Promoting flexibility from prosumers through a novel generic characteristics model

Topic: (4) Active prosumer's participation

Natapon WANAPINIT[1](1), Anke WEIDLICH(2), Jessica THOMSEN(1)

(1) Fraunhofer Institute for Solar Energy Systems ISE (2) University of Freiburg

Motivation and objective

Energy storage and demand response from prosumers have significant potential to balance supply fluctuations, which facilitates the integration of wind and solar energy into energy systems [1]. Thus far, assessments of flexibility potential – especially from the demand side – are typically performed by case-specific models and focused on energy-intensive systems, e.g. [2,3,4]. As flexibility can stem from different prosumers, this resource-intensive method can impede the broad exploitation of flexibility potentials. This paper alternatively proposes a novel generic characteristics model (GCM) as a universal model for flexibility options. GCM reduces the need for model development and eases the barrier for potential assessment.

Methodology

GCM is based on an abstract description of a flexible system (or process) - a system whose realized operation can deviate from the plan. A system comprises of two interconnected levels: a physical level (SYS) represents real components in the system, and an administrative level (ADM) represents an operation control of the system, see figure 1. These levels respectively represent the Process and Operation zone in the Distributed Electrical Resources and Customer Premises domains at the Component Layer in the framework of Smart Grid Architecture Model (SGAM) [5].

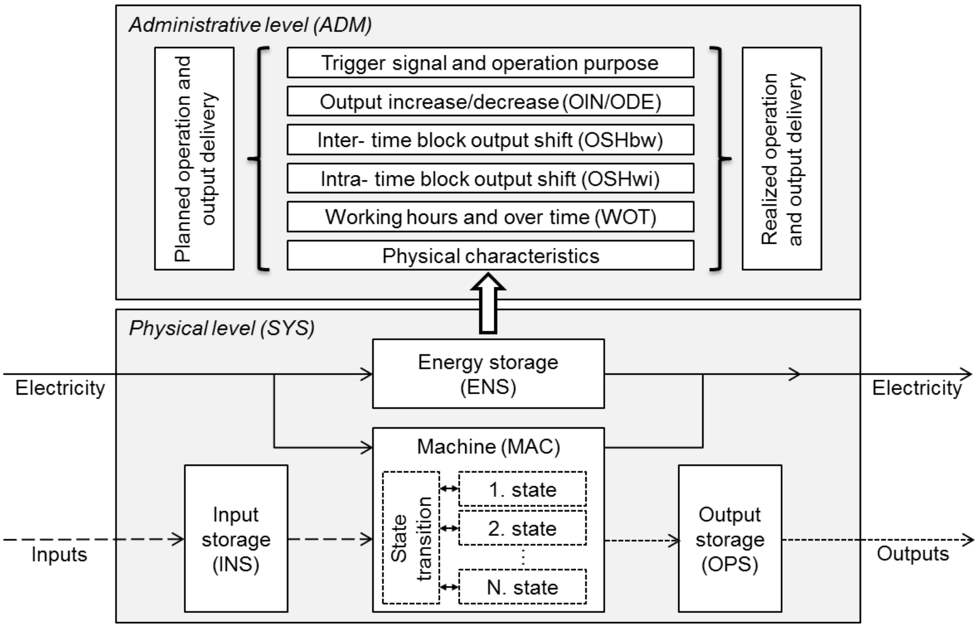


Figure 1: An abstract depiction of a flexible system

In flexible systems, flexibility arises from storage units, operation of the machine or administrative decisions: to change (increase or decrease) output delivery, to shift output delivery, or to adjust work hours. GCM models a flexible system by its generic internal characteristics and constraints, such as: capacity of in/output flows; storing and transferring capacities and efficiencies of storage units; operation ramp rate, state-dependent efficiencies and minimum/maximum runtime of the machine; shiftable peak, volume and time horizon of the output delivery; working schedule of the system; and related operation costs. In GCM along with a timestep, a time block, a group of adjoining timesteps, is introduced so that characteristics such as the inter-day (block) or intra-day shift can be modelled. Deviation from the plan, i.e. activation of flexibility, corresponds to trigger signals, an operational purpose, and constraints of the system.

Results and conclusion

In this paper, GCM is used to characterize and model examples of flexible systems, described in table 1. The terms in brackets refer to the related GCM components, shown in figure 1.

[1] Jungautor, Fraunhofer Institute for Solar Energy System ISE, Heidenhofstrasse 2, 79110 Freiburg Germany, +49 761 4588 5221, natapon.wanapinit@ise.fraunhofer.de

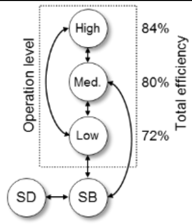
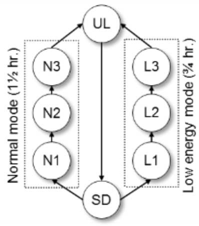
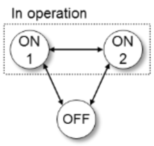
	System description	Machine state diagram*	Flexibility options
System 1	A 1-MW_{el} gas-fired combined heat-and-power unit (MAC) delivers heat (output) to a communal district. Generated electricity is sold and fed into the grid. The planned operation is to minimize energy loss.		• Flexible operation level (MAC) • 1.5 MWh thermal storage (OPS) • There is no flexibility from the output delivery, as the delivered heat must match the heat demand.
System 2	A washing machine (MAC) in a shared flat is used four times a week in a normal mode. Its usage (output), finished washing cycle, is planned a week in advance.		• Operation in a low energy mode, shorter washing cycle, as an alternative to the normal mode (MAC). • Output delivery is shiftable: within ± 2 hours on the same day (OSHwi) or delayed to the next day (OSHbw).
System 3	A production plant with two identical, ON/OFF production lines (MAC) is committed to delivering 100 units of products at 5 pm each workday. The planned operation is to produce just enough for the daily delivery.		• Flexible number of lines in operation (MAC) • A storehouse of 150 units capacity (OPS) • Daily output delivery can deviate up to ±10 units per day; the deviation needs to be recovered in adjacent days (OSHbw). • Operators' lunch breaks between 12:00 – 13:00 can be rescheduled which allows the production during midday (WOT).

Table 1: Example of flexible systems and their descriptions;
** Arrows indicate allowable transitions between states; "SD" Shutdown, "SB" Stand-by, "UL" Unload*

To illustrate the dynamics of a flexible system, system 3 is modelled with a variable electricity price as a trigger signal and the objective of flexibility utilization to minimize the costs of electricity. The resulting operation deviates from the plan so that the electricity demand during periods with high electricity prices is reduced or avoided, see figure 2. The plant over-produces on Monday; excess products are stored and delivered on later days (#4). On Wednesday, output production and delivery are decreased, which is compensated on Thursday (#5). The flexibility option to work during lunch breaks is not utilized due to the high additional compensation costs.

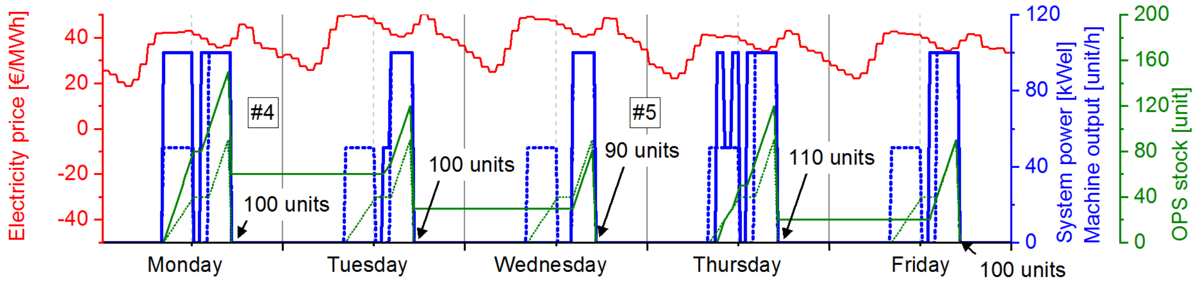


Figure 2: Results of system 3; dotted lines represent the planned operation, whereas, unbroken lines represent realized operation; arrows indicate the time and volume of daily product deliveries; on average, electricity prices on Tuesday and Wednesday are higher than other weekday.

The proposed GCM captures characteristics of various flexible systems and serves as a universal modelling tool. Through its predefined characteristics and structure, GCM can aid the characterization and assessment of flexibility options from prosumer's side. Moreover, actors – prosumers, market agents or DSO – can communicate the information regarding flexibility options with each other via GCM, which supports the utilization of flexibility.

Literature

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