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Data centres' power profile selecting policies for Demand Response: Insights of Green Supply Demand Agreement

Robert Basmadjian [a,*], Lukas Müller [b], Hermann De Meer [b]

[a] ONE LOGIC, Ludwigstrasse 12, 94032 Passau, Germany
[b] University of Passau, Instrasse 43, 94032 Passau, Germany

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ABSTRACT

Demand Response mechanisms serve to preserve the stability of the power grid by shedding the electricity load of the consumers during power shortage situations in order to match power generation to demand. Data centres have been identified as excellent candidates to participate in such mechanisms. Recently a novel supply demand agreement have been proposed to foster power adaptation collaboration between energy provider and data centres. In this paper, we analyse the contractual terms of this agreement by proposing and studying different data centres' power profile selecting policies. To this end, we setup a discrete event simulation and analysed the power grid's state of a German energy provider. We believe that our analysis provides insight and knowledge for any energy utility in setting up the corresponding demand supply agreements.

1. Problem statement

Few will doubt that the power grid is a critical infrastructure, which directly affects many aspects of modern life. Conventionally, the power grid's stability can be characterised by three different operational states: *Normal*, *mission-critical* and *emergency*. In normal state, the grid is operating under usual conditions, whereas during mission-critical state, the power grid is still operational, however the power demand is high bringing the grid to its limits. Emergency state refers to the fact that a blackout occurred causing parts or the whole power grid to break down. In other words, the above mentioned three states correspond respectively to the following three grid-scale scenarios: Daily time/cost-optimised, day-ahead/day-off price or reliability, and ancillary services and emergency. Nowadays, with the advent of renewable energy sources (e.g. photovoltaic), the major challenge is to keep the stability of the power grid (prevent blackouts to happen), and hence preserve normal operational state, by matching the power generation to demand.

Recently, Demand Response (DR) mechanisms have been proposed with-in the context of "Smart Grid" in order to preserve the stability of power grid – hence to cope with the sudden changes of power demand and generation. The main objective of such mechanisms is to match power generation to demand by changing the electricity load of the consumers in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardised [1]. Lately, data centres have been investigated for their participation in DR mechanisms [2,3]. It was shown that they are good candidates due to their highly automated infrastructure as well as significant energy usage. To this end, a novel supply demand agreement for power adaptation collaboration between energy provider and data centres was

* Corresponding author.
E-mail addresses: robert.basmadjian@onelogic.de (R. Basmadjian), muell253@stud.uni-passau.de (L. Müller), demeer@fim.uni-passau.de (H. De Meer).

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proposed by [4], which defines power relevant contractual terms for both parties. Furthermore, based on the proposed terms, the authors introduced a "fair" power profile selecting policy. In short, whenever the energy provider detects a shortage/surplus situation, it requests from the participating data centres for their collaboration. Every data centre, upon receiving such a request, sends back either a *negative acknowledgement* or at least one *power profile*. The former case denotes that the data centre is refusing to collaborate whereas in the latter case, based on its local power adaptation flexibilities (e.g. running data centre on UPS or own diesel generator, shifting/shedding workload to reduce power consumption, heating up/cooling down the data centre, etc.), the data centre sends back to energy provider one or more power profiles. After receiving all the profiles, the energy provider needs to apply a *power profile selecting policy* in order to choose appropriately profiles of different data centres to fulfil its needs in terms of shortages/surplus. The authors of [4] called the proposed selecting policy "fair" due to the fact that the burden of power adaptation collaboration is distributed fairly among the data centres.

In this paper, we analyse the power adaptation collaboration between the energy provider and data centres by taking into account the different contractual terms of the proposed supply demand agreement of [4]. For this purpose, in addition to the *fair* power profile selecting policy, we introduce two new policies namely *cost-saving* and *peak-avoidance*. The former policy is used in order to minimise the cost that energy provider needs to pay as incentive to data centres for the carried out adaptation, whereas the latter is devised to circumvent any power grid instability by avoiding power peaks that might happen during the recovery phase of the performed adaptation. Consequently, we setup a discrete event simulation and analysed the power grid's state of a German energy provider E-on[1] in 2011. We identified power shortage situations and conducted power adaptation collaboration using the aforementioned three different policies, where 15 k data centres were involved with different sizes and power adaptation capabilities. The policies were compared by taking into account different metrics derived from the proposed supply demand agreement of [4]. The results show that each of the studied three policies has its own advantages and inconveniences based on the examined circumstances. We believe that the obtained results contribute as providing insights not only to *energy utilities* in setting up DR programs with data centres but also to *regulatory bodies* (e.g. US Federal Energy Regulatory Commission) who play a key role in formulating DR mechanisms and energy market design. It is worth pointing out that in this paper we do not differentiate between numerous stakeholder of the energy market such as Distribution System Operator (DSO), Transmission System Operator (TSO), and Energy Service Provider (ESP) and use only Energy Provider to refer any of the above mentioned stakeholder. Also, the power adaptation collaboration between data centre and its IT customers concerning Service Level Agreements is out of the scope of this document and interested readers can refer to [5,6].

[1] https://www.eon.de/de/eonde/pk/home/index.htm.

The rest of this paper is organised in the following manner: Section 2.1 presents the architectural overview of the power adaptation collaboration concept adopted in this paper. The used contractual terms as well as monitoring parameters are given in Section 2.2. The algorithmic overview of the different policies used in the analysis is illustrated in Section 2.3. In Section 3, we present the setup configuration of the analysis and give the results. Related work and conclusions are given in Sections 4 and 5 respectively.

2. Study methodology

2.1. Architectural overview

As mentioned in Section 1, the concept of power adaptation collaboration was investigated in [3]. It takes one step further from previously proposed approaches by taking into account Energy Provider (EP) – Data Centre (DC) as well as Data Centre – IT Customer (ITC) sub-ecosystems. To this end, as Fig. 1 depicts, a three-tier architecture has been considered: *Level I, II* and *III*. More precisely, the Level I (*Connection*) contains all the specificities of the involved infrastructure of EPs and DCs. Consequently, the monitoring as well as control of the infrastructure are performed by the Connection level. The Level II (*Negotiation*) corresponds to the decision-making logic implemented in the form of agents to enable power adaptation collaboration. Thus this level needs to interact with Level I, in order to read the current status (e.g. shortage situation) and enact certain power adaptation requests to the involved infrastructure, as well as with Level III which includes the contracts to foster power adaptation collaboration between EP – DC – ITC. Therefore, three different types of contract have been developed in [3]:

1. **GreenSLA** (Green Service Level Agreements) contracts are agreements between DCs and ITCs, which reflect the agreed scope for the data centre to operate in an energy-aware manner and at the same time guarantee a certain level of quality of services (QoS) for the IT customers.
2. **GreenSDA** (Green Supply Demand Agreements) contracts are agreements between EPs and DCs, which define the flexibilities and energy-related contractual terms that these parties grant each other.
3. **GreenWSOA** (Workload Services Outsourcing Agreements) contracts are agreements among federated data centres that set rules for the geographical shifting of workload.

It is worthwhile to mention that the proposed DR approach of [3] is used to preserve the stability of the power grid by either applying it in normal operational state (i.e. to reduce energy costs) or at most during mission-critical state in order to bring the grid back to its normal operational state. Further details on the architectural overview of the proposed approach can be found in [3]. Next, we introduce the contractual terms of the GreenSDA