Renewable and Sustainable Energy Reviews 42 (2015) 429–445

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Energy efficiency and renewable energy integration in data centres. Strategies and modelling review

Eduard Oró*, Victor Depoorter, Albert Garcia, Jaume Salom

Catalonia Institute for Energy Research, IREC, Jardins de les Dones de Negre 1, 08930 Sant Adrià de Besòs, Barcelona, Spain

ARTICLE INFO

Article history:
Received 29 January 2014
Received in revised form
26 August 2014
Accepted 15 October 2014

Keywords:
Data centre
Energy efficiency
Renewable energy
Green computing
CO_2 emissions
Numerical models

ABSTRACT

The continuous growth in size, complexity and energy density of data centres due to the increasing demand for storage, networking and computation has become a worldwide energetic problem. The emergent awareness of the negative impact that the uncontrolled energy consumption has on natural environment, the predicted limitation of fossil fuels production in the upcoming decades and the growing associated costs have strongly influenced the energy systems engineering work in the last decades. Therefore, the implementation of well known and advanced energy efficiency measures to reduce data centres energy demand play an important role not only to a supportable growth but also to reduce its operational costs. The carbon footprint is greatly influenced by the energy sources used. Therefore, there have been recent efforts to exploit and reuse or combine green energy sources in data centres to lower brown energy consumption and CO_2 emissions. This paper presents a comprehensible overview of the current data centre infrastructure and summarizes a number of currently available energy efficiency strategies and renewable energy integration into data centres and its characterization using numerical models. Moreover it would be necessary to develop dynamic models and metrics for properly understand and quantify the energy consumption and the benefits of applying the incoming energy efficiency strategies and renewable energy sources in the data centres. Thus, the researches or investors will be able to compare with reliability the different data centre designs and choose the best option depending on the renewable energy sources and capital available.

Contents

* Corresponding author. Tel.: +34 933 562 615.
E-mail address: eoro@irec.cat (E. Oró).

http://dx.doi.org/10.1016/j.rser.2014.10.035
1364-0321/

1. Introduction

During the last years, the rapid increase of cloud computing, high-powered computing and the vast growth in Internet use have aroused the interest in energy consumption and carbon footprint of data centres. This increase of energy consumption is mainly due to the high density of Information Technologies (IT) equipment and to the fact that they run 24 h a day, the 365 days of the year. It is well known that, as critical operations of some companies heavily rely on the proper functioning of data centres, significant efforts in ensuring suitable environment conditions and security measures are spent in the design of these infrastructures.

The energy demand per square metre of data centres, which is up to 100 times higher than for office accommodations, increased significantly during recent years. This is mainly due to the decrease in processing server sizes and more efficient use of space and server processing which are challenging facilities to provide more power and cooling capacity. Actually, up to half of the total energy consumption is attributed to cooling which in turn produces vast amounts of waste heat. Energy consumption of data centres can be unnecessarily high due to the inadequate localization of cooling and packed server rack layouts and the poor airflow management. Moreover, it is not easy to improve airflow management without the use of modelling tools. Another aspect which has contributed to inefficient energy consumption of data centres is that the main concern for their operators is the reliability rather than energy efficiency. Hence, most of data centres are designed based on the worst case scenario and then all the mechanical components are oversized enhancing both the investment and the operational cost. However, since power densities in data centres are reaching levels that lead to limitations, the implementation of energy efficiency strategies is now observed as a way to solve these problems. Thus the benefits of reducing energy inputs at various levels of the life cycle of data centres are the reduction in costs and the improved reliability induced by less dependence on the utility grid. Consequently, the development of effective and efficient measures to reduce both computing and cooling demands is imperative.

In this sense, Kant [1] envisioned data centres evolving from owned physical entities to potentially outsourced, virtualized and geographically distributed infrastructures that still attempt to provide the same level of control and isolation that owned infrastructures do. He defined a layered model for such data centres and provided a detailed treatment of the state of the art and emerging challenges in storage, networking, management and power/thermal aspects. On the other hand, Uddin et al. [2] proposed a guideline for data centre managers to properly design and implement virtualization in data centres. This guideline would help to achieve sustainable energy efficient data centres to ensure the reduction of overall emission of greenhouse gases and the implementation of sustainable businesses. Additionally, in various works Uddin et al. [3–5] proposed strategies and techniques for energy efficiency and CO_2 mitigation in data centres to lower the effects of global warming. Some of these strategies were addressed to measures such as reducing frequent hardware purchases, power/cooling cost reductions, workload consolidation and physical server reduction. Moreover, they spotlighted the importance of implementing green metrics and proposed a methodology to choose suitable metrics for measuring data centres efficiency and performance in terms of energy efficiency, cost savings, green initiatives and CO_2 emissions.

As a result of the continuous growing in size and complexity of data centres, the understanding of their design aspects is worthy to be carried forward, as well as existing or upcoming inadequacies and challenges that would have to be addressed. One of these challenges will be the implementation of energy efficiency strategies to decrease the total energy operational demand; these techniques are able to achieve a considerable energy saving with a small economical investment. Another challenge is the integration of renewable energy sources (RES) in data centres to reduce their energy dependency from the grid and reduce also the CO_2 emissions, but this system requires a high investment cost; nowadays these implementations are under study for many researchers. To our knowledge, any literature review on the implementation of energy efficiency strategies and integration of RES into data centres is available. Thus, this paper summarizes what has been done in this direction and presents some numerical models used to characterize partial and complete operation of data centres. As well, it introduces some promising research topics in the energy efficiency and RES implementation in data centres.

2. Data centres overview

A data centre could be defined as a structure, or group of structures, dedicated to the centralized accommodation, interconnection and operation of IT and network telecommunications equipment providing data storage, processing and transport services, together with all the support facilities for power supply and environmental control with the necessary levels of resilience and security required to provide the desired service availability [6].

2.1. Physical structure

This unique infrastructure is divided in three spaces: IT room, the data centre support area and the ancillary spaces. The IT room