.2 The practical potential of DR varies in real-time depending on many factors like the time of activation, the local price of electricity, market price of industrial products or substituting alternative energy forms, economic cycle in the industry, time available before activation, duration and frequency of demand response. For example, the potential based on heating or cooling systems is available only in heating or cooling periods, the potential based on lighting systems varies depending on the daylight etc.

3.3 Features of potential DR resources:

- Electricity can be substituted partly or totally by other energy forms.
- The demand is sensitive to the electricity price like an industrial process where the electricity constitutes a major share of the total manufacturing costs.
- The end-user is not very sensitive to the time of using electricity i.e. the demand can be shifted to another time without causing any major harm for the end-user.
- The electricity supply can be interrupted for a period of time without causing any major harm for the end-user.

3.4 Electric boilers are used for heat production especially in hydro dominated power systems. Typically, there is also an alternative way for heat production using oil or other fuels. Electricity is used for heat production if the electricity price results in lower production costs than the optional energy forms. The heat production is switched to other energy forms when the electricity price is higher than the break-even price. The demand of electricity is then reduced accordingly. There is an economic incentive for DR depending on the price relation between electricity and the alternative fuels. The unit size of electric boilers in connection with district heating or industrial processes is typically on a MW scale.

3.5 The aluminium industry is an example of an industrial process where the costs of electricity constitutes a substantial share of the total manufacturing costs. The industrial end product is sold in the world market and the manufacturing costs should remain below the market price of the industrial product. Depending on the stored amount of the industrial products and the overall market situation, the industrial end-users may have an economic incentive to reduce the demand or stop the process totally for a period when the electricity price exceeds the critical threshold price. There is an economic incentive for DR. In the process industry DR can be typically activated on a MW scale.

3.6 A suitable DR resource is an industrial process that is based on sub-processes where there are intermediate stores for the sub-products or redundant process lines. A sub-process or a redundant process line can be stopped for a short period without causing any interruptions in the whole process and without having any major impact on the product volume. Examples can be found in the pulp and paper, metal and chemical industry. Typically, DR can be activated on a MW scale. Experiences show that the potential DR resources are biggest if the duration of the response lies within a range of 1-4 hours.

3.7 Direct electric space heating, water heating, ventilation and cooling of houses constitute a DR potential where the electricity supply can be interrupted for a short period of time (1-2 hours) without reducing the quality of living standard harmfully. The individual units are small compared to the potential in the industrial processes. In a house there may also be alternative ways for space heating like fireplaces or non-electric stoves. Then, even longer interruptions in the electricity supply can be tolerated.

## 4 Pre-requisites and barriers for bidding DR in the market places

4.1 When DR resources are used as a commercial product the demand has to be measured in order to verify the response. Telemetering of demand is a pre-requisite for utilisation of DR resources, but does not guarantee any DR participation. Typically, the major industrial end-users have telemetering systems. Lately, the market players have invested a lot in telemetering even in the case of small end-users. They justify these investments as a pre-requisite to introduce new sales products and to enhance DR.

4.2 The requirements for the participation and bidding in a market place as well as the characteristics of the products in the market places may limit the interest of end-users for direct DR bidding. The requirements apply for example to participation fees, minimum bid volumes, securities. The product characteristics should also match with the characteristics of DR resources. Products with duration of 1-4 hours seem to be most suitable for DR resources. Currently, only some major industrial end-users are actively bidding DR resources in the market places. An aggregator can collect small DR resources together and bid a bigger amount to overcome the minimum requirement.

4.3 If the price is the driving force for DR, the price signal has to be passed through to the end-users in real time. If the end-users are participants in the market places or exposed to the spot market prices directly, they have an incentive to follow the price setting in the market places. Otherwise, the price has to be communicated to the end-users somehow or the end-user must authorize a counter-party to adjust the demand during high prices by using remote control. Fixed-price contracts do not favour accurate activation of DR resources during high price spikes in the market.

4.4 Even if the circumstances for the utilisation of DR resources are favourable, activation of the DR resources may require additional investments or advance preparations that mean additional costs. These costs may not be covered by the economic benefit when being activated very seldom during some hours. Therefore, the end-users would like to have predictable revenues to be interested in DR. This may be one reason why the end-users are not actively bidding in the energy-only markets.

4.5 The deregulation of the electricity market is still in process. The market participants are not always familiar with the opportunities they have; how to be active in the market and have an impact on the price setting in the market places and the security of supply. The traditional way of thinking is that electricity has to be supplied when it is needed by the end-users. Information about the benefits of DR could lead to a more active exploitation of potential DR resources.

## 5 Demand resources used as contracted power system reserves

5.1 To maintain the power system balance the TSOs acquire generation or demand resources to be used as operational reserves that are activated automatically or manually. DR is an option for generation if it meets the technical and other requirements. The requirements may concern for example the minimum volume of activated power, activation time, minimum duration of the participation, availability of the volume during a year etc. Additional investments are normally needed for automatic activation of DR resources.

5.2 Parts of the reserves are used in case of disturbances either in the grid or power plants and parts of them are used continuously for real-time balancing purposes (often called balancing market or regulating power market). The activation of these reserves is done centrally by the TSOs. The TSOs pay an availability fee for maintaining the DR resources in a state of readiness. An availability fee or reduced tariffs create foreseeable revenues for the end-users. The agreement may cover a shorter (days) or a longer (years) period.

5.3 In addition to the operational reserves there may be national arrangements where a body (TSO or somebody else) is obliged to maintain peak load resources to maintain an adequacy in the power system during the peak hours. DR resources can be optional in these cases as well, if they meet the technical and other requirements.

## 6 Summary

6.1 Demand response (DR) is experienced in two different forms:
1) Driven by the prevailing prices; and
2) Contracted resource as power system reserve.

6.2 *Driven by the prevailing prices*. By bidding of demand resources in the market places the end-users optimize their use of electricity during high price spikes. DR during a short time period (hours) will positively contribute to the market balance during peak load periods and also to eventual imbalances in the real-time operation. DR during a longer period will also have an effect on the energy balance. Establishment of market places, where a short term market price for electricity is cleared, has created the opportunity for DR bidding.

6.2.1 A tariff structure based on a power demand fee can be a direct incentive for DR.

6.2.2 The price difference in time-of-use tariffs can give rise to DR by shifting the demand from the high price period to the low price period. Investments in technical solutions may be needed to enable the change in the demand pattern. This kind of DR cannot be utilised as a resource in the real time operation for security of supply. It will flatten out the load curve and thus contribute positively to the power balance.

6.3 *Contracted resource as power system reserve*. DR as a contracted resource is used as power system reserves in real-time operation in order to maintain the power system balance and security of supply. In these cases the primary reasons for their activation are the physical imbalances locally or on the system level or heavy load flows in the transmission or distribution networks. The availability of the DR resources is guaranteed by the contracts including availability fees. If the DR is used to reduce load flows on the networks, the resources must be located in specific places (e.g. close to off-shore wind connection). In the other cases there may also be specific requirements for the location of the resources.

6.4 Some countries have established special peak load arrangements using DR resources together with power plants as additional power system reserves.

6.5 A substantial amount of DR has already been exploited as contracted resources and mainly by the TSOs There are still potential resources left. The DR potential usually depends on the industry structure. All the potential is not available whenever needed.

6.6 Small customers can also contribute to the DR. However, the smaller the demand resources are the bigger the implementation costs are per end-user. The benefits that may be achieved from implementing DR resources of the small end-users may not cover the implementation costs.

6.7 Telemetering on an interval basis is a necessity for utilisation of the DR. Additional investments may be needed in the processes of the end-user as well.

6.8 Economic incentives are pre-requisites for activation of the potential DR resources

6.9 The impact of DR depends on the specific market situation and market arrangements. If a higher degree of DR participation in the market places will be targeted special attention has to be paid to the market design and product characteristics in the market places. A careful consideration is needed if the DR resources are contracted by the market players in order to be activated in the market places.

# ANNEX

## EXAMPLES OF UTILISING DR RESOURCES

- The Nordic Countries
- Spain
- Great Britain
- Greece
- The Netherlands

## 1. Examples of utilising demand response resources in the Nordic countries

1.1 Electric boilers in the Nordic countries represent a capacity of more than 2000 MW and their energy consumption is more than 10 TWh/a, if the electricity prices are low. Use of electric boilers is totally dependent on the relation between electricity and oil prices i.e. DR is driven by the market prices.

1.2 There is no exact information available on the price driven DR in the market places. However, some periods of high prices have been afterwards statistically analysed. The results indicate in these cases a demand response of 200-300 MW in Finland, 500-1000 MW in Norway and 700-1000 MW in Sweden.

1.3 Time-of-use charges in the sales and transmission/distribution tariffs can give rise for investments in heating installations in the houses that are supplied in the night time and the accumulated energy will be utilised during the day time (for example floor heating). Similarly, electrically heated warm water tanks can be supplied during the night time for using the warm water during the day time. Additional investments in a bigger size of the tank are needed. In these cases, eventual additional investments are covered by lower prices during the night time. Once the investments have been made these examples contribute positively to the load curve on the long term by increasing demand during the night time only. From the end-user's point of view these installations contribute to the security of supply as well. They are not sensitive to strained power balances which normally occur during the day time. The critical point to make use of these installations is the moment when the decisions on the investments are made. This is usually in the construction phase of the houses.

1.4 Time-of-use tariffs have incentivised the end-users to invest in technology which can draw benefits from the price difference between day and night time. The same incentive should come from the market prices if there is a difference during day and night time.

1.5 In Norway, the regulation obliges network companies to offer special tariffs for customers operating electric boilers and having available alternative boilers based on fuel sources. The amount of interruptible load having special transmission tariffs is about 1000 MW. The same rule applies to customers having a particular risk of disconnection due to network conditions. In these cases special tariffs incentivise that DR resources are used to maintain security in the transmission/distribution networks.

**DR resources acquired by the TSOs:**

1.6 In Denmark, Energinet.dk has pilot projects where 50 MW of back-up generation is used as operational reserves. The technical potential of DR in the Danish industry is estimated to be 380 MW, which is equal to about 7 % of the peak demand in Denmark.

1.7 In Finland, Fingrid has acquired 545 MW demand resources in the process industry for a four year period to be used as frequency controlled disturbance reserves (120 MW) and fast active disturbance reserves (425 MW). Fingrid has also contracted a possibility to acquire more demand resources if needed. The technical potential of DR in the Finnish process industry is estimated to be about 1280 MW (including 545 MW already acquired by Fingrid), which is equal to about 9 % of the peak demand in Finland. A price level of at least 300 €/MWh should usually activate these resources.

1.8 In Norway, Statnett is running a Regulating Capacity Options Market (RKOM) for acquiring reserves for disturbances and balancing purposes. Both generation and demand resources can bid. Maximum weekly acquisition from DR resources has amounted to about 1480 MW (equal to about 6 % of the national peak demand) consisting of large industrial end-users. The offered volume has been bigger. The acquired resources are paid a premium for being available in the regulating power market. The weekly premium of winter 2005/06 has varied from 100 to 400 €/MW. The end-users decide their bid price in the regulating market.

1.9 Statnett has recently made an agreement with 8 companies for the right to reduce the power demand of these companies up to 370 MW (in total 765 GWh/a). These options are a tool for Statnett if it becomes necessary to reduce consumption for a short period in order to reduce the risk for rationing. The criteria for the choice of the companies are based on consumption, geographical location, flexibility and cost related to each option. About 20 companies participated in the tendering process.

1.10 Statnett is encouraging retailers to bid aggregated DR resources in RKOM. There are two pilot projects going on, the aggregated volume is about 25 MW in both cases. The estimated technical potential of back-up generation is about 500 MW in Norway.

1.11 It has been estimated that DR potential in Norway (excluding electric boilers) that will be activated when the market prices are higher than 70 €/MWh could contribute with about 14 TWh/a to the energy balance.

1.12 In Sweden, Svenska Kraftnät has contracted 90 MW demand resources to be used as fast active disturbance reserves. Svenska Kraftnät has a temporary responsibility to acquire peak load resources (either generation or demand resources) in addition to operational reserves. For the winter period 2006/07 the contracted capacity of demand resources amounts to 503 MW corresponding to about 25 % of the total amount of acquired peak load resources. The offered DR capacity was bigger.

## 2 Examples of utilising demand response resources in Spain

2.1 Since 1988 the industrial end-users (aluminium, paper, metal, chemical industry) have been able to choose a special tariff voluntarily. They are about 200 customers with a demand over 5 MW (in total about 2.000 MW). The TSO can (when informing in advance) request them to limit the demand during 45 minutes, 3 hours, 6 hours or 12 hours. The annual maximum duration (in hours) and number of demand reductions requested by the TSO is defined for each end-user. The end-users receive a discount both in fixed and variable charges depending on the times they are requested to limit their demand in a year.

2.2 The TSO REE uses these resources when there are physical imbalances between supply and demand, never due to economic reasons. Each time demand reductions are requested the reasons for reductions have to be justified by the Industry Ministry.

2.3 The yearly number of days, when REE has requested demand reductions, has normally been varying between 0-4 days. In 2001, demand reductions were requested during 10 days.

2.4 The industrial tariff will soon disappear. REE is discussing with the industry how to use these resources for ancillary services, having economical signals like generation has to bid.

2.5 In Spain, there are also time-of-use tariffs which give economic signals for demand response.

## 3 Examples of utilising demand response resources in Great Britain

3.1 In GB, National Grid utilises a number of 'balancing services' when balancing the transmission system. Demand is able to participate in a number of these services.

3.1.1 **Demand Management** is an increase in active power generation by back-up generation or demand reduction by large electricity consumers, minimum of 25 MW, across a minimum of 2 consecutive settlement periods (settlement periods are half hourly). This service is procured through bilateral agreements.

3.1.2 **Fast Reserve** is an increase in active power generation or demand reduction used to cater for rapid rates of change in demand, e.g. TV pick ups, following receipt of an instruction from National Grid. Active power must start within 2 minutes of the despatch instruction at a delivery rate in excess of 25 MW/minute and should be sustainable for a minimum of 15 minutes. This is procured through a combination of monthly tenders and, in some circumstances, bilateral agreements. The indicative demand side volume for this service is 760 MW.

3.1.3 **Firm Frequency Response**. This is the firm availability of Dynamic and/or Non Dynamic frequency response in nominated service periods. This is procured through a monthly tender for a single or multi month contract. This is used daily for dynamic frequency response.

3.1.4 **Frequency Control by Demand Management (FCDM).** Provides frequency response through interruption of demand customers. The electricity demand is automatically interrupted when the system frequency transgresses the low frequency relay setting on site. The demand customers who provide the service are prepared for their demand to be interrupted for a 30 minute duration, where statistically interruptions are likely to occur between approximately ten to thirty times per annum. This service is procured bilaterally, typically through Agents, acting as a single point of contact for a portfolio of demand sites. Each site must delivery a minimum of 3 MW within 2 seconds, currently this service provides a potential of about 200 MW of response.

3.1.5 **Standing Reserve** is active power held in reserve to manage the unplanned mismatch between generation and demand during particular times each day (e.g. short term plant losses, plant shortfalls, and demand forecast error). Participants must have a response time of 20 minutes or less with the ability to provide the service for at least 2 hours and have a recovery period of a maximum of 20 hours. There must also be the ability to provide the service three or more times a week. This service is contracted via an annual tender process, open to non-synchronised generation and demand e.g. OCGTs, metal smelting, chemical processing, refrigeration etc. Service providers receive an availability fee (£/MW/h) for maintaining units in a state of readiness to provide reserve and an utilisation fee (£/MWh), paid when the service is instructed - payment is made against the delivered volume. This service is typically used daily.

3.2 National Grid has the capacity to request demand reduction from a DNO (Distribution Network Operator). The demand reduction usually takes the form of voltage reduction rather than cutting off demand totally. Voltage reduction is usually sufficient to meet the first 2-3 stages of demand reduction. National Grid will call the DNO where the demand reduction is needed and manually request the demand reduction, stating how many stages are requested and for how long. Up to 20% reduction in demand can be requested to be dropped within 5 minutes. Demand is reduced in 5% steps (each 5% is referred to as a 'stage'). This form of demand reduction would only be requested where all other available options in terms of system operation had been exhausted (e.g. commercial DSR services).

## 4 Examples of utilising demand response resources in Greece

4.1 In the Greek system the DR resources are used mainly as power system reserves in real-time operation in order to maintain the power system balance and security of supply. The DR resources do not participate in the market.

4.2 The DR resources contain the following:

4.2.1 Special tariffs are used for some industrial consumers e.g. aluminium, metal and paper industry. This industrial tariff started twenty years ago and very soon will disappear.

4.2.2 The Ministry of Development and the Regulatory Authority for Energy decisions about the load reduction for the summer period of the year 2005 and 2006 (for industrial end-users 150 kV and 20 kV) or some other similar decisions in the future, depend on the power system situation.

4.2.3 Schedules from the TSO about the interruption of irrigation (that policy is under the Ministry of Development and the Regulatory Authority for Energy decisions). A yearly approximation is about 3 or 4 days maximum under requested demand reduction.

4.2.4 Load shedding in some distribution lines (20 KV) in the automatic or manual mode, after the decision of the TSO and cooperation with the Distribution Network Operator.

4.2.5 Some special tariffs in the total demand are based on a daily basis, in particular time duration. The main target for this resource is to regulate the demand profile basically in the low level of demand (decrease the difference between maximum and minimum demand).

4.2.6 Another one is a certain number of demand reductions requested by electricity producers mainly by lignite mines. The level of the reduction and the duration of this reduction is decided by the TSO.

4.2.7 There are studies in progress for the introduction of measures that should offer motives to consumers to reduce their consumption during system peaks.

## 5 Examples of utilising demand response resources in the Netherlands

5.1 In the period 2003-2004 the Dutch Ministry of Economic Affairs carried out a policy study regarding Security of Supply in the Netherlands. This study also included an analysis of demand side response potential in the wholesale as well as the retail sector.

5.2 Hereafter some conclusions are summarized:

- the total demand response potential in the wholesale sector is about 1700 MW (20% of total peak demand of this sector), from which 1000 MW is currently utilised and 700 MW is not exploited yet
- 65% (650 MW) of the utilized wholesale demand response is contracted capacity, 35% (350 MW) is self-dispatched

- of the 1700 MW potential, for almost 1600 MW  the break-even point for shutting down lies around market prices between 300 and 500 €/MWh. The last 100 MW becomes attractive at prices around 1000 €/MWh
- the 1700 MW consists of 1200 MW in the industry (20% of total industrial demand) and some 500 MW in the non-industrial sector, of which 400 MW comes from greenhouse farming (almost 60% of greenhouse farming demand) and the remainder from gas storage demand
- more industrial potential is available at prices above 2000 €/MWh
- in the non-industrial wholesale sector demand response becomes attractive at peak prices that are around 80 times higher than the average price (for 2004 this would have been at price levels > 2800 €/MWh)
- the quality of the demand response (capacity x duration) is highest in the chemical sector, average capacity per user is around 160 MW, demand can be shut down during a couple of days
- in the retail sector (households) the potential is about 700 MW in the short term and around 1200 MW in the long run
- demand response initiatives in the retail sector are withheld because of:
    - lack of smart metering systems and data communication infrastructure to the supplier
    - the free-rider problem

*Sources:*
- *"Demand response scan retail electricity consumers", SenterNovem, June 2004 (in Dutch only)*
- *"Demand response utilisation in the liberalised electricity market", Deloitte, May 2004 (in Dutch only)*

5.3 TenneT is currently contracting 300 MW of wholesale demand response reserves as so-called emergency reserves. This is almost 50% of the contracted wholesale demand response capacity in the market.