Future Generation Computer Systems 78 (2018) 330–342

Contents lists available at ScienceDirect

Future Generation Computer Systems

journal homepage: www.elsevier.com/locate/fgcs

Optimized flexibility management enacting Data Centres participation in Smart Demand Response programs

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HIGHLIGHTS

- Scheduling and optimizing Data Centres operation.
- Data Centre participation in Smart Demand Response programs.
- Data Centre flexible energy resources.
- Electronic marketplace for trading energy flexibility and ancillary services.

ARTICLE INFO

Article history:
Received 26 November 2015
Received in revised form
26 February 2016
Accepted 5 May 2016
Available online 21 May 2016

Keywords:
Data Centre
Smart Demand Response
Flexible energy resources
Optimization and scheduling
Energy and Ancillary Services Marketplace

ABSTRACT

In this paper we address the problem of Data Centres (DCs) integration into the Smart Grid scenario by proposing a technique for scheduling and optimizing their operation allowing them to participate in Smart Demand Response programs. The technique is leveraging on DCs available flexible energy resources, on mechanisms for eliciting this latent flexibility and on an innovative electronic marketplace designed for trading energy flexibility and ancillary services. This will enact DCs to shape their energy demand to buy additional energy when prices are low and sell energy surplus when prices are high. At the same time DCs will be able to provide increased energy demand due to a large un-forecasted renewable energy production in their local grid, shed or shift energy demand over time to avoid a coincidental peak load, provide fast ramping power by turning on their backup fossil fuelled generators and injecting the energy surplus in the grid and finally provide reactive power regulation by changing their power factor. Numerical simulations results considering traces of an operational DC indicate the great potential of the proposed technique for supporting DCs participation in Smart Demand Response programs.

1. Introduction

The Data Centre (DC) services business is blooming but, as it is usually the case, this is only one side of the story: the growing demand of their services increases their demand on energy resources, which directly translates to higher operational costs, not to mention the detrimental impact to the environment and, as such, to the society as a whole. Besides the significant economic and environmental impact, the annual increasing energy demand of DCs poses the severe risk of supply shortage and instability in the electricity network. This may cause exponentially increasing side effects. On one hand to the local economy, which may suffer accidental black-outs, and on the other hand to the normal operation of the DC, as it is expected to provide continuous operation and guaranteed availability (i.e. 99.995% for Tier 4 DC). All these factors are putting DC business in a risky position and creating higher pressure on the DC administrators on cutting down the energy demand and implicitly the associated bills.

The recent advances in digital technologies and renewable energy production have incubated the Smart Grid concept. It allows for bidirectional communication between utilities and their customers, as well as sensing along the distribution lines, while it integrates both traditional brown and green energy sources such as

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http://dx.doi.org/10.1016/j.future.2016.05.010
0167-739X/

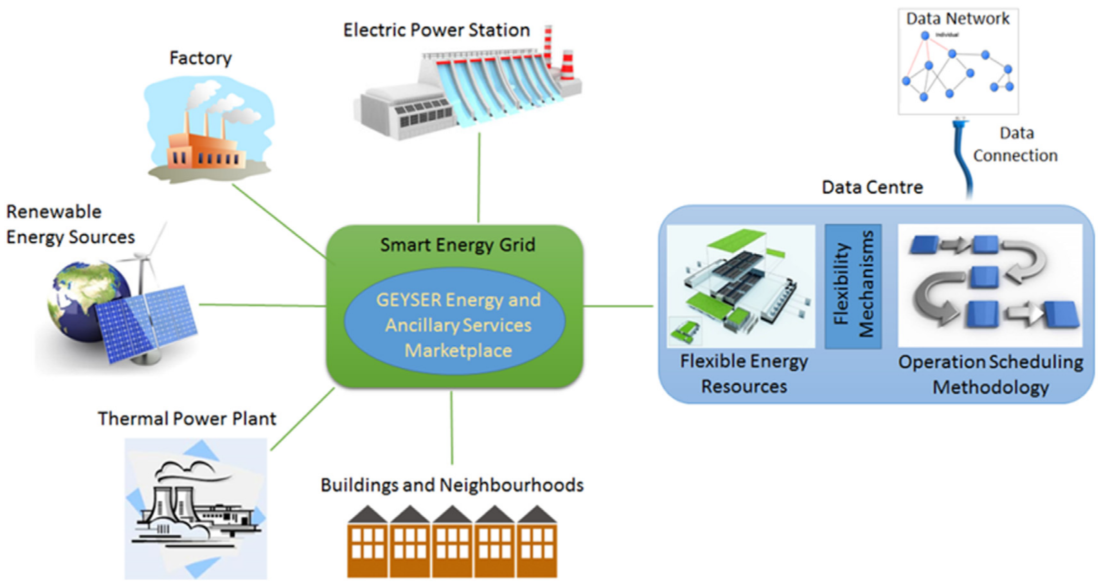

Fig. 1. DCs at the intersection of smart energy and data networks. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

photovoltaic panels, wind turbines, geo-thermal power plants, etc. However, the integration of Renewable Energy Sources (RES) into the grid has added a level of uncertainty due to the intermittent and unpredictable nature of green energy generation. Variations in energy production, either surplus or deficit, may threaten the security of supply, leading to energy components overload and culminating with power outage or service disruptions. The problem is exacerbated by the lack of capabilities for energy storage, thus forcing the energy producers to shed their generation to match their customers' energy demand by deploying fast-reacting power reserves to maintain grid balance. To this end, utility companies have defined Smart Demand Response (DR) programs providing possibility for consumers to play a significant role in the operation of the electricity grid by shaping their energy demand to meet various grid level goals and obtaining in exchange financial benefits. Typically, at the beginning of a billing period, a regulation signal is sent to every customer specifying the desired energy profile for each of them. If a customer accepts the signal, it is required to schedule its operation for meeting the desired profile.

Utility companies must trade with commercial players to a far greater extent than nowadays in order to use flexibility products as a more cost-effective and reactive alternative to grid reinforcements. Accordingly, in our vision DCs are expected to be transformed into such flexible energy players providing different levels and types of flexibility to the interested stakeholders such as Distribution System Operator (DSO) or District Heating Operator, with a view to become adjustable and adaptive energy consumers able to participate in DR programs. Nevertheless, currently there are limited active links between, DCs on one hand or, in general, ICT networks and smart grid operators on the other hand. Practically, no energy or information exchange exists among them. Exacerbating this situation, DCs are operated in an uncoordinated way and their energy efficiency has been so far addressed in an isolated way. DCs have large, yet mostly unexploited, potential regarding their energy demand flexibility. Through this potential they can contribute to efforts for managing more efficiently energy at local grid level, while enabling optimized operation of the electricity grid.

2. DCs as technological hubs integrated in the smart grid

To address such energy integration concerns, within the FP7 GEYSER European R&D project [1], we have proposed the innovative approach of considering DCs as conceptual and technological hubs at the crossroad of energy (electricity, thermal, or a combination of the two) and data networks enacting the exploitation of their latent flexibility for achieving synergies and integration with other grid energy resources (see Fig. 1). In the context of the smart grid the DCs may act as *energy prosumers*, being both energy providers, exploiting on-site green or brown energy resources, and consumers with significant energy needs. We have defined *mechanisms for eliciting DC internal latent energy flexibility* by considering non-electrical cooling devices such as thermal storage, IT workload temporal and spatial migration through data networks, and dynamic usage of electrical storage devices or diesel generators.

The DCs active participation in exploiting the smart grid resources (when and where they become available), as well as their larger flexibility for the optimal management of energy networks is enacted through the *GEYSER Marketplace* concept. The marketplace is available in two variants: (i) an Energy Marketplace allowing the DCs to participate as active energy players buying and selling energy and (ii) an Ancillary Services Marketplace allowing DCs to trade with the DSO their capability to alter their energy profile and respond to ancillary services requests. Leveraging on proposed flexibility mechanisms, a *technique for scheduling and optimizing DC's flexible energy resources operation* is defined allowing DCs to adjust their energy demand profile to meet various smart grid level objectives and accordingly to achieve a major holistic smart city-level efficiency of urban energy networks.

As a result of the innovative GEYSER approach, the DCs are able to schedule and optimize their resources operation and as a consequence, to adjust their energy consumption aiming to buy energy from the Energy Marketplace when the prices are low (due to increased generation) and sell extra energy when prices are high, thus decreasing their operational costs. Also DCs have the technological capabilities for scheduling their operation to potentially respond to ancillary services requests by: (i) shaping their energy demand to provide additional load following reserve for large un-forecasted wind ramps, (ii) shedding or shifting energy demand over time to avoid a coincidental peak load in the grid, (iii) feeding in the smart energy grid the energy (either power or heat) produced by turning on their backup fossil fuelled generators (despite quite inefficient and highly pollutant, gaining, however, a net financial reward by the energy provider, who will avoid to