An Uncertainty Evaluation of the Reference Standards Data for Solar Radiation and Wind Speed Data

Kwang Deuk Kim, Sang Yeob Kim, Chang Yeol Yun, Dok Ki Jo
New and Renewable Energy Research Division, Korea Institute of Energy Research, Korea
{ kdkim, sykim, yuncy, dokkijo}@kier.re.kr

Abstract

We measured the solar radiation since 1982 and wind data as renewable energy resources and carried out the uncertainty evaluation depending on authentic standards as ISO, GUM, and IEC. These data are collected at the several locations in Korea. Whereby measured data become standards data through the evaluation and the credibility are gained. We judge the credibility of data by expression of reliability quantitatively. In additional, the standards data are able to approach anywhere and it will be used to support of related research and industry.

1. Introduction

Recently, using the fossil fuel resources is restricted through its abuse and exhaustion, and that consequentially causes a global warming. According to the reason, the world increases the interest that is stability and use of renewable energy which is clean energy with environment. Therefore, the property data of renewable energy is needed for developing and supplying the energy. These data are became the standards in order to supply and evaluate the renewable energy in industry and technology fields.

Therefore, we evaluated and measured the solar radiation and wind data and processed the measured data for evaluation through certified standards. Those are complied with NREL (National Renewable Energy Laboratory), WMO (World Meteorological Organization), ISO (International Organization for Standardization), and GUM (Guide to the expression of Uncertainty in Measurement) standards. Whereby these data become reference standards and gains the credibility after the evaluation. For the reliability data, we correct the measuring instrument with correction period. These data are evaluated as 1,140 cases about 16 areas (solar) and 20 areas (wind). We achieve credibility and provide accurate information to user.

According to the results, we judged a credibility of data by expression of reliability quantitatively. In additional, the reference standards data are possible to approach anywhere and will be used for the supporting related industry and policy making.

2. Data Collection and Processing

We constructed the measurement system based on wireless network in order to measure the solar radiation and the wind data.

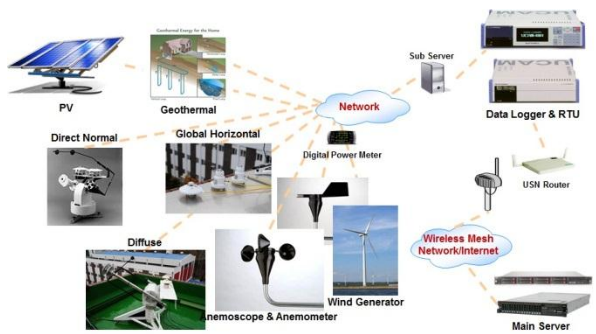

Figure 1. Measurement system structure based on wireless network

We carried out the uncertainty evaluation using the measured data that are processed by the monthly mean at 16 areas. Table 1 shows measurement items and number of cases.

Table 1. Measurement items and number of cases

Item	Period	Number
Global Normal Radiation	2008.6~2008.12	12
Direct Normal Radiation	1991.1~2008.12	192
Direct Horizontal Radiation	1996.8~2009.12	12
Diffuse Horizontal Radiation	1996.8~2009.12	12
Wavelength Radiation	2009.1~2009.12	4
Global Horizontal Radiation	1982.1~2008.12	192
Direct Normal Radiation (clear sky)	1992.1~2008.12	192
Extraterrestrial Radiation		192
Clear Sky Radiation	1992.1~2008.12	192
Radiation on Sloped Surfaces	1996.8~2008.12	120

In order to collection of data, weather station has been equipped in Fig. 2 such as wind speed, wind direction, temperature, and humidity.

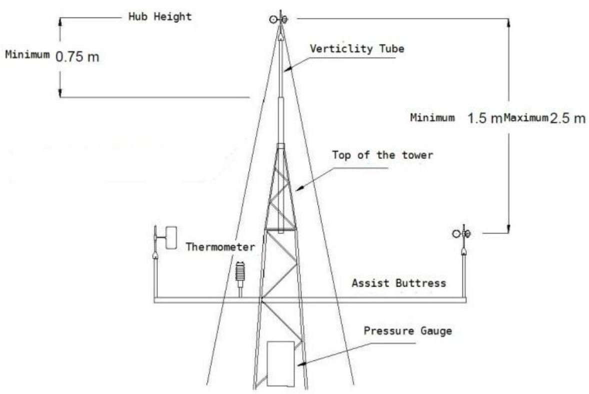

Figure 2. Example of the weather station

In order to evaluation of wind speed, it was performed at 20 areas. Table 2 shows a list of areas and measurement period.

Table 2. Measurement locations

Location	Period	Location	Period
Yu su ji	2001.9~2002.8	Sin san	1999.8~2000.7
Se man gum	2000.10~2001.9	Han su	2000.9~2001.9
Bi ueng do	1999.8~2000.7	Ko san	2001.2~2002.1
Me bong	2001.11~2002.10	Mok po	1999.5~2000.4
Young dang	1998.12~1999.11	Gu jea	2001.10~2002.9
Sub ji	1998.8~1999.11	Yung duk	2001.6~2002.5
U do	1999.1~1999.12	Hang wan	2001.10~2002.9
Il kwa	1999.6~2000.5	Jung dong jin	2001.11~2002.10
Ha mo	1999.3~2000.2	Tea gi san	2001.11~2002.10
kim ryung	1999.9~2000.8	Sam yang	2000.11~2001.11

And then, we collected and served the data in website such as direction, humidity, pressure, temperature, and energy density so on.

3. Uncertainty Evaluation

In this session, we explain the uncertainty evaluation of solar radiation and wind speed data. The uncertainty is a non-negative parameter characterizing the dispersion of the values attributed to a measured quantity. Evaluation follows are observed by GUM and ISO standards. The results of evaluation are used by the comparison values when other person measured these radiations. And the measurement is corrected when those are measured within the margin of error (uncertainty).

3.1 Solar Radiation Data

The uncertainty evaluation formula was made based on GUM. The basic formula is as in the following. A table 1 shows a relative expanded uncertainty (B type) of measurement equipment.

$$y = x + b$$

x : measurement value
b : calibration value of measurement equipment

Table 3. Relative expanded uncertainty

	Pyheliopmeter (Direct Normal)	Pyranometer (Global)
Calibration	1.6	4.2
Field Data (Best Practice)	5	5

The combined standard uncertainty is made based on basic formula as follows.

$$u_c = \sqrt{u^2(x) + u^2(b)}$$

This formula is expressed as a standard uncertainty of measurement values that are calculated from several different inputs. This formula is divided into type A and type B in detailed.

$$u(x) = \frac{S}{\sqrt{n}} \quad u(b) = \frac{U_x + U_f}{2} \times x$$

S : standard deviation
n : number of values
U_x : calibration uncertainty
U_f : real environment uncertainty

Finally, the expanded uncertainty is as in the following. This formula has a level of confidence (95%) and the constant k as 2.

$$U = k \times u_c$$

The expanded uncertainty is expressed as follows. And a table 3 shows results of uncertainty evaluation of the normal radiation.

measurement value $\pm$ expanded uncertainty

Table 4. Results of global horizontal radiation

Area	Measured value / Expanded uncertainty (kcal/m²/d)											
	1	2	3	4	5	6	7	8	9	10	11	12
Chuncheon	1801	2476	3182	3961	4332	4274	3481	3632	3238	2589	1795	1555
	197	260	335	383	434	455	377	390	344	275	191	169
Gangneung	2025	2570	3154	3950	4291	3925	3407	3306	3052	2719	2057	1853
	220	271	334	397	427	420	393	351	328	271	218	187
Seoul	1695	2390	3007	3757	4030	3743	2797	3095	3037	2610	1769	1484
	187	248	312	379	413	410	309	324	322	270	183	163
Wonju	1813	2480	3124	3943	4298	4155	3413	3565	3235	2747	1889	1629
	197	253	318	395	422	436	367	374	333	270	190	175
Seosan	1970	2723	3414	4185	4570	4284	3490	3766	3468	2968	1993	1705
	202	273	342	411	456	472	366	396	359	294	202	178
Cheongju	1939	2631	3209	4029	4435	4116	3502	3585	3271	2852	1970	1672
	202	282	349	405	428	421	369	379	331	280	216	179

Daejeon	1942	2692	3347	4166	4395	4042	3578	3711	3301	2924	2066	1758
	212	295	335	414	454	437	403	424	346	288	220	194
Pohang	2114	2722	3260	4073	4379	4053	3535	3564	3018	2813	2224	1991
	238	327	343	400	428	430	441	383	338	288	247	206
Daegu	1984	2623	3299	4040	4340	3998	3502	3425	3050	2803	2088	1860
	239	291	354	407	425	407	379	354	311	276	215	194
Jeonju	1803	2422	3096	3932	4207	3894	3378	3451	3168	2832	1951	1619
	191	251	319	392	415	409	364	373	331	283	201	167
Gwangju	1989	2690	3369	4138	4409	3956	3525	3677	3350	3042	2180	1802
	204	277	340	403	433	428	384	402	369	317	229	184
Busan	2211	2820	3303	3980	4307	3963	3623	3804	3120	2965	2324	2055
	241	320	351	396	447	433	418	431	326	297	247	216
Mokpo	1981	2721	3480	4302	4577	4214	3874	4214	3577	3215	2244	1795
	207	287	354	418	453	436	418	427	362	313	225	177
Jeju	1242	2025	2921	3905	4322	4022	4231	3952	3213	2865	1915	1287
	144	253	328	391	432	408	475	420	330	287	203	158
Jinju	2304	2937	3534	4197	4421	3963	3680	3732	3308	3164	2398	2161
	241	296	354	410	433	414	416	391	335	316	237	209
Yeongju	1939	2567	3266	4055	4441	4129	3492	3523	3249	2821	2032	1769
	205	270	330	411	448	481	393	397	356	276	205	176

The example of steps is as follows (Chuncheon);

1. Calculate the standard deviation using monthly means
2. Calculate type A and type B uncertainty as 52.97 and 82.84 (kcal/m^2/d)
3. Calculate the combined standard uncertainty as 98.33 (kcal/m^2/d)
4. Finally, calculate the expanded uncertainty as 197 (kcal/m^2/d)

3.2 Wind Speed Data

In order to the uncertainty evaluation, a formula is based on IEC, GUM and ISO standards. First, type A is expressed as follows. Where $S_{a,j}$ is the standard deviation and $\sqrt{N_j}$ is number of measurement within the wind speed section. The number of measurement is used as 600 commonly (average of 10 minutes, 1Hz).

$$(u_{v,i})_A = \frac{S_{a,j}}{\sqrt{N_j}}$$

And next, type B is expressed as follows that evaluates a correlation among correction, operation characteristic, and measurement factors so on.

$$(u_{v,i})_B = \sqrt{u_{v1,i}^2 + u_{v2,i}^2 + u_{v3,i}^2 + u_{v4,i}^2 + u_{dv,i}^2}$$

Where $u_{v1,i}$ is a uncertainty of anemometer correction, $u_{v2,i}$ is a uncertainty of anemometer's operation, $u_{v3,i}$ is a uncertainty of floating distortion, $u_{v4,i}$ is a uncertainty of uncertainty of floating distortion in field, and $u_{dv,i}$ is a uncertainty of data processing equipment. Each of the formula was existed in detail as GUM and IEC standards. Table 5 shows general type B uncertainty values. Where, *v* is value of wind speed.

Table 5. General type B uncertainty values

$u_{v1,i}$	*0.1 (m/s)*
$u_{v2,i}$	*0.072+0.0072v (m/s)*
$u_{v3,i}$	*0.01v (m/s)*
$u_{v4,i}$	*0 (m/s) (no consideration)*
$u_{dv,i}$	*0.03 (m/s)*

The combined standard uncertainty and expanded uncertainty are each expressed as follows. The expanded uncertainty has a level of confidence (95%) and the constant k as 2.

$$u_i = \sqrt{(u_{v,i})_A^2 + (u_{v,i})_B^2} \qquad U = k \times u_i$$

Table 6. Results of evaluation

Area	Wind speed (m/s)	Type A (m/s)	Type B (m/s)	Expanded uncertainty (m/s)
Yu su ji	3.65	0.14	0.15	0.40
Se man gum	4.46	0.16	0.15	0.45
Bi ueng do	4.48	0.17	0.16	0.46
Me bong	8.04	0.30	0.19	0.71
Young dang	6.61	0.23	0.17	0.57
Sub ji	6.26	0.20	0.17	0.52
U do	7.04	0.23	0.18	0.58
Il kwa	6.02	0.18	0.17	0.50
Ha mo	9.50	0.39	0.20	0.88
kim ryung	6.15	0.22	0.17	0.56
Sin san	5.14	0.16	0.16	0.46
Han su	6.08	0.20	0.17	0.52
Ko san	5.14	0.16	0.16	0.46
Mok po	2.90	0.13	0.14	0.39
Gu jea	4.26	0.17	0.15	0.45
Yung duk	6.14	0.18	0.17	0.50
Hang wan	6.59	0.24	0.17	0.60
Jung dong jin	3.66	0.13	0.15	0.39
Tea gi san	6.19	0.21	0.17	0.53
Sam yang	7.85	0.33	0.18	0.75

These values can be decisive role as standard data. According to the results, expanded uncertainty has values between 0.39 and 0.88.

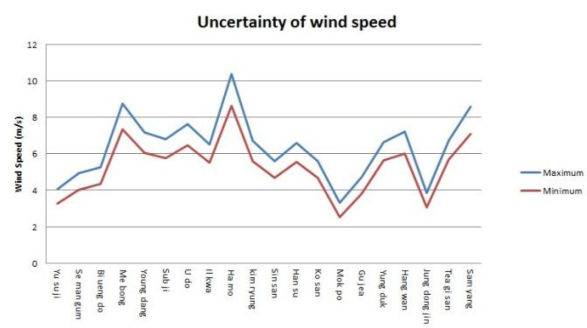

Figure 3. Uncertainty of wind

We made the thematic maps based on standard data. And these are served user through the website. In Fig. 4 and 5 show the thematic maps about the solar radiation and wind.

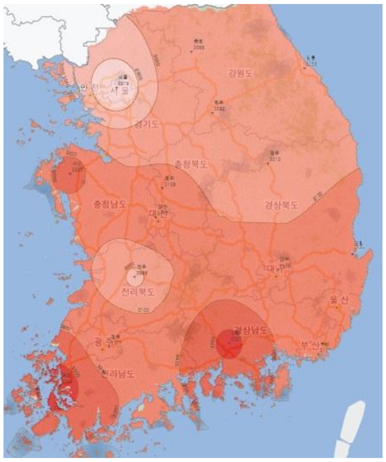

Figure 4. Thematic map of solar radiation

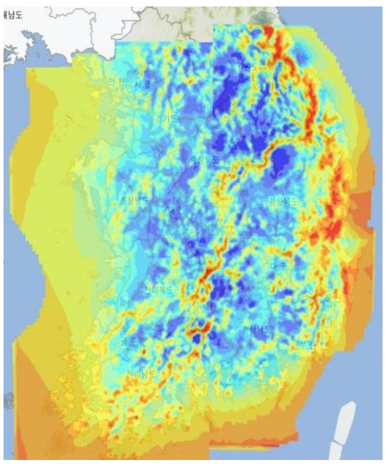

Figure 5. Thematic map of wind

4. Conclusion

In this work, we evaluated and collected the solar radiation and wind data and processed the measured data for evaluation through certified standards. Those were complied with NREL, WMO, ISO, IEC, and GUM standards. Whereby these data became reference standards and gained the credibility after the evaluation. For the reliability data, we corrected the measuring instrument with correction period. In order to quality control of data, we complied with DQMS, and SERI QC. We evaluated as 1,140 cases about 16 areas (solar) and 20 areas (wind) for reference standards. And we achieved a credibility of data and provided accurate information to user. In case of solar, the margin of error of uncertainty was small compared to its measured data. And then, the uncertainty of wind speed was presented between 0.39 and 0.88. It also was small compare to its measured data. A small margin of error means that is possible to measure more accurately.

As results, we judged a credibility of data by expression of reliability quantitatively. These data were utilized as national reference standards. In additional, the reference standards data are possible to approach anywhere and will be used for the supporting related industry and policy making.

References

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