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Development of test reference year using ISO 15927-4 and the influence of climatic parameters on building energy performance

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ABSTRACT

Along with growing concern about energy consumption from the building sector, computer simulations play an important role to analyze the performance of buildings and building systems. A test reference year (TRY) is widely adopted as a representative weather data to get reliable outcomes from the simulations. TRYs of the major 18 locations in South Korea were determined using the method presented by ISO 15927-4 to assure the objectivity of the results from the building energy simulations. The TRY should represent the main climate parameters of the long-term data as close as possible. TRYs were compared with the long-term measured data of 10 years to evaluate their representativeness. According to the statistical results, TRYs in this study have a good representativeness of the weather data for South Korea. The relative influence factors of different climatic parameters on the building energy are important to establish the strategies to minimize the energy consumption. The relative impacts of climatic parameters – air temperature, relative humidity, solar irradiance and wind speed - were numerically determined using a dynamic energy simulation and different types of buildings. It is obvious that air temperature has a strong effect on the energy demand in winter, but on the other hand, solar irradiance is the primary climatic parameter in summer. The energy demand caused by the dehumidification in summer should be considered with solar irradiance and air temperature for the climate of South Korea. Wind speed has a minor effect on the energy demand all year round.

1. Introduction

Demands to minimize energy use have been growing with the concern on green and sustainable environment. The energy consumption by buildings accounts for 21% of the total final energy consumption of South Korea. However, the change in the industrial structure has been accelerated expanding the proportion of the building sector due to the economic growth, which leads to the increase in nearly 4% of energy consumption by buildings compared with that of the last decade [1]. With this inevitable trend, it is important to study the energy performance of buildings and building systems, such as heating, air-conditioning, photovoltaic systems, etc., to achieve energy-efficient design and operation. In this regard, employing energy simulation software became an essential practice in the design process. Weather data are one of the important factors that have a significant influence on the results of energy performance from simulations, so that it is required to use reasonable and reliable weather data [2]. However, neither standard weather data of South Korea for the energy simulations have been established, nor researches on that topic have been carried out so far. Accordingly, the objectivity of the results by building simulations is always under debate. Only Energy Plus [3], developed by the United States Department of Energy, provides weather data for four locations in South Korea. However, these are insufficient to represent a capricious Korean climate by region, which is caused by the complex mountainous terrain over the Korean Peninsula.

As climatic conditions can vary considerably from year to year, there is a need to derive standard weather data to represent typical long-term climate conditions. A number of methods to generate the typical weather data have been widely developed by various

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researchers for building designs, building systems and built environment studies; Typical Meteorological Year (TMY) [4–6], International Weather Year for Energy Calculation (IWEC) [7] and Test Reference Year by Europe (TRY), etc.

The method to determine a TRY is presented by ISO 15927-4 [8] with four climatic parameters, air temperature, relative humidity, solar irradiance and wind speed. In the selection process of the standard weather data, different weighting factors can be assigned to some key climatic parameters such as air temperature, relative humidity, solar irradiance, etc. These weighting factors can express the relative importance of particular climatic parameters on building energy performance. Even though the four climatic parameters may have different influences on the energy demand of buildings, the ISO 15927-4 gives the same weight for air temperature, solar irradiance and relative humidity to understand the climatic characteristics at a location. The TRYs provide weather data of one year that characterize the climatic conditions at a location over a reasonably long period of time. By employing the method of ISO 15927-4, a TRY is broadly adopted by various researchers. Wong et al. [9] developed and compared the two main methods for TMY and TRY to select typical weather data using measured hourly data for 30 years. It was appreciated that the monthly building energy performance simulated from the two methods was in a good correlation with the simulated long-term monthly mean consumption of the three decades. Lee [10] investigated TRYs of the major seven cities in South Korea derived from 20 years of meteorological data recorded during the period 1986–2005. However, their raw data went out of date, which cannot keep up with the recent climate, and the reliability of the raw data would not be assured, because the years from 1986 to 1998 contain only recording data for every three hour. The representativeness of the method, described in ISO 15927-4 to develop TRYs for five North Italian locations, was discussed by Pernigotto et al. [11]. The researchers compared the TRYs and long-term measured weather data as well as evaluated the energy performance computed by both weather data by simulating different simplified buildings. Rahman und Dewsbury [12] discussed methods of selecting typical weather data and described the selection of TRYs of Malaysia. The various weighting factors for the climatic parameters, air temperature, relative humidity, solar irradiance and wind speed, were evaluated in the realistic range of building performance for the tropical climate. Kalamees et al. [13] proposed a new method to select the energy reference year for many applications using the weather data modified based on ISO 15927-4. Monthly dependent weighting factors for the main climatic parameters were determined and applied into a method to create the cold Finnish reference year data.

In this study, TRYs of the major 18 meteorological locations in South Korea were generated using ISO 15927-4 to assure the reliability of the results from building energy simulations. Thus, the hourly weather data from the last 10 years, measured by Korea Meteorological Administration, were utilized to develop the TRYs. Since TRYs should represent the main climate parameters of long-term data as close as possible, the representativeness of the TRYs was verified by comparing the statistical characteristics of them. Furthermore, the relative influence factors of the climatic parameters – air temperature, relative humidity, solar irradiance and wind speed - on building energy consumption were investigated in accordance with types of a building and climatic zones in South Korea.

2. Preparation of test reference years using ISO 15927-4

2.1. Selected locations

The Korean Peninsula is surrounded by the Yellow Sea westwards, the East Sea eastwards and the East China Sea southwards. The Taebaek Mountains are located along the east coast line of the peninsula, which makes the Korean topography east high and west low. The slope of the mountains drops sharply toward the east coast and reaches the west coast gradually. Korea is geographically located on the middle latitude temperate climate zone, so that four seasons – spring, summer, autumn and winter – are clearly presented. It is cold and dry in winter because of the continental atmospheric pressure from Siberia, but in summer it is hot and humid due to the maritime atmospheric pressure from the North Pacific. The weather is mostly fine in spring and autumn by the migratory high pressure. The range of annual mean air temperature is 10–15 °C, and annual mean relative humidity is 60–75 RH%. The mean humidity remains 50–65 RH% in winter and goes up to 70–85 RH% in summer. The range of annual precipitation is 1000–1900 mm, and especially 50–60% of the annual precipitation is concentrated in the summer period because of monsoon and typhoons. The monsoon starts from the southern part of Korea at the middle of June and it moves toward the north lasting around 30 days. And then, on average, about three typhoons created at the North Pacific have a strong influence on the Korean climate in summer. Seasonal wind direction is obvious: the wind in winter blows from northwest and in summer from southwest [14,15].

South Korea is divided into three climatic zones (I – III) according to the Regulation 2015-1108 for Energy Conservation in Buildings stated by the Ministry of Land, Infrastructure and Transport of Korea [16]. Fig. 1 illustrates the annual average air temperature during the years 1981–2010 within the three climatic zones and shows the main 18 meteorological stations operated by Korea Meteorological Administration. In this study, TRYs of the 18 locations were developed using ISO 15927-4. The information of the locations in accordance with the climatic zone is listed in Table 1 [15].

2.2. Weather data source

The TRYs in this study contain hourly values of the following climatic parameters: air temperature, relative humidity, global horizontal irradiance (GHI), diffuse horizontal irradiance (DHI), direct normal irradiance (DNI), wind speed, wind direction, air pressure, cloud cover and precipitation. Hourly measured data for 10 years (2005–2014) was obtained from Korea Meteorological Administration. Missing values less than 6 h in a row were complemented by linear interpolation and unnatural jumps or singular values were identified and corrected. DHI and DNI are required to generate TRYs, which can be utilized for building energy simulations. However, Korea Meteorological Administration does not provide DHI and DNI, but only GHI. According to the relationship that the sum of DHI and DNI is GHI, once DHI or DNI is estimated, the missing irradiances can be determined. In this research, the DNI was multiplied by the cosine of the zenith angle for the case of a horizontally orientated surface. DHI was calculated by Skartveit and Olseth's hourly diffuse fraction model [17]. This model was developed with hourly solar elevation, clearness index, an hour-to-hour variability index and regional surface albedo as input parameters. The reliability of this model was verified by Lanini [18] in order to apply it to worldwide stations. The researcher discussed that this model performed best for the purpose in comparison to the other diffuse fraction models proposed by Maxwell [19], Perez et al. [20], Boland et al. [21], and Helbig [22].

2.3. Generation of test reference year

In principle, if a real-measured year existed within the long-term data, in which each month is representative of the long term conditions, this year could be used as a reference year.