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Reducing Energy Consumption of Light Rail Train by using CO_2-Controlled Ventilation for Air Condition

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***Abstract*—**This paper present reducing the energy consumption of light rail train by using co2-operated ventilation for air-conditioning. To achieve this precious goal, this paper proposes the use of co2-operated ventilation in order to reduce the energy used for air-conditioning purpose. The energy of co2-operated air-conditions and CAV (convention system) was simulated and analyzed by HAP software. The result of train simulation report has shown clearly that co2-operated air condition consume less energy and is cost energy effective as compared to CAV(conventional system).

***Keywords*—** CO_2, HAP, CAV, Air-Condition

I. Introduction

Rail train has been recognized as the most energy sufficient and compatible transportation made. In fact, reducing the energy consumption of rail vehicle is a key issue. The rail train consumes in addition to the energy needed for train motion, a share of electricity for comfort purpose. About 20% to 40% of the energy consumed by the vehicle is used for ventilation and air-conditioning. Nowadays, optimizing the energy used for comfort purpose is a key issue because the air-conditioning accounts the biggest share of comfort energy[1,2].

To satisfy the antagonistic needs of passengers' comfort and low-cost energy by rail-way companies, The passengers care always their comfort and air quality while the operating company needs to conserve the operating energy. It is always difficult to satisfy both at same time , but there is made balancing between these antagonistic to reduce energy consumption and to satisfy the passenger . in train, ventilation is considered to be one of the most important factors for maintaining acceptable indoor air quality in any space . many types of ventilation systems encounter problems to control minimum supply air and thus to consume minimum amount of energy. But a ventilation system based on registration of increasing co2 concentration can facilitate in solving the given problem. Such a technology is called co2-based demand controlled ventilation (DCV)[2,3,4].

The experience and field studies have shown that the level of carbon can be a reliable indicator and quite a cheap instrument of the air quality and ventilation rate. Co2-based demand controlled ventilation system controls the amount of supply outdoor fresh air in a train depending on a number of people. People are the main source of co2 in a train. If a number of people in coach is doubled, the co2 level will accordingly double. If one or few people leave at the coach or the saloon, the level of co2 will proportionally decrease. Thus DCV saves energy solely by not heating or cooling unnecessary amount of outdoor air [3,4]. The benefits of such ventilation are maximal when a number of people continuously changes in train, in extreme climate condition or when the electricity cost is quite high. Co2 concentration in the coach is a good indication of the number of passenger actually present. Installation of co2-sensor and a control circuit for ventilation therefor allows a demand-oriented energy efficient ventilation of passenger coaches[1,3].

HAP(Hourly Analysis Program) software will analyze the energy of co2-controlled air-condition and CAV (conventional system) in order to show clearly that co2-operated air condition consume less energy comparing to the conventional system. HAP estimates annual energy use and energy cost for HVAC and non-HVAC energy consuming system in a building or train by simulating its operation for each of 8.760 hours in a year[2,4].

There are steps using HAP to energy analysis:
-Defining the problem
-Data gathering
-Data entry into HAP
-Generation of simulation Report
-Evaluation of result

II. Definition of the Scope

Normally an energy analysis compares energy use for two or more scenarios . this paper is estimating and comparing the energy use of two design scenarios:

- CAV which is deliver comfort to spaces with similar load
- VAV which is designed with the supply a quantity of fresh air flow. This case describes accurately the quantity of occupant in train[1,3,5].

Based on this, equipment like supply fan, space(door, window, wall and roof of train) and the coach interior data will be sized[4,5,6].

III. DATA GATHERING

This involves gathering data for Addis Ababa Light Rail Train, its environment and its air system data.

A. *Train location*

The light rail train considered in this study is situated in Addis Ababa, capital of Ethiopia, located at 39° longitude, 9° latitudeand at an elevation 2450.0 meter[7,8,9].

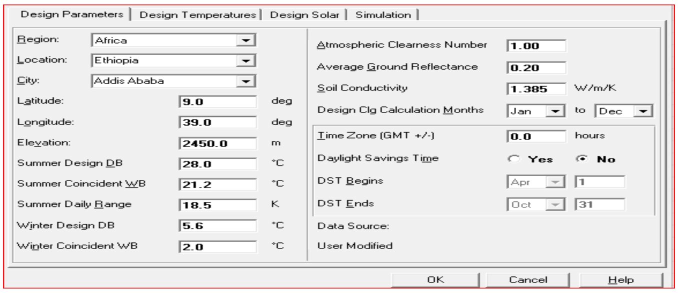

Figure 1. Space input data

B. *Weather data*

The weather data includes monthly maximum and minimum dry bulb and wet bulb temperature, design DB temperature for both summer and winter, summer coincident WB, winter coincident WB, region, location, city, latitude, longitude, elevation , and sunshine hour, for the area of interest, which are collected from the National Metrology Agency(NME)[10,11,12].

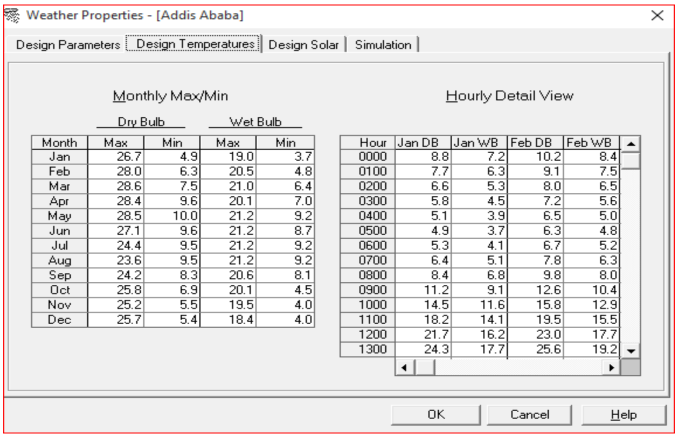

Figure 2. Weather Input Data

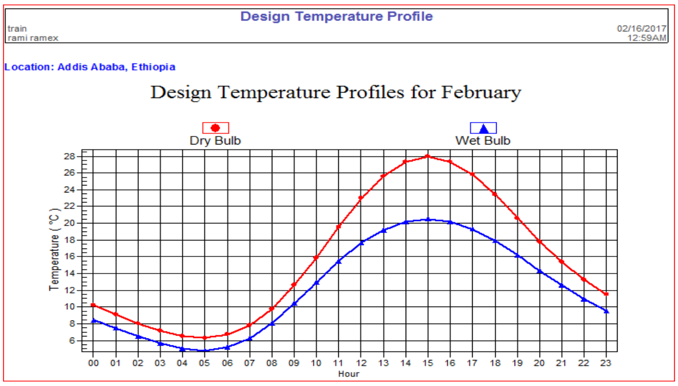

Figure 3. Design Temperature Profile

C. *Train Structure*

The dimension of the passenger compartment in LRT which is to be air conditioned is 23.6x2.65 m in size. It has one floor. It has one floor. The exterior wall of the train is made of stainless steel and the roof of the passenger compartment is low concrete roof. The floor in passenger saloon is structured with polyurethane rubber and covering by PVC floor covering and its length is 23600 mm. the doors are made of aluminum alloy materials. The doors and windows use glass[13,14].

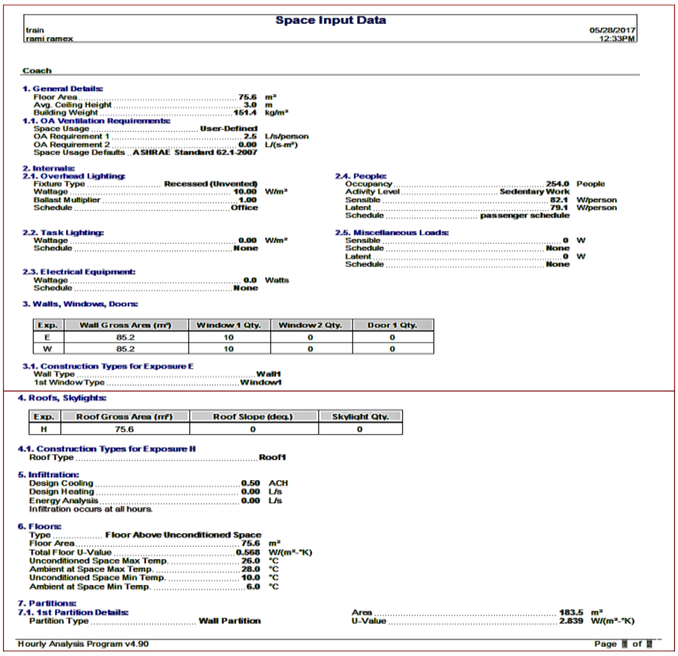

Figure 4. Space Input Data for Train

D. *Passenger Flow*

The rated passenger is 286 person in one tramcar(width 64 seat and 6 standing person per m2)[15]. The HAP software needs an input data the numbers of occupants or passenger in the train per hour. Passenger flow is not same for work days and holidays[16,17] . Based on observation, estimation and interviews, the number of passenger per hour is as follows:

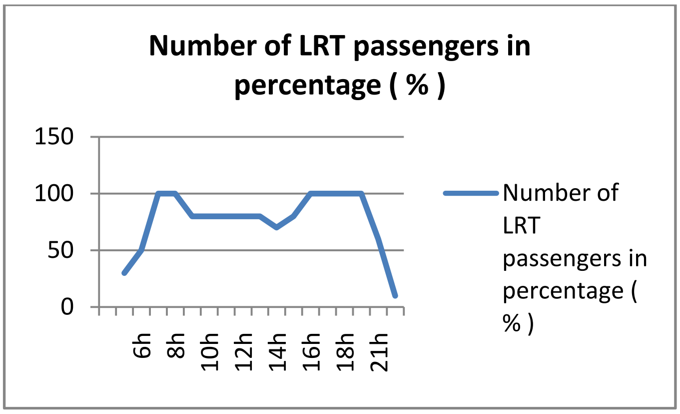

Figure 5. Number of passenger at workdays

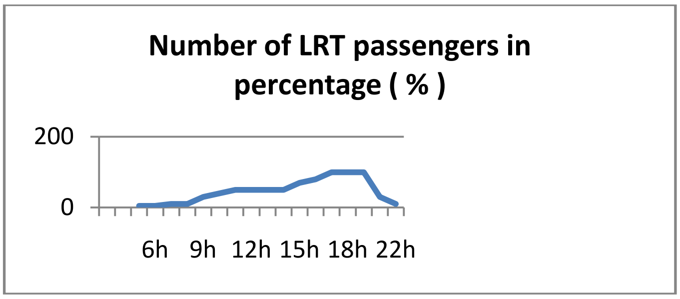

Figure 6. Number of passenger at holidays

IV. RESULT

A. Conventional system simulation Report

After running the simulation with the HAP software, the Annual energy consumption is summarized in the above table. CAV system which is the conventional system consumes 38,013 kWh annually. This amount of energy consumption concluded from CAV scenarios will be compared with VAV system one.

TABLE I. ANNUAL ENERGY CONSUMPTION

Component	train locomotive
HVAC Components	
Electric (kWh)	33,322
Non-HVAC Components	
Electric (kWh)	4,691
Totals	
Electric (kWh)	38,013

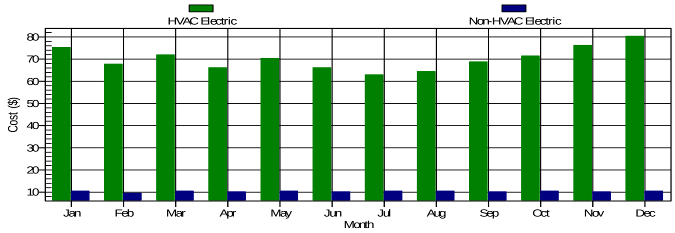

Figure 7. Monthly Energy Cos

B. VAV (controlled by co2) system simulation report

TABLE II. ANNUAL ENERGY CONSUMPTION

Component	Train locomotive
HVAC Components	
Electric (kWh)	25,535
Non-HVAC Components	
Electric (kWh)	4,691
Totals	
Electric (kWh)	30,226

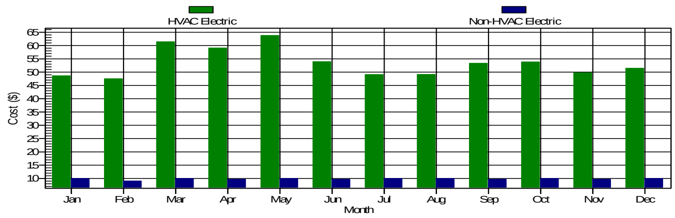

Figure 8. Monthly Cost

CONCLUSION

This paper showed that air-condition controlled by co2 system has benefit for both the train operator and passengers. HAP programme produced by Carrier for simulating energy use and calculating energy costs was used to analyse the energy consumption of CAV(conventional system) and VAV(which is controlled by co2) system. The air-conditioned controlled by co2 which has a variable speed fan controls outdoor fresh based on number of passenger. Such system is energy cost effective and consumes less energy in terms of electric. It reduces electricity requirements when an actual occupancy level is below than the design occupancy level during the demanded periods. It creates also improved indoor air quality by increasing ventilation when co2 level rises to unacceptable level.

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