

Determining Data Centre PUE with a Digital Twin

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Summary: The Power Usage Effectiveness is an important metric in assessing data centre energy efficiency. Regulations require constant monitoring of data centre energy consumption. This paper presents a method to calculate the (Interim) Power Usage Effectiveness of an HPC data centre using a Digital Twin in a robust and flexible way by identifying all necessary meters, providing a robust, continuous data collection mechanism and arbitrary time ranges.

Keywords: HPC, digital twin, data centre, energy efficiency, metrics

Introduction

Data centres have become an integral part of modern, digital societies. They provide services for every day life, emerging trends such as AI, for research and the digital quality infrastructure. The growth of data centres has led to an increase in energy consumption. Ireland forecasts that by 2027 the energy demand of data centres in the country will make up up 31 percent of the total energy consumption [1]. To ensure efficient energy usage, standards and efficiency requirements for data centres have been introduced. One such standard is the Blue Angel certificate for data centres [2]. It is mandated for new data centres of the federal government in Germany by the climate protection programme 2023 [3]. The Blue Angel defines the Power Usage Effectiveness (PUE) as the central metric to quantify efficient energy usage.

Measuring the PUE as required by the Blue Angel is challenging in a legacy setup. Several steps are necessary: the proper electric and heat meters must be identified; data needs to be acquired continuously; finally, the data must be converted into matching units for the eventual PUE calculation. This paper presents a method to perform these steps using an HPC data centre Digital Twin [4].

Measurement data acquisition for PUE

The Blue Angel uses the PUE definition of the ISO 30134 standard [5]:

$$\text{PUE} = \frac{E_{\text{DC}}}{E_{\text{IT}}} \quad (1)$$

where E_{DC} is the total data centre energy consumption and E_{IT} is the IT equipment energy consumption. Both are annual values in kWh. Building annual sums will cancel seasonal effects and one-off events. If the PUE is calcu-

lated for a shorter period, it becomes the Interim Power Usage Effectiveness (iPUE).

The Digital Twin needs to collect data from electricity meters. The data needs to be split between IT equipment, e.g. servers, network components, storage and backup, and other energy consumers in the data centre, such as cooling, lighting, lifts, fire alarm system and office spaces.

A standard electricity meter might be reset, e.g. due to maintenance or replacement. This will result in incorrect PUE calculation, if only the annual accumulated power consumption is read at the beginning and end of a year. To make the computation robust against such faults, the Digital Twin continuously collects the power consumption in 15 minute intervals from the electricity meters, stores these values and integrates over them to obtain the annual power consumption.

The electric energy used for cooling should be measured, but this is not feasible for all setups. The data centre at hand shares a central cooling infrastructure with the entire campus, making direct measurement impractical. Instead, heat meters in the cooling water supply line measure the power, with data collected by the Digital Twin. As per Annex B, a conversion factor of 0.4 is applied to convert chilled water power to electric energy, and all heat meter readings are multiplied by this factor.

Calculating PUE

Table 1 lists all relevant meters of the PTB data centre. The Sub-Distribution (SD) meters 1 – 4 measure the IT equipment energy usage in the data centre. Cooling is measured on the two supply lines via the so-called KMZ 12/17 and 6/12 heat meters. Since the PTB data centre is located in a mixed-use building, using the entire building energy consumption over-estimates the PUE. It was decided to only include energy con-

Table 1: Meters in the data centre

Meter	Unit	Factor
Sub-Distribution 1	kW	1.0
Sub-Distribution 2 (UPS)	kW	1.0
Sub-Distribution 3	kW	1.0
Sub-Distribution 4	kW	1.0
KMZ 12/17	kW	0.4
KMZ 6/12	kW	0.4

sumption directly associated with the data centre and exclude all office and shared spaces. With the selected meters, the PUE can be computed as:

$$E_{IT} = SD\ 1 + SD\ 2 + SD\ 3 + SD\ 4 \quad (2)$$

$$E_{Cooling} = 0.4 * (KMZ\ 12/17 + KMZ\ 6/12) \quad (3)$$

$$E_{DC} = E_{IT} + E_{Cooling} \quad (4)$$

$$PUE = \frac{SD\ 1 + SD\ 2 + SD\ 3 + SD\ 4 + E_{Cooling}}{SD\ 1 + SD\ 2 + SD\ 3 + SD\ 4} \quad (5)$$

The Digital Twin calculates the PUE as follows: all metering results are put into mean windows. The heat power values are multiplied by the scalar conversion factor of 0.4. Three sums are calculated, the IT equipment work (2), the cooling work (3) and the overall data centre work (4). It is possible to use work and not power for the ratio. Figure 1 shows the iPUE development for September 2024 in the HPC data centre. Variations can be observed due to different use of the system, as well as ambient temperature. Figure 2 shows the correlation between the per day average outside temperature and the PUE. A linear fit describes the data well:

$$iPUE(T) = 1.453 + 0.00285(T - 10) \quad (6)$$

The model is centred around 10°C which corresponds to the approximate mean annual temperature for Germany.

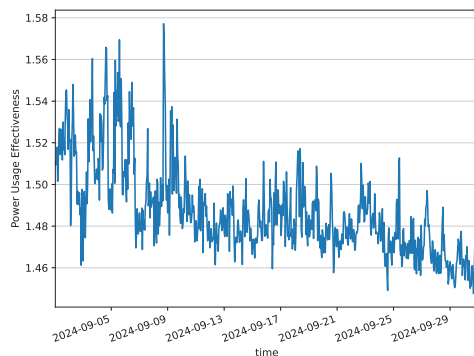


Figure 1: iPUE visualisation using 1h average window

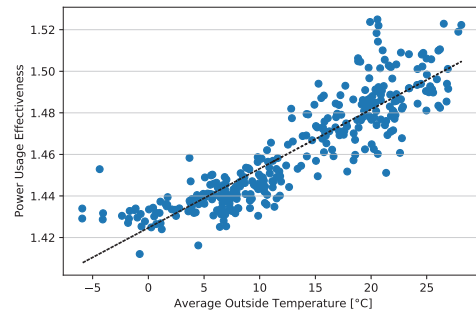


Figure 2: Correlation between outside temperature and iPUE calculated using a 24h average window with a linear model

Conclusion

This paper presented a way to compute the PUE of an HPC data centre with a Digital Twin. Two advantages of the Digital Twin have been shown: the possibility to correct data in case of meter faults and the ability to compute the iPUE through high data resolution.

The automatic PUE calculation can be used to generate automatic reporting on Green IT goals and the required yearly report for the Blue Angel certificate. Furthermore, it allows data centre operators to quantify events in terms of iPUE that are otherwise lost in the yearly average. A similar approach can be used for other data centre metrics. The PUE model can be included into the system simulation that is included with the Digital Twin.

References

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