New software for generation of typical meteorological year

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Abstract: The correct selecting of typical meteorological year is an important factor for accurate building energy simulation. In this study, the Sandia method has been applied to prepare the new TmyCreator software for selecting the proper data as the typical meteorological year (Tmy2). Also, the results of this new software have been compared with the available Tmy2 weather data file for two cities. It is found that, the results of TmyCreator software have good agreement with the old created Tmy2 weather data file for these cities.

Keywords: Typical meteorological year; Building energy simulations; Finkelstein–Schafer statistics

1. Introduction

The weather data is the most important factor for building energy simulation software. The hourly data of meteorological parameters such as solar radiation, dry bulb temperature, relative humidity, wind speed, atmospheric pressure and etc are usually needed to simulate building energy.

Many methods have been suggested to provide the typical meteorological year. Typical meteorological year has been presented in different types for examples Tmy2 (NREL 1995) and WYEC2 (ASHRAE 1997) in the United States and Canada and TRY (CEC 1985) in the Europe. The Tmy2 and WYEC2 typical weather years contain more solar radiation and illumination data than older formats such as Tmy (NCDC 1983), WYEC (ASHRAE 1985) and TRY (NCDC 1981).

From 1970 to 1983, Ashrae commissioned three research projects to represent weather year data for energy calculations (WYEC), which used the TRY format but included solar data (measured data, if available or calculated based on cloud cover and type). In the early 1990s, Ashrae began to update the WYEC data set. New WYEC data sets were listed in Tmy format, and calculated hourly illuminance data, data quality as well as source flags, were included [1].

Typical meteorological year has been obtained in various types and for different cities in the earth's surface. Apple L.S. Chan [2] reviewed various types of typical weather data sets in a paper and then the Finkelstein–Schafer statistical method applied to analyze the hourly measured weather data of a 25-year period (1979–2003) in Hong Kong. A. Kalogirou [3] presented the generation of a type 2 typical meteorological year (Tmy2) for Nicosia, Cyprus. Also, Joseph. C. Lam [4], Zhang Qingyuan[5] and T. N. Anderson[6] in the different researches, provided the various typical meteorological years based on different year periods and in many places of the Earth’s surface. The author (A. Ebrahimpour[7]) in previous research, created the typical meteorological year data from the measured weather data of a 14-year period (1992–2005) in Bandarabass using Sandia method [8].

In spite of this fact, the majority energy simulation softwares use typical Meteorological Year, so the exact values are necessary in order to correct estimation of the building energy consumption at the year. In this study, the Sandia method [8] has been used to create the TmyCreator software. Using the TmyCreator software, the typical meteorological year can be select from the measured weather data of a available year period (such as 1961–2010) in a city. The result of TmyCreator software has been compared with the available Tmy2 weather data file for various cities such as Salt Lake City.

2. Sandia method

The Sandia method is an empirical approach that selects individual months from different years of the period of record. For example, in the case that contains 30 years of data, all 30 Januarys are examined and the one judged most typical is selected to be included in the Tmy. The other months of the year are treated in a similar manner, and then the 12 selected typical months are concatenated to form a complete year. Because adjacent months in the Tmy may be selected from different years, discontinuities at the month interfaces are smoothed for 6 hours on each side. The Sandia method selects a typical month based on nine daily indices consisting of the maximum, minimum, and means dry bulb and dew point temperatures; the maximum and mean wind velocity; and the total global horizontal solar radiation. For each month of the calendar year, five candidate months with cumulative distribution functions (CDFs) for the daily indices that are the closest to the long-term CDFs are selected. The CDF gives the proportion of values that are less than or equal to a specified value of an index. Candidate monthly CDFs are compared to the long-term CDFs by using the following Finkelstein-Schafer (FS) statistics for each index.

$$FS = (1/n)\sum_{i=1}^{n}\delta_i \qquad (1)$$

Where, δ_i is absolute difference between the long-term CDF and the candidate month CDF at xi and n is the number of daily readings in a month.

Because some of the indices are judged more important than others, a weighted sum (WS) of the FS statistics is used to select the 5 candidate months that have the lowest weighted sums. The weighting factors listed in Table 1 for Tmy type.

$$WS = \sum w_i FS_i \qquad (2)$$

Where, w_i is weighting for index and Fs_i is *FS* statistic for index.

All individual months are ranked in ascending order of the WS values. A typical month is then selected by choosing from among the five months with the lowest WS values the one with the smallest deviation from the long-term CDF. In Hall's original method, persistence structures characterized by frequency and run length of days are included. The persistence of mean dry bulb temperature and daily global horizontal radiation are evaluated by determining the frequency and run length above and below fixed long-term percentiles. For mean daily dry bulb temperature, the frequency and run length above the 67th percentile and below the 33rd percentile are determined. For global horizontal radiation, the frequency and run length below the 33rd percentile are also determined. The persistence data are used to select, from the five candidate months, the month to be used in the Tmy. The highest ranked candidate month in ascending order of the WS values that meet the persistence criterion is used in the TMY. Then, the 12 selected months were concatenated to make a complete year and smooth discontinuities at the month interfaces for 6 hours each side using curve-fitting techniques. [9 & 10]

Table 1: The weighting factors in Sandia method

Wearher index	**weighting factor**
Maximum dry bulb temperature	1/24
Minimum dry bulb temperature	1/24
Mean dry bulb temperature	2/24
Maximum dew bulb temperature	1/24
Minimum dew bulb temperature	1/24
Mean dew bulb temperature	2/24
Maximum wind speed	2/24
Mean wind speed	2/24
Total horizontal solar radiation	12/24
Direct normal solar radiation	--

3. Tmy2 selection procedure in TmyCreator software

For using the TmyCreator software, The hourly measured weather data of Dry Bulb Temperature {C}, Dew Point Temperature {C}, Relative Humidity {%}, Atmospheric Pressure {Pa}, Wind Direction {deg}, Wind Speed {m/s}, Global Horizontal Radiation {Wh/m2},Direct Normal Radiation {Wh/m2} and Diffuse Horizontal Radiation {Wh/m2} have been prepared.

In Sandia method, the hourly measured data of dry bulb temperature, dew point temperature and wind speed have been used to select the Tmy2. So, calculating the maximum, minimum, and mean dry bulb and dew point temperatures and the maximum and mean wind velocity during a day and total global horizontal solar radiation during a day have been based on hourly measured data in TmyCreator software.

Other remained data in the Tmy2 weather file has not been calculated and the default values of Energyplus document software have been used [11].

4. The TmyCreator software

To use the TmyCreator software (Figure 1) the hourly measured weather data must be prepared for the desired period (such as 1990-2010). Also, the hourly measured weather data are the Dry Bulb Temperature {C},Dew Point Temperature{C}, Relative Humidity{%}, Atmospheric Pressure{Pa}, Wind Direction {deg},Wind Speed {m/s}, Global Horizontal Radiation{Wh/m2},Direct Normal Radiation{Wh/m2} and Diffuse Horizontal Radiation{Wh/m2}.

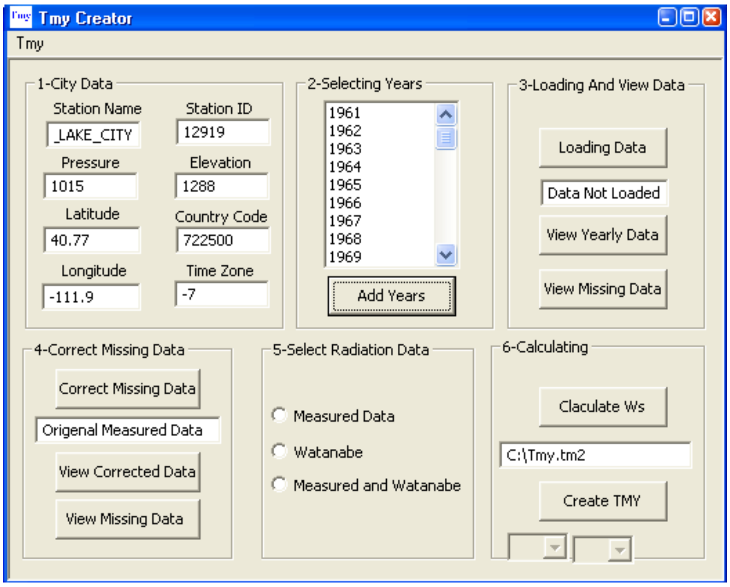

Figure 1: The TmyCreator software

4.1. Correct Missing Data

The TmyCreator software corrects the missing data using other available data as following method:

The missed data = (the amount of after three hour+ the amount of before three hour)/2

5. Validating the TmyCreator software

To validating of the TmyCreator software two methods have been used. In the first method, the Tmy2 weather data for the two city of the USA have been created by TmyCreator software from hourly weather data and the created Tmy2 file have been compared with the created Tmy2 weather data by NREL[1].

5.1. Comparing the Tmy2 Weather file

In the first stage, the 30 year period (1961-1990) hourly weather data for two city of the USA have been provided from the NCDC[2] and NSRDB[3] (for solar radiation data) and using this data the Tmy2 weather file have been created by TmyCreator software . Then the information about of selected year in the Tmy2 weather file created by TmyCreator software and NREL has been compared.

The Table 2 and 3 shows the number of not available hourly weather data for Abilene and Salt Lake City in USA in the year. It can be seen that the missing data for Abilene City is more than Salt Lake City.

The result of running the TmyCreator software using this hourly weather data for mentioned cities have been displayed in the Table 4 and 5.

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[1] National Renewable Energy Laboratory
[2] http://www1.ncdc.noaa.gov
[3] http://rredc.nrel.gov

Table 2: number of not available hourly weather data for Abilene in the year

Year	Wind Direction{deg}	Wind Speed{m/s}	Dry Bulb Temperature{C}	Wet bulb Temparature{C}	Dew Point Temperature{C}	Relative Humidity{%}	Atmospheric Pressure{Pa}	Global Horizontal Radiation	Direct Normal Radiation	Diffuse Horizontal Radiation
1961	981	2	2	2	2	2				
1962	665	2	2	2	2	3				
1963	702			1	1	1				
1964	227	4	4	4	4	4				
1965	5883	5836	5836	5837	5837	5836				
1966	5914	5840	5840	5840	5840	5840				
1967	5888	5840	5840	5841	5841	5840				
1968	5880	5840	5840	5840	5840	5840				
1969	5864	5840	5840	5840	5840	5840				
1970	5854	5840	5840	5841	5841	5840				
1971	5854	5840	5840	5840	5840	5840				
1972	5845	5840	5840	5840	5840	5840				
1973	166	149	151	156	157	2501				
1974	156	92	97	99	100	601				
1975	286	209	203	216	219	246				
1976	280	208	210	222	225	703				
1977	240	165	159	165	168	179				
1978	245	203	197	205	206	213				
1979	308	205	205	204	206	229				
1980	224	147	146	150	150	159				
1981	217	99	106	107	108	113				
1982	92	2	2	2	2	2				
1983	263	1	1	1	1	1				
1984	84	1		1	1	1				
1985	108			1	1					
1986	186									
1987	233	1	1	1	1	2				
1988	209									
1989	140	1								
1990	171									

Table 3: number of not available hourly weather data for Salt Lake City in the year

Year	Wind Direction{deg}	Wind Speed{m/s}	Dry Bulb Temperature{C}	Wet bulb Temparature{C}	Dew Point Temperature{C}	Relative Humidity{%}	Atmospheric Pressure{Pa}	Global Horizontal Radiation	Direct Normal Radiation	Diffuse Horizontal Radiation
1961	387	1	1	1	1	1				
1962	322									
1963	296			2	5					
1964	363	1								
1965	320									
1966	190		1		1					
1967	186					1				
1968	421				8					
1969	318			1	3					
1970	301			12	12	12				
1971	159			1	1					
1972	201									
1973	210	1	1	1	1	1				
1974	195	1		1	2					
1975	309	1								
1976	350	6	2	2	7	1				
1977	301	91	78	75	91	80				
1978	285	13	7	3	14	6				
1979	269		1		2					
1980	359									
1981	258									
1982	193									
1983	217			1	1					
1984	284				2					
1985	323	1	1	1	1	1				
1986	323	2	2	3	3	2				
1987	216			1	1					
1988	179									
1989	274			1	1					
1990	409			1	1					

Table 4: Compared result of TmyCreator software and available Tmy2 data by NREL for Salt Lake City

	City Name	Salt Lake	
		Name of years used by NREL	Name of years used by TmyCreator software
1	JANUARY	1976	1976
2	FEBRUARY	1971	1973
3	MARCH	1967	1987
4	APRIL	1976	1976
5	MAY	1989	1988
6	JUNE	1968	1968
7	JULY	1976	1976
8	AUGUST	1973	1989
9	SEPTEMBER	1972	1972
10	OCTOBER	1967	1968
11	NOVEMBER	1962	1962
12	DECEMBER	1965	1965

Table 5: Compared result of TmyCreator software and available Tmy2 data by NREL for Abilene City

	City Name	Abilene TX	
		Name of years used by NREL	Name of years used by TmyCreator software
1	JANUARY	1974	1974
2	FEBRUARY	1980	1961
3	MARCH	1961	1961
4	APRIL	1969	1969
5	MAY	1981	1981
6	JUNE	1979	1979
7	JULY	1974	1988
8	AUGUST	1981	1970
9	SEPTEMBER	1962	1970
10	OCTOBER	1980	1980
11	NOVEMBER	1977	1971
12	DECEMBER	1967	1979

In these tables the selected year for each month of the year by TmyCreator software and NREL have been showed. It can be seen that the TmyCreator software selected the years for 7 month like as selected year in NREL weather data for Salt Lake City and also selected the years for 6 month like as selected year in NREL weather data for Abilene City. Complete dissimilarity years selected for each month in the NREL file and the file produced by TmyCreator software is the following reasons:

1- As shows in Table 2 and 3, the missing data for these cities is more and not known that NREL How corrected the missing data when created the Tmy2 weather data file. The TmyCreator software corrects the missing data using other available data as following method :

The missed data = (the amount of after three hour+ the amount of before three hour)/2

2- Because the solar radiation data have important role in selecting the year of the Sandia method, it not known that NREL used of hourly measured radiation data or predicted data.

So, we can say that the TmyCreator software is acceptable.

6. Conclusions

In this study, the Sandia method has been applied to prepare the new TmyCreator software for selecting the proper data as the typical meteorological year (Tmy2). Also, the results of this new software have been compared and it is found that, the results of TmyCreator software have good agreement with the old created Tmy2 weather data file. Using this software the Tmy2 weather file can be prepared for anywhere of the earth. The Tmy2 weather data file have been prepared for 6 city of IRAN (Tehran, Tabriz, Esfahan, BandarAbass, Shiraz, Boshehr and Yazd).

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