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Model-based Assessment of the possible Future Demand Response Utilization in Germany for Different Renewable Energy Deployment Scenarios

Bachelor Thesis

by

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1. Introduction

With an increasing share of intermittent renewable energy sources (RES) in energy systems, the balancing of electric supply and demand has become increasingly challenging. The fluctuating supply of RES does not necessarily fit with the electric demand given in a region. One mean to make up for this deficit may be to store the excess energy produced by RES in energy storage systems [28]. In times of high supply and low demand these storage systems can be filled, whereas when the opposite is the case they can be emptied.

For the above mentioned application, one of the most suitable storage technologies, at a large scale, is the Pumped Hydro Energy Storage (PHES). The potential of PHES is generally regarded to be very limited due to the requirements posed by the site at which the plant is to be erected, especially in Germany [15]. Nevertheless, [5] stated that since 2010 a trend can be observed that the PHES capacities in Germany more rapidly increase than in the past. The potentials in Europe are especially high in the Alps region and Scandinavia [15]. Apart from PHES, other technologies can be used to balance intermittent RES. These technologies include other energy storage options such as Compressed Air Energy Storage (CAES) (diabatic and adiabatic), Lithium-Ion Battery Energy Storage (LiBES), Hydrogen Energy Storage (HES) and Vanadium Redox-flow Battery Energy Storage (VRBES), as well as balancing options such as the charging of electric vehicles.

Due to the geographical and physical limitations in place, suitable alternatives to the storage of energy through PHES need to be found. In this search a promising alternative appears to be demand response (DR).

DR is defined by [23] as:

> 'Changes in electric use by demand-side resources from their normal consumption patterns in response to changes in the price of electricity, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized.'

As noted by [24] it is very difficult to draw a line between the terms DR, load management and demand-side management. DR takes a different approach from power generation technologies (section 2.2.1 - 2.2.4 & section 2.2.7). Instead of focusing on the supply of power when demanded it concentrates on adjusting the demand curve. This decreases peak loads in the electricity grid. Following from this, electricity providers can decrease the reserve capacity they need to hold back. Hence higher full load hours (FLH)s (for a definition of the term FLH refer to section 2.2.7) and therefore a more efficient and economic usage of existing power plants can be expected [38]. Another very important benefit of DR is the ability to partly replace standing fossil reserves needed to balance intermittent RES generation. This is especially important in the case of high shares of intermittent renewable energy technologies in the energy system [1]. Fossil standing reserves decrease the system performance when regarding their low FLH and high fuel costs [38]. DR is a good countermeasure for this development avoiding costs and CO_2 emissions. However DR is also beneficial for the electricity consumer for example through incentives to increase his/her demand given when the electric load in the grid is very low. A counter example would be the discouragement through high energy prices when the electric load is high [1]. Nevertheless the development of DR in energy systems has been hindered due to several factors. Changes induced by DR affect the consumption patterns of consumers. Therefore the utilisation of DR may be hindered by a lacking acceptance of the altered consumption pattern. According to [38] the following points contribute to the largest obstacles for DR programmes:

- Lack of information- and communication infrastructure
- Lack of understanding of the benefits provided by DR
- Increased complexity of systems integrating DR in comparison to conventional solutions
- Unsuitable market structure and missing incentives

For further elaboration on the four above-mentioned challenges please refer to [38, pp. 4425].

The way DR programs may be conducted can vary substantially. According to [23] DR programs can be classified into two main groups: Incentive-based and time-based DR. These can further be subdivided into the categories in figure 1.1.

[14, 1, 13] undertake similar categorisations but with a slightly different wording using price-based DR instead of time-based DR.

It has to be noted that DR may flatten out fluctuations in the demand patterns of a region but usually the total energy consumed is not reduced, merely rescheduled. There is however the exception of demand shedding, as described in section 2.2.8. Generally the aim of DR can be seen as to increase the flexibility of electricity demand. [1, 38] Especially short notice demand flexibilisation can be regarded as the key concept of DR due to modern communication technologies being used.

In this work the utilisation of DR in different renewable energy deployment scenarios for the scenario years 2030 and 2050 is examined. The aim is to get a better insight into the behaviour of DR in the context of the German energy system. To reach this aim several sensitivity analyses by means of renewable energy deployment scenarios have been performed. As to gain a broader understanding of the system's response, DR

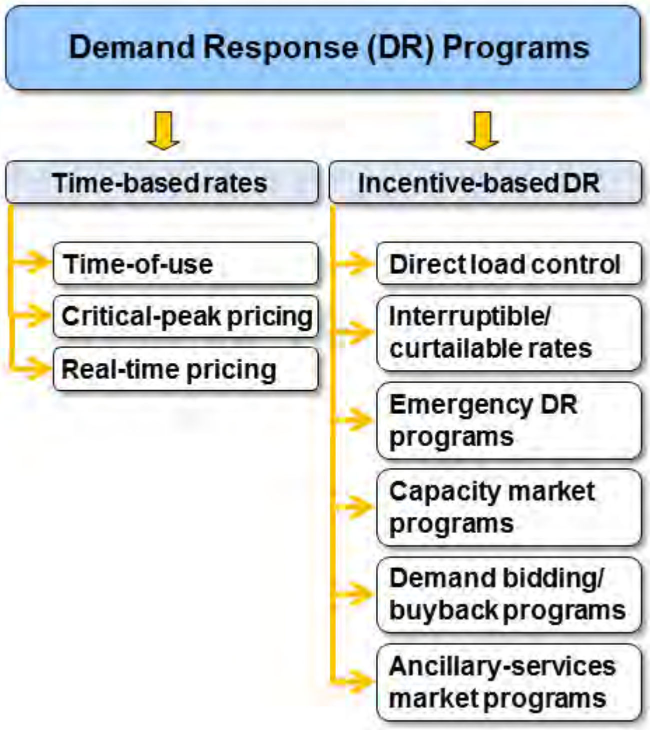

Figure 1.1.: DR classification in accordance with [23]

is also examined in combination with other parameters. These are conventional FLH, annually stored PHES energy and curtailed fluctuating renewable power. Concerning the behaviour of these parameters in combination with DR the following hypotheses have been established:

1. Utilisation of DR is influenced by fluctuating renewable technologies.
2. Utilisation of DR is influenced by different degrees of deployment of fluctuating renewable technologies.
3. Conventional FLH are decreased whenever the utilisation of DR is increased.
4. An increased utilisation of DR leads to less curtailed fluctuating renewable power.
5. An increased utilisation of DR reduces the annually stored PHES energy.

Hypothesis 1 and 2 result from the intrinsic characteristic of DR to create a rather flexible demand shape and therefore enhance the ability to react to fluctuating supply. Hypothesis 3 is based on the reasoning, that whenever there is a high utilisation of DR in a system, the need for conventional power plants to satisfy peak demand is reduced. Furthermore hypothesis 4 is based on the assumption that DR may increase the demand at times where fluctuating RES are exceeding the original demand. Thus, increasing the amount of usable energy and decreasing the curtailed power. Following from the assumption that DR and PHES are competing over peak demand, an increase of one technology would lead to a decrease in the other. Therefore leading to hypothesis 5.

In the course of this work these hypotheses are going to be tested with the results of simulations with the energy systems model Renewable Energy Mix (REMix) (for further elaboration on REMix refer to section 2.1).

In the following thesis, firstly the relevant parts of the energy systems model REMix (cf. section 2.1) are qualitatively elaborated. Subsequently the data basis and the variations of the latter are summarised. Following the results of this thesis are presented as well as discussed. Finally the main findings are summarised, future prospects of further investigations are suggested and a critical evaluation is conducted.