Increased electricity demand flexibility enabled by smart grid: Impacts on prices, security of supply and revenues in Northern Europe

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Overview

The power sector is undergoing major changes with increased integration of renewable energy (RE) technologies like solar, wind and hydro power on the power supply side. The challenges related to regulation and balancing of energy systems with a high share of renewable intermittent power are well known. Increased flexibility on the demand side, in the form of moving electricity consumption from peak to off-peak periods, is one way of handling varying power generation from RE sources. Currently, however, this type of short-term flexibility on the demand side, i.e. a consumption pattern with less difference between off-peak and peak periods and that may adjust on an hourly basis to variations in supply, is limited. There are two main reasons for the current lack of demand flexibility: First, most consumers are not exposed to real-time pricing (RTP), implying that they have no incentives to move consumption to periods with low prices. Second, technical solutions for automatic adjustment of consumption are today limited, meaning that flexible - or smart - energy usage requires user's action. The objective of the current study is to analyze how a development towards better demand side management will affect the power system in terms of need for peak power capacity, technology mix in electricity production, electricity prices and system costs. The analysis focuses on the North European electricity market (the Nordic countries[1], Germany, UK and the Netherlands).

Methods

Country-specific estimates from IEA on potential short term (within day) demand flexibility are used to define four scenarios regarding future demand flexibility. The electricity market impacts of the different demand flexibility levels are then analyzed applying an power market model that is detailed in time and space and calibrated for the expected electricity system in 2020. The power market model applied is based on the Balmorel model structure which is a convex and linear partial equilibrium model simulating generation, transmission and consumption of electricity under the assumption of competitive markets (see e.g. Ravn 2001, Ravn, Hindsberger et al. 2001). The current model version covers the Nordic countries, Germany, the Netherlands and the UK. The model is calibrated with updated 2012 power system data for all model countries and provides a specifically detailed representation of the Nordic countries. The model, which is deterministic in a one year (or one week in the short-term mode) time frame, calculates the electricity production per technology, time unit and region, minimizing total system costs for a given electricity demand and under certain capacity constraints regarding production and transmission. The associated dual variables, or shadow prices, show the marginal production costs, which reflect the electricity price when assuming competitive markets. For each scenario, market clearing conditions are analyzed by applying two different modes of the model: i) a long-term (one year) optimization horizon, including all 52 weeks divided into 34 time segments per week, and ii) a short-term (weekly) optimization horizon with an hourly time resolution.

Results

Some of the model simuilation results are shown in Table 1 and Figure 1.Table 1 shows modelled electricity prices in the different scenariosin selected model countries while Figure 1 shows the change in production mix in all model countries in a scenario.

[1] In this study Iceland is excluded from the term "Nordic countries".

Table 1. Average prices (total, peak and off-peak) in the "baseline" scenario, and change in price for the different demand response scenarios, selected model countries.

		"baseline" scenario (price in €/MWh)	Demand flexibility scenarios (change in €/MWh)		
			"moderate"	"full"	"high"
Denmark	Total average	**50.7**	-0.4	-0.8	-1.6
	Peak (8 a.m. to 8 p.m.)	**66.5**	-1.4	-3.0	-6.0
	Off-peak	**41.9**	+0.2	+0.4	+0.9
Germany	Total average	**50.0**	-0.4	-1.0	-1.8
	Peak (8 a.m. to 8 p.m.)	**68.0**	-1.7	-3.5	-6.8
	Off-peak	**40.1**	+0.2	+0.3	+0.8
Norway	Total average	**43.8**	+0.1	-	+0.2
	Peak (8 a.m. to 8 p.m.)	**47.5**	-0.2	-0.2	-0.3
	Off-peak	**41.8**	+0.2	+0.2	+0.5

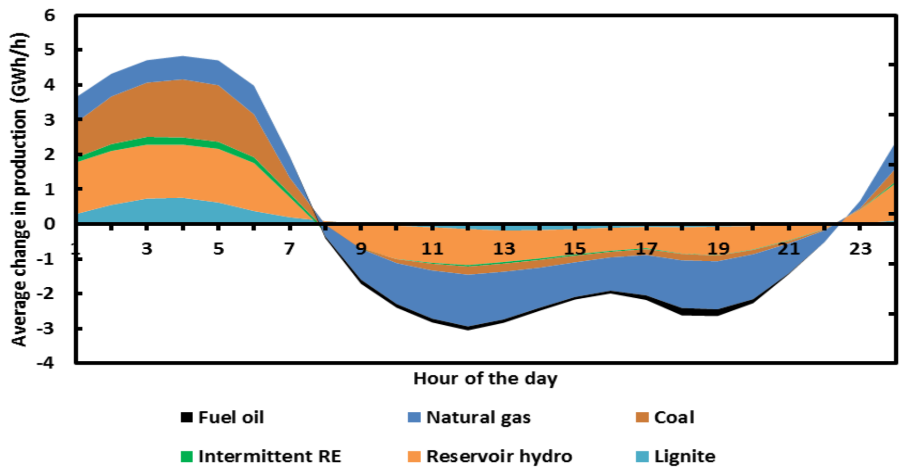

Figure 1. Change in the hourly North European production mix (GWh/h) caused by the increase in demand response, "full" flexibility scenario (all model countries, all-year average)

Conclusions

The results show that the need for peak power technologies and balancing reserves using oil and natural gas decreases when demand flexibility increases. The most significant changes in the production mix take place in countries with relatively high shares of thermal power (Germany, the Netherlands and the UK). The average price during peak hours (between 8 a.m. and 8 p.m.) reduces by €3.7/MWh in the Netherlands and by €3.5/MWh in Germany when assuming that the flexibility potentials estimated by IEA are utilized by the demand side. The combined decrease in production and day hour prices implies that the revenues from electricity generation decrease up to 44% and 8% for oil condensing power and gas power in the scenario assuming the highest demand flexibility. Prices in off-peak hours will as expected increase for increasing short term demand flexibility, but the off-peak price rise is generally minor. The effects of demand flexibility are found to be larger in the winter than in the summer. Generally, the impacts of demand flexibility are largest in periods of high demand and low supply. The overall impacts of demand flexibility will hence depend on the general supply-demand balance in addition to the mix of production technologies available. The model analysis shows that coal power production during night hours will increase significantly. Hence, given the electricity production system and fuel prices assumed in this study, increased short term demand flexibility is likely to increase greenhouse gas emissions from electricity production. Our results indicate that the system benefits, in terms of reduced need for peak capacity and increased security of supply are larger than the economic benefits for the consumers. Moreover, the producer surplus will decrease with increasing demand flexibility. Therefore, policies stimulating to increased flexibility on the consumer side are needed to fully utilize the potential system benefits from increased demand flexibility.