Workshop on Renewable Energy-Powered Datacenters

http://events.femto-st.fr/workshop-datacenters-2019/en

October 14-16, 2019, in Besançon, France

Last update: October 4, 2019

The FEMTO-ST Institute and the University Bourgogne Franche-Comté (UBFC) are hosting this workshop on renewable energy-powered datacenters. It is co-organized by the FEMTO-ST Institute and the IRIT laboratory. It intends to bring together people from academia and industry working in all related fields (IT, electrical engineering, control systems, thermal engineering, etc.), and enable them to share their latest progress and discuss current challenges.

The workshop is supported by the DATAZERO project (www.datazero.org) under grant no. ANR-15-CE25-0012 of the French National Research Agency (ANR).

1 Program

Monday 14 October

12:00-14:00	Registration, lunch and coffee
14:00-14:15	Welcome address Laurent Larger (FEMTO-ST - UBFC - France)
14:15-15:45	**Session 1: The DATAZERO project** • *DATAZERO: the big picture* Jean-Marc Pierson (IRIT – Univ. Toulouse 3 – France) • *Phase-based tasks scheduling in data centers powered exclusively by renewable energy* Patricia Stolf (IRIT – Univ. Toulouse 2 – France) • *Mixed integer linear programming approach to optimize the hybrid renewable energy system management for supplying a stand-alone data center* Marwa Haddad (FEMTO-ST – UBFC – France)
15:45-16:15	Coffee break
16:15-18:15	**Session 2: Testbed and distribution** • *Transform your power network* Ciaran Forde (EATON – Ireland) • *Efficiency, reliability, and opportunities for renewable-powered datacenters* Timothy Hansen (South Dakota State Univ. – USA) • *Power hardware-in-the-loop test bench* Suyao Kong (FEMTO-ST – UBFC – France) • *SeDuCe: a testbed powered by renewable energy for research on thermal and power management in datacenters* Jean-Marc Menaud (IMT Atlantique Nantes – France)

Tuesday 15 October

8:30-10:00	Bus trip to Belfort
10:00-11:00	**Visit of FCLAB and demo of H2SYS fuel cell systems**
11:00-11:30	**Demo of the DATAZERO PHIL testbed**
11:30-12:30	**Visit of Extendo Datacenter's datacenter in Belfort**
12:30-13:30	Lunch at Le Pilotis
13:30-15:00	Bus trip back to Besançon
15:00-16:00	**Session 3: Energy and economics** • *An interdisciplinary approach to demand response with data centers* Sonja Klingert (Univ. Mannheim – Germany) • *Environmental and economical assessment for net zero energy data centres* Joaquim Romaní Picas (Catalonia Institute for Energy Research – Spain)
16:00-16:30	Coffee break
16:30-18:00	**Session 4: Negotiation** • *Infrastructure-agnostic and multi-objective power planning between datacenter and electrical sources* Léo Grange (IRIT – Univ. Toulouse 3 – France) • *Cooperative management of IT and electrical systems* Georges Da Costa (IRIT – Univ. Toulouse 3 – France) • *Reducing energy costs in data centers by integration with renewable energy sources: experimental environment and real data center considerations* Ariel Oleksiak (Poznan Supercomputing and Networking Center – Poland)
18:00-19:00	**Session 5: Energy constraints** • *Scheduling sequential tasks on a parallel cluster under power constraint* Laurent Philippe (FEMTO-ST – UBFC – France) • *Solid oxide fuel cells for powering data centres and waste heat recovery for district heating* Joaquim Romaní Picas (Catalonia Institute for Energy Research – Spain)
19:00-20:00	Free time
20:00-22:00	Social event – Dinner in Besançon

Wednesday 16 October

9:00-10:30	**Session 6: Towards green datacenters in the real world** • *Assuring safety properties of data centers as critical infrastructures* Florian Niedermeier and Hermann de Meer (Univ. Passau – Germany) • *Experience from designing and operating a local datacenter: challenges and constraints in integrating renewables* Fabien Hazebroucq (Extendo Datacenter – France) • *State of the art and challenges in green datacenters: electrical and IT points-of-view.* Robin Roche (FEMTO-ST – UBFC – France) Patricia Stolf (IRIT – Univ. Toulouse 2 – France)
10:30-11:00	Coffee break
11:00-12:00	**Round table: What future for datacenters?**
12:00-12:15	Closing ceremony Jean-Marc Pierson (IRIT – Univ. Toulouse 3 – France) Jean-Marc Nicod (FEMTO-ST – UBFC – France) Robin Roche (FEMTO-ST – UBFC – France)
12:15-13:30	Lunch

2 Abstracts

Georges Da Cost (IRIT – Univ. Toulouse 3 – France)
Cooperative management of IT and electrical systems

Datacenter ecological impact becomes a major concerns due to the increase of on-line services. To reduce the carbon footprint and energy consumption we use game theory methods to create a cooperation between the Information Technology (IT) part and Electrical part of datacenters in the particular case of having local renewable sources.

Ciaran Forde (EATON – Ireland)
Transform your power network

This presentation shall explore the conventional thinking with respect to electrical infrastructure for data center design. It acts as a call for a general rethink as to the purpose and functionality of conventional data center electrical designs and explores the possibilities for change. From the outset the data center industry has been correctly focused on efficiency. But is that still the right or main problem to address ? are there wider issues that pose an existential threat not only to the data center industry but to information and communication industry at large. Data Centers do not function in isolation they are by definition connected in terms of IT and Power. We explore what changes are happing outside the data center environment that are likely to impact the design and operation of a modern data center. We also explore a variety of current and emerging technologies and review their likely impact and place within next generation data center design.

Léo Grange (IRIT – Univ. Toulouse 3 – France)
Infrastructure-agnostic and multi-objective power planning between datacenter and electrical sources

Using on-site renewable energy sources (RES) and storage devices to power datacenters is actively studied nowadays, as it is a promising perspective to reduce their ecological footprint. Due to the intermittent nature of common RES, being able to adapt both the power consumption of the datacenter and the use of energy storage devices is required to use efficiently the renewable energy. We propose to abstract such an infrastructure by two independent black-box systems: A power producer takes care of the RES and storage devices; a power consumer manages the datacenter itself. An optimization module cooperates with these two systems to find best power production and consumption

plans for an upcoming time window. Each system having different goals, we propose a multi-objective approach based on SPEA2 genetic algorithm for finding an approximation of the Pareto front of the feasible plans. Evaluating the outcome of a power plan for electrical or computing system is however computationally costly. To reduce the number of evaluations of these objective functions, a common method is to use a cheap surrogate. For this purpose an online approach for black-box function approximation is presented, using Haar wavelets to achieve dimensionality reduction of time series. The performance of our approach is evaluated with maximization of quality of service and minimization of greenhouse gaz emission as respective objectives.

Marwa Haddad (FEMTO-ST – UBFC – France)
Mixed integer linear programming approach to optimize the hybrid renewable energy system management for supplying a stand-alone data center

The trend toward server-side computing and the exploding popularity of Internet services due to the increasing of demand for networking, storage and computation has created a world-wild energetic problem and a significant carbon footprint. These environmental concerns prompt to several green energy initiative aiming either to increase data center efficiency and/or to the use of green energy supply. In this regard, As part of the ANR DATAZERO project, many researchers are working to define main concepts of an autonomous green data center only powered by renewable energies. Thus, the present paper proposes a mixed integer linear program to optimize the commitment of a hybrid energy system composed of wind turbines, solar panels, batteries and hydrogen storage systems. The approach is used to supply a data center demand and takes the weather forecasts into account at the time of optimization. Different time window resolution are applied in order to verify the best time window for decision making.

Timothy Hansen (South Dakota State Univ. – USA)
Efficiency, reliability, and opportunities for renewable-powered datacenters

Modern data centers consume large amounts of electricity, resulting in high operational costs. Worldwide, about 8% of all electric energy consumed is by datacenters, and this is expected to continue to grow with increasing dependence on Internet-based services. Many datacenter owners are investigating alternative energy sources to reduce the high operational costs and dependence on traditional power plants, but a near-100% uptime must still be maintained. In this talk, the efficiency and reliability of traditional AC-powered datacenters will be compared with a DC architecture, including the impact of increasing amounts of photovoltaic (PV) energy and wide-bandgap power electronic converters. Additional opportunities for cost reduction by direct participation in power system operations will also be discussed.

Fabien Hazebroucq (Extendo Datacenter – France)
Experience from designing and operating a local datacenter: challenges and constraints in integrating renewables

Extendo Datacenter is a local, independent and "100% French" datacenter located in Belfort. Fabien Hazebroucq lead the design and construction of the datacenter. From the start of the project, the use of renewable energy sources as well as energy efficiency measures was considered. His presentation will discuss the challenges and constraints the design, construction and operation teams faced.

Sonja Klingert (Univ. Mannheim – Germany)
An interdisciplinary approach to demand response with data centers

Worldwide, data center energy consumption is on the rise, both per data center site and in total. Highly fluctuating loads can pose a huge challenge for the electrical power grid, which additionally needs to integrate increasing shares of electricity from volatile renewable energy sources. Data centers have been identified as ideal candidates for managing power demand, often in the context of demand response programs. Modeling the interaction of data centers with the smart grid or a legacy energy market, in research a high potential for power flexibility in data centers has been estimated, however, in reality data center demand response is rarely accounted for. There is a set of reasons for this inconsistency: on the one hand, most models account for a specific situation in an imaginary or represented real data center looking at a limited set of power management strategies which are not applicable for a wide variety of data centers. On the other hand, an important part of parameters for realising demand response with data centers is regularly left out of the picture, be it general business models, legal obstacles or the nature of people taking management decisions in data centers. This paper aims at bridging the gap between current research and reality by exploring these reasons through an interdisciplinary approach.

Suyao Kong (FEMTO-ST – UBFC – France)
Power hardware-in-the-loop test bench

Introduction of the conception of the PHIL platform at UTBM Belfort, which represents the power system test

bench linked to the DATAZERO project. The objective of the test bench is to validate experimentally the control decisions taken by the modules, while ensuring the system reliability. While the long-term control decisions are optimized using forecast data provided by the power decision module (PDM), the power flows are determined with a real-time (short-term) control algorithm considering the long-term decisions and real environmental conditions. Hence, real-time communication is required between modules and PHIL equipment to send/receive data.

Jean-Marc Menaud (IMT Atlantique Nantes – France)
SeDuCe: a testbed powered by renewable energy for research on thermal and power management in datacenters

With the advent of Cloud Computing, the size of datacenters is ever increasing and the management of servers and their power consumption and heat production have become challenges. The management of the heat produced by servers has been experimentally less explored than the management of their power consumption. It can be partly explained by the lack of a public testbed that provides reliable access to both thermal and power metrics of server rooms. In the first part of this talk, we will describe SeDuCe, a testbed that targets research on energy and thermal management of servers, by providing public access to precise data about the power consumption and the thermal dissipation of 48 servers integrated in Grid'5000 as the new ecotype cluster. We will present the chosen software and hardware architecture for the first version of the SeDuCe testbed, and we will propose some improvements that will increase its relevance. In the second part, we will describe the architecture of the renewable energy power supply. we will also present its state of progress and the possibilities offered to researchers.

Florian Niedermeier and Hermann de Meer (Univ. Passau – Germany)
Assuring safety properties of data centers as critical infrastructures

Power Grids and and some Data Centers need to be categorized as critical infrastructures. Regarding the former, many services essential for human health and well-being depend on electrical power (e.g., provisioning of water or communication). A potential negative effect on grid stability has therefore to be ruled out. Regarding the latter, Data Centers are indispensable in an increasing number of industries as they provide services like storage, communication and data processing. As such, certain Data Centers have to be categorized as critical infrastructures. Generally, software used in critical infrastructure must be engineered in compliance with certain safety standards (e.g., IEC 61508). In these standards, the use of formal methods is recommended to achieve functional safety for safety integrity levels (SILs) of 2 and higher. Therefore, model checking is applied to Data Centers participating in demand-response programs for renewable energy intake.

Ariel Oleksiak (Poznan Supercomputing and Networking Center – Poland)
Reducing energy costs in data centers by integration with renewable energy sources: experimental environment and real data center considerations

The talk will present an experimental environment created in the Laboratory of Energy Efficiency at Poznan Supercomputing and Networking Center (http://labee.psnc.pl) that includes servers powered by renewable energy coming from a photovoltaic system. We present a virtual heat and energy model of this micro data center. Then we show the heuristic algorithm based on power capping that takes into account energy supply from the photovoltaic system and reduces costs of energy consumed by the micro data center. The talk will also include analysis and plans towards the integration of renewable energy sources with the whole data center. It includes analysis and plans to use renewable energy from a photovoltaic farm and the re-use of waste heat from the data center in external buildings.

Laurent Philippe (FEMTO-ST – UBFC – France)
Scheduling sequential tasks on a parallel cluster under power constraint

Energy consumption is a major aspect to consider when designing large scale high performance computing HPC systems. Integrating renewable energy sources to the power supply of an HPC system is an efficient solution to lower its carbon footprint, but it is one faced by challenges since the power production of most renewable sources is variant while the power consumption of the system varies with the workload. Advanced workload management techniques in combination with powering down idle machines allow to increase the efficiency of this solution. We tackle here the problem of scheduling independent tasks on a multi-machine platform that is exclusively run with green energy. We propose different power constrained scheduling algorithms, and evaluate them through an experimental study on an HPC model that considers the possibility to switch machines on or off.

Jean-Marc Pierson (IRIT – Univ. Toulouse 3 – France)
DATAZERO: the big picture

As the need for cloud services has been growing steadily, the size and energy consumption of datacenters have increased significantly over the past years. Due to economic and environmental constraints, energy efficiency in

datacenters and greenhouse emissions have become a major concern. Renewable energy is widely seen as a promising solution to supply datacenters using local energy, without greenhouse gas emissions. However, the intermittent power generation resulting from the use of renewable energy imposes a paradigm change in the way energy and computation activities are managed. On the one hand, service placement and scheduling may be used on the IT (information technologies) side to adapt to the available power. On the other hand, the storage units may be used to lessen power generation variations. Existing literature and actual deployment mainly design optimization algorithms including the entire system (from cloud service to electrical management, the latter often being neglected or simplified). Conversely to these approaches, we propose a solution where each side optimizes its own objectives, both interacting through a negotiation loop process to reach a common agreement. In this talk, we present DATAZERO, a project developing this idea to ensure high availability of IT services, avoiding unnecessary redundancies, under the constraints due to the intermittent nature of electrical and cloud services flows.

Joaquim Romaní Picas (Catalonia Institute for Energy Research – Spain)
Solid oxide fuel cells for powering data centres and waste heat recovery for district heating

Data centres are very energy intensive facilities which also produce a significant amount of heat. Moreover, heating and cooling of buildings represent 50% of Europe final energy use. Therefore, recovering data centres waste heat for heating is a promising option for reducing the environmental impact. However, DC waste heat is at temperatures about 40°C, while district heating networks require temperatures of 70-90°C. Solid Oxide Fuels Cells (SOFC) can power data centres with direct current at high efficiencies, while producing heat at high temperature. The objective of this project is to investigate data centres powered with SOFC for maximizing waste heat recovery for district heating.

Joaquim Romaní Picas (Catalonia Institute for Energy Research – Spain)
Environmental and economical assessment for net zero energy data centres

The rapid increase of cloud computing, high-powered computing and the vast growth in internet use have aroused the interest on environmental impact of data centres. An economic and environmental assessment is presented for different data centre sizes, climate locations, energy concepts, and sets of energy efficiency measures, with especial emphasis on the implementation of renewables such as PV and wind energy. This assessment is based on parametric analysis carried out with models developed on RenewIT project. The main metrics used in the evaluation are the total cost of ownership and the non-renewable primary energy consumption. The results show that detailed optimization considering information of local constraints is the key to seek for a cost effective option.

Robin Roche and Patricia Stolf (IRIT – Univ. Toulouse 2 and FEMTO-ST – UBFC – France)
State of the art and challenges in green datacenters: electrical and IT points-of-view

As datacenters worldwide are consuming more and more energy, it has become crucial to consider both IT and electrical aspects in their design and operation. This presentation will briefly review the state of the art of green datacenters under both points-of-views, and will also review the challenges associated to transitioning from existing infrastructure to future datacenters powered solely by renewable energy sources.

Patricia Stolf (IRIT – Univ. Toulouse 2 – France)
Phase-based tasks scheduling in data centers powered exclusively by renewable energy

Data centers are considered nowadays as the factories of the digital age, being currently responsible for consuming more energy than the entire United Kingdom. On the other side, the global total capacity of renewable power increases continuously. The combination of these two factors calls for new approaches in designing data centers powered only by renewable energy sources. Our work focuses on task scheduling optimization under a power envelope, and on the way to handle power starvation, i.e. when the available power does not provide sufficient resources to execute a given workload. To do so we utilize the concept of task degradation through cross-correlation to find where to place the tasks in order to reduce the data center profit degradation. The results show that our algorithm could obtain more than 34% increase in profit when compared to algorithms from the literature, while fulfilling the power profile and resources constraints.