Benchmark of data centre energy performance

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ABSTRACT

Data centres are characterized by high power demand and rapid growth rate. Hasty construction and unclear identifications of power demand often leads to improper design and inefficient energy use in data centres. This paper presents a recent study conducted to determine an empirical energy use pattern of data centres. Measured energy end use data and benchmarking results obtained from six data centres are reported. It is found that data centres consume approximately three to seven times more power than that of typical commercial office space. These facilities are significantly over designed in terms of total power demand, HVAC system capacity and size of UPS. Potential opportunities for improving energy efficiency of data centres can be expected.

INDEX TERMS

Data centre; Energy use; Power demand; Efficiency; Benchmark

INTRODUCTION

Information and Communication Technology (ICT) involves universal adoption of computers and Internet tools to conduct the new rising e-commerce, and facilitate the development of other businesses. Networks making up today's Internet are linked by installations that are called data centres, server farms and Internet hotels. Data centre, in this instance, is a generic term used to describe a facility that houses concentrated digital equipment to perform one or more of the following functions: store, manage, process and exchange digital data and information; such facilities are typically set up for web hosting, central depository information bases of government organizations and research units, intranets, financial transaction processing, telecommunications, and other activities (Beck, 2001; Tschudi, 2003). For the proper function of computing equipment, data centre as a facility is required to provide guaranteed reliable power supply, security, cooling and connectivity to Internet.

Studies (Beck, 2001; Miller, 2002; Mitchell-Jackson, 2002, 2003; Tschudi, 2003) have shown that the concentration of densely packed computing equipment, high cooling load requirement and around-the-clock running schedule of data centre have led to power demand that is much higher than that of a typical residence or commercial office building.

The study is conducted to determine an empirical energy use pattern of data centres and develop model for examining data centre energy consumption and power demand. This paper presents the measured energy end use data and the benchmarking results obtained from case studies carried out in six corporate data centres in Singapore.

Computing equipment in this paper refers to various digital equipment such as servers, networking devices, data storages, monitors, which deal with information processing, storage, management and transfer.

Corporate data centre refers to the data centre owned and operated by a single corporation to deliver information service. Such facilities can be found in government organizations, banks, research units and universities, etc.

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METHODS

The study employs modelling, field measurement and benchmarking as main approaches. A model of data centre energy performance was developed as the basis of this study. The model involved both various energy consuming components and other significant variables such as space, environmental condition, which effect energy consumption and power demand in data centres. Field measurement focused on electrical energy use, indoor environmental conditions, space usage and others. Accurate electrical power and energy measurements were highlighted. A true energy meter instrument was especially developed for the studies. Based on the data obtained, benchmarking was performed to examine energy performance among data centres. Statistical analysis included error analysis of raw data, correlation analysis and multiple regression. The research design and procedure is shown systematically in Figure 1.

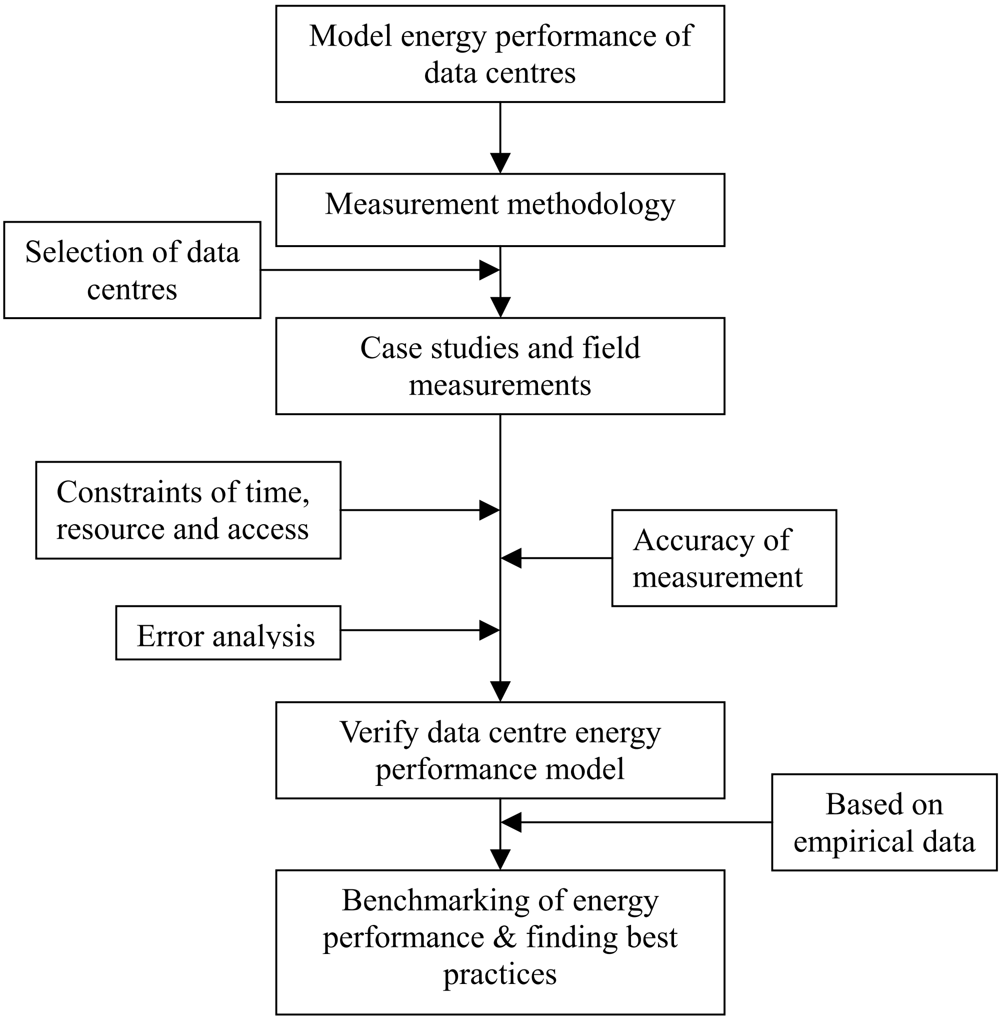

Figure 1 Research design and procedure.

RESULTS

Measured data and benchmarking results are presented in this section.

Total Data Centre Energy Use Index

The actual total data centre power demand densities varied from 257 to 595 W/m^2, with a mean of 386±125 W/m^2 at 95% confidence level. Energy consumption per square metre over gross data centre floor area ranged from 2248 to 4998 kW h/year/m^2. The mean value is

3311±1024 kWh/year/m^2. Although there was a wide variation among data centres with respect to energy consumption and power demand, the results show that power demands of these facilities were three to seven times higher than the 80 W/m^2 demanded by the typical commercial office space in Singapore (CTBP, 2003).

Energy End Use Breakdown

In a typical data centre, energy end use components include computing equipment, HVAC, lighting, energy loss in UPS and other auxiliaries such as office equipment, building control system, circuit breaker and diesel generator.

Among these, HVAC, computing equipment and UPS are the main energy consumers. Figure 2 illustrates the integrated breakdown of energy end use in the data centres studied.

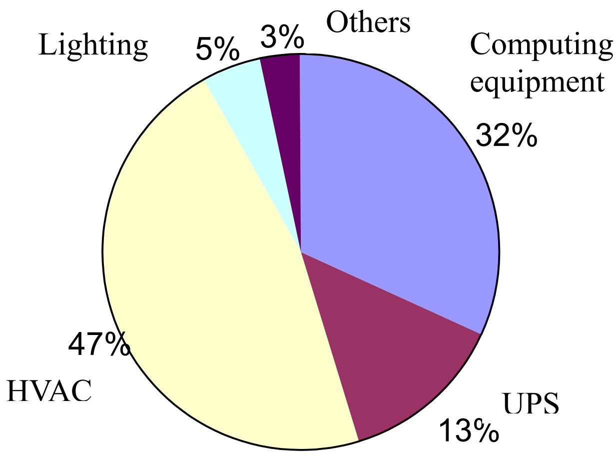

Figure 2 Data centre energy end use breakdown.

Comparison between Actual Power Demand and Initial Power Request

Studies conducted by Lawrence Berkeley National Laboratory (LBNL), the US (LBNL, 2003) and other researches have shown that overestimated power demand of computing equipment led to over designed circuit capacity, oversized HVAC and UPS, inefficient energy use and unnecessary capital investment. For the purpose of determining local data centres' design performance, benchmarking was conducted among both local data centres and those studied by LBNL. Figure 3 presents comparisons of actual and designed power demand densities of computing equipment.

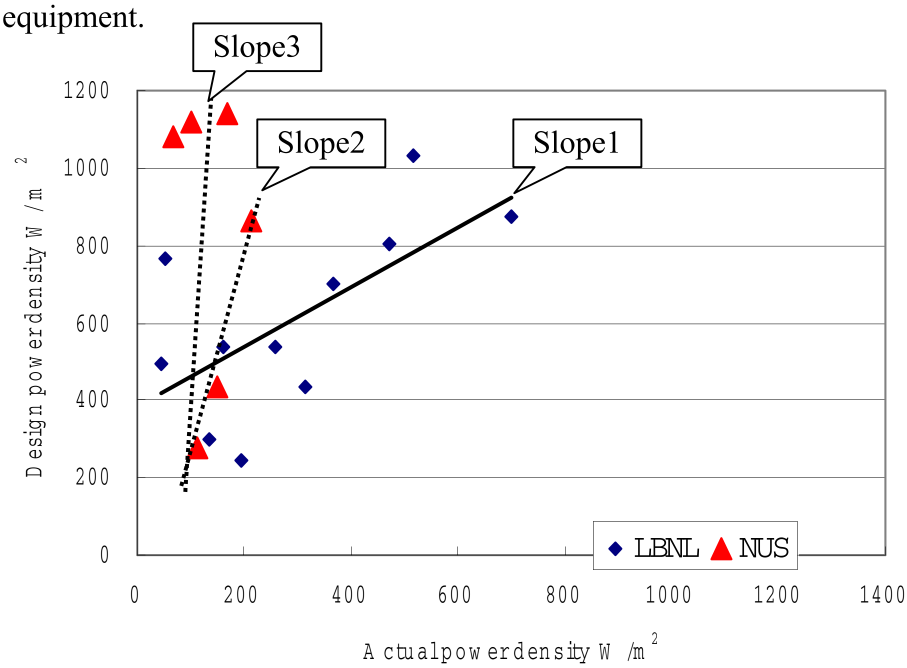

Figure 3 Actual and design power demand of computing equipment.

Slope1 represents a trend of neutral over-design rate of the data centres studied by LBNL. By comparison, slope2 presents a greater vertical trend, which indicates the optimal situation of local data centres. Average over-design rate of local data centres represented by slope3 indicates an even worse situation. This has determined the common problems of over designed data centre facilities and over demanded power from utilities. Local data centres are facing a much tougher challenge of improving energy performance. Wider investigations and benchmarks are necessary to be conducted.

HVAC Performance Efficiency

HVAC systems typically consume 30–50% of the power load, and represent the major energy saving potential in data centres. Ratio of dividing the power demanded by HVAC with that demanded by computing equipment may be a coefficient indicating HVAC system working performance and efficiency. Figure 4 shows the calculated ratios of the data centres studied. The high ratios shown in Figure 4 indicate poor cooling efficiencies in data centres. It shows that a poor cooling performance is often associated with a high over design rate of HVAC. Therefore, overdesign is determined to be the significant reason for poor cooling efficiency. Figure 5 shows over design situation of HVAC systems.

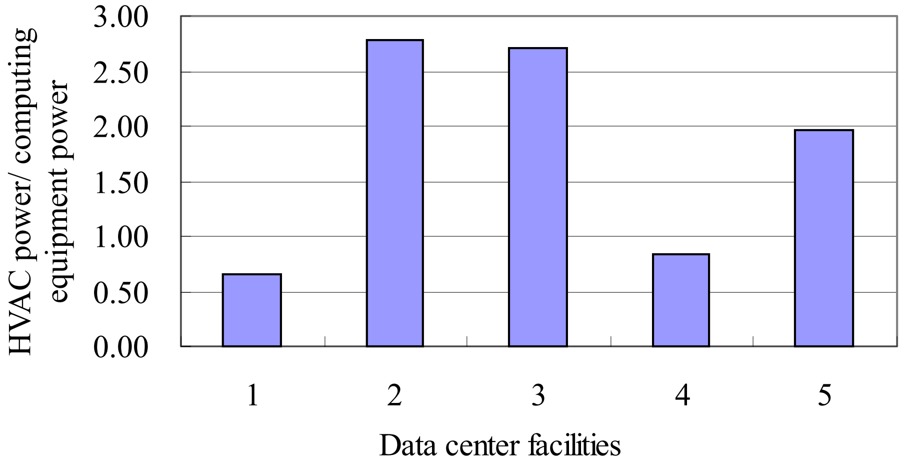

Figure 4 HVAC performance efficiency indicator

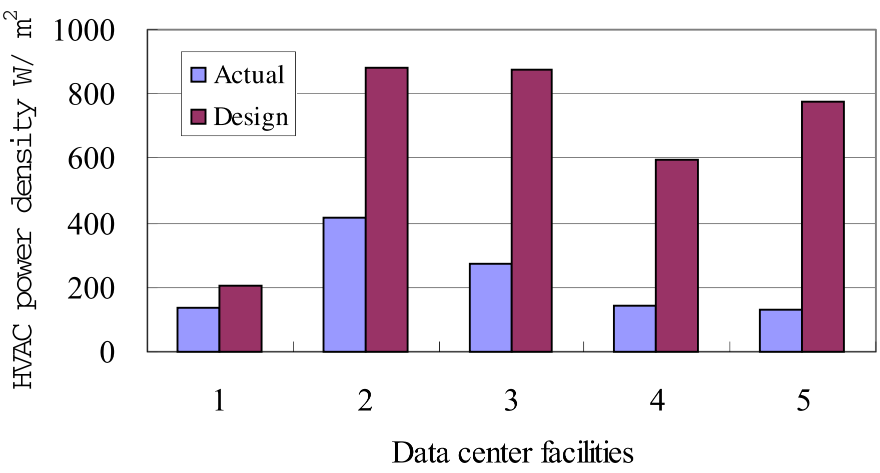

Figure 5 Actual and design power demand of HVAC system

DISCUSSION

Measured data and benchmarking results obtain by this study show that power demand of a data centre is three to seven times more than the 80 W/m^2 demanded by typical commercial office space in Singapore. This is mainly due to the concentration of computing equipment and high cooling demand of HVAC system. However, the energy inefficient operation is another substantial reason. Overdesign is the main reason for the inefficient energy use in data centres, which also results in highly wasteful capital investment. The current situation of over design and the wide variation of energy performance in data centres reflect the lack of common design standard and guideline of such facilities. Future investigations and benchmarking studies are greatly valuable to set up the database and develop best practices for better data centre design and operation. Lack of routine energy performance measurement and verification is another significant reason of poor energy efficiency. Frequently, facilities managers know little about the power demand and energy consumption of data centres or the equipment efficiencies. This could be attributed to the lack of instrument and relevant knowledge. Training of energy consumption measurement and setting up a routine energy efficiency assessment policy are necessary.

Computing equipment, HVAC and UPS are the main energy end user in data centres. Potential opportunities for energy saving, therefore, are expected to be targeted on these consumers, through accurate load estimate and the applications of smart design and new energy efficient technologies.

CONCLUSION AND IMPLICATIONS

Incomprehensive database establishing the power demand and energy use of data centres had led to over design and poor efficiency in data centre facilities. The measured data and benchmarking results obtained by the study offer better understanding of the energy performance in data centres. Designers and developers can use the results as references for the design of new projects. Such a study should contribute to the development of wide benchmarking activities.

The study illustrates that data centre consume enormous energy. Power demands of such facilities are often highly over estimated and supporting systems such as HVAC and UPS were over designed. This has not only led to the high operating cost but also cause unnecessary capital investment. Efforts of improving energy efficiency in data centres are needed in both design and operation stages.

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