Sizing of Energy Sources for a Green DataCenter with 100% Renewable Supply

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GreenDays – Toulouse – July 2018

July 3th, 2018

Data Centers and energy efficiency

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- increasing the energy efficiency of data-centers
- supplying data-centers with only green energy

DATAZERO: an innovative Datacenter model

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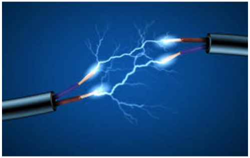
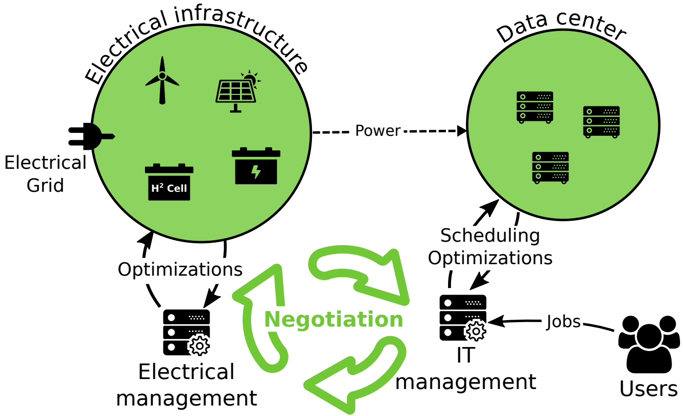


Adapting the IT load to
the available power
&
Adapting the power to
the incoming IT load

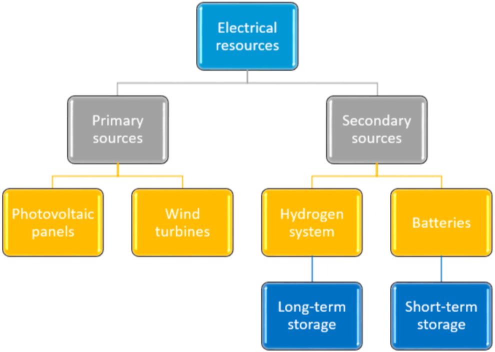
while using a mix of only green energy sources (without grid power usage)

DATAZERO: the big picture



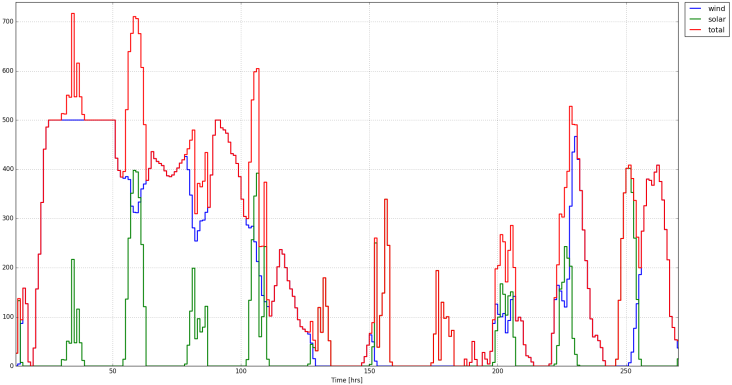
Architecture of the system

The electrical sources used to power the data center are divided into 2 different types:



Problematic

Primary sources has intrinsic characteristics: Intermittence



Problematic

question point?

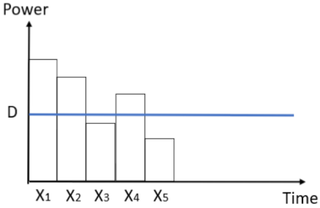
- How is it possible then to meet the data center power demand?
- Is it possible to characterize the primary power obtained in order to get a continuous maximal power using storage sources?

Sizing strategy

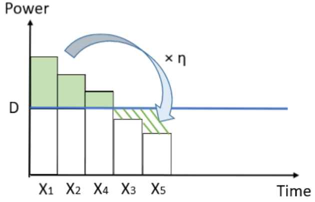
⇒ determining **the maximum continuous power** during one year

⇒ the overproduction covers the underproduction using storage elements

For instance:



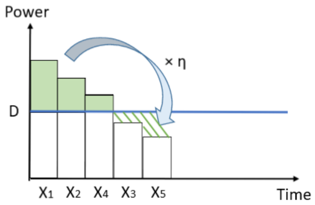
Sizing strategy



$$(x_1 - D) \times \eta + (x_2 - D) \times \eta + (x_4 - D) \times \eta + (x_3 - D) + (x_5 - D) = 0$$
$$(x_1 + x_2 + x_4) \times \eta - 3D\eta + (x_3 + x_5) - 2D = 0$$
$$(x_1 + x_2 + x_4) \times \eta - (3\eta + 2) \times D + (x_3 + x_5) = 0$$

$$D = \frac{(x_1 + x_2 + x_4) \times \eta + x_3 + x_5}{3\eta + 2}$$

Sizing strategy



General formula

$$D = \frac{\eta \sum_1^k x_i + \sum_{k+1}^n x_i}{n - k(1-\eta)} \quad (1)$$

where: η= The storage efficiency, n=number of values sorted, k= is the number of time slots where the renewable energy production is bigger than the demand

Sizing strategy

The approach consists in:

1. Calculation of the electrical production of the primary sources
2. Sorting production values in a descending order
3. Computing D using dichotomy on k
4. Proceeding to the sizing of storage elements

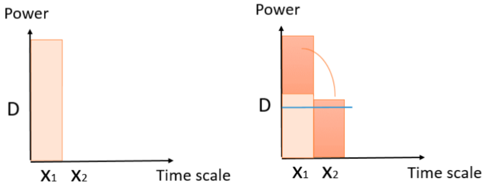
Short-term storage

- It consists in using the battery to cover the lack of production during hours in the same day

- Compute D with the same formula in (1) for each day taking into account the efficiency of the battery $\eta_{batt} = 0.8$ $\Longleftrightarrow$ 365 values of D

Short-term storage

For instance,



Production Values

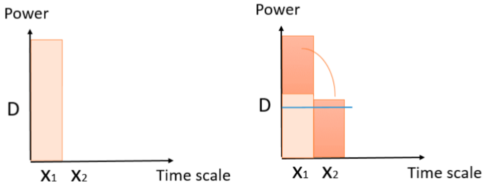
- $X_1 = 10$
- $X_2 = 0$

The energy production of the first day:

$$D1 = \frac{0.8 \times 10}{2 - (1 - 0.8)} = 4.44$$

Short-term storage

For instance,



Production Values

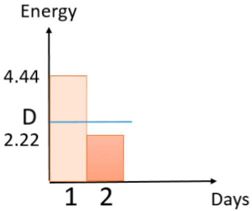
- $X_1 = 5$
- $X_2 = 0$

The energy production of the second day:

$$D2 = \frac{0.8 \times 5}{2 - (1 - 0.8)} = 2.22$$

Short-term storage

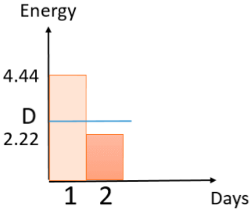
The energy production during these two days:



- Battery are used only for the daily scale
- How the first day could compensate the second day?

Combination with long-short term storage

The Long-term storage or seasonal offset consists in using the hydrogen system to compensate the lack of energy produced during one year



Taking into account the efficiency of both fuel cell and electrolyzer $\eta_{H2} = \eta_{el} \times \eta_{fc} = 0.4$, the demand would be calculated as follows :

$$D = \frac{0.4 \times 4.44 + 2.22}{2 - (1 - 0.4)} = 2.85 \quad (2)$$

While computing the double compensation, this value of D is an lower bound

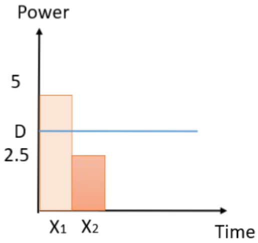
Long-term storage

In case of an overproduction day, where energy production is greater than the demand, hour by hour, the overproduction can be stored within a long term storage device (H_2)

- Compute the average of power for each day. $\Longleftrightarrow$ 365 values of daily average.
- Calculate again D following the equation (1) taking into account $\eta_{H2} = \eta_{FC} \times \eta_{el}$.

Long-term storage

For instance the upper bound is computed as follows:



$$M1 = \frac{10+0}{2} = 5 \qquad M2 = \frac{5+0}{2} = 2.5$$

$$D = \frac{5 \times 0.4 + 2.5}{1.6} = 3.21 \qquad (3)$$

Compensate production between days by considering the daily production as an average of the production: ⇒upper bound

D computing

Once both bounds computed, the demand D can be computed using a binary search approach:

$$LB \leq D \leq UB$$

1. Identifying the over/lower production depending on D
2. Moving the bounds and another value of D to balance the over/under production (by taking storage efficiency into account)

Sizing of the storage system

- How the energy should be splitted (in/out)) between batteries and hydrogen system ?

Chosen policy

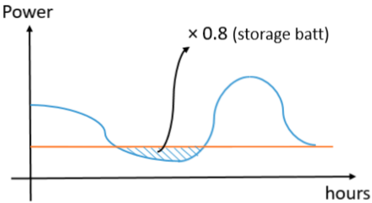
overproduction day : the battery has to store/deliver at least the underproduction, the remainder of the production is stored as H_2

underproduction day : the battery has to store/deliver at least the overproduction, the remainder of the underproduction is delivered by H_2

Sizing of the storage system

Battery on a overproduction day

The battery stores/delivers the amount of underproduction energy



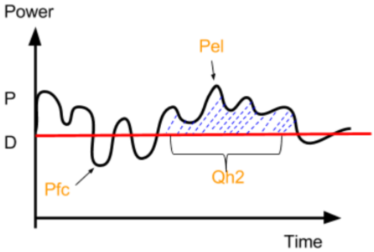
Battery on an underproduction day

The battery stores/delivers the amount of overproduction energy

Sizing of the storage system

H_2 on an underproduction day

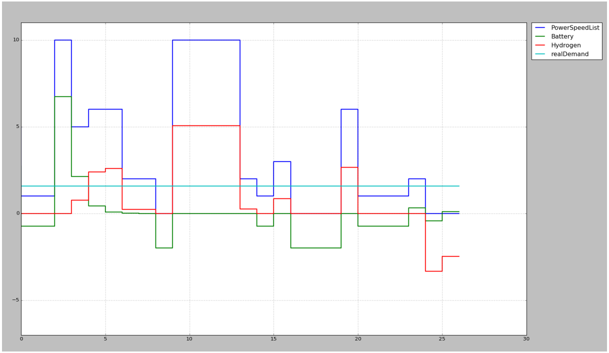
The H_2 system stores/delivers the energy needed to complete the battery



- $P_{ez} = max$
- $P_{fc} = min$
- $Q_{H2} = \sum P_i$

Results

The simulation of this sizing are made with python for 27 hours:



PowerList = [5, 1, 1, 10, 5, 6, 6, 2, 2, 0, 10, 10, 10, 10, 2, 1, 3, 0, 0, 0, 6, 1, 1, 1, 2, 0, 0]

Conclusion – Perspectives

Following this sizing strategy, for any production values, we are able to :

- propose a sizing of the production part
- propose a sizing of the storage part

Issues

The sizing is obtained using data downloaded for a specific year.
⇒ Finding a robust sizing for the next years
⇒ Finding an economical appropriate sizing (80/20% paradigm))

Thank you for your attention