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# Study on energy saving possibility of digital variable multiple air conditioning system in three office buildings in Shanghai

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ABSTRACT

The objective of this paper was to study energy saving possibility of DVM air conditioning system compared to all-air system with constant air volume and primary air fan-coil system. Three office buildings are selected to study the impact of outdoor air temperature and air-conditioning load on energy consumption of the above three systems. eQUEST was used to simulate the annual building performance. The simulation results indicate that energy saving potentiality of DVM air conditioning system is significant under part load condition because of its indoor unit independently controlled characteristic and good regulating characteristics; for office building with boundary condition in standard GB 50189-2005, energy saving potentiality of DVM air conditioning system is significant when building area is less than 20,000 $m^2$, or primary air fan-coil system with two sets of water source screw chiller is more available.



## 1. Introduction

Multi-connected air condition (heat pump) unit was born in Japan in the 1980s, and has been widely used and rapidly developed due to its several advantages, such as easy maintenance, wide range capacity output, precise capacity control and high SEER (seasonal energy efficiency ratio). It has become one of the most commonly used central air conditioning systems in small commercial buildings and civil buildings. Compared with centralized or semi-centralized air conditioning system, multi-connected air conditioning system is simpler in structure and easier to install. Outdoor unit is smaller and occupies less space than that of centralized or semi-centralized air conditioning system. Each indoor unit of multi-connected air conditioning system is independently controlled. And its energy loss is lower than that of the other two systems due to its only once heat exchange in heat transfer process.

At present, there have been several studies relevant to multi-connected air conditioning system. William [1] analyzed energy saving potential and market factors of refrigerant systems that vary flow and volume. Zhang [2,3] and Zhao [4] addressed experimental study on performance of digital variable multiple air conditioning system under part load conditions. Huang [5] conducted an experimental study on operating characteristics of ducted air conditioning unit with digital scroll compressor and conventional scroll compressor under refrigerating and heating condition. Hu and Yang [6] discussed the relationship between the opening degree of electronic expansion valves and the compressor output ratio. Zhou [7] developed a simulation module for variable refrigerant volume (VRV) air conditioning system on the basis of EnergyPlus. Several papers addressed control strategy of VRV air conditioning system by Shi et al. [8–11]. Kim et al. [12] applied fuzzy logic to control refrigerant distribution for the multi type air conditioner. Wu [13] and Xia [14] studied control scheme and optimization control of VRV air conditioning system. And evaluation standard for multi-connected air condition (heat pump) unit [15–18] has been formulated.

The studies above are mainly focused on operating characteristics, control strategies and evaluation method of multi-connected air conditioning system. However, up to now, seldom researches have been conducted on energy saving possibility of multi-connected air conditioning system. In practical applications, DVM air conditioning system, all-air system with constant air volume and primary air fan-coil system are commonly used in office buildings. Therefore, the effects of outdoor air temperature and air-conditioning load on energy consumption of the above three kinds of air conditioning systems are analyzed in this paper. The reasons for energy consumption difference are studied and energy saving possibility of DVM air conditioning system is analyzed.

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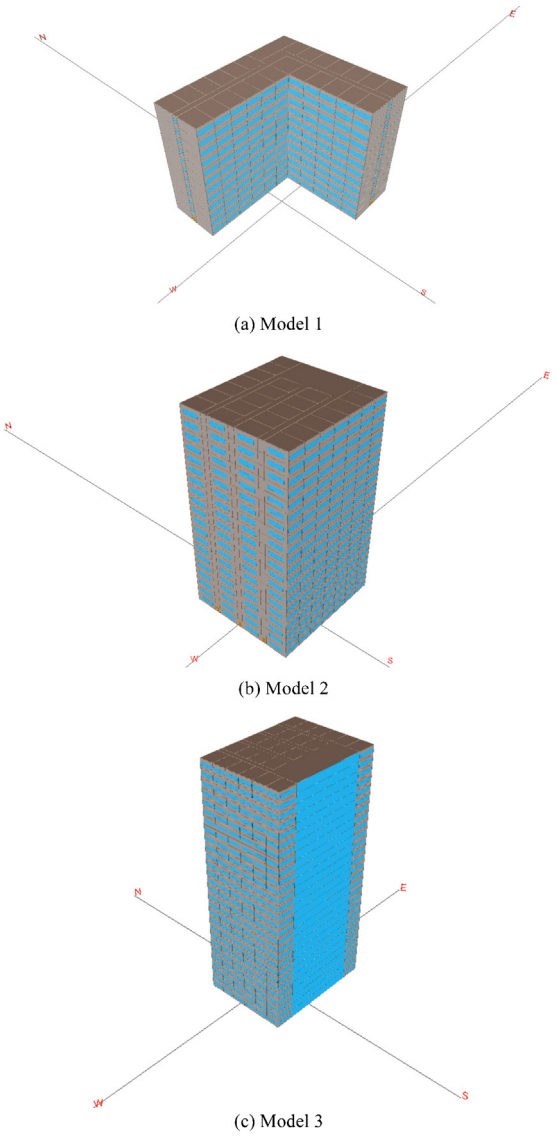

(a) Model 1

(b) Model 2

(c) Model 3

**Fig. 1.** Building models.

## 2. Project simulation research

### 2.1. Building description

This study researched three office buildings in Shanghai where employees worked from Monday to Friday. Energy-consuming equipment are powered on and off according to the workday. 3D models of the buildings are shown in Fig. 1. There are 16, 24, and 28 stories above ground for the three office buildings, respectively, and 24 air-conditioning rooms on each floor. Building area of the three buildings are 23,040 $m^2$, 36,288 $m^2$ and 48,384 $m^2$, respectively. The ratio of external window area to external wall area are 0.54, 0.60, and 0.63, respectively.

### 2.2. Parameter settings in eQUEST software simulation

eQUEST is an easy to use building energy use analysis tool which provides results with an affordable level of efforts. It is accomplished by combining a building creation wizard, an energy efficiency measure wizard and a graphical results display module with an enhanced DOE-2.2-derived building energy use simulation program. Parameters of building envelope, indoor environment and air-conditioning system in eQUEST are set as follows.

**Table 1**
Air conditioning systems.

| System | Type |
|---|---|
| System 1 | DVM air conditioning system |
| System 2 | All-air system with constant air volume with two sets of water source screw chiller |
| System 3 | Primary air fan-coil system with two sets of water source screw chiller |
| System 4 | All-air system with constant air volume with two sets of air source screw heat pump |
| System 5 | Primary air fan-coil system with two sets of air source screw heat pump |

**Table 2**
Model and capacity of outdoor and indoor units (kW).

| Unit | Model | Rated cooling capacity | Rated heating capacity |
|---|---|---|---|
| Indoor unit | AVXCMH040EF | 4.0 | 4.5 |
| Outdoor unit | RVXVHT140GF | 40.0 | 45.0 |

#### 2.2.1. Parameters of building envelope and indoor environment

The building layout was set based on the software rendered model of the actual building plan. After the model wall was completed, the inside areas were partitioned into air conditioned areas consisted of general offices, and non-air conditioned areas accounted for all other areas. The software parameter settings included a north-facing orientation, light steel frame walls for building wall construction, general and low-E glass, and window openings percentage on each side of the building. *U*-values of the exterior wall and the roof are 1.0 $W/m^2$ K and 0.7 $W/m^2$ K, respectively.

In addition to the building envelope, occupancy, lighting power density and equipment power are also parameters that affect a building's energy consumption and therefore must be set in the software. The internal loads with the initial simulation model give the occupancy density at 4.0 $m^2$ per person; the lighting power density is 11.0 $W/m^2$, and the plug power density is 20 $W/m^2$. The cooling set point is 25 °C during the building's operating hours.

Parameter settings of building envelope, indoor heat, indoor air design temperature and humidity are able to meet the requirement of design standard for energy efficiency of public buildings GB 50189-2005.

#### 2.2.2. Air-conditioning system parameters

DVM air conditioning system, all-air system with constant air volume and primary air fan-coil system are commonly used in office buildings. Five air conditioning systems as presented in Table 1 are selected to study the energy saving possibility of DVM air conditioning system.

The weather data are from the Central Weather Bureau of Shanghai. DVM air conditioning system is composed of 1 outdoor unit and 12 indoor units, and its settings in eQUEST include model and capacity of DVM outdoor and indoor units as presented in Table 2. In all-air system with constant air volume, one air conditioner unit is installed to handle and supply air for 24 rooms on each floor. Parameter settings of all-air system with constant air volume and primary air fan-coil system in eQUEST, such as parameters of fan, pump, transport system, and chiller or heat pump are presented from Tables 3–6, respectively, which are able to meet the requirement of standard GB 50189-2005.

The same fresh air volume for the above five air conditioning systems makes no contribution to energy consumption comparison, so the designed outdoor air flow rate per person is set