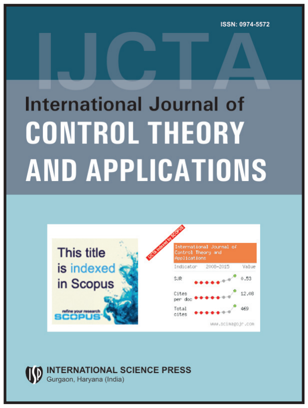

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Energy Conservation with Fuzzy Logic Controller Towards Green Telecommunication

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Abstract: Green telecommunication aim to reduce the carbon emission, energy consumption and encourages the use of green energy technologies. Base Transceiver Station (BTS) shelter uses free cooling fans to optimize the air conditioners towards Green telecommunication. BTS cooling system was modelled and performance energy saving was analysed for Chennai using energy plus software and the RC model of the shelter with Matlab Simulink. The Building Control Virtual Test Bed (BCVTB) is acting as interface between Matlab and Energy plus software and also used as user interface for taking out simulated data. In this paper the free cooling potential of various climatic locations in India has been indexed by simulating the BTS shelter model with various climate data. The main contribution of this paper is to provide the data of free cooling potential of the about 59 climatic locations. This will help to take informed decision for installing free cooling system and also will act as aid for cross validation of energy savings. This also validate the performance of the free cooling control using fuzzy logic controller for 59 climatic locations.

Keywords: Free cooling, Fuzzy logic control, Energy plus model, Energy Efficiency, Green telecommunication.

1. INTRODUCTION

Green Telecommunication work aims for reduced use of fossil fuel and enhanced use renewable energy sources[1] to avoid pollution and global warming. Free cooling fans contributes reducing the energy consumption in case of continuously operated installations such as BTS shelter etc. These fan gets switched ON, when the atmospheric temperature goes below certain threshold. It is necessary to have knowledge of the free cooling potential across India in order to have the informed decision for installing the free cooling fans. The climate locations situated in various states and having different drastic climate conditions are available at various websites. Some cities exposes extreme high temperature during summer and extreme very low temperature during winter. Some regions undergoes narrow variations of temperature. The net contribution of the free cooling fans for the whole year can be obtained only if the full year simulation is carried out. BTS shelter[2] for Chennai region was detailed and the energy savings are estimated. Using the fuzzy controller and the Energy Plus model the power consumed by the air conditioner and the free cooling fans are obtained by data simulations. The same is compared for 59 locations.

2. LITERATURE RIVIEW

Maco Sorretino et. al., [3] are optimized air conditioning system with free cooling system. Fatima Amara et. al., [4] are reviewed the simulation various thermal model of building energy consumption. Peder Bacher et. al., [5] studied for identifying suitable model for heat dynamics of buildings. Fayaz bakhsh et. al., [6] studied the effect of change of building parameter and compressor cycles. Jingran Ma et. al., [7] studied economic model predictive control with pre cooling in HVAC system. Xiu feng Pang et. al., [8] simulated energy plus with real time building management system compared actual performance of building with expected performance. Husamettin Bulut et. al., [9] analysed free cooling potential in HVAC system for Istanbul, Turkey. Boubekeur Dokkar et. al., [10] studied Chimney and underground pipe for optimizing energy in BTS shelter. For Indian scenario it necessary to establish the relative performance index for the free cooling system. This paper address research gap that which city gives best free cooling across India and what is the relative performance among them.

3. METHODOLOGY

The mathematical model for BTS shelter temperature [2] is given in equation (1)

$$V_o(z) = \frac{0.01303}{(z - 0.987)}(V_{od} + I_b R - R(P(z) - I_L(z))) \quad (1)$$

where, $V_o(t)$ – Room temperature °C, $V_i(t)$ – Outside temperature °C, R – Lumped Shelter Equivalent Resistance °C/W, C-lumped Shelter Equivalent Capacitance W Hr./°C, P-Air Conditioner /Free cooling capacity in W, I_L – Equipment Load W, $I_b(t)$ – Shelter (envelope) thermal load W, V_{od} – the design minimum temperature of the BTS shelter it is 27°C.

The shelter absorbs heat from atmosphere which is considered as variable I_b. The same is obtained from the Energy Plus software. The I_b varies throught the year. The equipment heat load of the BTS shelter is 3000 watts. The air conditioner taken as 1.5 TR capacity = 1.5 × 3.5 = 5250 W is the equivalent cooling kW.

The ASHRE equation for finding BTU/ Hr. is $\frac{\text{Btu}}{\text{Hr}} = 1.1 \times \text{CFM} \times (\text{T1} - \text{T2})$

Taking Cubic feet per Minute (CFM) of the free cooling fan as 1200, then the free cooling fans out put in watts can be calculated using (2). The T1 room temperature is taken as 27°C and T2 is the atmospheric temperature obtained from Energy Plus.

$$\frac{\text{Btu}}{\text{Hr}} = 1.1 \times 1200 \times 9/5(27 - \text{T2})$$

$$\text{TR} = 1.1 \times 1200 \times 9/5(27 - \text{T2})/12000$$

$$\text{Watts} = 1.1 \times 1200 \times 9/5(27 - \text{T2})\ \frac{3.5}{12}$$

$$\text{Watts} = 693(27 - \text{T2}) \quad (2)$$

The BTS shelter envelope modelled in Energy plus [2] used for simulation. The fuzzy controller operates the air conditioner for the set temperature of 27°C to 32°C. However when the atmospheric temperature goes below 27°C the fuzzy controller select the free cooling fans. As the free cooling fans consumes about 25% of the air conditioner thus there is saving in energy. The BCVTB act as interface between Matlab and the energy plus. The Matlab Simulink contains the RC model (called EP model in [2])which considers the variations heat absorbed by the BTS shelter in watts and also the equipment load. It also contains the air conditioner model and the fan model and fuzzy controller. The BTS shelter absorbs heat from atmosphere. It is most efficient to use the heat absorption instead of considering the variation in atmospheric temperature [2] for atmospheric influence on room temperature. For each simulation step the Energy Plus software gives the sensible cooling load of the BTS shelter. The BTS equipment produces heat in the BTS shelter which is taken as constant throughout the year. These thermal currents in watts fed to the EP model in the Matlab Simulink. The Air conditioner or the free cooling fans draws the thermal current in opposite direction in order to maintain the shelter temperature. Electrical thermal analogy has been applied in the EP model.

4. SIMULATION SETUP

The Figure 1 show the Simulation set up for energy conservation study. The BTS shelter model is included in Energy Plus, The EP model, air conditioner, free cooling fans and fuzzy logic running in the Simulink. The Simulink provides set point to the Energy Plus via BCVTB. On receipt of set point the Energy Plus gives out the sensible cooling load. The Ptolemy model is shown in Figure 2(a) and the Data Flow diagram is shown in Figure 2(b).

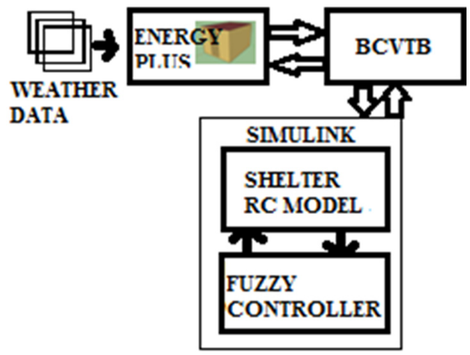

Figure 1: Simulation Setup for determining BTS shelter cooling load and other parameters

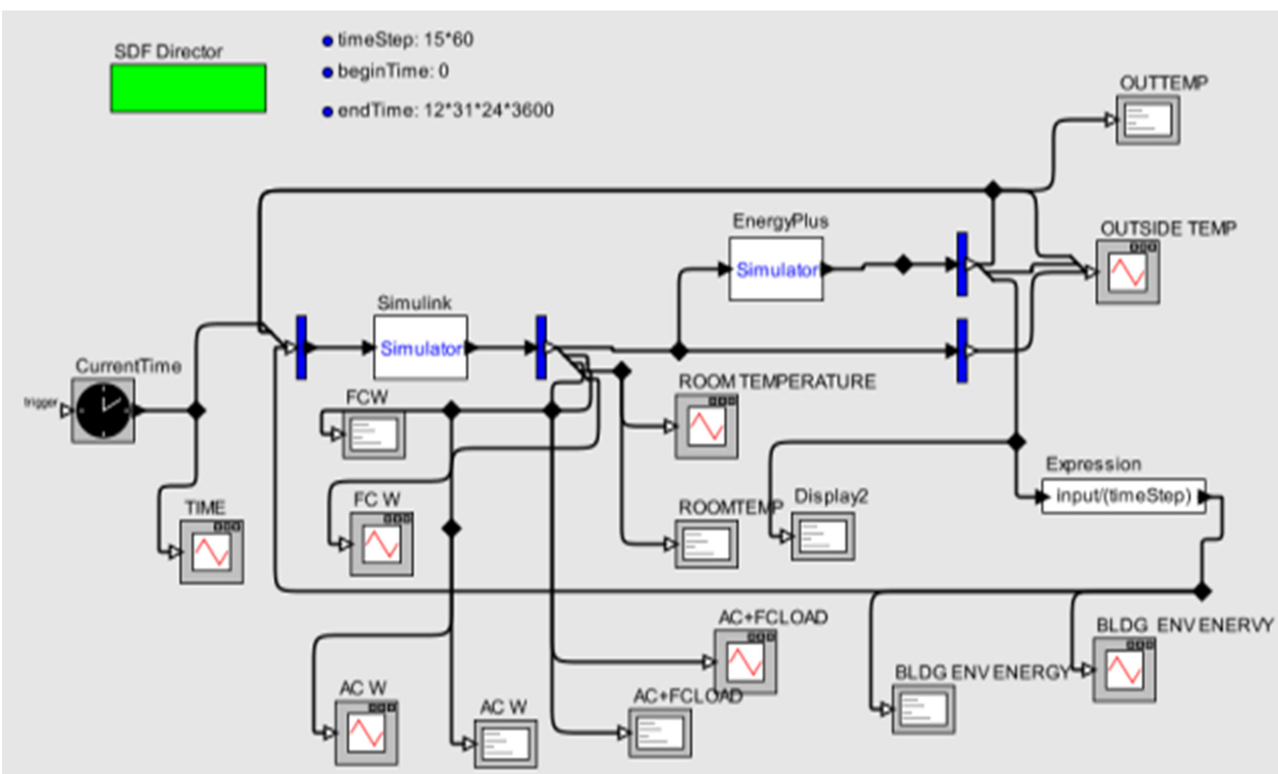

Figure 2: (a) The Detailed Ptolemy Diagram interfacing Matlab and Energy plus software for simulation [2]

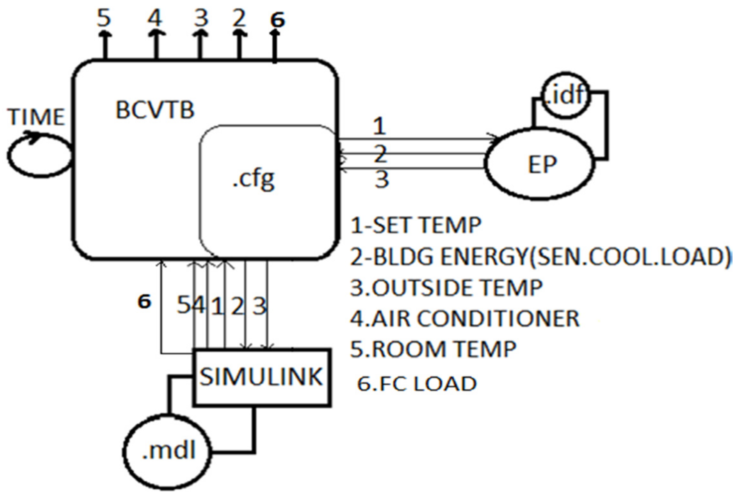

Figure 2: (b) The DATA flow diagram among the softwares[2]

For each simulation about 35000 data sample of each AC load, free cooling load, outdoor temperature and indoor temperature are taken out from BCVTB.

5. SIMULATION

The simulation for the 59 locations are carried out using the simulation setup and by changing the weather data obtained from Energy Plus website [11]. From the simulated data, the top and the least performing sites for energy saving are identified by arranging the energy consumption in ascending order. The close look of the energy saving performance Shillong and Trichirapalli are indicated below.

A. Close Look of Shillong Climate Performance

For Shillong the peak summer occurs on AUG. Simulations has been carried out for three days between 12th AUG to 14th AUG. The performance of fuzzy logic controller is shown in Figure 3.

Table 1
Legend for graph

S.No.	*Legend*	*Description*
1	EPRT	Shelter Inside Temperature °C
2	OT	Atmospheric Temperature °C
3	EPACW	Power Consumed By The Air Conditioner In Watts
4	EPFCW	Power Consumed By The Free Cooling Fans In Watts
5	BE-S-S	Heat Absorbed The Shelter Watts At Shillong During Peak Summer
6	BE-S-W	Heat Absorbed The Shelter Watts At Shillong During Peak Winter (Zero)
7	BE-T-S	Heat Absorbed The Shelter Watts At Trichirapalli During Peak Summer
8	BE-T-W	Heat Absorbed The Shelter Watts At Trichirapalli During Peak Winter

For Shillong city, normally the atmospheric temperature not exceeding the 27°C during summer. Due to this the air conditioner is required only about 105 minutes throughout the year. The Figure 5 show the shelter temperature during peak winter. The Figure 4 and 6 shows the power consumed during summer and winter respectively.

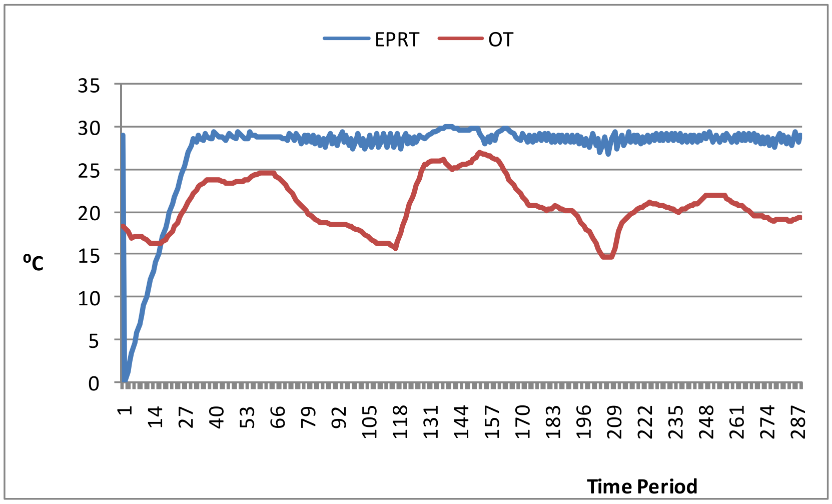

Figure 3: The Peak summer Days simulation for Shillong 12-AUG to 14-AUG

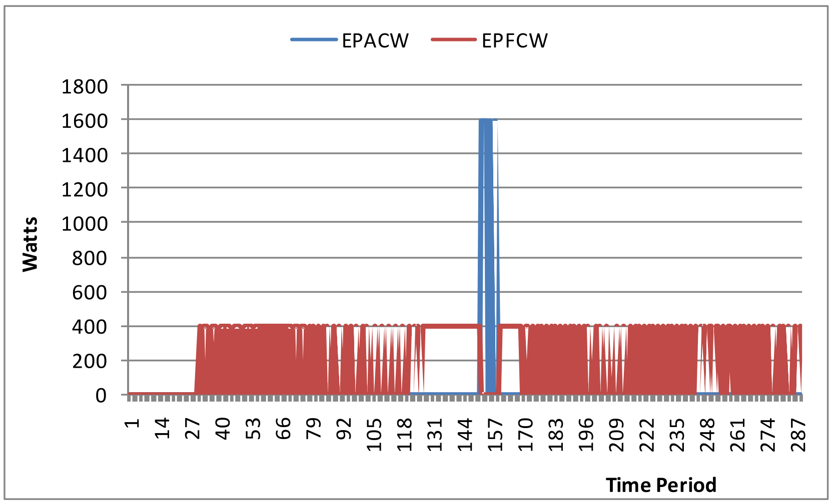

Figure 4: The Peak summer Days Power Consumption for Shillong 12-AUG to 14-AUG

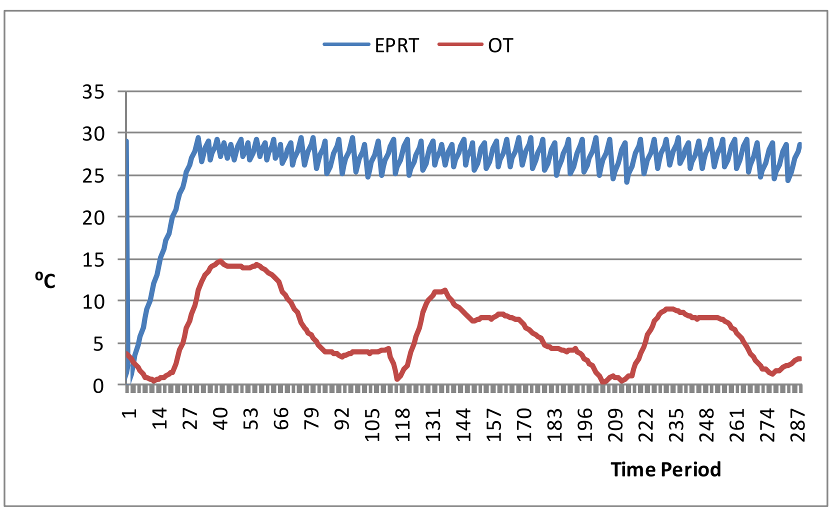

Figure 5: The Peak winter Days simulation for Shillong 31-DEC to 1-JAN

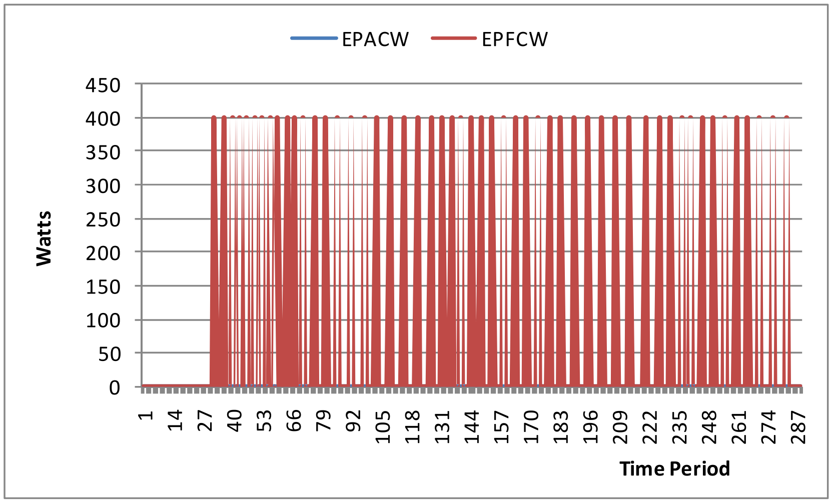

Figure 6: The Peak winter Days power consumption for Shillong 31-DEC to 1-JAN

B. Close Look of Trichirapalli Climate Performance

The Figure 7 shows the peak summer simulation for Trichirapalli in which the atmospheric temperature exceeds 40°C due to this, the air conditioners runs most of time during summer. Figure 8 shows the operating period of loads. During winter as shown in Figure 9 the temperature varies between 30°C to 20°C. Due to this, the free cooling fans contributes more and thus energy saving and is indicated in Figure 10.

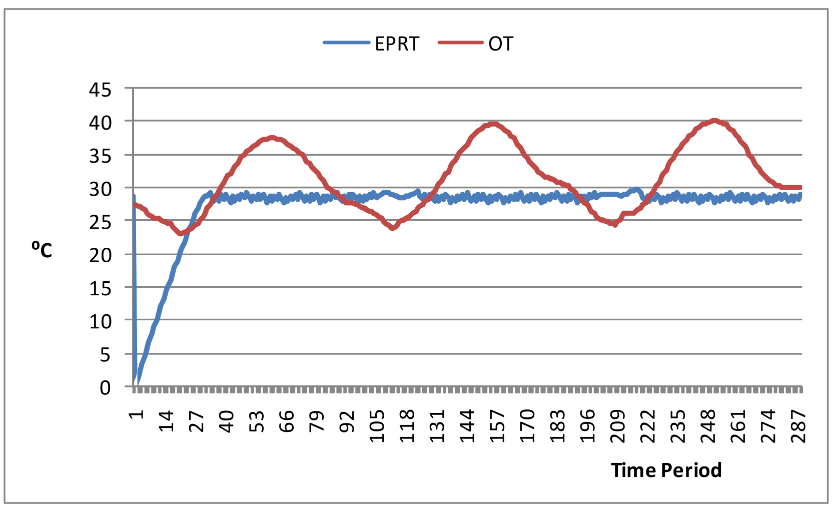

Figure 7: The Peak summer Days simulation for Trichirapalli 19-MAR to 21MAR

C. Heat Absorption of Shelter

As shown in Figure 11 the heat absorption by the shelter for Shillong is varies from 290.6 watts to zero during winter. For Trichirapalli the same was from 708.476 watts to zero.

D. Free Cooling Index and Absolute Free Cooling Index

The free cooling index and the absolute index are described using the following formulae. The absolute free cooling index shows only the air conditioner was running instead of free cooling fans. The air conditioner

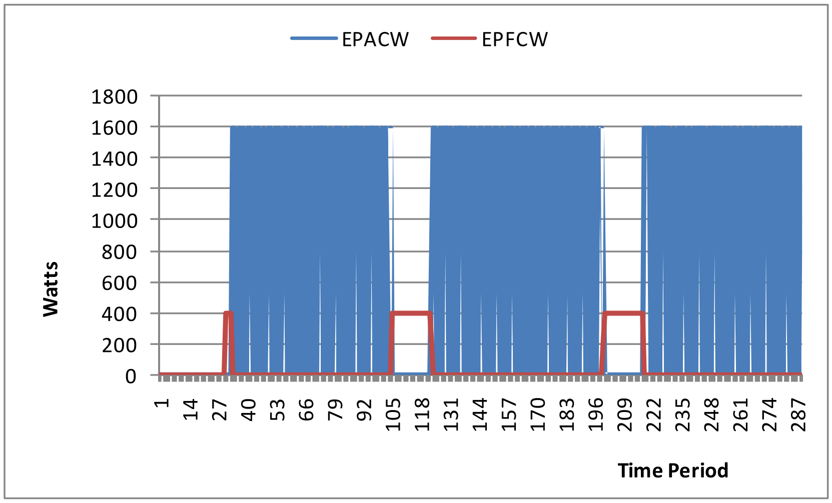

Figure 8: The Peak summer Days power consumption for Trichirapalli 19-MAR to 21MAR

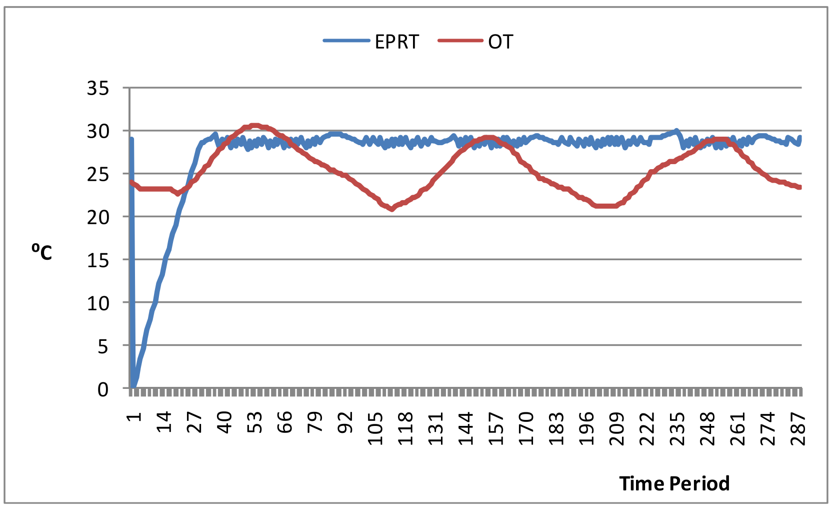

Figure 9: The Peak winter Days simulation for Trichirapalli 31-DEC to 02-JAN

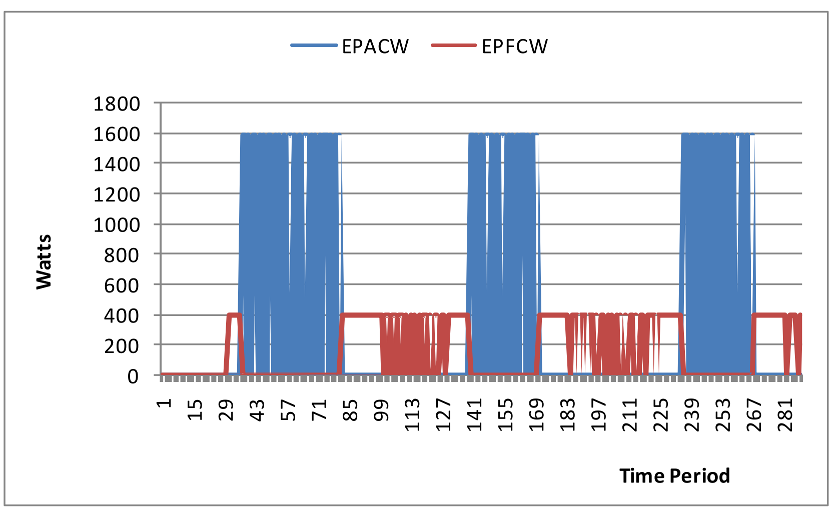

Figure 10: The Peak winter power consumption for Trichirapalli 31-DEC to 02-JAN

consumes about 1590 watts and the free cooling fans consumes 400 watts. Using these formula the free cooling index has been determined in the full year simulations

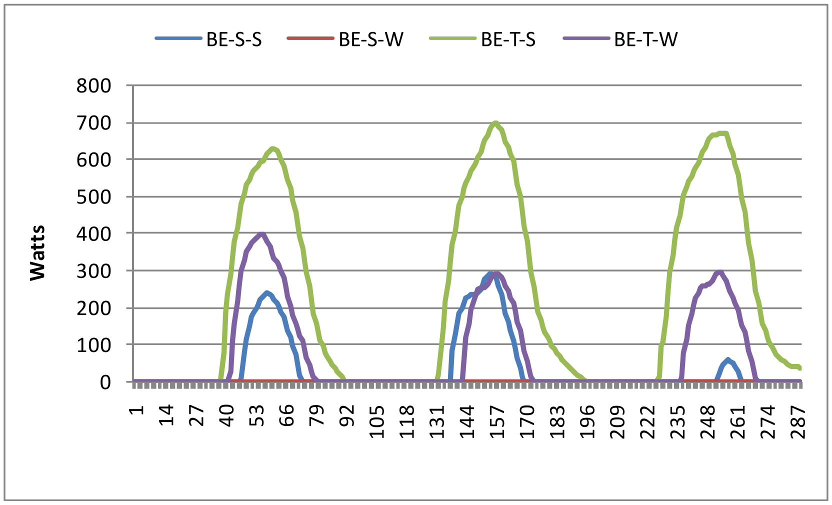

Figure 11: The BTS shelter heat absorption for Shillong and Trichirapalli

$$\text{Free cooling index} = \frac{\text{FA}}{\text{AC} + \text{FA}}$$

where, FA is free cooling fans energy consumption for whole year and AC is Air conditioner energy consumption for whole year.

$$\text{FC ratio} = \frac{\text{Power consumed by Airconditioner (AC)}}{\text{Power consumed by Free cooling fans (FA)}}$$

$$\text{FC ratio} = \frac{1590}{400} = 3.975$$

$$\text{Absolute Free Cooling Index \{AFCI\}} = \frac{3.975 \times \text{FA}}{\text{AC} + 3.975 \times \text{FA}}$$

6. RESULT AND DISCUSSION

The simulations results are tabulated in Table 2. As shown, the Shillong gives very good free cooling performance, which has the index of about 0.99. The minimum temperature goes to 0 and maximum goes to about 27. Trichirapalli gives about the index of 0.13. The maximum and minimum temperature for outdoor and the BTS shelter are also indicated for the 59 locations. The maximum heat absorbed by the BTS shelter in different locations also shown in the table. The Shillong city absorbs minimum heat during summer and the Bhubaneswar city absorbs maximum heat of 892 watts during summer As seen from the table the Minimum and the maximum temperature of the shelter are maintained with in the limit by the controller. Thus the fuzzy logic controller is validated for 59 locations.

7. CONCLUSION

The free cooling fans are installed for optimizing the air conditioner in the BTS shelter for energy conservation towards Green telecommunication. The decision for installing free cooling fan is normally decided using the temperature of climate data at various locations. However it is necessary to have the relative performance index in order to analyse/give importance for the free cooling installation. Thus the free cooling index was worked out and tabulated using Energy plus software and Matlab. The ratio of the power consumed by free cooling fan

Table 2
Free Cooling Potential Index

S. No.	*City*	*Shelter Min Temp °C*	*Shelter Max Temp °C*	*Out Min Temp °C*	*Out Max Temp °C*	*Max Shelter Heat (W)*	*AC (KWh)*	*FA (KWh)*	*Total KWh*	*FCI Index*	*AFCI Index*
1	Shillong	24	30	0	27	290.6	2	1193.1	1195.1	0.99	0.99
2	Imphal	24.4	30.3	1.2	37	585.1	1129.9	1682.6	2812.5	0.6	0.86
3	Sundernagar	24.1	30.3	0	37.6	610.2	1337.6	1364.9	2702.5	0.51	0.8
4	Bangalore	26.5	30.1	13	36.6	555.8	1963.6	1737.6	3701.2	0.47	0.78
5	Belgam	26.2	30.2	10.3	38.2	616.8	2082.5	1647.8	3730.3	0.44	0.76
6	Dehradun	24.6	30.2	3.3	40.1	656.4	1882.8	1449.3	3332.1	0.43	0.75
7	Dibruhgarh	25	30.3	5	37.4	537.9	2088.5	1580.7	3669.2	0.43	0.75
8	Ranchi	25.3	30.3	6.8	41.6	707.4	2354.5	1598.1	3952.6	0.4	0.73
9	Chitradurg	26.4	30.2	11	38.3	633.6	2634.9	1669.3	4304.2	0.39	0.72
10	Pune	25.4	30.4	4.9	41	675.6	2603.5	1545	4148.5	0.37	0.7
11	Jagdelpur	25.4	30.3	6	40.9	665.8	2825.5	1537.9	4363.4	0.35	0.68
12	Tezpur	25.7	30.4	9.2	35.2	530.4	2910.6	1390.9	4301.5	0.32	0.66
13	Jorhat	25.5	30.3	7.6	37.6	584.7	2842.6	1335.7	4178.3	0.32	0.65
14	Indore	25.1	30.2	6.3	41.8	791.1	3187	1340.6	4527.6	0.3	0.63
15	Saharanpur	23.9	30.3	0.1	41.5	706.6	2838.6	1119.3	3957.9	0.28	0.61
16	Guwahati	25.4	30.4	5.8	37.4	602.5	3252.2	1302.7	4554.9	0.29	0.61
17	Bhopal	25.8	30.2	9	43.5	822.9	3372.3	1335.6	4707.9	0.28	0.61
18	Jabalpur	25.3	30.3	7.4	42.7	728.8	3403.4	1309.6	4713	0.28	0.6
19	Aurangabad	25.6	30.1	8.2	41.5	775.6	3556.5	1305.7	4862.2	0.27	0.59
20	Mangalore	27.4	30.4	18.3	36.4	562.3	3913.6	1604	5517.6	0.29	0.62
21	Hyderabad	26.4	30.3	11.7	41.2	703.3	4043.7	1315.1	5358.8	0.25	0.56
22	Jamnagar	25.4	30.3	6.1	38.9	626.1	3980.5	1183.9	5164.4	0.23	0.54
23	Sholapur	26.5	30.2	11.3	43	738.3	4194.8	1294.3	5489.1	0.24	0.55
24	Raipur	25.7	30.3	8	45.1	792.9	4083.9	1203.1	5287	0.23	0.54
25	Raxaul	25.2	30.3	5.6	39.2	611.7	3824.1	993.7	4817.8	0.21	0.51
26	Nagpur	25.7	30.3	8.4	44.6	821	4110.5	1164.9	5275.4	0.22	0.53
27	Ratnagiri	27.3	30.4	16.2	35	553.8	4347.6	1387.1	5734.7	0.24	0.56
28	Lucknow	25	30.4	4.8	44.3	820.9	3871.5	967.8	4839.3	0.2	0.5
29	Hissar	24.8	30.3	3.2	46.1	841.1	3803.9	913.1	4717	0.19	0.49
30	Gorakhpur	25.2	30.3	5.4	44	770.5	4036.5	947.3	4983.8	0.19	0.48
31	New Delhi	25.1	30.4	5.2	44.3	800.9	3945.9	882.6	4828.5	0.18	0.47
32	Rajkot	25.5	30.3	6.1	43.9	874.3	4334	1117.6	5451.6	0.21	0.51
33	Trivandrum	27.9	30.3	20.2	38.6	548.7	4562.7	1431.4	5994.1	0.24	0.55
34	Jaipur	24.9	30.3	5.1	42.9	757.1	4097.4	947	5044.4	0.19	0.48
35	Akola	26.1	30.2	10.3	45	791	4420.7	1110.3	5531	0.2	0.5
36	Amritsar	26.1	30.2	10.3	45	810.6	4420.7	1110.3	5531	0.2	0.5
37	Patna	25.4	30.4	5.6	43	763.7	2603.5	1545	4148.5	0.37	0.7
38	Allahabad	25	30.3	4.5	46	817.1	4182.9	894.2	5077.1	0.18	0.46
39	Panjim	27.6	30.4	18.9	35.1	582.3	4668.1	1296.1	5964.2	0.22	0.52
40	Kota	25.8	30.3	8.8	45.6	881.6	4354.3	950.3	5304.6	0.18	0.46

S. No.	City	Shelter Min Temp °C	Shelter Max Temp °C	Out Min Temp °C	Out Max Temp °C	Max Shelter Heat (W)	AC (KWh)	FA (KWh)	Total KWh	FCI Index	AFCI Index
41	Jodhpur	24.5	30.3	0.4	42.8	749.2	4327.7	911.5	5239.2	0.17	0.46
42	Bhubaneswar	26.6	30.3	13.8	45.8	892	4646.2	1114.1	5760.3	0.19	0.49
43	Gwalior	24.7	30.3	2.8	45.5	785.9	4233.4	833.4	5066.8	0.16	0.44
44	Kolkata	26.2	30.3	10.9	41.2	694.4	4640.7	990.6	5631.3	0.18	0.46
45	Jaisalmer	24.9	30.3	3	45.6	813.4	4458.1	862.6	5320.7	0.16	0.43
46	Goa-Panjim	27.2	30.4	16.6	36.6	565.5	4880.1	1202.5	6082.6	0.2	0.49
47	Bhagalpur	26	30.3	10.3	43.4	745	4706.7	859.3	5566	0.15	0.42
48	Kurnool	26.9	30.3	14.1	43.8	777.7	4964.4	1034.6	5999	0.17	0.45
49	Ramagundam	26	30.3	9.9	45.5	779.8	4868.6	964.6	5833.2	0.17	0.44
50	Bikaner	24.3	30.1	0.7	46.6	846.4	4511	750.2	5261.2	0.14	0.4
51	Veraval	26.3	30.3	12.4	37.8	594	5037.2	926	5963.2	0.16	0.42
52	Mumbai	26.7	30.3	14.2	38.5	651.6	5178.8	968.2	6147	0.16	0.43
53	Ahmedabad	25.9	30.3	8.9	44.2	770.4	5031.2	826.7	5857.9	0.14	0.4
54	Vishakapatnam	26.6	30.3	13	37.3	636.2	5237.7	957.4	6195.1	0.15	0.42
55	Barmer	25.5	30.3	6.5	45.3	882.7	4954.1	774.1	5728.2	0.14	0.38
56	Surat	26.6	30.3	12.9	42.5	766.6	5308.1	823.4	6131.5	0.13	0.38
57	Chennai	26.7	30.3	14.5	39.5	632.2	5442.5	937.1	6379.6	0.15	0.41
58	Nellore	27.6	30.2	18.7	43.2	736.8	5657.7	857.3	6515	0.13	0.38
59	Trichirapalli	27.6	30.3	19.2	41.8	704.8	5678.7	859.5	6538.2	0.13	0.38

in watts to the total power consumed by air conditioner and the free cooling fans are considered for indexing. The indexed table can be used for making not only free cooling system in BTS shelter but also other energy conservation purpose too. The proposed Fuzzy controller performs better function and maintain the required temperature within the specified limit. The minimum free cooling index also provides a better savings than consuming energy generated using fossil fuel.

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