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BattSim-GDC Simulator: How much battery your green datacenter needs?

Enida Sheme*1 Igli Tafa1, Fatmir Basholli*1

1Polytechnic University of Tirana, Department of Computer Engineering, Albania, esheme@fti.edu.al, itafa@fti.edu.al
1Albanian University, Department of Engineering, Tirana, Albania, fatmir.basholli@albanianuniversity.edu.al

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Abstract

Green datacenters topic has been highly researched in the last decade. Main sources of clean energy currently used to feed datacenters are solar, wind and geothermal. Their intermittence poses a challenge in the research field of green datacenters. Thus, the need of an energy storage device becomes present, to store the overproduced energy, while using it when there is not enough clean energy production. In this paper, we pose the question: "How much battery is appropriate for the needs of a given datacenter, while trading-off the cost of the battery and the overproduction of clean energy"? For this, we analyze, design, and implement a simulator called BattSim-GDC, to simulate different scenarios to find the best combination between clean energy quantity and battery size, aiming the lowest waste of renewable (clean) energy production. For this study, the input energy taken in consideration is solar. The results, obtained after the simulator's implementation, show that BattSim-GDC simulator is a necessary tool to be taken in account from administrators, when projecting a green datacenter.

Introduction

The revolution of big data has brought a need for hyperscale datacenters, which consume immense amount of energy and produce Megatons of carbon dioxide per year, based on a study of 2020 [1]. Researchers and administrators of datacenters are constantly aiming to achieve higher energy efficiency levels, to reach their environmental, social, and governance (ESG) goals [2-3].

Thus, datacenters operating in solar, wind and/or geothermal energy, are facing challenges regarding their intermittent nature. Certain periods of time, clean energy production is more than is needed and viceversa, the need is higher than the production of clean energy. At this point, being able to calculate the appropriate amount of energy storage device, e. g. battery, to balance the production with the need, becomes a requirement.

In this paper, we address this research question: How much battery is appropriate for the needs of a given datacenter, while trading-off the cost of the battery and the overproduction of clean energy? To answer this question, we have analyzed, designed, and implemented a simulator, called BattSim-GDC. The renewable energy we refer to is solar. The energy consumption refers to a datacenter of 100 servers, performing a synthetic workload for a full year. The total input values for the energy consumption are 8760, referring to number of hours in a year.

The remainder of this paper is organized as follows. Next section describes related work on the subject of simulators for green datacenters. Furthermore, we illustrate the process of analysis, design, and implementation of the simulator. In the end, we conclude the paper with conclusions and discussions on future work.

Material and Method

Many simulators address the issue of resource sharing in datacenters. CloudSim [4] is one of the most popular simulators used to test different algorithms on virtual physical resources. Nevertheless, in this section we will focus on a list of publications on simulators tackling the sustainability and/or greenness of a datacenter.

Authors at [5-6] present the implementation of a workload scheduling algorithm in CloudSim, aiming to maximize the renewable energy utilization, minimize the energy used from the grid and optimize battery usage.

Philharmonic [7-8], an energy aware cloud controller simulator for geographically-distributed clouds, controls the cloud's resource allocation dynamically to both consolidate resources and adapt to volatile geotemporal inputs.

ReRack [9] is an extensible simulation infrastructure that can be used to evaluate the energy cost of a data center using renewable energy sources, composed of a simulation and an optimization component. It requires a model that can simulate both the data center power usage and the location-dependent variability of the power generation source (solar and wind).

Authors at [10] present Sim2Win, a data center simulation framework that can replay any set of different power management strategies in the face of any set of markets for power flexibility.

As a part of a research project named BlueTool, the authors at [11] present Green Data Center Simulator (GDCSim), an iterative green data center design framework, for the design and development of energy-efficient data centers.

Sustainable datacenter simulator [12] represents an excel-based tool designed to help DC operators assess 16 different sustainability metrics. Five important categories of these sustainability metrics are energy efficiency, greenness, performance and productivity, air management, and storage metrics.

Different to the mentioned simulators, our simulator BattSim-GDC focuses on trading-off the battery size with the total area of solar panels needed by a green datacenter, aiming the highest efficiency between clean energy production and consumption.

The simulator design

The simulator aims to analyze and predict the amount of available energy in the battery over specific moments in a chosen time-period. We base the design on the concept of the battery as a finite state machine with 4 possible states at any time t: Full, Discharging, Charging or Empty. Therefore, there are 16 possible state transition combinations, as shown in "Figure 1". Practically, all these combinations are feasible except for the Full - Empty and Empty - Full transitions which are generally limited by the charge/discharge rate of the battery during a certain period of time. Possible triggers from one state to the other depend on the amount of available solar energy in a moment of time t, referred to as RE(t) (Renewable Energy) and the datacenter energy needs in that moment t, referred to as consum(t). Other affecting factors are the value of the stored energy in the battery, E(t), and the maximum energy capacity of the battery named Efull.

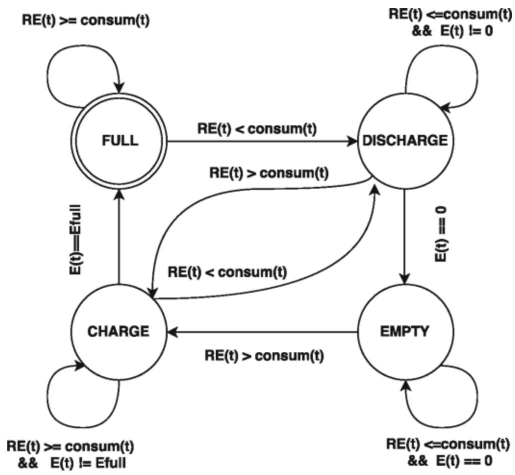

Fig. 1. Battery states over time represented as a finite state machine.

The simulator implementation and results

The pseudocode for developing the simulator is given below as a set of 8 steps, at "Fig. 2". BS (0) refers to the initial Battery State assigned to Full, assuming the battery is fully charged when the simulation begins running. Each of the 16 'current - next' state combinations are assigned a combination number (named combinationNr), which calculates the energy (E(t)) the battery will have on every t. The loop repeats 8760 times, corresponding to the renewable energy and consumption input data (every hour of the year).

Algorithm 1. Simulator tasks

```
BS(0) ← FULL , t ← 1
repeat
   Define BS(t) = f[BS(t − 1), RE(t), consum(t)]
   Define combinationNr = f[BS(t − 1), BS(t)]
   Calculate E(t) = f[E(t − 1), combinationNr]
until t ≤ 8760
greenCoverage = annual [RE(t) − over(t)]/annual [consum(t)]
Print charge(t), discharge(t), overproduction(t), grid(t), greenCoverage
```

Figure 2. The pseudocode for developing the simulator

We have run the simulation tool by changing the input of battery size in different scenarios, varying from 0 to 1 kWh, 10 kWh, 100 kWh, 1MWh and 10MWh. We input the number of m^2 solar panels, the percentage of renewable energy we want to operate our datacenter with (a number from 0 to 1), referring as green coverage. We input also the consum(t), an Excel input file, representing the energy consumption of 100 servers over a synthetic workload in a year. The result after each simulation shows the level of overproduced energy, which is wasted. A datacenter operator would require this value to be zero. By empirical experiments, we found the best values between the required green coverage and battery size, aiming zero wasted renewable energy.

Conclusions and Discussion

The renewable energy sources are a promising means of energy supply for current datacenters. Nevertheless, they can be in excess or less than needed because of their variability, bringing the need of batteries as energy storage devices. In this paper, we investigate the impact of battery size in green coverage and green energy loss.

We built a battery simulator to provide the amount of available battery energy every time t in a chosen time period. Also, it provides the necessary information to calculate the most efficient amount of battery capacity in order to maximize the utilization of clean energy. This is a valuable tool to help datacenter operators decide on the best combination of solar panels quantity and battery size, that fits their strategies on operating datacenters with green energy.

Furthermore, we plan to propose an improvement of this simulator, by using genetic algorithms to find the optimal combination between solar panels and battery size over a given green datacenter.

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