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SWEET P+D NEDELA

Netztarife für Dezentrale Laststeuerung

sweet swiss energy research for the energy transition

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Summary

The need to optimize grid expansion costs by managing flexible loads, which is one of the key research topics of the SWEET PATHFNDR consortium, has prompted interest in dynamic tariff designs. However, current distribution grid operators (DSOs) predominantly rely on static tariff structures, which provide imprecise incentives for load shifting. This project, NEDELA, aims to address this challenge by implementing an interface for transmitting dynamic tariffs to EMS within Groupe-E's grid area. Through field studies and simulations, the project evaluates different tariff designs' effectiveness in reducing grid peak-load and preventing rebound peaks. Key achievements include the development of a WEB-API for tariff transmission, successful trials demonstrating EMS flexibility, and the launch of the Vario Tariff for 2024. The findings contribute to advancing grid efficiency and promoting user acceptance of dynamic tariffs.

Résumé

La nécessité d'optimiser les coûts d'expansion du réseau en gérant les charges flexibles, ce qui est l'un des principaux thèmes de recherche du consortium SWEET PATHFNDR, a suscité l'intérêt pour les conceptions tarifaires dynamiques. Cependant, les gestionnaires de réseaux de distribution (GRD) actuels s'appuient principalement sur des structures tarifaires statiques, qui fournissent des incitations imprécises au déplacement de la charge. Grâce à des études sur le terrain et à des simulations, le projet évalue l'efficacité de différentes conceptions tarifaires pour réduire la charge de pointe du réseau et prévenir les pics de rebond. Les principales réalisations comprennent le développement d'une interface WEB-API pour la transmission des tarifs, des essais réussis démontrant la flexibilité des EMS, et le lancement du tarif Vario pour 2024. Les résultats contribuent à faire progresser l'efficacité du réseau et à promouvoir l'acceptation des tarifs dynamiques par les utilisateurs.

Zusammenfassung

Die Notwendigkeit, die Netzausbaukosten durch die Steuerung flexibler Lasten zu optimieren - eines der Kernthemen des SWEET PATHFNDR-Konsortiums, hat das Interesse an dynamischen Tarifstrukturen geweckt. Die derzeitigen Verteilnetzbetreiber (VNB) verlassen sich jedoch überwiegend auf statische Tarifstrukturen, die nur ungenaue Lastverschiebungssignale senden. Anhand von Feldstudien und Simulationen bewertet das Projekt die Effektivität verschiedener Tarifdesigns bei der Verringerung der Netzspitzenlast und der Vermeidung von Rebound-Spitzen. Zu den wichtigsten Ergebnissen gehören die Entwicklung einer WEB-API für die Tarifübertragung, erfolgreiche Versuche zur Demonstration der Flexibilität von EMS und die Einführung des Vario-Tarifs für 2024. Die Ergebnisse tragen dazu bei, die Netzeffizienz zu steigern und die Akzeptanz dynamischer Tarife bei den Nutzern zu fördern.

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Abbreviations

DSO Distribution grid operator

EMS Energy Management System

EV Electric Vehicle

HP Heat Pump

1 Introduction

1.1 Background information and current situation

Despite the need to reduce grid expansion cost by shifting flexible loads such as electric vehicles (EV) and heat pumps (HP) in a grid-serving manner, today:

- most distribution grid operators (DSOs) in Switzerland currently still use static tariff designs such as constant high-low tariffs. Compared to dynamic tariff designs, static high-low tariffs provide a much less precise signal for shifting flexible loads in a way that alleviates the grid.
- there is no commonly agreed standard for transmitting such tariff signals to market participants. A common standard would greatly help developers of energy management systems (EMS) to offer the flexibility of their customers without having to re-program a different price interface for each distribution grid operator.

Dynamic tariffs can signal grid bottlenecks more accurately. However, depending on their design, dynamic price signals can also lead to “herding” and unintended consequences in the form of so-called “rebound peaks” during the times with the lowest tariff value. When the volumes of automatically controlled loads increase, these new peaks may exceed the magnitude of the old peak, which the tariff was meant to address (Winzer and Hensler-Ludwig 2024).

The NEDELA project is part of the **SWEET PATHFNDR** consortium, which investigates pathways to an efficient future energy system through flexibility and sector coupling.

1.2 Purpose of the project

The NEDELA project wants to develop and field-test an interface for transmitting dynamic tariffs to EMS in the grid-area of Groupe-E and test the effectiveness of different tariff designs for reducing grid peak-load and avoiding rebound peaks through a field-study and simulations.

It will test tariff design suggestions from PATHFNDR work-package 7, and feed back the results regarding tariff impact and tariff acceptance. Tariff approaches which achieved the best results in the NEDELA project will be subsequently tested in the PATHFNDR project and compared to other approaches for remunerating flexibility in a simulation.

1.3 Objectives

The detailed objectives of the NEDELA project are:
Q1. Which interface definition is suitable as an industry standard for the transmission of corresponding tariff signals to home energy management systems (HEMS)?
Q2. What are the hurdles and problems in introducing a dynamic grid tariff and in implementing the interfaces?
Q3. What effect do different tariff variations have on the maximum grid load and the system costs (energy + grid)?
Q4. How are the tariffs accepted by end customers?

2 Executive summary of the activities and results to date

Since the start of the project, we have

- *Developed and tested a WEB-API for transmitting dynamic tariffs:*

  During workshops with EMS providers, there was a broad agreement that dynamic tariffs should be transmitted to APIs via a REST-API web-interface based. The details for the publication format of the tariffs were defined after exchanges with various EMS providers and Groupe E implemented such a WEB-API that started publishing virtual tariffs from August 2023 and publishes the newly introduced Vario-Tarif starting from January 2024. The WEB-API is described on Groupe E's website[1] and the tariffs[2] are also accessible. In general, it was encouraging to see the wide agreement about the preference for utilizing a Web-API for tariff transmission, and the widespread interest of EMS developers in implementing and testing the API.

  So far, the WEB-API for transmitting dynamic tariff signals of the Vario tariff has been implemented by the following energy management system providers:

  - **CLEMAP Load Management**
  - **Eigenverbrauchsmanager Smart Energy Engineering**
  - **evcc**
  - **Optinergy**
  - **Smart Energy Link**
  - **SOLAR MANAGER**
  - **SOLECO Optimizer**
  - **sun2wheel**

  Based on previous work from Groupe-E and results during the NEDELA project, a similar Web-interface has been developed as part of the **"ESIT" P&D project** by Swisspower. Currently discussions are ongoing in order to define a possible future standard for this DSO-EMS.

- *Tested a dynamic tariff signal on 5 different sites with 4 different EMS systems:*

  Small pilot projects / trials were initiated for 5 different test sites with 4 different EMS systems and some are still running. The trials illustrate that EMS can reduce customer bills by shifting flexible loads in response to dynamic tariffs in some, but not in all cases. As illustrated in Figure 1, our preliminary conclusion is, that the Vario tariff provides very good incentives to move customer peak-load to off-peak periods. While in absence of the Vario tariff, the customer peak-load often occurred during hours with high grid load (Figure 1, top), the introduction of the Vario tariff was able to move customer peak-load to off-peak hours (Figure 1, bottom).

[1] https://www.groupe-e.ch/de/energie/elektrizitaet/privatkunden/vario

[2] https://api.tariffs.groupe-e.ch/v1/tariffs?start_timestamp=2024-03-11T00:00:00+01:00&end_timestamp=2024-03-12T00:00:00+01:00

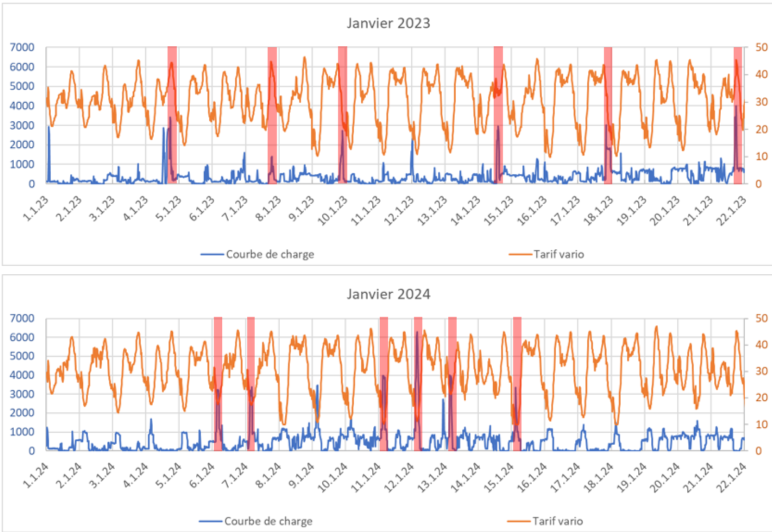

Figure 1: Load curve of a sample customer without vario tariff (top) and with vario tariff (bottom).

A more detailed evaluation of pilot projects is expected in S2 2024.

Our evaluation of the field tests plans to discuss the effectiveness of VARIO dynamic tariffs, in the term of, but not limited to, load profiles and the costs of end-users based on the data sampled (or the ongoing field tests) from multiple EMS systems for various customers.

As illustrated in Figure 2 and discussed in Winzer and Hensler-Ludwig (2024), the impact of dynamic tariffs on grid peak-load depends on the volume of loads which react to the tariff signal. During the first years, when the volume of loads that react automatically to the tariff signal is small, dynamic tariffs reduce grid peakload, because loads are shifted to off-peak hours (Figure 2,a). However, during later years, when the volume of loads that react automatically to the tariff signal increases, without further adjustments to mitigate overcoordination, herding behaviour in response to dynamic tariffs could result in a peak that exceeds the original grid peakload (Figure 2,b).

- *Launched the Group-E Vario dynamic tariff for 2024:*

  Groupe E developed the formula that allows to calculate the dynamic Vario tariff. The Vario tariff together with the other tariffs available for 2024 were published on Group E's website. The tariffs were sent to ElCom as required by the regulator. Groupe E further implemented the tariff in its billing system.

  The formula for the vario tariff, which is tested during 2024 is as follows[3]:

$$Price_i = (NL_i - NL_{24h} + F) \cdot \frac{\sum_{i=15min}^{24h} NL_i \cdot DT_i}{\sum_{i=15min}^{24h} NL_i \cdot (NL_i - NL_{24h} + F)}$$

  Where:

[3] https://groupee.sharepoint.com/:b:/s/MediaPoint/EWa9SaoQ4mNBn1EMbcwdc3ABD1-dnc1SXpZ8FEGsKcn0Lg?download=1

- $Price_i$= vario tariff during quarter hour i
- NL_i= Gridload during quarter hour i
- NL_{24h}= average Gridload during the day
- F= Variability factor, for 2024 this equals to +35
- DT_i= Double tariff during the quarter hour i

The Vario tariff is proportional to the difference between the grid load NL_i during hour i and the average gridload during the day NL_{24h} plus an offset F, and includes a daily scaling factor to ensure that a customer whose load follows the grid load profile NL_i pays the same in case of the vario tariff and the double tariff. This ensures, that only customers whose load profile is more beneficial than the grid load profile pay less under the vario tariff than under the double tariff.

- *Investigated how attractive the new tariff is for end customers:*

  Siemens investigated how attractive the load-dependent tariff of Groupe-E would be for end-customers. This was first done for a preliminary tariff in July 2023, and then again for the final tariff in September, after its publication. To this end, the savings that an optimizer can achieve compared to a conventional state-of-the-art controller were assessed. This was done by means of whole-year simulations. A Rule-based Model Predictive Controller (RMPC) with a receding horizon of 24h was used for the optimization. The necessary forecasts for PV production, electrical baseload, and heat consumption for room heating and domestic hot water were generated by data-driven forecasters (i.e., without a-priori knowledge), as it must also be done in a real product. The optimization algorithm used was thus very close to a real product.

  The HVAC cost savings were assessed for a single-family home (SFH) and a large multi-family home (MFH). They were found to be around 10% for the MFH and around 15% for the SFH. This shows that it can be attractive for end customers to shift their heat pump operation according to a grid-friendly tariff.

- *Simulated the impact of different tariff designs:*

  ZHAW simulated the impact of tariffs on households which are equipped with different combinations of flexible leads (electric vehicles, heat-pumps, batteries) and PV (Winzer and Hensler-Ludwig, 2024). Simulation results suggest, that while dynamic tariffs proportional to the gridload forecast can help to reduce system peak-load in case of a low share of flexible loads which react automatically to tariff signals (Figure 2, a), the overcoordination and herding behavior of automatically controlled loads may lead to rebound peaks that exceed the original peak-load in case of higher share of flexible loads which react automatically to tariff signals (Figure 2, b). A simple capacity price on customers individual peak-load achieves a much smaller impact but seems to avoid overcoordination because it creates an incentive to spread loads across time.

(a)

(b)

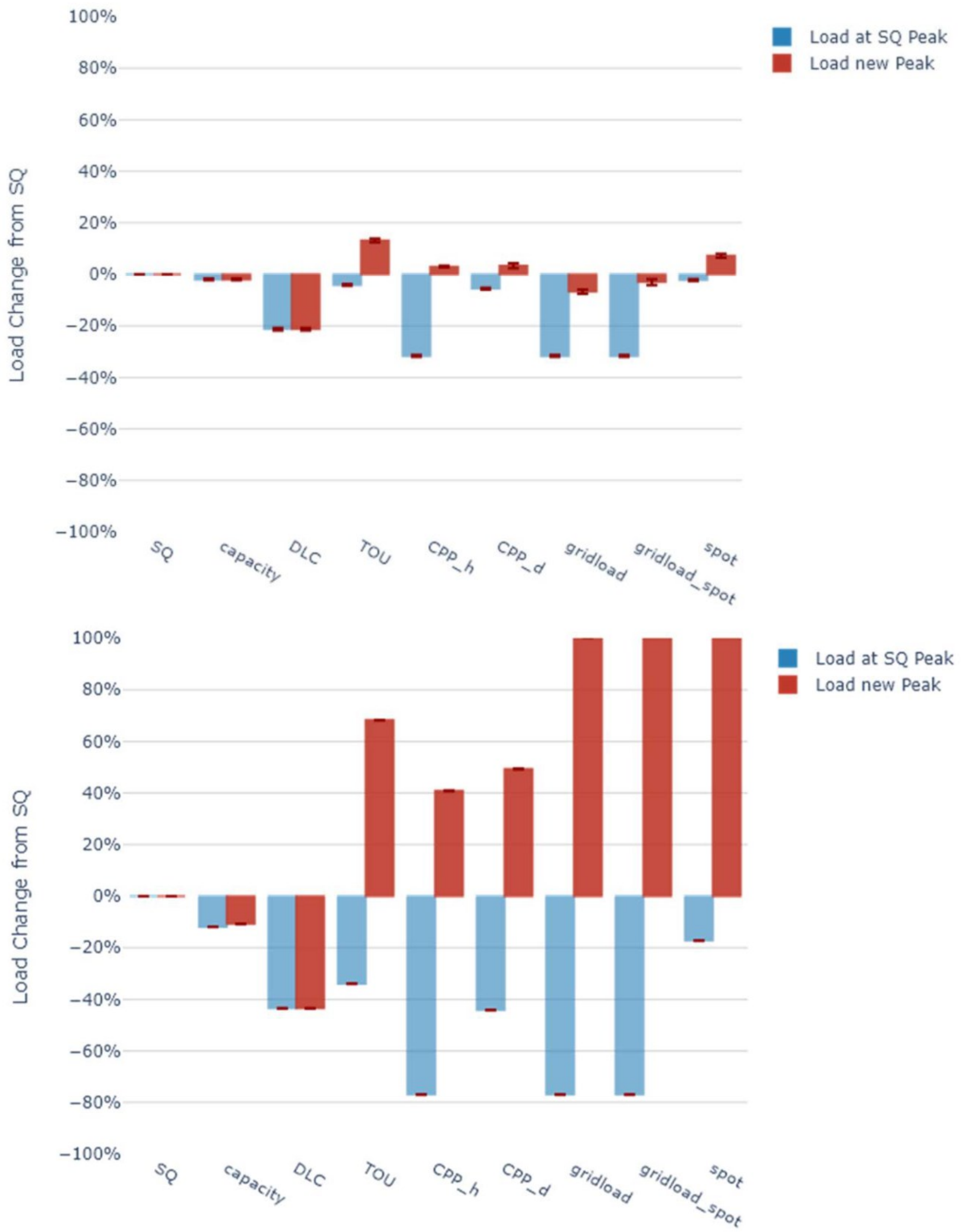

Figure 2: Change in peak-load compared to the status quo (SQ) scenario which assumes a constant per-kWh tariff if all residential electric vehicles, heat-pumps, and batteries connected in 2020 (a) and the 2050 (b) are automatically controlled in response to capacity tariffs (capacity), time-of-use tariffs (TOU), hourly and daily critical-peak prices (CPP_h and CPPd), tariffs proportional to gridload (gridload), gridload and spot (gridload_spot) and proportional to spotprices only (spot) as well as direct load control (DLC). Blue bars correspond to the hour when the day when the load reaches its peak in the SQ scenario. Red bars correspond to the day when the hour when the load reached its peak in the respective tariff scenario. Source: Winzer and Hensler-Ludwig (2024).

Results have been presented to the PATHFNDR consortium on several occasions, and will be compared to other flexibility incentives, such as market-based flexibility procurement in a simulation using the RESIM environment which will be financed by PATHFNDR supplementary funding in the course of 2025.

- *Tariff evaluation model development and analysis*

  Empa developed the tariff evaluation models and optimization problems for various techniques, i.e., electric vehicles, heat pumps, domestic hot water, and a living laboratory NEST as a specific building archetype at Empa, which allows us to evaluate the impact of dynamic tariffs from Groupe – E and ZHAW. The tariff evaluation models for techniques are based on the measurement data and their statistic knowledge, as the transportation behaviours of EVs, the heat pumps and boilers behaviours under various weather patterns.

  Empa simulated the hourly time-series load curves for different techniques given the 2024 Groupe –E Vario tariff. The evaluation results between Groupe – E Vario tariff and the classic double tariff (as a benchmark) demonstrated that the dynamic tariff is successful in peak shifting under different scenarios. Empa also simulated the hourly time-series load for different techniques given the tariffs designed by ZHAW, for the purpose of their calibration.

  A part of Empa's results has been presented by Peter Cuony at the Verteilnetzforum. The results are not included here due to the reason of future publication.

- *Experiment preparation on the NEST at Empa:*

  Empa prepared the tariff evaluation experiment for dynamic tariff designs on the living laboratory, the NEST building at Empa. This experiment will optimally adjust the operational set points of the EV, batteries, domestic hot water, and heat pumps in the real-time response to dynamic tariffs by minimizing the end-user cost without sacrificing their comfort. The experiment preparation including: 1) modelling of project-relevant flexibility loads, 2) implementing baseline controllers to serve as a benchmark case;3) Simulating a controller that can consider tariff signals.

3 Outputs and outreach to date

Publications (peer-reviewed or others)

Description:
Winzer, Christian, and Patrick Hensler-Ludwig. 2024. “Design and Impact of Grid Tariffs.” Energies 17 (6): 1364. https://doi.org/10.3390/en17061364.
Winzer, Christian, and Hongliang Zhang. 2024. “Cost Focus versus Comfort Focus: Evidence from a Discrete Choice Experiment with Swiss Residential Electricity Customers.” The Energy Journal 45 (2): 209–35. https://doi.org/10.5547/01956574.45.2.cwin.
Cuony, Peter, Federica Bellizio, Cédric Chanez, Philipp Heer, and Christian Winzer. 2023. “Dynamische Tarife für ein effizientes Stromsystem | VSE,” July 19, 2023. https://www.strom.ch/de/nachrichten/dynamische-tarife-fuer-ein-effizientes-stromsystem.
Winzer, Christian, and Patrick Dümmler. 2023. “Versorgungslücken im Strommarkt schliessen.” Die Volkswirtschaft, June. https://dievolkswirtschaft.ch/de/2023/06/versorgungsluecken-im-strommarkt-schliessen/.

Elsenbast, Wolfgang, and Christian Winzer. 2024. “Dynamische Netztarife und ihre Alternativen.” ENERGIEWIRTSCHAFTLICHE TAGESFRAGEN 74 (January): 39–43

Public oral and visual presentations (scientific or broad audience)

Description:
Cuony and Winzer: “Dynamische Tarife bei Groupe-E und NEDELA Projekt”, VSE Tarif Workshop, Aarau, 2023
Christian Winzer: „Network Tariffs for Decentral Load Control”, PATHFNDR Research Seminar, Zurich, 16th April 2024

4 References

Winzer, Christian, and Patrick Hensler-Ludwig. 2024. “Design and Impact of Grid Tariffs.” *Energies* 17 (6): 1364. https://doi.org/10.3390/en17061364.