(3) PV/T system energy generation prediction model

In this research, only the variables with great effects were extracted with combinations of variables obtained from a correlation analysis and PV/T system energy generation prediction model was suggested. In case of electrical energy generation model, a highly reliable model with 0.995 of R^2-value was obtained with two variables of solar radiation and power of PV/T product, like in Equation 1. In case of thermal energy generation model, it could be organized into total four variables of solar radiation, outdoor air temperature, transmission-absorption rate and heat loss coefficient like in Equation 2 and R^2-value was 0.994. Interactions between the variables were taken into account and prediction model was obtained as in Equation 3 and 4 and model coefficients are shown in Table 4.

$$\dot{q}_{elec} = f\left(H_T, P_{max}\right) \tag{1}$$

$$\dot{q}_{ther} = f\left(H_T, T_a, F_R\left(\overline{\tau\alpha}\right)_n, F_R U_L\right) \tag{2}$$

$$\dot{q}_{elec} = \alpha_0 + \alpha_1\left(H_T\right) + \alpha_2\left(P_{max}\right) + \alpha_3\left(H_T \cdot P_{max}\right) \tag{3}$$

$$\dot{q}_{ther} = \alpha_0 + \alpha_1\left(T_a\right) + \alpha_2\left(H_T\right) + \alpha_3\left(F_R\left(\overline{\tau\alpha}\right)_n\right) + \alpha_4\left(F_R U_L\right) + \alpha_5\left(H_T \cdot F_R\left(\overline{\tau\alpha}\right)_n\right) \tag{4}$$

Table 4. *Linear prediction model coefficients*

	α_0	α_1	α_2	α_3	α_4	α_5	R^2	Std.Dev.
$\dot{q}_{elec}$	-1.1E-15	+1.0E-16	+5.2E-15	+0.866			0.995	0.061
$\dot{q}_{ther}$	-0.808	+0.028	-0.026	+0.000	-0.098	+1.000	0.994	0.310

ENERGY SIMULATION

Flow chart for net zero energy system in Figure 3 shows the annual energy consumption of LD-IDECOAS and the annual energy generation in PV/T system. Entering weather data and product information in PV/T system generation model suggested calculates the energy density which is the energy generation per unit area. Area required for PV/T is to be obtained after considering the amount of energy consumed and calculated area differs by load type. Optimum solar fraction where the amount of energy consumed and that of energy generated become the same is sought by repeating the process of looking for the optimum design spot with change in solar fraction after setting design basis load.

If installing pilot system in particular cities within each climate area, TRNSYS 17, a program for calculating weather data of the cities and load, was adopted to calculate the required load of system. Electric and thermal load changing by condition of the outside air was calculated to maintain the setting values of 24℃ of temperature and 55% of humidity in a space measuring $33m^2$ using LD-IDECOAS. At this moment, 300CMH of constant air volume was supplied and only the weather conditions applicable to the operating region were reflected.

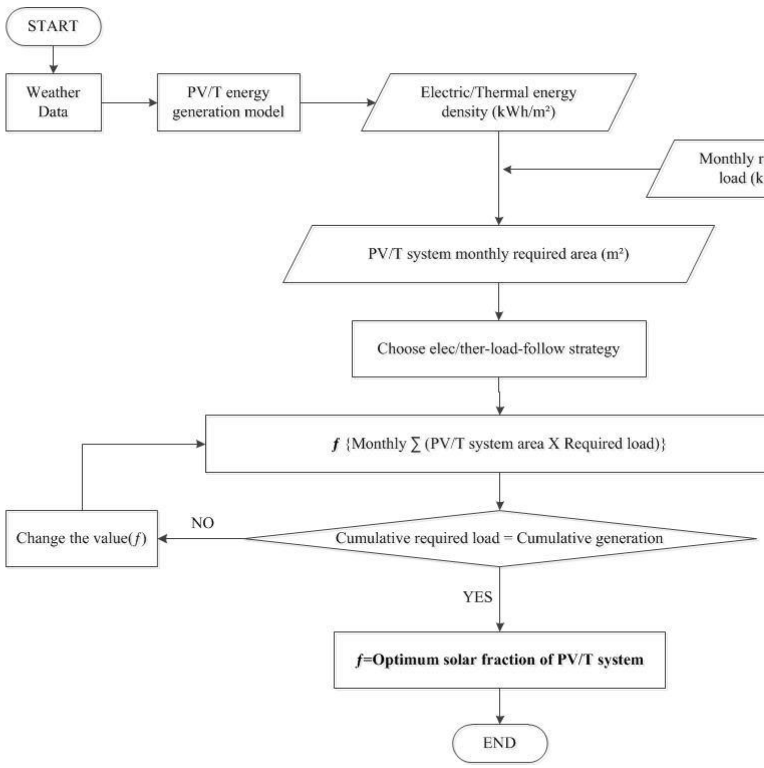

Figure 3. *Optimization of solar fraction flow chart*

This research showed the result of calculation by city using commercial PV/T product features (Table 5). Maximum daily load in monthly average during annual operable hours and required area were calculated in accordance with PV/T system energy generation model. Peak load and maximum area occur between July and August with the highest temperature, humidity and solar irradiance (Table 6).

Table 5. *PV/T product characteristics*

P_{max}	V_{mpp}	I_{mpp}	η_r	β
250W	30V	8.34A	15.4%	0.40%/°C
T_{NOCT}	$T_{Oper\ range}$	$F_R\overline{(\tau\alpha)_n}$	$F_R U_L$	Area
47°C	-40~85°C	0.67	$4.06\mathrm{W/m^2°C}$	1.62

Table 6. *Peak load and required PV/T system area*

	Peak-load (kWh/day)		Maximum area (m^2)	
	Electric	Thermal	Electric	Thermal
Singapore(Af)	36.91	108.47	47.74	30.42
Bangkok(Aw)	37.95	107.33	52.68	32.42
Hongkong(Cfa)	38.67	103.27	73.77	46.43
Nagoya(Cfa)	36.86	97.51	56.57	32.32
Seoul(Dfa)	27.63	67.93	63.51	36.02
Beijing(Dwa)	26.79	65.38	62.58	37.28

Since electric load is a variable that is most greatly influenced by solar radiation, peak load appeared in the regions with the best solar irradiance. Furthermore, thermal load shows peak load at the equator as it is influenced not only by solar fraction but temperature to a great degree.

OPTIMUM SOLAR FRACTION OF PV/T SYSTEM

For PV/T system optimum solar fraction, the rate where total energy consumed during operating period and energy generated from PV/T system become the same was looked for. To verify a tendency depneding on latitude, Table 7 shows average weather conditions during the operating period and required load with solar fraction.

As a result, not only peak load but average load, it is known that electric load is affected by solar radiation and thermal load is affected by solar fraction and temperature. Figure 4 shows that solar radiation is generally in inverse proportion to solar fraction designed for electric. And solar fraction designed for thermal load is more influenced by the outdoor air temperature than solar fraction designed for electric load is.

Table 7. *City weather conditions and PV/T system optimum solar fraction of city*

City		Singapore	Bangkok	Hongkong	Nagoya	Seoul	Beijing
Latitude		1°N	13°N	22°N	35°N	37°N	39°N
Avg. Radiation (kWh/m^2)		6.0	7.5	5.4	5.0	4.0	4.8
Avg. Temp (℃)		26.6	27.7	25	22.6	22.9	23.4
Required load (kWh/yr)	Elec	323.37	320.45	248.02	159.69	93.61	91.89
	Ther	778.64	744.12	580.66	267.30	175.90	177.06
Optimum solar fraction	Elec	44.91%	30.84%	33.42%	37.46%	39.18%	32.41%
	Ther	70.47%	50.11%	53.10%	65.56%	69.08%	61.64%

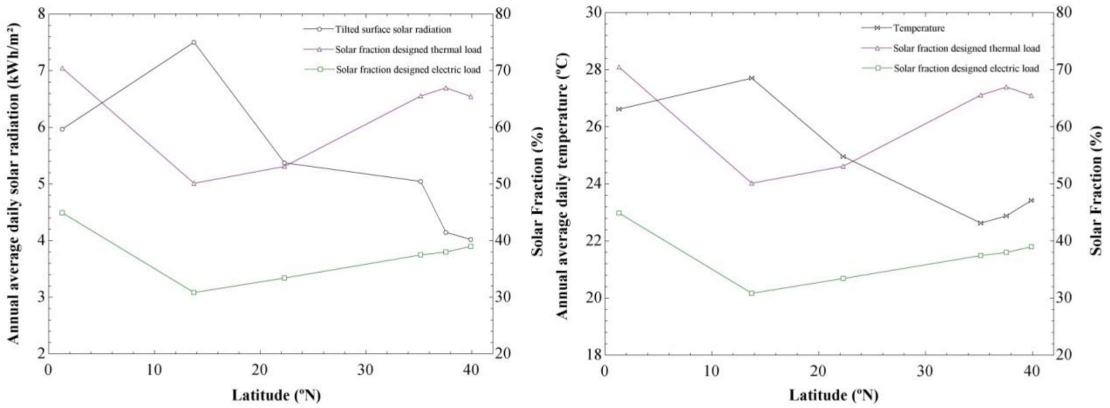

Figure 4. *Relationship between PV/T system solar fraction and weather conditions*

CONCLUSIONS

In this research, it is the optimum design method for net zero energy of PV/T system applied to LD-IDECOAS pilot system. Suggesting a model which can predict the energy generation of PV/T system by entering weather condition and product information, a method to obtain optimum solar fraction at design stage was suggested. The main results of this research are as follows.

First, PV/T system has the biggest effect on solar radiation among other weather conditions. The results of an analysis on variables of energy generation model shows more than 60% of correlation ratio and this indicates that it wields a great influence on the installation angle and latitude of region.

Second, PV/T system solar fraction designed electric load can be predicted with solar radiation. It shows a tendency of fraction being in inverse proportion to solar radiation varying depending on latitude.

Third, PV/T system solar fraction designed thermal load affects not only solar radiation but the outdoor air temperature. The general movement is decided by radiation with greater influence, however, the result of comparing latitude in small dynamic range has proved that the influence differs by temperature.

ACKNOWLEDGEMENTS

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korean government (No. 2012001927), and the Korea Evaluation Institute of Industrial Technology grant funded by the Korean Government (No. 10045236)

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