# Solution based on the DCIM model to assist in the energy efficiency process of small and medium data centers

Alexandre Barbosa de Souza[1], Flávio Barcelos Braz da Silva[2], Gustavo Maia de Almeida[3], Filipe Leôncio Braga[4]

[1]*Instituto Federal do Espírito Santo – Reitoria*
*Avenida Rio Branco, 29056-264, ES/Vitória, Brasil*
alexandre.souza@ifes.edu.br, alexandre_bsouza@hotmail.com
[2]*Instituto Federal do Espírito Santo – Campus Serra*
*ES-010 Km 6,5, 29173-087, ES/Serra, Brasil*
flaviobarcelos@ifes.edu.br
[3]*Instituto Federal do Espírito Santo – Campus Serra*
*ES-010 Km 6,5, 29173-087, ES/Serra, Brasil*
gmaia@ifes.edu.br
[4]*Instituto Federal do Espírito Santo – Campus Cariacica*
*Rodovia Governador José Henrique Sette, 29150-410, ES/Itacibá, Brasil*
filipe.braga@ifes.edu.br

**Abstract.** In the current scenario of large data centers, the increase in demand for the provision of digital services coupled with the increase in the volume of traffic generated by these services has driven the excessive and increasing consumption of energy needed to supply and maintain the availability and quality of the services provided. In order to improve and increase Energy Efficiency in Data Centers, several solutions are available (policies, methods, metrics, tools, etc.) that assist in the process of implementing and maintaining modern and efficient Energy Management. However, small and medium data centers also have characteristics similar to large data centers. Only with consumption on a smaller scale but with the same challenges of increasing energy efficiency. However, small data centers do not have the input and / or infrastructure available to large ones to implement solutions related to Energy Efficiency, thus becoming a challenge in the area. This work proposes the implementation of a solution based on the existing model on the DCIM platform (Data Center Infrastructure Management), performing real-time monitoring of some of the infrastructure characteristics of the Data Center environment that will assist in Energy Management aiming to achieve the maximum Energy Efficiency without impacting the quality of its services. For this purpose, a physical layer will be implemented using SBC (Single Board Computers) equipment that will function as a centralizer of the information collected through sensors responsible for monitoring the Data Center environment, and an application layer that, in possession of the information collected, it will carry out the treatment and analysis, resulting in analytical data, alerts and reports that will serve as a basis to assist in the Energy Management process.

**Keywords:** DCIM, Energy Efficiency, Data Center, PUE, Artificial Intelligence.

## 1 Introduction

The popularization of the use of the Internet across the most diverse types of devices, such as computers, notebooks, mobile phones, tablets and devices or equipment that employ IoT technology, has contributed to the growing demand for storage and availability of data, directly influencing the increased demand of traffic of this type of information. Such demands cause data center facilities to increase energy consumption. However, in such facilities, the best practices regarding the use of electricity for energy efficiency has not match the demand growth.

# 2 Overview

## 2.1 Data Centers

Data Centers are physical facilities used by companies to host computer equipment to provide services to their users and storage of data and information. We commonly associate the term "Data Center" with internet providers or Information Technology (IT) equipment installations of large companies, but considering Geng's definition [1] we observe that the term has a broader application both in size and in the services that they provide.

According to Geng [1] the term “Data Center” can have several meanings, among which we can highlight computer room, server room, software laboratory, high performance laboratory, among others.

## 2.2 EIA/TIA 942 Standard

A The EIA/TIA 942 Standard created TIA - Telecommunications Industry Association and EIA - Electronic Industries Alliance is a document that aims to standardize the design and infrastructure of the construction of Data Centers. Such document is also responsible for establishing the classification of Data Leveled Centers (TIER). According to the standard, Data Centers can be classified in levels ranging from 1 to 4 and it is based on the set of subsystems that they possess and that will be made available by the Data Center to their clients. Among some characteristics that are taken into account in the classification, we can highlight: the existence of redundant power for IT equipment, redundancy of HVAC equipment, existence of power generating systems and the number of hours that the Data Center is unavailable per year.

## 2.3 Energy Efficiency

The increasingly growing and high electricity consumption of Data Centers has generated an alert in the American government, and in March 2015 the US government issued Executive Order 13693 [4] which sets specific objectives for Data Centers in relation to Energy Efficiency. Among its objectives, we can pinpoint: the optimization of electricity consumption focusing on the efficiency and performance of their activities, the monitoring of energy consumption through the installation of power meters, the implementation of metrics to monitor the intensity of energy usage and the establishment of an indicator to serve as a goal regarding the efficiency of electric energy consumption. The latter was implemented in the form of indexes, between 1.2 and 1.4 for new Data Centers and 1.5 for Data Centers already in operation. These indices are obtained by calculating the effective power used by the Data Center, known as Power Usage Effectiveness (PUE).

## 2.4 Power Usage Effectiveness (PUE)

The PUE is an indicator created by The Green Grid, a non-profit organization that aims to encourage the adoption of energy efficient practices in Data Centers. The PUE indicator can be obtained through the equation:

$$PUE = \frac{Total\_Facility\_Energy}{IT\_Equipment\_Energy}. \tag{1}$$

Where Total Facility Energy refers to energy consumption caused by auxiliary equipment (air conditioning, ventilation, lighting, emergency energy sources, etc.) and IT Equipment Energy refers to consumption caused by IT equipment (computers, servers, switches, etc.). Tschudi [2] also points out that, regarding the installed power in the Data Center, the use of PUE is important, since the greatest efficiency gains are in the auxiliary systems operated by the Data Center and not in the computer equipment, as such equipment already operate with a high degree of efficiency.

To measure the power used by the Data Center, Kosik [3] proposes that the energy should be measured at different points, such as: the power transformer, the Data Center distribution board, the UPSs and in other power panels. By collecting and providing additional data about these different electrical components, such information can be used to increase energy efficiency.

### 2.5 Data Center Infrastructure Management (DCIM)

Data Center Infrastructure Management (DCIM) is a management model for data centers. Geng [1] proposes that the term "DCIM" does not have a clear origin and there is no exact and accepted consensus on its definition, thus adopting the definition proposed by Gartner as "the integration of information technology disciplines and facilities management to centralize the monitoring, management and intelligent capacity planning of critical systems in a data center."

We define the DCIM model more concisely as a platform comprised of interconnected hardware, software and services, whose objective is to manage, in real time, the infrastructure and operation of a Data Center, utilizing technologies that monitor the physical environment through CCTV, access control devices, temperature sensors, physical presence detection sensors, humidity sensors, smoke detection sensors, energy metering and air conditioning, generators, lighting monitoring, among others. The DCIM model also encompasses the IT environment through management of assets, network, maintenance, and others. The model provides opportunities to improve the quality of the services provided and energy efficiency of the environment.

## 3 Case Study

Educational institutions typically build laboratories for teaching and research. These laboratories often need equipment and technological resources to provide their users, such as teachers, researchers, students, or guests, with an environment that meets their needs. These environments need a number of resources for their proper operation, such as computers, servers, network switches, air conditioning, emergency reserve power systems (UPSs), lighting, which are also the main resources used by Data Centers, as proposed by Tschudi [2].

According to the EIA/TIA 942 Standard, which classifies Data Centers in levels according to the set of characteristics that they possess, we can classify a teach and research laboratory of an educational institution as a TIER 1 Data Center, observing the IT infrastructure that it contains and that is necessary for the execution of its activities. Likewise, monitoring the environment is also necessary for its management, ensuring availability and constant service quality improvement. Monitoring can also provide invaluable resources for maximizing energy efficiency. Generally, the resources allocated to the implementation of teaching and research laboratories have a focus on the acquisition of specific equipment that will be used to perform their designed activities, not taking into account the resources for monitoring the environment.

The present work proposes the implementation of a solution based on the DCIM model that can be used in an environment whose characteristics are in accordance with the EIA/TIA 942 Standard for Data Center classification, specifically at TIER-1 level, such as small and medium Data Centers.

The solution is implemented through hardware, software and sensors that act together, providing real-time monitoring and management that is commonly present on both physical and IT layers of a Data Center structure.

### 3.1 Environment

The environment used to implement and test the solution was the Theoretical and Computational Physics Laboratory – LFTC. This laboratory is one of several laboratories available at the Cariacica campus of the Federal Institute of Espírito Santo (IFES) college and is actively used on physics research. The LFTC provides its users with the technological resources necessary for performing research activities, among those we can highlight the simulation of physical and mathematical models. These simulations use specific hardware resources for long periods of time, thus there is a need for high availability and a suitable environment for the proper operation of the equipment.

Currently, the LFTC has the following equipment: 01 (one) workstation computer, 01 (one) server computer, 05 (five) desktop PCs with 02 (two) monitors each, 01 (one) network switch and 01 (one) 12000-BTU Air Conditioning system. Table 1 presents the approximate power consumption of each equipment.

Table 1. Approximate Power Comsumption

| Equipment | Power (W) |
|---|---|
| Workstation | 1100 |
| Server | 900 |
| Desktop | 300 |
| Monitor | 100 |
| Switch | 50 |
| Ar Conditioning | 1200 |
| UPS | 980 |

The workstation and the server run 24/7, all year long, to provide LFTC users with remote access to the operating environment for execution and monitoring of processes related to their projects. Consequently, there is a need to keep the air conditioning of the environment where the equipment is located always on.

We can perform the preliminary calculation of the laboratory's PUE using the information on Table 1 as a reference, considering, for the IT load, only the power consumption of the workstation, server, and network switch, which are all connected to the UPS. Using Equation 1 to calculate the PUE index we have:

$$\boldsymbol{PUE} = \frac{(1200W + 1500W + 1100W + 900W + 50W)}{(1100W + 900W + 50W)} = 2,31. \tag{2}$$

Thus, according to the EIA/TIA 942 Standard, we can verify that the LFTC presents an inefficiency index (2.31) in relation to the energy consumption of the whole place.

### 3.2 Equipment

The solution was implemented using specific hardware, software and sensors that monitor the systems (hardware and software) and the physical environment where the laboratory is located.

The solution prototype uses a Single Board Computer (SBC) equipment, more specifically the Raspberry Pi, working together with an Arduino SBC board and is coded in Python programming language. The Arduino board is responsible for the communication and operation of the sensors responsible for the physical monitoring of the environment (temperature, smoke, physical presence, energy).

We chose a Single Board Computer (SBC) due to its low cost and wide range of resources offered for both hardware and software implementations. The SBC monitors the workstation´s usage and the simulations performed by those, as well as the file servers and desktops available to users to carry out their activities. The monitoring of equipment covers their hardware, the status of the systems installed on them and the services that are offered to users. It also monitors logical security, whose importance has gained more attention during the COVID-19 pandemic, due to constant cyber-attacks to facilities worldwide. If any type of abnormality occurs on the IT layer, the solution notifies, in real time, whoever is responsible for the laboratory.

Regarding the environment´s physical layer, we implement sensors on the SBC to collect information about the laboratory´s physical environment, such as temperature, smoke, physical presence and energy consumption. A CCTV webcam works as a monitoring system with the sole purpose of recording security incidents, such as improper access, behavior not consistent with the purpose of the site, or any other type of occurrence. It also helps in controlling the physical access to the laboratory. Additionally, the physical layer sensors are used for monitoring ambient temperature, smoke detection, physical presence detection and energy consumption monitoring. Data collected by the sensors is processed and used as an input to algorithms that employ artificial intelligence techniques to recognize users' usage patterns. They also look for possible anomalies in energy consumption, such as higher or non-standard consumption of certain equipment that can lead to failure or malfunctioning, higher consumption outside laboratory opening hours, higher consumption during opening hours that are not consistent with the activities performed during the period, among others. Such information can be used to identify opportunities to increase energy efficiency and make a better use existing infrastructure.

### 3.3 Current Scenario

Due to the current pandemic situation, IFES has adopted a policy of suspending all on-site activities on its campuses. Therefore, the managers who are responsible for LFTC chose to shut down all equipment on the laboratory. As of now, there is not enough teaching and research activities on the laboratory that would require keeping the equipment always on and in full operation. In this scenario, there is practically no energy consumption.

### 3.4 Next Steps

As soon as IFES on-site activities return to normal, the activities related to the implementation of the solution will resume. The tests related to the acquisition of data through physical layer sensors will also be resumed. The data gathered will then be treated to serve as a basis for decision making, to help determine the best energy efficiency actions. Data will be collected at the laboratory´s electric switch board panel, through monitoring and metering systems.

The management and monitoring of the air conditioning that serves the laboratory will also be implemented so that the solution, based on of the information collected about its operation, can make better usage recommendations. Based on the data contained on Table 1, we can simulate the approximate monthly energy consumption of the IT equipment shown on Table 2.

Table 2. Approximate Consumption

| Equipment | Quantity | Power (W) | Daily Use (hours) | Consuption (KWh/Monthly) |
|---|---|---|---|---|
| Workstation | 01 | 500 | 12 | 180 |
| Servidor | 01 | 500 | 12 | 180 |
| Desktop | 05 | 300 | 10 | 450 |
| Monitor | 05 | 100 | 10 | 150 |
| Switch | 01 | 50 | 24 | 36 |

For a more accurate PUE calculation, we need data from the laboratory's auxiliary equipment (air conditioning, ventilation, lighting, emergency energy sources, etc.). With the data collected by the installed sensors, we should be able to calculate the energy consumption of laboratory equipment in a more detailed and accurate way, providing a more solid and realistic basis for employing the PUE method to obtain the efficiency of electric energy consumption index for the laboratory.

## 4 Conclusion

Due to the current pandemic, on-site activities on all educational institutions have been suspended for the time being, compromising the timetable for implementing the solution. Considering that the LFTC has suspended its activities, the energy consumption of the environment is negligible. Nevertheless, for security reasons, we decided to leave the CCTV function of the SBC equipment operational, for the purpose of monitoring and controlling access to the laboratory. If there is any physical activity on the laboratory, the prototype will send a notification to those who are responsible for it. The notification contains details about the access to the laboratory, such as the detection of individuals and possible objects taken from it.

Additionally to physical monitoring, monitoring of IT equipment is also in place on the laboratory, collecting information about processors, memory, hard drives and graphic cards, for all IT assets.

Despite having only a few of its features and functionalities implemented, the solution has proven to be of great value as a DCIM model based implementation. Each of its features, both those that are already in operation and those that will be implemented, provide promising material for future research, mainly in the area of energy efficiency.

## References

[1] H. Geng. *Data Center Handbook*. Wiley, 2015
[2] W. Tschudi. *Data Center Energy Efficiency Opportunities*. Lawrence Berkeley National Laboratory. 2020
[3] W. J. Kosik. *Energy and Sustainability in Data Centers*. Hewlett-Packard Company, 2015
[4] Executive Order 13834, available in https://www.fedcenter.gov/programs/eo13693/#regs, United States, 2016
[5] C. Gough, I. Steiner and W. A. Saunders. *Energy Efficient Servers*. Apress Open, 2015
[6] L. C. Bradley. *Handobook of Data Center Management*. CRC Press, 1994