International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 6 June 2022, pp: 656-663 www.ijaem.net ISSN: 2395-5252

Estimate of Infiltration Rate for Best Performance of an In-Door Air Conditioning System.

Engr. Dr. Efosa Obaseki, Ewurum Tennison. I
Department of mechanical engineering, federal polytechnic nekede, owerri.
Department of mechanical engineering, federal polytechnic nekede, owerri.

Submitted: 01-06-2022 Revised: 10-06-2022 Accepted: 15-06-2022

ABSTRACT
The study, estimate of infiltration rate for best performance of an in-door air conditioning system, was successfully carried out. The researchers adopted a survey design approach and randomly selected buildings within Owerri Municipal. Measurements of room dimensions were taken and the values were used to determine room volume, infiltration rate, ventilation, room area and cooling system capacity. MATLAB was used to analyze the tabular data. Training of room volume and infiltration data using levenberg marquardt algorithm at 70% training data, 15% test data and 15% validation data respectively revealed that the best performance level was 106.0012 at epoch 1 and this matches infiltration rate of 14.263 m^3/hr . Cooling capacity best performance level was found to be 8.7406Tons at epoch 1. Also, The regression coefficient of 1 and correlation coefficient of 0.8746 from data analysis and regression graph indicated that there is a close and positive relationship between infiltration rate and air conditioner performance. The standard error was observed to be 4.2981 when root mean square error was 11. The P-value and degrees of freedom of the generated regression model are consistent with the P-value and degrees of freedom of ANOVA model, and that proves correctness of the regression model. In addition, standard deviation between capacity of equipment and infiltration rate data was 9.1310 at confidence interval of (-21.2133, 6.6173) and hypothesis of 0, which accepted null hypothesis that there is a significant relationship between performance(capacity) and infiltration rate.
Smoothing spline, linear interpolant and general model sin1 curve fittings, adequately proved that the infiltration rate for best performance of in-door air conditioning system was maximum of $15m^3/hr$.
The area graphs also indicated that a sustainable best performance level happens between serial number 1 to 4 and that is in agreement with the stated maximum value. MATLAB script/function was also generated for viewing the neural network model, performance graphs and fitting curves.
Keywords ---- MATLAB, algorithm, training data, cooling capacity, infiltration rate.

I. INTRODUCTION

Background of the Study

Outdoor air that flows through a building either intentionally as ventilation air or unintentionally as infiltration is important for two reasons. Dilution with outdoor air is a primary means of control of indoor air contaminants, and the energy associated with heating or cooling this outdoor air is a significant, if not a major, load on the heating and air-conditioning system. Thus knowledge of the magnitude of this air flow is needed for maximum load conditions to properly size air conditioning equipment (Prathibah, 2017). Jackravut and Nutthaphong (2016) stated that thermal characteristics of a building, to a greater extent depend on room size, infiltrations, building materials, wall orientation, window and door sizes, etc. The energy consumption from a cooling system (air conditioner), also depends on room air volume.

Desai(2012) defined infiltration as entering of outside air into the room to be air conditioned. He further stated that infiltration depends on height of the room, length of the room, width of the room and number of air changes per hour. The term one infiltration, means the

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 6 June 2022, pp: 656-663 www.ijaem.net ISSN: 2395-5252

equivalent volume of outside air that leaks into the room space to be air cooled.

There are no doubts that infiltration increases both sensible and latent heat loads on the cooling system. The study also claimed that the value of load on cooling system due to infiltration rate/room volume is 49.1 times the value of room volume under one unit difference of relative humidity. Hence, this research aimed at studying estimate of infiltration rate for best performance of an in-door air conditioning system.

Statement of the Problem

Napoleon, Odinah & Takao(2020)defines minimum infiltration supply rates for various conditions. These rates have not been arrived at according to experts working in the field.

Air leakage or infiltration is the sum of all parallel air flows through cracks and other openings into or out of a building without regard to flow direction. The air leakage rate describes the relative tightness of a building. The rate can be measured under standardized condition. The building is either pressurized or depressurized and flow is measured as a function of pressure difference between inside and outside (Desai, 2012).

Reviewed studies on performance of in-door air conditioning system, done by the authors, consistently proved that infiltration rate affects the performance of cooling systems. It was also discovered that increasing room volume, tends to increase infiltration and hence, sensible and latent heat loads that increases energy consumption. This is making it very pertinent to determine an estimate value of infiltration rate to achieve best performance. Increasing room volume will also increase infiltration rate which affects people comfort and raises energy consumption of cooling system. As well, decrease in room volume, decreases infiltration rate, minimizes energy consumption but may not necessarily assured human comfort or best performance. It is on this note that the researcher aims at determining the estimate of infiltration rate for best performance of a cooling system.

Purpose of the Study

The purpose of this study is to estimate infiltration rate for best performance of an in-door air conditioning system. The study will also evaluate if there is a significant relationship between infiltration rate and performance of air conditioning system.

Significance of the Study

The result of this study will be beneficial to building engineers and air conditioner manufacturing engineers in the following ways:

1. This study will help building engineers to make use of appropriate dimensions of room sizes during design and construction of buildings to ensure effective cooling.
2. Air conditioner manufacturers may deploy the result of the study to manufacture cooling systems that will perform satisfactorily.

Research Question

Is there any relationship between infiltration rate and performance (capacity) of an In-door air conditioner?

Hypothesis

Null hypothesis, H_0 = there is a significant relationship between infiltration rate and performance (capacity) of an In-door air conditioner versus **Alternative hypothesis,** H_i = there is no significant relationship between infiltration rate and performance (capacity) of an In-door air conditioner.

Scope of the Study

The building dimensions used in this work are taken from buildings within South East of Nigeria and hence, the result of the study may not be applicable to other parts of Nigeria or Western World. Therefore, the study will be applicable to all buildings within South-East of Nigeria.

Review of Related Literature

The review of the related literature is discussed under the following: conceptual framework and empirical framework.

Conceptual Frame

Concept of in-door Air Conditioner

Air conditioning (often referred to as air on, AC or A/C) is the process of altering the properties of air (primarily purity, movement, humidity and temperature) to favorable conditions, typically with the aim of distributing the conditioned air to an occupied space is to improve comfort. In the most general sense, air conditioning can refer to any form of technology humidification, de-humidification, heating, cooling, cleaning, ventilation, or air movement that modifies the condition of air. In general, the air conditioner is a device (most commonly a home appliance or automobile system) that lowers the air temperature. The cooling is most done using a simple refrigeration cycle, but sometimes the evaporation is used, commonly for the comfort of cooling in buildings and motor vehicles. In construction, a complete system of heating, ventilation and air conditioning is referred to as "HVAC" (Desai, 2012).

Concept of Infiltration

Infiltration is the uncontrolled flow of air through openings in the building envelope driven

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 6 June 2022, pp: 656-663 www.ijaem.net ISSN: 2395-5252

by pressure differences across the shell. The terms infiltration and air leakage are sometimes used synonymously but are different, though related, quantities. Infiltration is balanced by an equal amount of exfiltration since, except for transient conditions; there is no net storage of air in a building. Air leakage is the sum of all parallel air flows through cracks and other openings into or out of a building without regard to flow direction.

Concept of cooling load

The two main components of a cooling load imposed on an air conditioning plant operating during hot weather are as follows: Sensible heat gain: When there is a direct addition of heat to the enclosed space, a gain in the sensible heat is said to occur. The sensible heat gain may occur due to the following reasons:

(a) The heat flowing into the building by conduction through exterior walls, doors, windows, floors and ceiling are due to temperature difference on their two sides. (b) The heat received from solar radiation. It consists of

1. The heat transmitted directly through the glass of windows and
2. The heat absorbed by walls and roofs exposed to solar radiation and later on transferred to the room by conduction.

(c) The heat conducted through interior partition from rooms in the same building which are not conditioned.

(d) The heat given off by lights, motors, cooking operations, etc.

(e) The heat liberated by the occupants.

(f) The heat gain from the fan work. Latent heat gain: When there is an addition of water vapor to the air of enclosed space, a gain in latent heat is said to occur. The latent heat gain may occur due to the following reasons: (a) The heat gain due to the moisture in the outside air entering by infiltration. (b) The heat gain due to condensation of moisture from occupants. (c) The heat gain due to condensation of moisture from any process such as cooking foods which takes place within the conditioned space. (d) The heat gain due to moisture passing directly into the conditioned space through partitions or permeable walls from the outside (Prathibha, Kodliwad, Busi, & Naga, 2017).

Empirical Framework

Jackravut and Nutthaphong (2016) studied a simplified air conditioning systems model with energy management. The study adopted a simulink matlab model and an experimental model. They concluded that the result from matlab simulink model and experiment model are consistent. Prathibha et al. (2017) studied design of air conditioning system for residential/office building. The classified air conditioning system operation into part A, basic principles of thermodynamics and part B, cooling load calculation. They concluded that accurate cooling load calculations, determine effectiveness of a cooling system. Napoleon et al. (2020) investigated review of the advances and applications of variable refrigerant flow heating, ventilating, and air-conditioning systems for improving indoor thermal comfort and air quality. They concluded that heating, ventilating and air conditioning system can provide a healthy indoor thermal environment with good air quality. Desai (2012) studied refrigeration and air conditioning for engineers. The results of his studies showed that infiltration is 46.1 times the value of room volume under one unit of relative humidity.

Research Methodology

The research methodology is discussed under the following headings: research design, area of the study, method of data collection, validation of data and method of data analysis.

Research Design

The study followed a survey design approach. Survey design is one in which a group of buildings are studied by collecting and analyzing data from only selected buildings that serves as the representative of the entire buildings and findings are generalized. Dimensions from the selected buildings would represent the entire building within the study area.

Area of the Study

The research was conducted within Owerri Municipal Council which is one of the local government areas in Imo State. It is between Owerri North and Owerri West. The representative buildings are located at No. 1036 West layout Prefab Uratta Housing Estate.

Method of Data collection

The researchers personally went to the selected buildings, after obtaining permission from the landlords, measured and recorded the dimensions of room sizes with the aid of measuring tape. Window and door sizes were also recorded. The obtained measurement was used to generate the tabular data that was subjected to MATLAB analysis.

Method of Data Analysis

MATLAB was used to analyze the tabular data. 15% of the original data serves as a validation data and 15% of the original data also serves as test data and 70% as a train data. Levenberg Marquardt was used as the training algorithm.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 6 June 2022, pp: 656-663 www.ijaem.net ISSN: 2395-5252

Design Analysis

$\text{Infiltration} = \frac{H \times L \times W \times G}{60}\ m^3/min$ .....(1.0)

Where H = height of the room;
L = length of room;
W= width of room;
G = number of air changes/hr

Load due to outside air will be both sensible as well as latent. It is given as below:

$\text{outside air sensible heat} = 20.43 \times Q_m(t_o - t_i)$ ....(1.1)

$\text{outside air latent heat} = 50Q_m(W_O - W_i)$ ....(1.2)

W and t means relative humidity and temperature respectively and Q is outside air volume flow rate.

$\text{sensible heat gain}, Q = U \times A \times CLTD\ \text{watts}$ ....(1.3)

U = overall heat transfer coefficient; A = wall area and CLTD = cooling load temperature difference.

$\text{heat gain through windows} = a \times GLF$ ....(1.4)

where a = glass area and GLF = glass load factor.

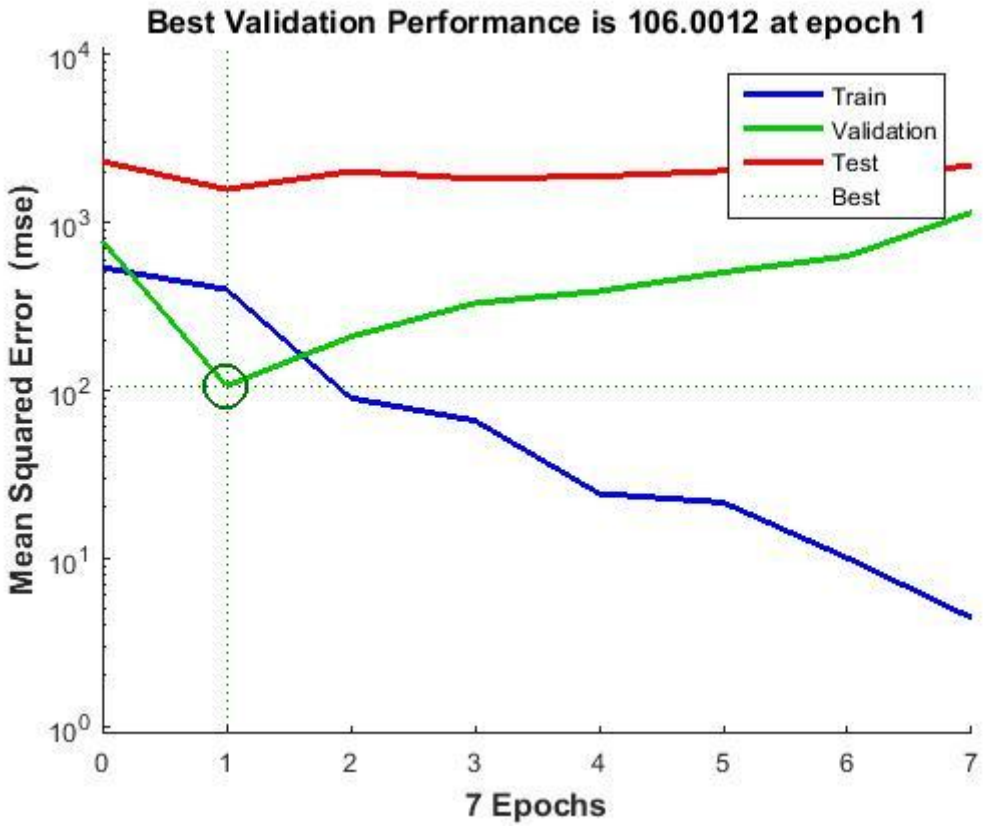
Presentation of Data Analysis

The tabular data gotten from the study is presented as shown below.

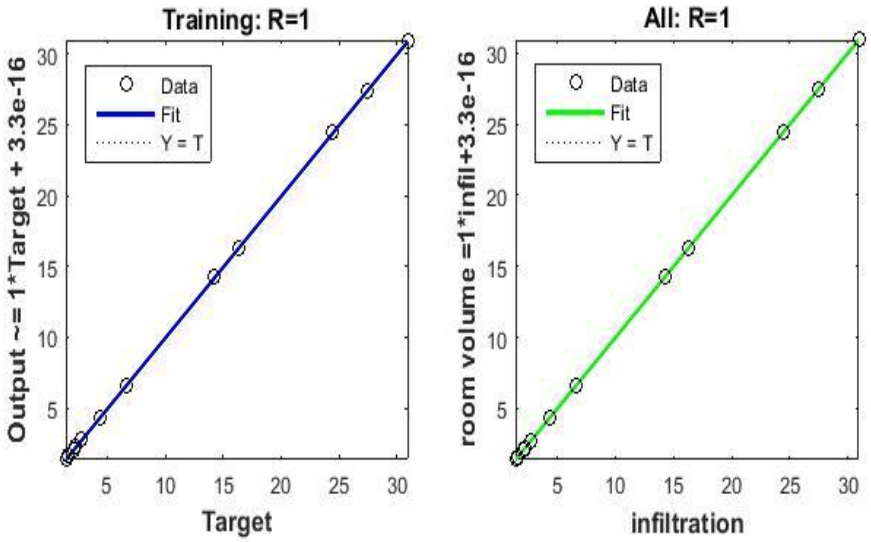
Table 1.0: below shows room volume, total infiltration, ventilation and room area.

NAME OF ROOM/SPACE	ROOM VOL (m^3)	TOTAL INFIL Q_{MT} (m^3)	VENT. Qvent (m^3)	ROOM AREA (m^2)
Room 1	61.238	30.896	42	200.364
Room 2	5180.175	16.29	26.46	82.225
Room 3	308.278	6.638	3.36	90.67
Room 4	206.244	14.263	25.2	60.66
Room 5	678.912	24.472	70	199.68
Room 6	40.426	1.424	2.5	11.89
Room 7	52.935	2.779	2.52	15.569
Room 8	73.824	4.361	3.5	21.713
Room 9	54.539	1.653	3.5	16.041
Room 10	660.8308	27.42	112	194.365
Room 11	112.047	2.057	3.5	32.955
Room 12	128.479	2.2489	3.5	37.788
Room 13	208.06	1.456	2.356	61.194

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 6 June 2022, pp: 656-663 www.ijaem.net ISSN: 2395-5252



Regression graph of capacity against infiltration is shown beblow.

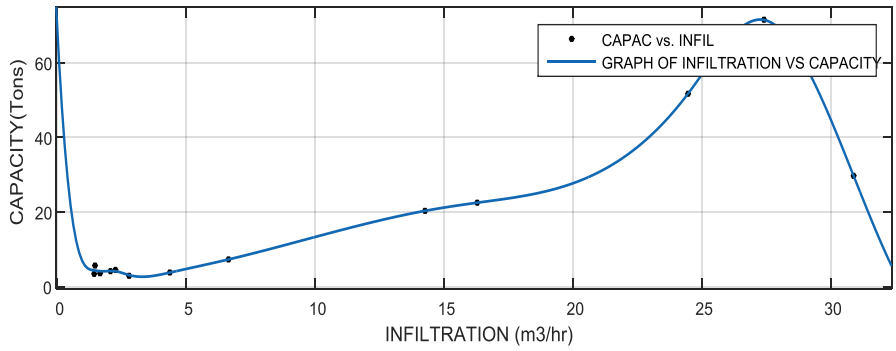


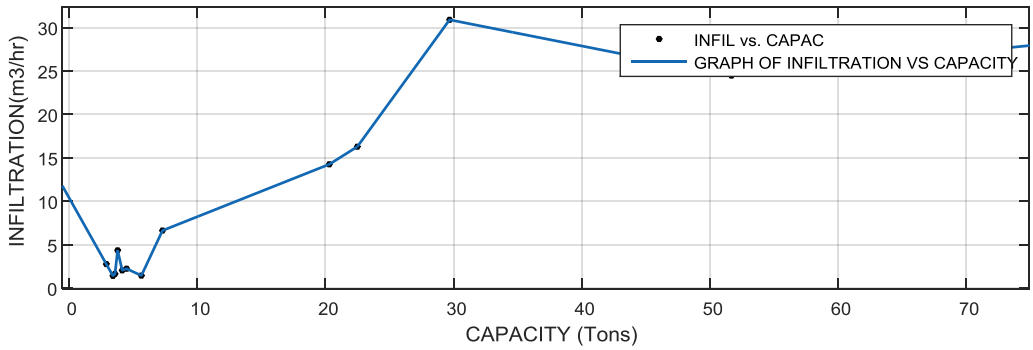
International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 6 June 2022, pp: 656-663 www.ijaem.net ISSN: 2395-5252

Table 1.1: below shows room volume, total infiltration, ventilation and Capacity of air conditioner.

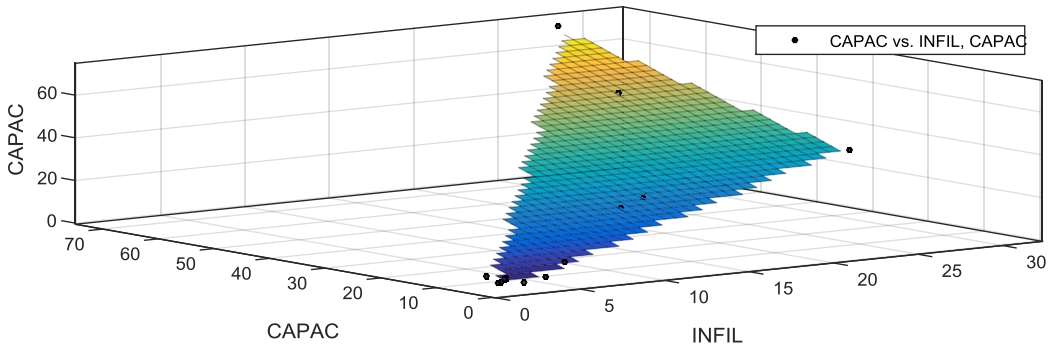
NAME OF ROOM/SPACE	ROOM VOL (m^3)	TOTAL INFIL Q_{MT} (m^3)	VENT. Qvent (m^3)	CAPACITY = RTH/3500 (Tons)
Room 1	61.238	30.896	42	29.68386
Room 2	5180.175	16.29	26.46	22.48338
Room 3	308.278	6.638	3.36	7.278687
Room 4	206.244	14.263	25.2	20.29576
Room 5	678.912	24.472	70	51.67699
Room 6	40.426	1.424	2.5	3.412411
Room 7	52.935	2.779	2.52	2.896382
Room 8	73.824	4.361	3.5	3.7785
Room 9	54.539	1.653	3.5	3.573547
Room 10	660.8308	27.42	112	71.50495
Room 11	112.047	2.057	3.5	4.135946
Room 12	128.479	2.2489	3.5	4.479082
Room 13	208.06	1.456	2.356	5.632464

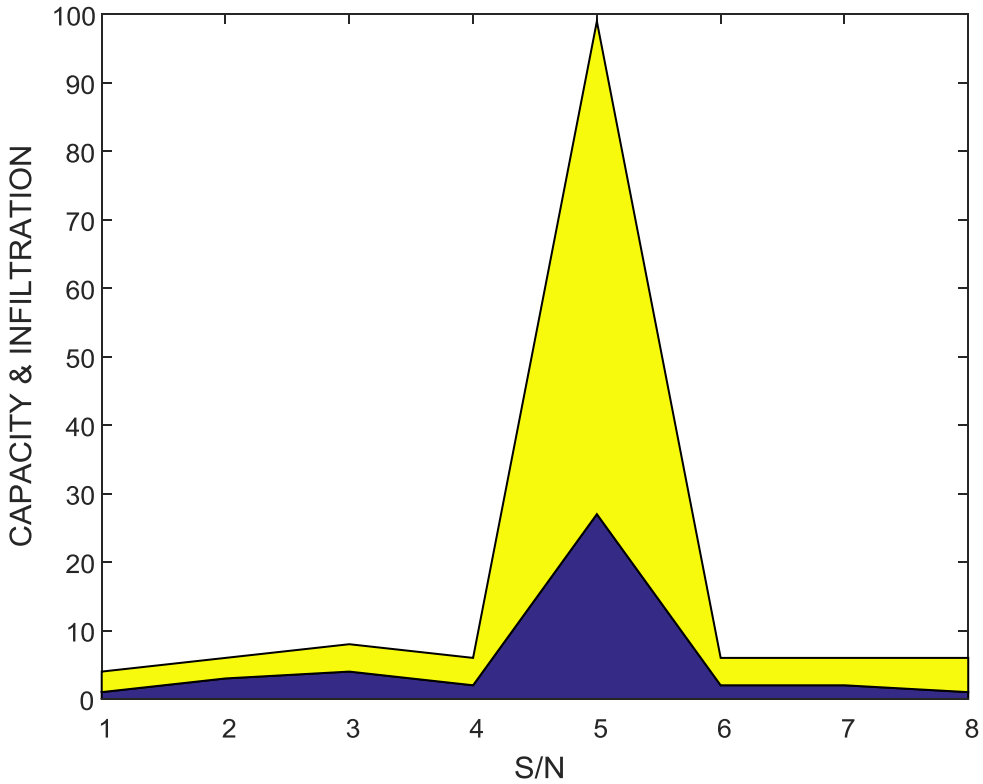
CURVE FITTINGS





International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 6 June 2022, pp: 656-663 www.ijaem.net ISSN: 2395-5252





AREA GRAPH OF CAPACITY AND INFILTRATION AGAINST SERIAL NUBMBER

II. DISCUSSION OF FINDINGS

The outcome of the study of estimate of infiltration rate for best performance of an in-door conditioning system, was discussed here. The data was analyzed using MATLAB. According to table 1.0, the original data was trained to achieve a network performance test level of 266.0675. A closed loop network yielded performance test level of 641.4498, which is reasonably higher and proves improvement/refinement. Training of room volume and infiltration data using levenberg marquardt algorithm at 70% training data, 15% test data and 15% validation data respectively revealed that the best performance level was 106.0012 at epoch 1 and this matches infiltration rate of 14.263 m^3/hr. The regression coefficient of 1 and correlation coefficient of 0.8746 from data analysis and graph indicated that there is a close and positive relationship between infiltration rate and air conditioner performance.

The MATLAB analysis also computed the linear regression model between capacity of equipment and infiltration rate as below;

$$\textbf{Capacity} = 1.7332 \times \textbf{Infiltration rate} - 0.37034$$

The standard error was observed to be 4.2981 when root mean square error was 11. The P-

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 6 June 2022, pp: 656-663 www.ijaem.net ISSN: 2395-5252

value and degrees of freedom of the regression model are consistent with the P-value and degrees of freedom of ANOVA model, that proves correctness of the model.

The standard deviation between capacity of equipment and infiltration rate data was 9.1310 at confidence interval of (-21.2133, 6.6173) at hypothesis of 0, which accepted null hypothesis that there is a significant relationship between infiltration rate and performance, capacity.
Smoothing spline, linear interpolant and general model sin1 adequately proved that the infiltration rate for best performance of in-door air conditioning system was maximum of $15m^3/hr$.
The area graphs also indicated that a sustainable best performance level happens between serial number 1 to 4 and that is in agreement with the stated maximum value.

III. CONCLUSION

Obviously, results from the study revealed that the estimated value of infiltration rate (volume) for best performance of an in-door air conditioning system is $15m^3/hr$ with optimal cooling load capacity and this is in agreement with Desai (2012) that air leakage or infiltration is the sum of all parallel air flows through cracks and other openings into or out of a building without regard to flow direction. The air leakage rate describes the relative tightness of a building. The rate can be measured under standardized condition and the typical leakage rates are 8 to 15 air changes per hour.

Recommendations

1. Building construction engineers should ensure that rooms that will carry cooling system are constructed based on the estimated value to avoid overloading of the cooling system.
2. Air conditioner manufacturers should design cooling systems whose capacity varies beyond the estimated infiltration rate.
3. This study can also be done in future using other training algorithms.
4. This research can also be done using multiple infiltration rates and other advanced program for generalization.

Research Question

Is there any relationship between infiltration rate and performance (capacity) of an In-door air conditioner?

Hypothesis

Null hypothesis, H_0 = there is a significant relationship between infiltration rate and performance (capacity) of an In-door air conditioner versus **Alternative hypothesis,** H_i = there is no significant relationship between infiltration rate and performance (capacity) of an In-door air conditioner.

```
>> [h,sig,ci] = ttest2(INFIL,CAPAC)

h =

     0

sig =

    0.2898

ci =

   -21.2133    6.6173
```

At hypothesis of 0, we accept null hypothesis that there is a significant relationship between infiltration rate and performance (capacity).

REFERENCES

[1]. Desai, P.S.(2012). Modern air condition and refrigeration for engineers. New Dehi: Khanna Publishers.
[2]. Jackravut, D. & Nutthaphong, T. (2016). A simplified air conditioning system model with energy management. Journal of International Electrical Engineering Congress,86(1),361-364.
[3]. Napoleon, E., Odinah,C.E. & Takao, S. (2020). Review of the advances and application of ventilation and air conditioning systems for improving indoor thermal comfort and air quality. International Journal of Energy and Environmental Engineering,2(1).
[4]. Prathibha, B.V.V., Ajay,K. , Busi, A.K & Naga, D. (2017). Design of air conditioning system for residential/office building. International Journal of Emerging Research in Management and Technology, 6(3).