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Aims and Scope

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Contents

Cascaded H-Bridge Multilevel Inverter using SPWM

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A B S T R A C T

This paper presents the concert of flying capacitor multilevel inverter and cascaded H-bridge multilevel inverter. To improve the performance of Flying Capacitor Multilevel Inverter (FCMLI) the switching pattern selection scheme is used. By this scheme the capacitor voltage fluctuation is reduced without using voltage feedback. The elimination of harmonics in a cascaded multilevel inverter (MLI) by taking the unequal of separated DC source is presented. DC sources may be batteries, solar cells, etc. A fundamental switching scheme is used, which achieves the fundamental in the output voltage while eliminating the lower order harmonics and to produce a nearly sinusoidal output. The FFT spectrums for the outputs are presented to study the reduction in the harmonics. The circuit is simulated using MATLAB/SIMULINK. The simulation results are verified.

Keywords: Embedded Controller, MATLAB/SIMULINK, H-bridge Multilevel Inverter, THD, Unequal Voltage Sources.

I. INTRODUCTION

Multilevel inverters have very important development for high power medium voltage AC drives. Quite a lot of topologies have found industrial approval;

a. Neutral Point Clamped Multilevel Inverter.

b. Flying capacitor Multilevel Inverter.

c. Cascaded Multilevel Inverter.

Maynard and Foch introduced a flying-capacitor-based inverter in 1992. The structure of this inverter is similar to that of the diode-clamped inverter except that instead of using clamping diodes, the inverter uses capacitors in their place. The cascaded multilevel inverters offer more than two voltage levels. A desired output voltage waveform can be synthesized from the multiple voltage levels with less distortion, at low switching frequency, higher efficiency, and lower voltage rating devices. An important question in designing an effective multilevel inverter is to ensure that, the total harmonic distortion (THD) in the output voltage waveform is small. A complete solution is obtainable for computing all possible switching angles that achieve the required fundamental voltages and eliminate the lower order harmonics [1]. On the other hand, it was assumed that the dc sources were all equal, which will probably not be the case in applications even if the sources are nominally unequal. Here, it is shown how the method in [2] can be extended to two unequal dc source inverter. Particularly, eliminating harmonics in a multilevel converter in which the separate dc sources do not have equal voltage levels is measured. Normally each phase of a cascaded multilevel converter requires n DC sources for 2n + 1 level. For many applications, to get several separate DC sources is difficult, and too many DC sources will be necessary many long cables and might lead to voltage unbalance among the DC sources. To reduce the number of DC sources necessary while the cascaded H-bridge multilevel converter is applied to a motor drive, a scheme is proposed in [3] that allow the use of two unequal DC sources to generate five level equal step multilevel inverter output. In this paper, the lower order harmonics are eliminated using two unequal DC voltages for H-bridges.

II. FLYING CAPACITOR MULTILEVEL

INVERTER

Fig. 1 shows a FCMLI, in this type of inverter uses a ladder structure of dc side capacitors where the voltage on each capacitor differs from that of the next capacitor. n-1 capacitors in the dc bus are needed to generate n-level staircase output voltage. Every phase-leg has an indistinguishable structure. The size of the voltage increment between two capacitors decides the size of the voltage levels in the output waveform of the inverter.

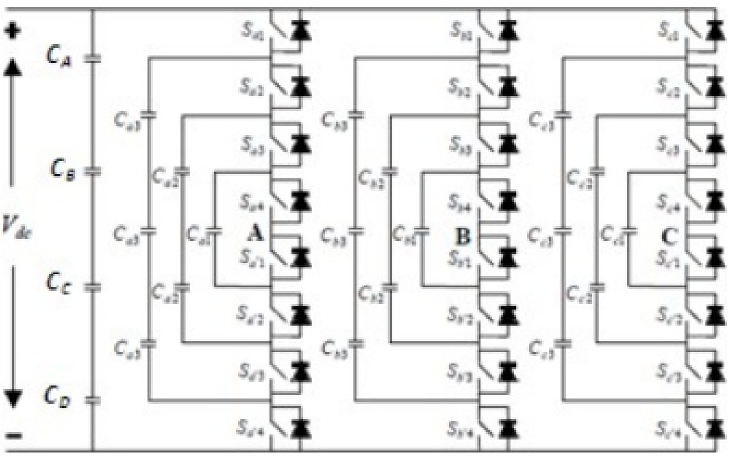

Fig. 1 Three phase flying capacitor multilevel inverter.

It is clear that three inner-loop balancing capacitors for phase leg A, Ca1, Ca2, and Ca3 are independent from those for phase leg B. Every phase legs segregate the same dc link capacitors, CA to CD. Table I shows the possible switch combinations to generate the five level output waveform.

The voltage synthesis in a five-level flying capacitor converter has more flexibility than a diode-clamped converter [4]. The voltage of the five-level phase-leg A output with respect to the neutral point o, VAo, can be synthesized by the different switch combinations.

TABLE I : SWITCHING STATES OF FIVE LEVEL MULTILEVELINVERTER

Output Voltage	Switching States Of MLI							
VAO	Sa1	Sa1	Sam-1	Sam	Sa’1	Sa’2	Sa’m- 1	Sa’m
V5=Vdc	1	1	1	0	0	0	0	0
V4=3Vdc/4	1	1	1	0	0	0	0	1
V3=Vdc/2	1	1	0	0	0	0	1	1
V2=Vdc/4	1	0	0	0	0	1	1	1
V1=0	0	0	0	0	1	1	1	1

III. CASCADED H-BRIDGE MULTILEVEL

INVERTER

The cascaded multilevel inverter consists of a series of H-bridge inverter. The general purpose of this multilevel inverter is to synthesize a desired voltage from several separate dc sources, like batteries, fuel cells, solar cells, and ultra capacitors. Fig. 2 shows a single- phase structure of a cascade inverter with separate dc sources [5]. Each separate dc source is connected to a single-phase full-bridge inverter.

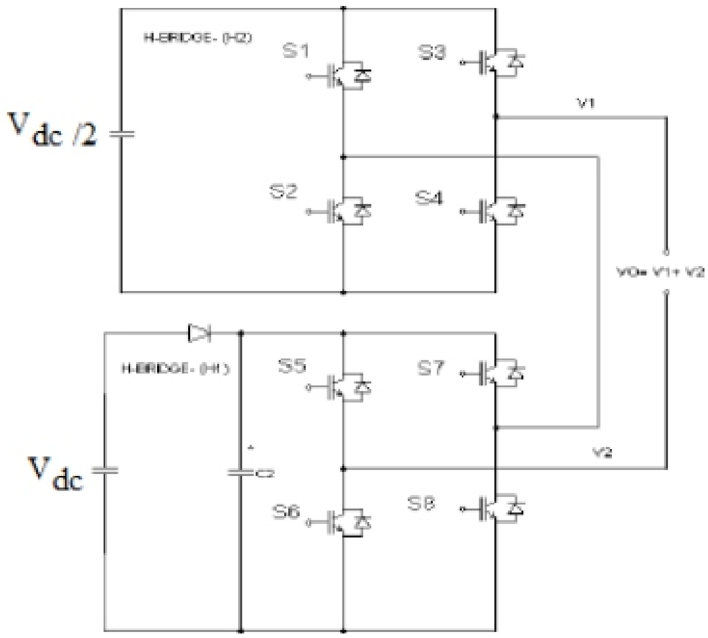

Fig. 2 Topology of a five level H-bridge cascaded multilevel inverter.

The topology offered in this paper employs two unequal dc sources to generate an equal step five level output. The proposed inverter consists of two H-bridges as shown in Fig.2. The main H - bridge (H_1) is connected to a dc source of V_{dc} and the second bridge ($H_{2)}$ is connected to a dc source of $0.5V_{dc}$. By suitably opening and closing the switches of H_1, the output voltage v1 can be made equal to $-V_{dc}$, 0, or $+V_{dc}$ similarly the output voltage of H_2 can be made equal to $-0.5V_{dc}$, 0, or $0.5V_{dc}$ and the cascaded output is shown in Fig.3. Therefore, the output voltage of the converter can have five possible values V_{dc}, 0.5Vdc, 0, $-0.5V_{dc}$, and $-V_{dc}$

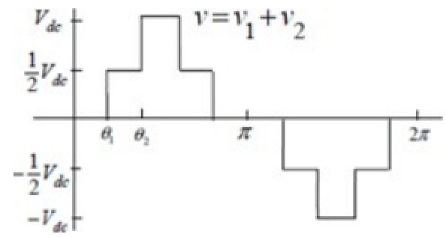

Fig. 3 Fundamental frequency waveform.

The DC source for the first H-bridge (H_1) is a dc source with an output voltage of V_{dc}, whereas the dc source for the second H-bridge (H_2) is a DC source voltage to be held at $V_{dc}/2$. The output voltage of the first H-bridge is denote by v_1 and the output of the second H-bridge is denote by v_2. Hence the output of this two dc sources cascaded H-bridge multilevel inverter is $v = v_1+v_2$. By opening and closing the switches of H_1 suitably, the output voltage v_1 can be made equal to V_{dc}, 0, or else $-V_{dc}$ when the output voltage of H_2 can be made equal to $V_{dc}/2$, 0, or else $-V_{dc}/2$ by opening and closing its switches suitably. Therefore, the output voltage of the inverter may have the values V_{dc}, $V_{dc}/2$, 0, $-V_{dc}/2$, and $-V_{dc}$ which are five levels. The output voltage of the cascaded multilevel inverter is

$$v = v_1 + v_2 \qquad (1)$$

i) Harmonics

The switching angles of the waveform will be adjusted to obtain the lowest output voltage THD. The harmonics orders and magnitude are depends up on the type of inverter and the control techniques. For example in single phase VSI, the output voltage waveform typically consists only of odd harmonics. The even harmonics are not present due to the half wave symmetry of the output voltage harmonics. The harmonic spectra depend on the switching frequency and the control method [6].

ii) Switching control of the inverters

There are number of modulation control techniques such as sinusoidal PWM method (SPWM) [7-11], space vector PWM method (SVPWM), selective harmonic elimination method (SHE) [12-14], and active harmonic elimination method [15], and they all can be used for inverter modulation control. For the proposed inverter control, a sensible modulation control method is the fundamental frequency switching control for high output voltage and Sinusoidal PWM control for low output voltage. In this paper, fundamental frequency switching control is used in H-bridge MLI [16].

IV. SIMULATION OF FCMLI AND CASCADED H-BRIDGE MULTILEVEL INVERTER

The performance of the proposed Flying capacitor multilevel inverter is verified through the simulation results.

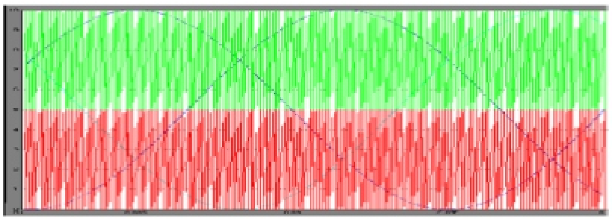

Fig. 4 Sinusoidal PWM signals for FCMLI.

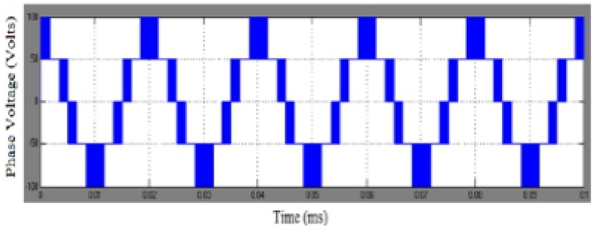

Fig. 5 Phase voltage of FCMLI.

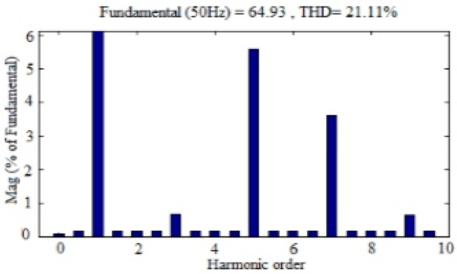

Fig. 6 FFT analysis of FCMLI voltage.

The Fig. 4 shows the sinusoidal PWM control for low output voltage. Fig. 5 and Fig. 6 show the FCMLI phase voltage, and FFT analysis of voltage respectively.

The performance of the proposed H-bridge multilevel inverter is verified through the simulation results. Fig. 7 shows the phase voltage of cascaded H-bridge multilevel inverter. Fig.8 shows the FFT analysis of voltage.

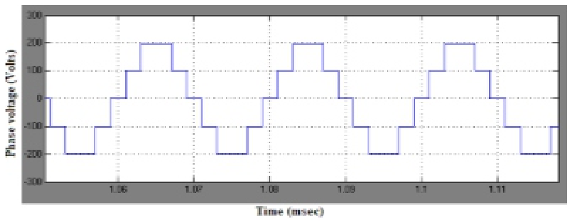

Fig. 7 Phase voltage of cascaded H-bridge multilevel inverter.

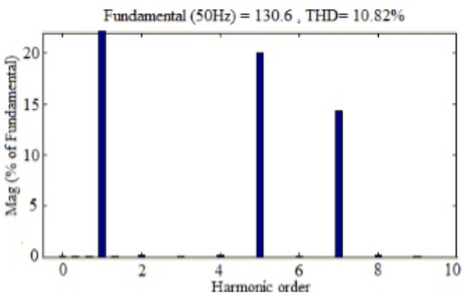

Fig. 8 FFT analysis of Cascaded H-Bridge MLI voltage.

TABLE II PERFORMANCE PARAMETERS OF FIVE LEVEL FCMLI AND H-GRIDGE MULTILEVEL INVERTER

Perameter	FCMLI	H-Bridge MLI
THD %	21.11%	10.82%

Table II shows the THD performance of five level FCMLI and cascaded H-bridge multilevel inverter. Comparing both MLI cascaded H-bridge multilevel inverer gives the less value of THD (10.82%).

V. CONCLUSION

The flying capacitor multilevel inverter uses a ladder structure of dc side capacitors where the voltage on each capacitor differs from that of the next capacitor. The sinusoidal PWM scheme is used for modulation control. In cascaded H-bridge multilevel inverter separated unequal DC sources are used to generate sinusoidal output. A fundamental switching scheme is used and produces a nearly sinusoidal output. This cascaded inverter design is to get the improved sinusoidal output of an inverter and gives reduced THD%. The elimination of harmonics in a cascade H-bridge multilevel inverter by considers the inequality of separated dc source. FFT spectrum shows the reduction in the harmonics in the output voltage.

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Grid Solar Hybrid Speed Controller for Electric Vehicle – A Working Model

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ABSTRACT

This paper work presents a pulse width modulation (PWM) speed control technique for a working model of grid solar hybrid electric vehicle. The integrated system consist of solar panel, charge controller, battery, step down transformer, diode rectifier, PMDC motor, speed controller and PIC Microcontroller 16F876A. The working model can able to run on dual mode- solar and electricity. It can also be driven independently either by solar or electricity. The battery can be charge from solar panel (10W) or by power supply. The household single phase A.C. power supply of 230V is converted into 12V D.C. using step down transformer and rectifying circuit. The working model can achieve energy saving, low carbon emission, environmental protection for the upcoming future of human life. The motor speed is controlled by PWM technique implementation using the programming burn in microcontroller. This technique is implemented on working model and its application results in reduced current consumption and removal of mechanical parts. The experimental result shows that the digital controller is able to follow the reference speed and hence, speed control is achieved the result is shown graphically.

Keyword: Hybrid electric vehicle, solar energy, Solar panel, PWM, PIC Microcontroller 16F876A, PMDC motor

I. INTRODUCTION

The whole world is moving towards the sources of energy which would never exhaust in future and do not harm environment. The environment is polluted mostly due to vehicles and rush of vehicles is increasing day by day and therefore fossil fuels are exhausted day by day. So, world is finding solution of this problem and in the pave with this they reached on electric vehicles. Electric vehicles are able to reduce pollution on tailpipe but at last pollution is increasing in power plants. To reduce the pollution at power plant also, world move towards renewable source of energy that is solar energy. Next challenge is that alone solar energy is not enough to drive the vehicle. So, at last world is now focusing on hybrid electric vehicles and trying to improve efficiency of hybrid electric vehicle. Here we are doing hybridization of solar energy with electricity.

The main objective of this paper is to study about hybrid electric vehicles and then design speed controller for hybrid electric vehicles. Here we are using PWM (pulse width modulation) technique for developing the speed controller of d.c motor for hybrid electric vehicles and at last we are implementing PWM technique by developing the hardware of working model and by studying the waveforms which is formed by working model. Eventually we are able to achieve our goals.

2. LITERATURE SURVEY

In recent years, so many researches are going on for developing hybrid electric vehicles without using non- renewable sources of energy or with using renewable source of energy. But to save environment peoples are more emphasis on non- renewable sources of energy. Solar energy is the best non- renewable source of energy to use in hybrid electric vehicles. Many researches on hybrid electric vehicles with hybridization of solar energy with electricity have done. For optimizing hybrid electric vehicles and electric vehicles simulation software MATLAB (Matrix laboratory) [1] and VBB (virtual bread board) [5] has been most commonly used. The physically developed models for hybrid electric vehicles and electric vehicles are also been presented by many researchers [2] [3]. In order to analyse cost, size, performance and to obtain best feasible condition configuration for hybrid electric vehicles and electric vehicles.

3. SYSTEM CONFIGURATION

The integrated system of working model consist of solar panel, charging system controller, PMDC motor, accelerator control, rectifier unit and batteries.

Fig. 1 is showing schematic diagram of the multisource solar/electric hybrid electric vehicle. Hybrid electric vehicle tends to use solar panel as a main energy source and plug in as an auxiliary energy source. Electrical energy is stored in battery and use to drive PMDC motor. PMDC motor is connected to the wheel of the motor. The IR sensor is connected near wheel of the hybrid electric vehicle which senses the speed of the electric vehicle and PWM is generated according to the speed of the motor and it controls the speed of the motor. The control on the motor (PMDC) is processed through the motor controller which give electronic commutation to the speed of the motor. The speed of the motor is derived using the electronic throttle (accelerator). Through the accelerator the current is reached in the H- bridge configuration and it apply the triggering pulses at the gate terminal of the MOSFETs (H- bridge configuration) controller circuit. When the battery get discharged (battery voltage is less than 11V) solar panel/ plug in starts charging the battery. Charge controller is used to select the mode of charging. When the solar energy is available is will charge the battery using solar panel and when solar energy is not available is will charged through plug in. Charge controller regulates the current from the main energy source and auxiliary energy source and fed the power into the battery.

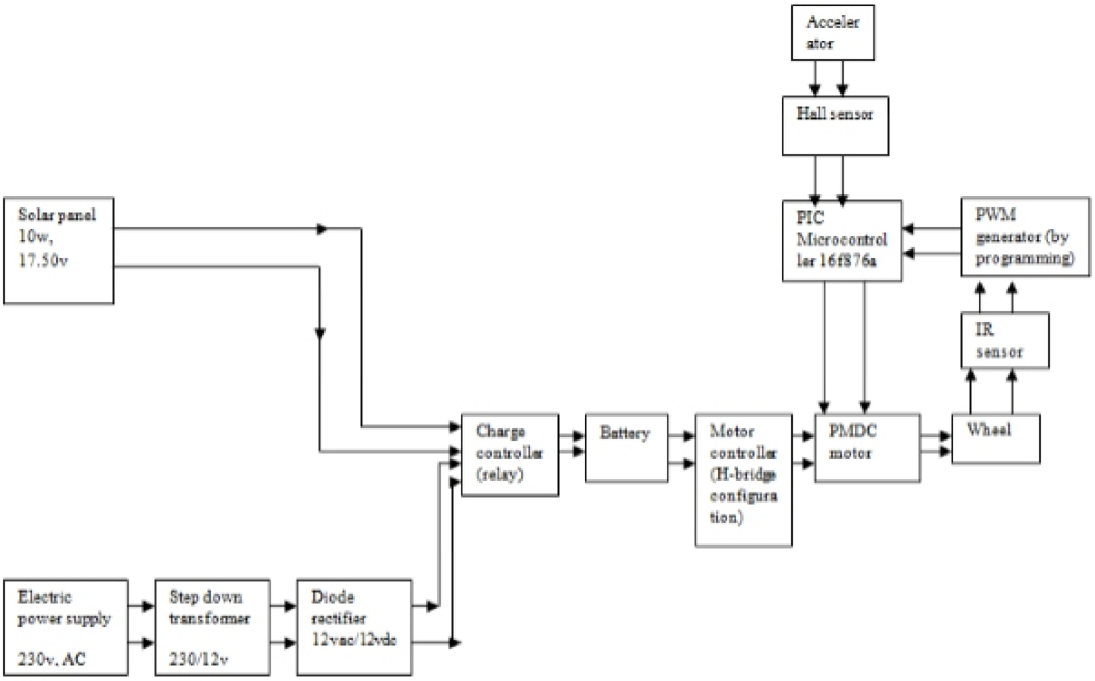

Figure 1: Overall Design of System Configuration

4. Hardware Implementation

The hardware implementation of proposed solar/electric hybrid vehicle's working model is shown in fig. 2, fig. 3 and fig. 4.

Figure 2: Hardware implementation of working model

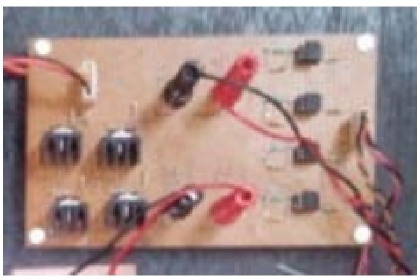

Figure 3: Connections of MOSFETs with battery and motor

Figure 4: Close view of circuit connections of working model

In order to confirm the benefits of the proposed system, an experimental prototype for an hybrid electric vehicle is developed. As shown in figure, the solar panel with a rating of 10w is connected to the working model of hybrid electric vehicle. In the actual hybrid electric vehicle we can place solar panel on the top of the vehicle to seize the solar energy and then control it with charge controller. During sunless condition, the battery is charged from household supply of 230V by converting it into 12V with the help of step- down transformer and with the help of rectifier circuit 12V a.c. supply is converted into 12V d.c. supply to charge the battery. The battery is charged always from the solar panel and it provides power to drive the wheel of the working model. Four N-channels MOSFET are used in circuit to drive D.C. motor. The MOSFETs are connected in the H-bridge configuration to drive the D.C. motor. To derive the motor in forward direction two MOSFETs are connected in positive to negative direction and to derive the motor in reverse direction remaining two MOSFETs are connected in negative to positive direction. The PWM signals are generated using programming in c language and that programming is burn into microcontroller 16f876A. The advantage of using microcontroller 16F876A is that it is having inbuilt ADC (analog to digital converter), port A is completely ADC having a capacity of 10bit. The PWM modulation frequency is set to be 5 KHz. The crystal oscillator frequency installed in microcontroller having a value of 3.57MHz. ADC having a capacity of 10 bit means 210 bit equal to 1024. It divides the value into tenth part and its resolution is 5/1024 equal to 0.00482V (maximum voltage of microcontroller is 5V).

5. TEST AND RESULT

For the working model of hybrid electric vehicle, we are using permanent magnet direct current motor (PMDC) having 4 poles, 0.125 horse power at 12V and 50 Hz. During the test, working model is fed through a 220V rectified dc- power supply, with the help of batteries. The battery can also be charged from solar panel having a rating of 10W. During test wheel is rotated at its full speed having a cyclic RMS of 256.9mv and positive duty cycle of 23.1%. Controlled acceleration is achieved by pulse width modulation (PWM) technique with the help of IR sensor placed in front of wheel. The wheel is driven with the help of accelerator and waveforms have been recorded through cathode ray oscilloscope (C.R.O.). Fig. 5 showing the waveform when wheel is at rest means when we are not accelerating the working model of hybrid electric vehicle. This time positive duty cycle is 11.2% and cyclic RMS of 252.7mv. Fig. 6 is showing the waveform on CRO when wheel is rotating at full speed that time positive duty cycle is 23.1% and cyclic RMS is 256.9mv. This time however, control algorithm limit the motor's acceleration by imposing pulse width modulation. Therefore, the efficiency and battery life of grid solar hybrid electric vehicles can be improved by using the technique PWM (pulse width modulation) and by using solid state switches like MOSFETs having a capability of limiting current transients.

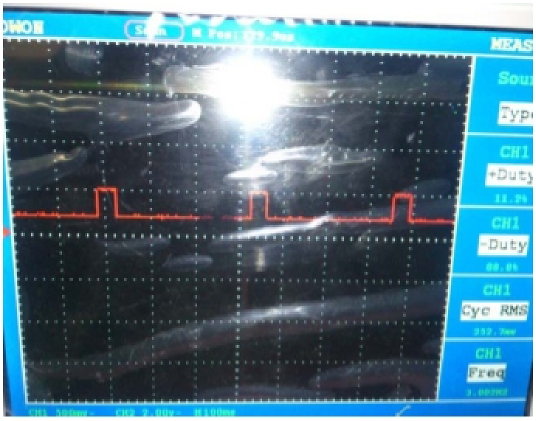

Figure 5: Waveform achieved at zero accelerator

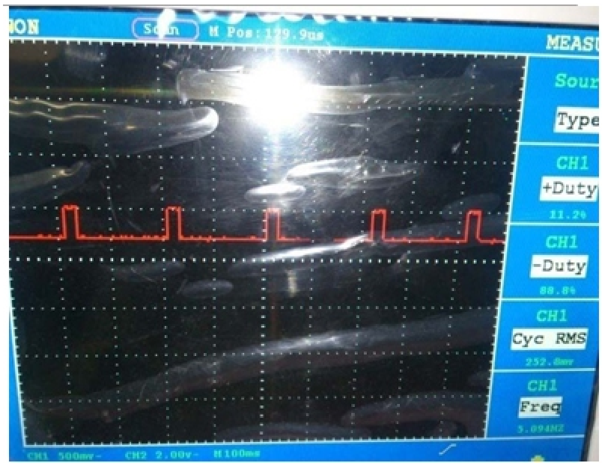

Figure 6: Waveform achieved at full accelerator

6. CONCLUSION

In this paper the working model for grid solar hybrid electric vehicle has been presented. The pulse width modulation speed control method is simple and inexpensive for D.C. motor control, implemented with a microcontroller 16F876A having an inbuilt analog to digital controller. This experimental result shows that hardware implementation of working model design prototype is suitable for actual designing of grid solar hybrid electric vehicle and this design is feasible and reliable for this kind of application. The aim of this project was to demonstrate that grid solar hybrid vehicle could be viable alternative to conventional vehicles and this could help to improve air quality in big cities, through the reduction in carbon dioxide emissions and by using renewable sources of energy (solar energy) we can reduce the world dependence on fossil fuel. The prototype realization is carried out successfully and the results have shown that the speed controller performs a stable and efficient motor control.

7. FUTURE SCOPE

1. Battery technology: battery technology should improve so that vehicle runs more efficiently. Life of battery should increase so that more consumers attract towards the hybrid vehicles with keep in mind that battery does not harm the environment.
2. Simulation software and testing equipment: simulation software like MATLAB and VBB are present to simulate electric vehicles but they are not giving exact result. For this improved simulation software will be design and testing equipment could also be design.
3. Renewable fuels: hybrid electric vehicles running on electricity that is not emitting pollution on the tail pipe but at the time of generation of electricity it is emitting pollution at the power stations and at last polluting the environment. So, for this renewable fuels like biodiesel and ethanol should be use.
4. Solar panels: solar panels designing should be improved making it more efficient. Reflecting mirror can be used for absorbing more sunlight so that more electricity will be generate and PV tracking systemcould be used for trapping more energy from sunlight and making vehicle more efficient.

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A New Evolutionary Approach to Power Fluctuations and Voltage Permanence Using SMES

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A B S T R A C T

The paper focuses on the power system oscillations, which has been recognized as one of the major concern in power system operation. Low frequency electromechanical oscillations are inevitable characteristics of power systems and they greatly affect the transmission line transfer capability and power system stability. Traditionally, power system stabilizers are being used to damp these oscillations. Unified power flow controller is a well-known FACTS device that can control power flow in transmission lines. Facts controller mainly used for solving various power system stability control problems. The energy storage devices are much helpful in supplying the instantaneous real power requirement of the system. Amongst the energy storage systems, the Superconducting Magnetic Energy Storage (SMES) system is recent and more research works are carried out to commercialise the same. The analysis is achieved through developing of software program using MATLAB.

Keywords: power fluctuations, Superconducting Magnetic Energy Storage (SMES)

1. INTRODUCTION

The Indian government has a plan of installed generation of 78,000MW by2012. The total demand capacity of India is expected to cross 950,000MW by 2030. By the year 2011- 12, the expected peak demand is 157GW and the per capita energy consumption is going to increase to an amount of 932kWh. With the exploitation of efficiency measures, a reduction in energy demand can be achieved in particular by introducing highly efficient electronic devices using the best available technology in all demand sectors. Flexible AC Transmission System (FACTS) technologies have been introduced recently in India to improve the efficiency of the transmission lines, to improve the quality of the power supply and reduce the cost of energy. Already SVC has been installed at Kanpur (2X±140MVAr), TCSC on Rourkela – Raipur 400kV line (40% fixed and 5 – 15% variable) and Kanpur – Ballabhgargh 400kV line. And many more are in planning level.

According to IEEE, FACTS, is defined as “alternating current transmission systems which incorporate power electronics based and other static controllers to enhance controllability and power transfer capability” . High power electronic devices play an important role in improving grid reliability with the use of energy storage systems, FACTS, distributed energy, and HVDC. The challenge facing the power system engineer today is 4 the usage of existing transmission facilities to a greater effect and efficiency which is very effectively obtained through FACTS technology. FACTS provide proven technical solutions to address new operating challenges which are presented today. The applications of FACTS devices in power systems are in the areas of power flow control, system stability and security enhancement, improving efficiency, power quality and protection.

2. GENERAL SYMBOL OF FACTS CONTROLLER

Storage systems can be used to protect sensitive production equipments from shutdown which is caused by voltage sag or temporary interruptions. These are generally DC storage systems such as UPS, batteries, superconducting magnet energy storage (SMES), storage capacitors or even fly wheels driving DC generators are used. The output of these devices can be supplied to the system through an inverter on a momentary basis by a fast performing electronic switch like GTO or IGBT etc. Sufficient energy is fed to the system to compensate for the energy that would be lost by the fault conditions like voltage sag or interruption.

However there are many different methods to mitigate voltage sags and swells, but the use of a custom Power device is considered to be the most efficient method. Flexible AC Transmission Systems (FACTS) for transmission systems, the term custom power pertains to the use of power electronics controllers in a distribution system, particularly, to deal with a variety of power quality problems. Just as FACTS improves the power transfer capabilities and stability limits, custom power makes sure customers get pre-specified quality and reliability of supply.

There are many types of Custom Power devices like Active Power Filters (APF), Battery Energy Storage Systems (BESS), Distribution static synchronous compensators (DSTATCOM), Dynamic Voltage Restorer (DVR), Surge Arresters (SA), Super conducting Magnetic Energy Systems (SMES), Static Electronic Tap Changers (SETC), Solid- State Transfer Switches (SSTS), Solid State Fault Current Limiter (SSFCL), and unified power quality conditioner (UPQC).

3. SMES

Superconductivity was discovered in 1911. In 1970s SMES was first proposed as an energy storage technology for power systems. SMES systems have fast response and high efficiency. Hence, electric utilities and military are focusing their attention towards SMES system. When compared with other energy storage technologies, SMES systems are costly. However, the integration of an SMES coil into the FACTS devices eliminates the cost for the inverter unit, which is the largest portion of the cost for the entire SMES system. Recently, high temperature superconductors are in the research stage. Such type is cost effective due to the reductions in.

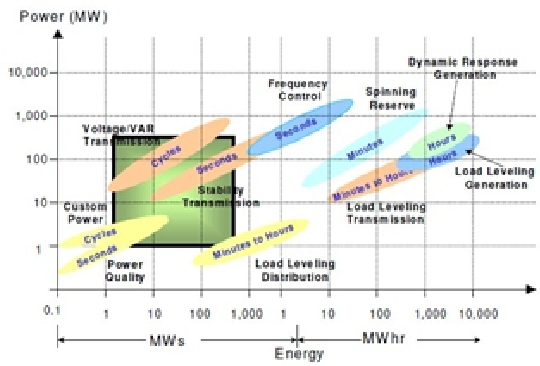
There are a number of ongoing SMES projects currently installed or in development throughout the world. In the SMES system the energy is stored in the magnetic field generated by the dc current flowing through superconducting coil. The inductively stored energy (E in joules) and rated power (P in watts) are the commonly given specifications for SMES devices. The energy and power are expressed as in equation

$$E = \frac{1}{2}LI^2; \quad P = \frac{dE}{dt} = LI\frac{dI}{dt} = VI$$

Where „L" is the inductance of the superconducting coil, „I" is the dc current flowing through the coil and V is the voltage across the coil. The energy is stored as circulating current. The energy can be drawn from an SMES unit with almost instantaneous response with energy stored or delivered over periods ranging from a fraction of a second to several hours. An SMES unit consists of a large superconducting coil at the cryogenic temperature. Figure 3.1 represents the block diagram of the SMES system. The superconducting coil is maintained at cryogenic temperature. This temperature is maintained by a cryostat that contains helium or nitrogen liquid vessels. A power conversion/conditioning system connects the SMES unit to an ac power system and it is used to charge/discharge the coil.

There are two types of power conversion systems. First one uses a Current Source Converter (CSC) to both interface to the ac system and charge/discharge the coil and the second type uses a Voltage Source Converter (SC) to interface to the ac system and a dc-dc chopper to charge/discharge the coil. The VSC and dc-dc chopper share a common dc bus.

The SMES coil is charged or discharged by applying a positive or negative voltage across the superconducting coil. The SMES system enters a standby mode operation when the average voltage across the coil is zero, resulting in a constant average coil current.



Energy and power Density (Wh/L –W/L)	Rated Capacity (MW)	Duration (hours)	Cycle Efficiency [%]	Energy Cost [$/kWh]	Power Capacity cost [$/kW]	Life (years)
0.2-2.5 Wh/L, 1000-4000 W/L [5], 0.5-5 Wh/L [8]	0.1-10 [4], [5]	milliseconds – 8 seconds[5]	97+[5], 90 [3],95[6]	1,000-10,000 [5]	200-300 [5], 350 [10]	20+ [5], 30 [6]

Figure 3.1: Block diagram of SMES system

Several factors such as coil configuration, energy capability, structure and operating temperature are taken into account in the design of the coil to achieve the best possible performance of an SMES system at the least cost. A compromise is made between each factor considering the parameters of energy/mass ratio, stray magnetic field and minimizing the losses for a reliable, stable and economic SMES system. The coil configuration can be a solenoid or a toroid.

The solenoid type is simple and cost effective. The operating temperature used for a superconducting device is a compromise between the cost and the operational requirements. An important possibility to reduce costs and increase competitiveness of SMES is the integration into existing FACTS, since this combination eliminates the cost for the inverter unit (part of the PCS), which is typically the largest portion of the cost for the entire SMES system. The development of higher temperature superconductors should also make SMES cost effective due to reductions in refrigeration needs.

4. SIMULATION AND RESULTS

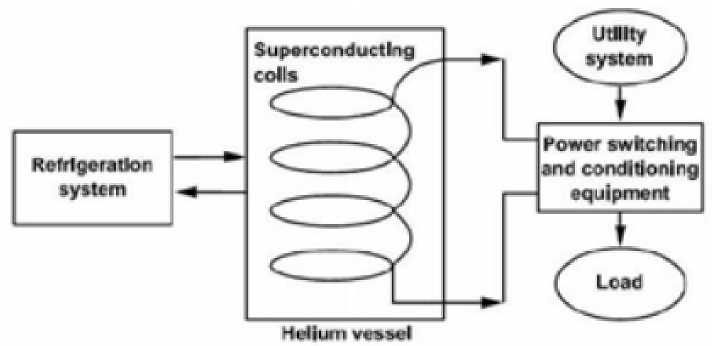


Figure 3.2: Technical/Economic Data

the transmission system. First the system has been simulated in MATLAB/SIMULINK environment. The performance of SSSC is investigated by voltage and current waveforms using simulation. The simulation diagram for SMES is used for controlling the power flow in circuit of SSSC is usually a multi-pulse and/or multilevel configuration.

SMES with two quadrant chopper control plays an important role in real power exchange. SSSC with and without has been developed to improve transient stability performance of the power system. It is inferred from the results that the SSSC with SMES is very efficient in transient stability enhancement and effective in damping power oscillations and to maintain power flow through transmission lines after the disturbances.

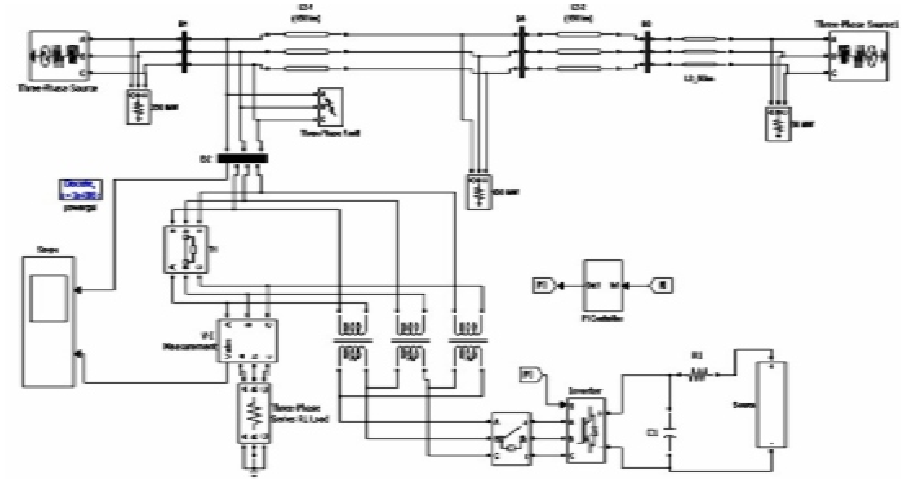


Figure 4.1: Simulation for SMES Power Flow control

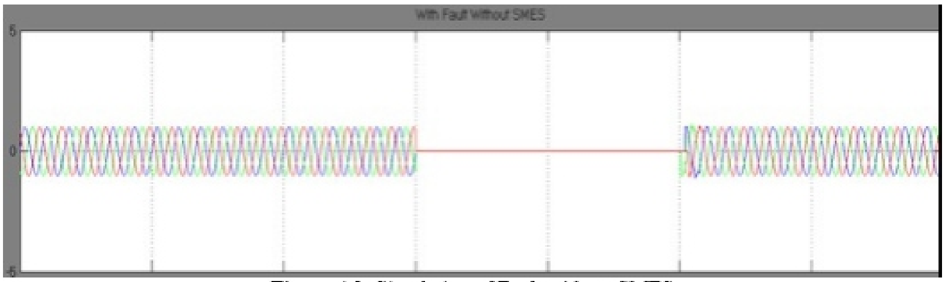


Figure 4.2: Simulation of Fault without SMES

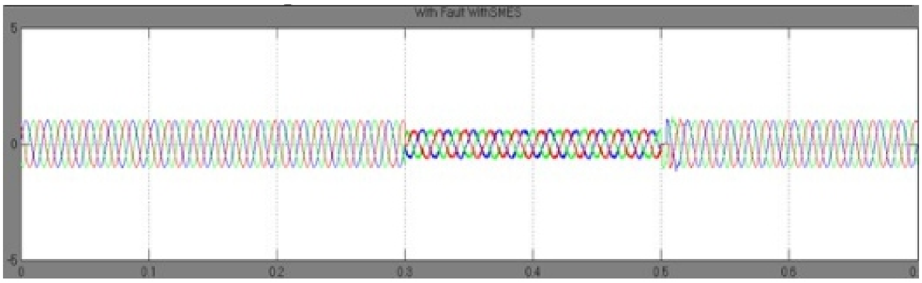


Figure 4.3: Simulation of Fault with SMES

5. CONCLUSION

The availability of electric power with high quality is crucial for the running of the modern society. If some sectors are satisfied with the quality of the power provided by utilities, some others are more demanding. To avoid the huge losses related to PQ problems, the most demanding consumers must take action to prevent the problems. Among the various measures, selection of less sensitive equipment can play an installation of restoring technologies, distributed generation or an interface device to prevent PQ problems. The dynamic performance of the SSSC with and without SMES for the test system are analysed with Matlab/simulink. In this SMES is used to maintain the power flow and to reduce the system damping. Also various FACTS controllers like Static Var Compensator (SVC), Static Synchronous Compensator (STATCOM), Unified Power Flow Controller (UPFC) etc., also to be incorporated likely.

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Music Synthesis using Sinusoid Generator, ADSR Envelope Generator and Composer Code

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ABSTRACT

The ability to synthesize waveforms through digital methods is a popular technique. This method can be found in many applications such as data communications devices (modems), software radios, and DTMF (Touch Tone) generators. One of its most familiar consumer oriented applications is in music synthesis. In this application, the musician often has control over many instruments and sound effects all from a single synthesizer. Waveform synthesis can be taught early in a typical Digital Signal Processing (DSP) course to illustrate some of the applications of sampling and reconstruction theory. In addition hands-on practice with waveform synthesis can be made very interesting in the context of computer music. Two tools used are a tone (sinusoid) generator and an ADSR envelope generator used to shape the amplitude of the tone, i.e. amplitude modulation. The amplitude of the tone can "fit" inside a curve often called the Attack-Decay-Sustain-Release (ADSR) envelope. These two tools form the basis of the project where we can experiment with computer-based music and musical synthesis using MATLAB's built-in sound capabilities and the PC's sound card.

Keywords: music synthesis, dsp, matlab, ADSR

I. INTRODUCTION

The ability to synthesize waveforms through digital methods is a popular technique. This method can be found in many applications such as data communications devices (modems), software radios, and DTMF (Touch Tone) generators. One of its most familiar consumer oriented applications is in music synthesis. In this application, the musician often has control over many instruments and sound effects all from a single synthesizer. Waveform synthesis can be taught early in a typical undergraduate Digital Signal Processing (DSP) course to illustrate some of the applications of sampling and reconstruction theory. In addition hands-on practice with waveform synthesis can be made very interesting in the context of computer music. In this paper we outline a waveform synthesis project in which we code two simple tools in MATLAB. These tools are a tone (sinusoid) generator and an envelope generator used to shape the amplitude of the tone, i.e. amplitude modulation. These two tools form the basis of the project where we can experiment with computer-based music and musical synthesis using MATLAB's built-in sound capabilities and the PC's sound card.

2. IMPLEMENTATION

The implementation of a music synthesizer (AM-based) involves three codes: 1) tone synthesizer or sinusoid generator, 2) ADSR envelope generator, 3) composer/player code. We assume digital synthesis at a rate of fs = 16,000 samples per second. At this rate we are able to reproduce all piano frequencies according to Nyquist theory.

2.1 ADSR Envelope Generation

The sound output of musical instruments does not immediately build up to its full intensity nor does the sound fall to zero intensity instantaneously. It takes a certain amount of time for the sound to build up in intensity and a certain amount of time for the sound to die away. The period of time during which a musical tone is building up to some amplitude (volume) is called the "attack time" and the time required for the tone's intensity to partially die away is called its "decay time." The time for final attenuation is called the "release time." Many instruments allow the user to hold the tone for a period of time which is known as the "sustain time" so that various note durations can be achieved. The amplitude of the tone can "fit" inside a curve often called the Attack-Decay-Sustain-Release (ADSR) envelope.

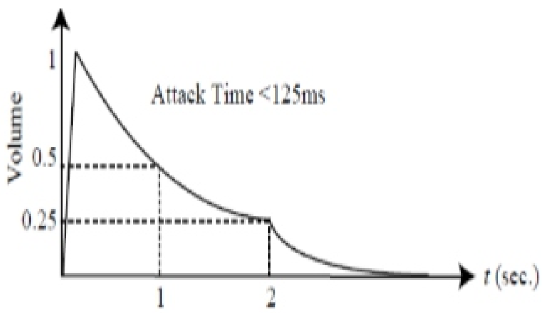
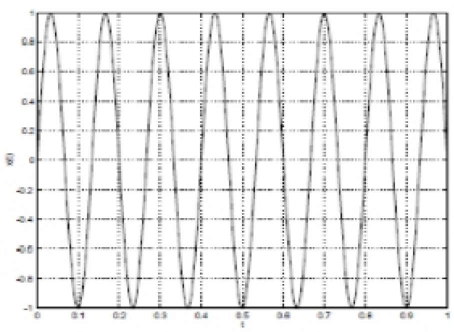


Figure 1: ADSR Envelope for Piano

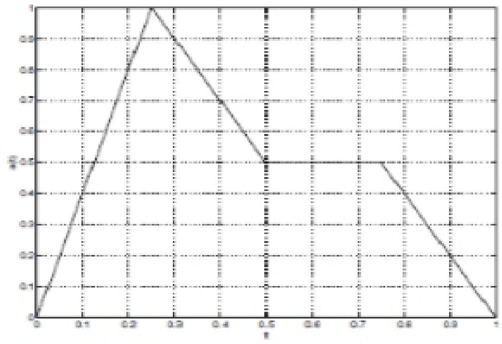
A synthesizer duplicates the intensity (volume) variation of the tone by multiplying (modulating) the amplitude of the sinusoid with a scale factor dictated by the ADSR envelope, a(t)

$$y(t) = a(t) * x(t) \qquad (1)$$

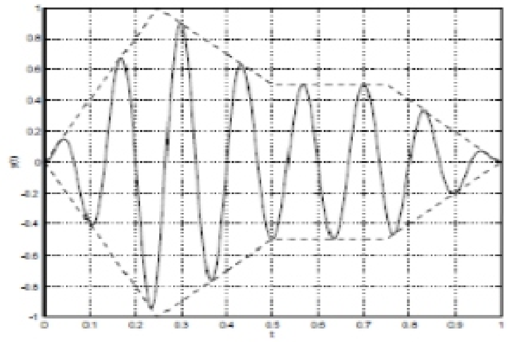
The resulting signal, y(t) is referred to as the amplitude- modulated (AM) tone.



(a)



(b)



(c)

Figure 1: (a) Sinusoid, (b) ADSR envelope, (c) Amplitude modulated (AM) Sinusoid

2.2 Envelope Generator

As described earlier, the envelope will give the sinusoid a volume characteristic which as a first approximation, imitates that of a real instrument. The envelope values are stored as a single vector so that a simple element-by-element product between the sinusoid vector and the envelope vector yields the amplitude modulated sinusoid. The envelope is constructed one segment (A, D, S, and R) at a time. We approximate each segment with a simple exponential which rises or decays asympotically to the target value. This approximation then leads to a simple digital filter implementation (difference equation) which we are familiar with, whose response yields samples of an exponential curve.

In addition, we allow for a gain parameter to control the speed at which the exponential reaches the target value. The difference equation is given by a single-pole filter,

$a(n)=\hat{a}g+(1-g)a(n-1)$

where a(n) are the envelope values, ˆ a is the target value, and g is the gain parameter.

C. Composer/Player Code

The final code segment generates sinusoids with the proper frequency and an ADSR envelope to amplitude modulate the sinusoid.

3. RESULT

3.1 MATLAB Code

Function to generate ADSR envelope

```
function[a]=adsr_gen(target,gain,duration)
fs=16000;
a=zeros(fs,1);
 duration=round(duration./1000.*fs);
 start=2;
stop=duration(1);
%attack phase
 for n=(start:stop)
a(n)=target(1)*gain(1)+(1-gain(1))*a(n-1);
end
%Sustain phase
start=stop+1; stop=start+duration(2);
for n=(start:stop)
a(n)=target(2)*gain(2)+(1-gain(2))*a(n-1);
 end
%Release phase
start=stop + 1; stop=sum(duration);
for n=(start:stop)
a(n)=target(3)*gain(3)+(1-gain(3))*a(n-1);
end
```

B. Function to generate sinusoid

```
function[x]=singen(f,fs,N)
n=(0:N-1);
x=sin(2*pi*f/fs*n);
```

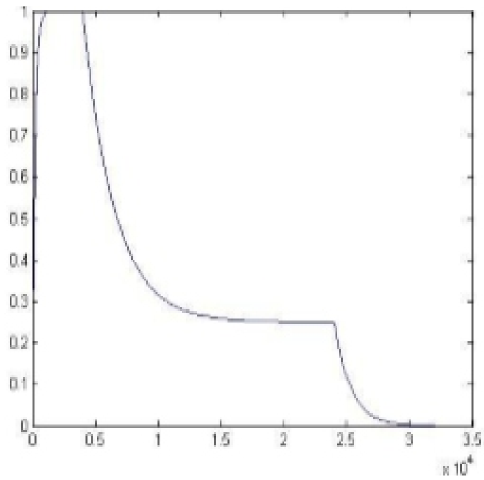
C. Composer/Player code

```
function [] = sound_play(f)
target=[0.99999;0.25;0];
gain=[0.005;0.0004;0.00075];
```

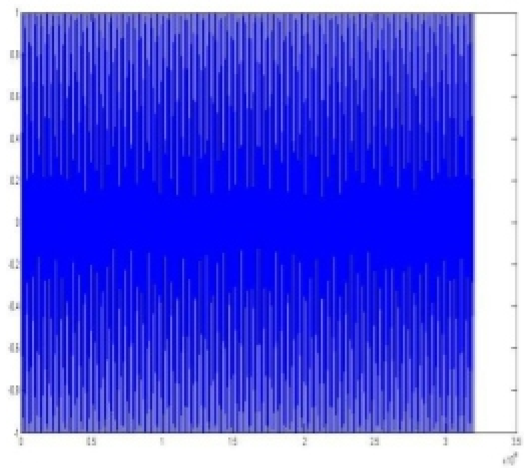
```
duration=[250;1250;500];
fs=16000; tot_dur=floor(sum(duration)/fs);
[adsr]=adsr_gen(target,gain,duration);
figure(1)
plot(adsr); x=singen(f,fs,length(adsr));
 figure(2)
plot(x);
b=adsr.';
y=b.*x; % Modulate wavplay(y,fs);
figure(3)
plot(y);
```

D. Output waveforms

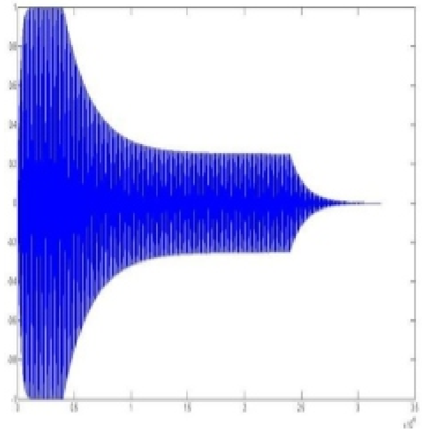
(i.)ADSR envelope



(ii) Sinusoid wave



(iii) AM Modulated signal



4. CONCLUSION

In this paper we have developed an exercise in computer music. The exercise consists of three MATLAB codes which synthesizes a tone (sinusoid), generates an ADSR envelope used to amplitude modulate the tone, and built a song from the modulated tones.

5. FUTURE SCOPE

Since the target application is computer music, the ideas can be extended to more general ideas in waveform synthesis.

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An Experimental Investigation of a Hybrid Home Air Conditioner Using R134a Refrigerant

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A B S T R A C T

Now a day's Air conditioning has become the basic necessity for human comfort from the last decade due to global warming. Innovation in air conditioning technologies continues, with much recent emphasis placed on energy and efficiency. Reducing the power consumption is the main criteria because the cost of electricity is increasing day by day. In most of the air conditioners refrigerants such as R11, R12, R22 etc. are used which contributes depletion of the ozone layer. This thesis proposes that by using low temperature eco friendly refrigerants such as R134a can reduces the cooling time of the room. Experimental results also show the comparison of COP at various loads and different condenser fan speed regulations. In general for a 1 tr room dimensions the load in the equipment is not more than 10000KJ/hr but in our experimental analysis we tested our 1 tr equipment with full load conditions i.e., 12960KJ/hr. Hence proposed system could be a new option for performance improvement of a room air conditioner by enhancing heat transfer of the evaporator and useful for domestic establishments.

Keywords: Cop – Refrigerant – Cooling Capacity – Ton of Refrigeration tr – Dry bulb Temperature – R134a – R22 – Carnot efficiency - Latent heat - Sensible Heat - Relative humidity - Specific humidity - Mass flow rate - volumetric efficiency.

1. INTRODUCTION

Innovation in air conditioning technologies continues, with much recent emphasis placed on energy and efficiency. Reducing the power consumption is the main criteria because the cost of electricity is increasing day by day so we have to reduce the power and coefficient of performance of the system should be increased or maintained the same. Selection of refrigerant is another criterion. Most refrigerants such as R11, R12, R22etc, used for air conditioning contributes depletion of the ozone layer as these refrigerants consists of Chlorine and Carbon atoms. It is very difficult to replace any other refrigerant with the existence product by the companies even though the new refrigerants are eco-friendly. In most countries manufacturing and use of CFCs has been banned or severely restricted due to concerns about ozone depletion.

The present thesis proposes that by using low temperature eco-friendly refrigerants can reduces the cooling time of the room and thereby reducing the power consumption. Working fluid selection for the refrigeration and air conditioning applications is based on three factors: safety (toxicity and flammability), environmental impact (stratospheric ozone), and performance. Considering these three, we used R134a as refrigerant.

Experimental results also shows the preheat of the refrigerant i.e., R134a to 50 C before entering into compressor which gives the maximum coefficient of performance and the comparison of COP at various loads and different condenser fan speed regulations. In general for a 1 tr room dimensions the load in the equipment is not more than 10000KJ/hr but in our experimental analysis we tested our 1 tr equipment with full load conditions i.e., 12960KJ/hr. Hence proposed system could be a new option for performance improvement of a room air conditioner by enhancing heat transfer of the evaporator and useful for domestic establishments.

2. EXPERIMENTAL SETUP

The vapour-compression uses a circulating liquid refrigerant as the medium which absorbs and removes heat from the space to be cooled and subsequently rejects that heat elsewhere. All such systems have four components: a compressor, a condenser, a thermal expansion valve, and an evaporator. Circulating refrigerant enters the compressor in the thermodynamic state known as a saturated vapour and is compressed to a higher pressure, resulting in a higher temperature as well. The hot, compressed vapour is then in the thermodynamic state known as a superheated vapour and it is at a temperature and pressure at which it can be condensed with cooling air. That hot vapour is routed through a condenser where it is cooled and condensed into a liquid by flowing through a coil with cool air flowing across the coil. This is where the circulating refrigerant rejects heat from the system and the rejected heat is carried away by either the air (whichever may be the case).

The condensed liquid refrigerant, in the thermodynamic state known as a saturated liquid, is next routed through an expansion valve where it undergoes an abrupt reduction in pressure. That pressure reduction results in the adiabatic flash evaporation of a part of the liquid refrigerant. The auto- refrigeration effect of the adiabatic flash evaporation lowers the temperature of the liquid and vapour refrigerant mixture to where it is colder than the temperature of the enclosed space to be refrigerated.

Our outdoor unit specifications are compressor – 0.75hp of emerson climate technology's limited model KCJ498HAG having 2.591 × 10-5 m2 displacement and 2800 rpm speed, condenser pipe perimeter 2.5cm condenser pipe length 1.35m condenser fan motor rated speed 1175rpm. We want to know the thermal performance that's why we set the pressure and temperature gauges at suction and discharge of the compressor i.e., at evaporator outlet and condenser inlet respectively. We did 3 regulations of condenser fan speed to determine the optimum speed.

Our indoor unit comprises of capillary tube as expansion device and evaporator coil, blower. We used 0.66'' dia and 5 feet length of capillary. We used napoleon AS- 12c53f150I4 model indoor unit. Mass flow rate of air coming from our evaporator blower is 633.87 kg/hr it is an observed value by using density of air and volume.

We fabricated an insulated cabin having dimensions of 8 × 4 × 8 feets of size and we applied sensible heat through electrical bulbs.

Load calculations for 1tr equipment:

- Dimensions for 1tr AC = 120 sq feet
- Room Dimensions = L × W × (4 × H) considering dimensions = 8 × 4 × 8 feets
- Heat flow due to the conduction (wall): Q = UA (To – Ti)

U = overall heat transfer coefficient To = Outside Temp.

Ti = Inside Temp.

A = Area through which heat is transferred Q = 1.45 × 8.95 × (32 – 19)

Q = 168.7 W Q = 0.168 KW

➢ Heat flow through Window:

➢ Size 4 × 4 Area = 1.218 × 1.218 m2 Q = UA (To – Ti)

U = 5.5 w/m2 k

Q = 5.5 × (1.218 × 1.218) × (32 – 19)

Q = 106.07 W Q = 0.106 W

➢ Heat flow through the door:

Thickness = 3.75 cm

Door size = 76 × 4 feets = 2.59 m2 U = 2.55 W/m2 k

Q = UA (To – Ti)

Q = 2.55 × 2.59 (25 – 19) Q = 39.6 W = 0.0396 KW

➢ Heat flow in bedroom:

➢ Total Heat = 4 occupants + 2 windows + door + 1 TV + 2

➢ Bulbs + 2 Walls + 1 ceiling 1 TV = 100 watts

1 occupants = 0.15 KW for 4 occupants = 0.15 × 4 = 0.6 KW

for 1 window = 0.106 KW door = 0.0396 KW for 1 bulb = 0.2 KW for 1 wall = 0.168 KW

Total Heat = 0.6 + 2 × 0.106 + 0.0396 + 0.100 + 2 × 0.2 + 2

× 0.168 + 0.168

Total Heat = 1.85 KW

➢ Heat flow in Hall:

Total Heat = 6 occupants + 2 bulbs + 1 TV + 1 System + door + 2 windows + 2 walls + 1 ceiling

Total Heat = 6 × 0.150 + 2 × 0.2 + 0.100 + 0.080 +0.0396 + 2

× 0.106 + 2 × 0.168 + 0.168

Total Heat = 2.235 KW

For 1 tr room dimensions we calculated load for hall and bedroom. The maximum load on the equipment for 1 tr room dimensions is not more than 10000 Kj/hr. But we test our equipment with 12960 Kj/hr i.e., full load conditions. We put 18 electrical bulbs of 200 W and each bulb gives 720 KJ/hr heat, the below figures shows our fabricated model.

3. OBSERVATIONS AND RESULTS

We set indoor temp as 19^{0}C

Condenser Fan Speed 1175 rpm, full Load 12960 KJ/hr

Table 3.1: Condenser Fan Speed 1175 rpm, 3/4th Load 10080 KJ/hr

S.No	Time	Outdoor Conditions		Indoor Conditions		Suction temp °C	Discharge Temp °C	Power Consumption		COP	Theoretical Cooling Capacity Tr	Practical Cooling Capacity tr	Mass Flow Rate of refrigerant Kg/min	Volumetric Efficiency of compressor %	Carnot η
		Ambient Temp. (T_{d1}) °C	Relative Humidity (ϕ_1) %	Dry Bulb Temp. (T_{d2}) °C	Relative Humidity (ϕ_2) %			Theoretical Power Watts	Practical power consumption Watts						
1	09:00	28.3	40	29	15	7	42	214	448	5.33	1.276	0.327	0.429	47	7.717
2	10:00	29.5	35	24.6	17	8	46	215	446	6.48	1.728	0.40	0.51	50	7.025
3	11:00	29.7	46	24.4	16	8	48	212	464	6.48	1.29	0.60	0.51	49	7.021
4	12:00	30.2	31	24.4	17	8	48	175	464	6.48	1.8	0.32	0.42	40.5	7.025
5	01:00	30.8	34	23.4	19	8	50	191	480	6.4	1.32	0.35	0.46	44	6.69
6	02:00	33.1	36	25	26	9	50	216	480	6.4	1.72	0.40	0.52	50	6.69
7	03:00	32	30	28	26	9	50	245	480	6.4	1.38	0.45	0.59	46	6.69
8	04:00	30.5	29	30	18	8	50	233	480	6.28	1.26	0.412	0.56	54	7.39
9	05:00	30	30	34	18	6	46	375	464	6.4	1.08	0.68	0.9	86	7.56
10	06:00	29	30	36	18	6	44	493	440	3.87	1.07	0.54	0.74	71	6.05

Table 3.2: Condenser Fan Speed 1175 rpm, 3/4th Load 10080 KJ/hr

S.No	Time	Outdoor Conditions		Indoor Conditions		Suction temp °C	Discharge Temp °C	Power Consumption		COP	Theoretical Cooling Capacity Tr	Practical Cooling Capacity tr	Mass Flow Rate of refrigerant Kg/min	Volumetric Efficiency of compressor %	Carnot η
		Ambient Temp. (T_{d1}) °C	Relative Humidity (ϕ_1) %	Dry Bulb Temp. (T_{d2}) °C	Relative Humidity (ϕ_2) %			Theoretical Power Watts	Practical power consumption Watts						
1	09:00	30.9	50	30	16	8	48	328	448	6.4	1.12	0.60	0.78	65	6.69
2	10:00	30	41	28.9	14	8	50	206	448	6.4	1.4	0.37	0.49	40	6.69
3	11:00	32.4	49	25.4	16	8	48	330	464	6.1	1.2	0.57	0.7	65	6.69
4	12:00	32.5	59	25.4	28	8	48	316	480	6.1	1.42	0.55	0.7	62	6.69
5	01:00	32.5	52	24.3	17	8	50	224	448	6.1	1.72	0.39	0.53	44	6.69
6	02:00	32.7	57	28	20	8	49	229	480	6.1	1.68	0.40	0.55	45	6.69
7	03:00	30.3	44	28.2	15	8	50	282	480	6.1	1.21	0.49	0.67	50	6.69
8	04:00	30	42	28	15	8	50	285	480	6.1	1.29	0.50	0.68	50	6.69
9	05:00	29	40	28	20	8	46	392	464	5.17	1.2	0.57	0.78	60	7.39
10	06:00	28	42	28	20	8	46	338	440	5.17	1.2	0.50	0.6	50	7.39

Table 3.3: Condenser Fan Speed 1175 rpm Load ½ Load 6480 KJ/hr

S.No	Time	Outdoor Conditions		Indoor Conditions		Suction temp °C	Discharge Temp °C	Power Consumption		COP	Theoretical Cooling Capacity Tr	Practical Cooling Capacity tr	Mass Flow Rate of refrigerant Kg/min	Volumetric Efficiency of compressor %	Carnot η
		Ambient Temp. (T_{d1}) °C	Relative Humidity (ϕ_1) %	Dry Bulb Temp. (T_{d2}) °C	Relative Humidity (ϕ_2) %			Theoretical Power Watts	Practical power consumption Watts						
1	09:00	25.8	46	22.9	22	4	42	391	432	5.37	0.589	0.60	0.78	70	7.2
2	10:00	29.4	47	23.3	22	4	44.5	412	432	5.09	0.648	0.60	0.79	71	6.7
3	11:00	29.8	44	21.1	25	5	46	399	432	5.09	0.81	0.60	0.79	71	6.7
4	12:00	29.8	44	20.4	24	4	47	328	432	5.09	0.732	0.47	0.63	61	6.4
5	01:00	30.5	37	20.1	26	4	47	378	448	5.09	0.74	0.55	0.73	70	6.4
6	02:00	31.5	43	20.0	28	4	47	412	456	5.09	0.81	0.60	0.79	76	6.4
7	03:00	32.0	41	19.6	31	4	47	277	440	5.09	0.691	0.45	0.53	50	6.4
8	04:00	29.8	42	19.1	28	3	46	412	432	4.7	0.48	0.55	0.72	70	6.4
9	05:00	27.7	44	18.5	30	3	46	449	424	4.7	0.72	0.60	0.79	76	6.4
10	06:00	29	42	16.8	39	3	46	449	450	4.7	0.648	0.64	0.79	76	6.4

Table 3.4: Condenser Fan Speed 1175 rpm Load 1/4th Load 3600 KJ/hr

S.No	Time	Outdoor Conditions		Indoor Conditions		Suction temp °C	Discharge Temp °C	Power Consumption		COP	Theoretical Cooling Capacity Tr	Practical Cooling Capacity tr	Mass Flow Rate of refrigerant Kg/min	Volumetric Efficiency of compressor %	Carnot η
		Ambient Temp. (T_{d1}) °C	Relative Humidity (ϕ_1) %	Dry Bulb Temp. (T_{d2}) °C	Relative Humidity (ϕ_2) %			Theoretical Power Watts	Practical power consumption Watts						
1	09:00	25.8	82	18.6	77	-1	44	460	412	4.52	0	0.60	0.79	87	6.044
2	10:00	25.9	79	18.6	78	-1	44	484	410	4.52	0	0.62	0.83	91.5	6.044
3	11:00	28.6	78	18.8	75	-1	44	460	410	4.52	0	0.603	0.79	76	6.044
4	12:00	28.7	73	19	72	2	45	431	410	4.46	0	0.55	0.739	80	6.395
5	01:00	28.7	69	18.5	64	2	45	549	415	4.46	0	0.704	0.94	90	6.395
6	02:00	28.6	71	18.6	66	2	45	507	415	4.46	0	0.65	0.869	95.2	6.395
7	03:00	28.3	61	18.6	67	-1	44	519	410	4.54	0	0.67	0.89	98	6.044
8	04:00	27.6	64	18.6	65	-1	44	500	410	4.52	0	0.65	0.85	93	6.044
9	05:00	26.7	70	18.5	73	-1	44	465	410	4.52	0	0.603	0.796	87.7	6.044
10	06:00	26.1	69	18.3	72	-1	44	348	410	4.52	0	0.452	0.596	65.7	6.044

Table 3.5: Condenser Fan Speed 1175 rpm No Load

S.No	Time	Outdoor Conditions		Indoor Conditions		Suction temp °C	Discharge Temp °C	Power Consumption							
		Ambient Temp. (T_{d1}) °c	Relative Humidity (ϕ_1) %	Dry Bulb Temp. (T_{d2}) °c	Relative Humidity (ϕ_2) %			Theoretical Power Watts	Practical power consumption Watts	COP	Theoretical Cooling Capacity Tr	Practical Cooling Capacity tr	Mass Flow Rate of refrigerant Kg/min	Volumetric Efficiency of compressor %	Carnot η
1	09:00	26.1	68	26.1	19.5	5	46	136	432	5.46	0.5	0.25	0.27	26	6.7
2	10:00	27.4	68	19.3	14	5	46	136	432	5.46	0.5	0.25	0.27	26	6.7
3	11:00	27.1	64	18.5	14	5	46	136	432	5.46	0.45	0.30	0.38	37	6.7
4	12:00	30.2	54	22.7	15.5	5	45	194	440	5.46	0.366	0.55	0.71	68	6.7
5	01:00	28.2	56	22	13.9	5	45	356	432	5.46	0.42	0.45	0.55	53	6.7
6	02:00	29.1	56	19	12.8	5	45	277	448	5.46	0.375	0.25	0.32	28	6.7
7	03:00	29	58	20.0	13.9	5	45	162	432	5.18	0.45	0.60	0.77	35	6.7
8	04:00	28	59	19.9	13	5	46	388	432	5.18	0.5	0.25	0.32	31	6.7
9	05:00	27.4	66	22	15.2	5	46	164	432	5.18	0.36	0.30	0.38	37	6.7
10	06:00	25	56	21	12	5	46	194	416	5.18	0.42	0.50	0.64	62	6.7

Table 3.6: Condenser Fan Speed 846 rpm 3/4th Load 10080KJ/hr

S.No	Time	Outdoor Conditions		Indoor Conditions		Suction temp °C	Discharge Temp °C	Power Consumption							
		Ambient Temp. (T_{d1}) °c	Relative Humidity (ϕ_1) %	Dry Bulb Temp. (T_{d2}) °c	Relative Humidity (ϕ_2) %			Theoretical Power Watts	Practical power consumption Watts	COP	Theoretical Cooling Capacity Tr	Practical Cooling Capacity tr	Mass Flow Rate of refrigerant Kg/min	Volumetric Efficiency of compressor %	Carnot η
1	09:00	29.3	41	27.9	26	6	48	469	432	4.47	1.26	0.60	0.78	75	6.6
2	10:00	30.3	34	27.7	21	6	50	339	432	3.60	1.176	0.35	0.47	45	6.3
3	11:00	31.7	35	27.4	19	6	50	488	440	3.60	1.05	0.50	0.68	65	6.3
4	12:00	31	41	27.3	24	6	50	533	440	3.60	0.924	0.55	0.74	71	6.3
5	01:00	31.2	35	28.2	17	6	50	534	440	3.60	1.155	0.55	0.74	71	6.3
6	02:00	30.9	42	26.6	23	6	50	534	438	3.6	1.15	0.55	0.74	71	6.3
7	03:00	29.5	34	28	18	6	50	436	440	3.6	0.945	0.45	0.60	58	6.3
8	04:00	28.5	34	27.6	15	6	48	391	432	4.47	1.2	0.50	0.65	62	6.6
9	05:00	27.6	29	28.5	18	6	48	313	432	4.47	1.68	0.40	0.52	50	6.6
10	06:00	27	36	27	15	6	48	353	432	4.47	1.26	0.45	0.58	56	6.6

Table 3.7: Condenser Fan Speed 846 rpm ½ Load 6480 KJ/hr

S.No	Time	Outdoor Conditions		Indoor Conditions		Suction temp °C	Discharge Temp °C	Power Consumption							
		Ambient Temp. (T_{d1}) °c	Relative Humidity (ϕ_1) %	Dry Bulb Temp. (T_{d2}) °c	Relative Humidity (ϕ_2) %			Theoretical Power Watts	Practical power consumption Watts	COP	Theoretical Cooling Capacity Tr	Practical Cooling Capacity tr	Mass Flow Rate of refrigerant Kg/min	Volumetric Efficiency of compressor %	Carnot η
1	09:00	25.3	48	20.6	27	4	48	352	416	4.8	0.90	0.50	0.6	63	6.29
2	10:00	27.5	49	21	28	4	48	352	424	4.8	0.60	0.50	0.6	65	6.29
3	11:00	27.9	46	20	29	4	48	352	424	4.8	0.48	0.50	0.6	65	6.29
4	12:00	27.8	42	20	27.5	4	48	316	424	4.8	0.40	0.45	0.59	57	6.29
5	01:00	28	39	19.8	28	4	48	387	424	4.8	0.60	0.55	0.72	69	6.29
6	02:00	28.7	39	20	29	4	48	383	424	4.1	0.7	0.45	0.59	56	6.69
7	03:00	28.3	39	19.8	31	4	48	352	424	4.8	0.5	0.50	0.66	60	6.29
8	04:00	26.6	39	19.2	29	4	48	277	416	4.1	0.4	0.40	0.52	50	6.29
9	05:00	24.9	40	18.9	31	4	48	211	416	4.1	0.25	0.30	0.39	38	6.29
10	06:00	25	41	19	35	4	48	246	416	4.8	0.41	0.35	0.46	44	6.29

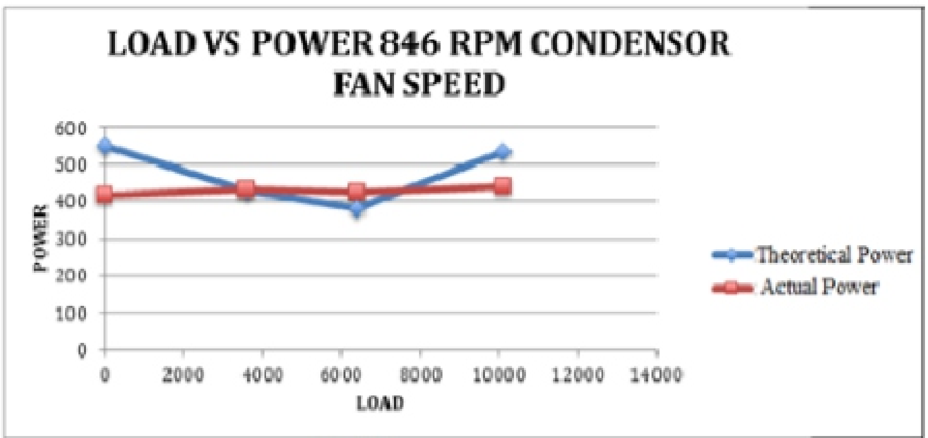
Table 3.8: Condenser Fan Speed 846 rpm 1/4th Load 3600 KJ/hr

S.No	Time	Outdoor Conditions		Indoor Conditions		Suction temp °C	Discharge Temp °C	Power Consumption		COP	Theoretical Cooling Capacity Tr	Practical Cooling Capacity tr	Mass Flow Rate of refrigerant Kg/min	Volumetric Efficiency of compressor %	Carnot η
		Ambient Temp. (T_{d1}) °C	Relative Humidity (ϕ_1) %	Dry Bulb Temp. (T_{d2}) °C	Relative Humidity (ϕ_2) %			Theoretical Power Watts	Practical power consumption Watts						
1	09:00	25.7	65	19.5	56	3	46	206	432	5.08	0.90	0.30	0.38	37	6.41
2	10:00	26.9	54	20.6	47	3	46	206	424	5.08	0.60	0.30	0.36	37	6.41
3	11:00	28.6	50	21.9	44	3	46	274	428	5.08	0.48	0.40	0.5	49	6.41
4	12:00	27.6	51	21.5	38	4	47	430	432	5.18	0.40	0.60	0.8	77	6.18
5	01:00	28.2	51	19.3	41	4	47	274	440	5.18	0.60	0.40	0.5	49	6.41
6	02:00	27.5	49	19.9	46	4	47	251	456	5.18	0.70	0.35	0.47	45	6.18
7	03:00	27.8	48	19.5	47	4	47	179	424	5.18	0.50	0.25	0.33	31	6.18
8	04:00	26.6	53	20.5	43	3	46	274	424	5.18	0.40	0.4	0.5	49	6.41
9	05:00	24.4	48	20.3	34	3	46	171	416	5.18	0.25	0.25	0.32	30	6.18
10	06:00	22.7	56	20	43	3	46	377	416	5.18	0.41	0.55	0.70	69	6.18

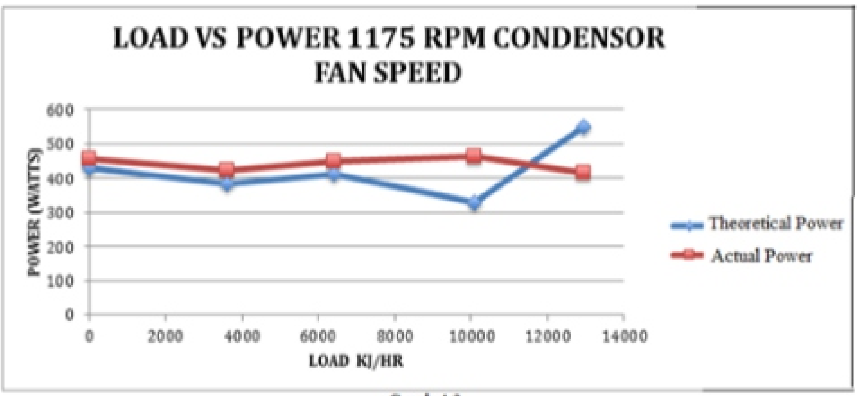
Table 3.9: Condenser Fan Speed 846 rpm No Load

S.No	Time	Outdoor Conditions		Indoor Conditions		Suction temp °C	Discharge Temp °C	Power Consumption		COP	Theoretical Cooling Capacity Tr	Practical Cooling Capacity tr	Mass Flow Rate of refrigerant Kg/min	Volumetric Efficiency of compressor %	Carnot η
		Ambient Temp. (T_{d1}) °C	Relative Humidity (ϕ_1) %	Dry Bulb Temp. (T_{d2}) °C	Relative Humidity (ϕ_2) %			Theoretical Power Watts	Practical power consumption Watts						
1	09:00	25.8	82	18.6	77	-1	44	460	412	4.52	0	0.60	0.79	87	6.044
2	10:00	25.9	79	18.6	78	-1	44	484	410	4.52	0	0.62	0.83	91.5	6.044
3	11:00	28.6	78	18.8	75	-1	44	460	410	4.52	0	0.603	0.79	76	6.044
4	12:00	28.7	73	19	72	2	45	431	410	4.46	0	0.55	0.739	80	6.395
5	01:00	28.7	69	18.5	64	2	45	549	415	4.46	0	0.704	0.94	90	6.395
6	02:00	28.6	71	18.6	66	2	45	507	415	4.46	0	0.65	0.869	95.2	6.395
7	03:00	28.3	61	18.6	67	-1	44	519	410	4.54	0	0.67	0.89	98	6.044
8	04:00	27.6	64	18.6	65	-1	44	500	410	4.52	0	0.65	0.85	93	6.044
9	05:00	26.7	70	18.5	73	-1	44	465	410	4.52	0	0.603	0.796	87.7	6.044
10	06:00	26.1	69	18.3	72	-1	44	348	410	4.52	0	0.452	0.596	65.7	6.044

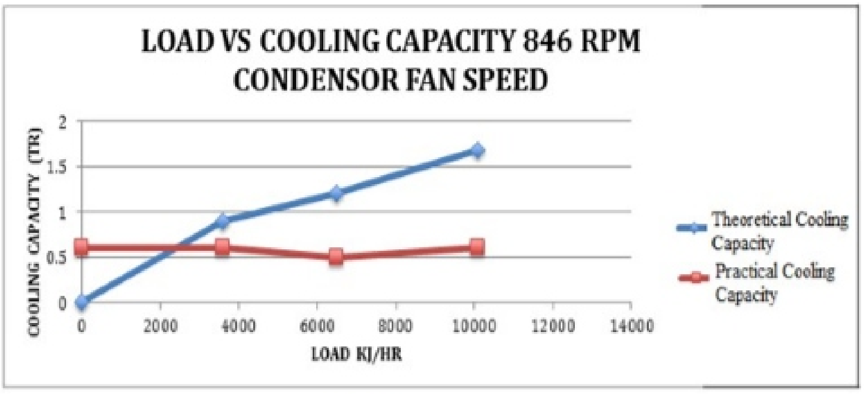
4. GRAPHS



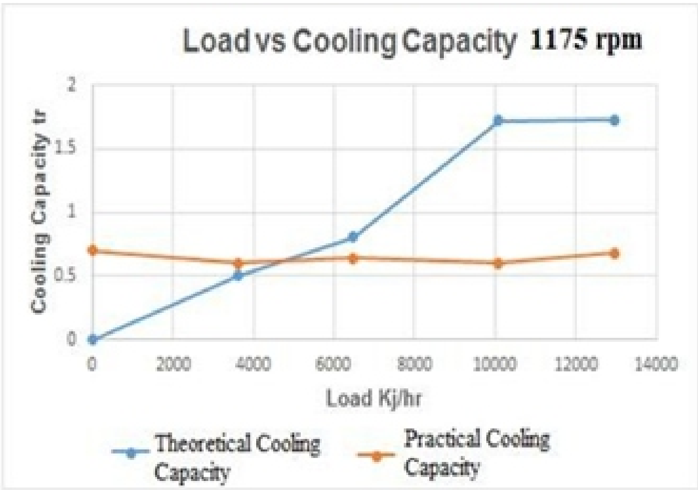
Graph 4.1



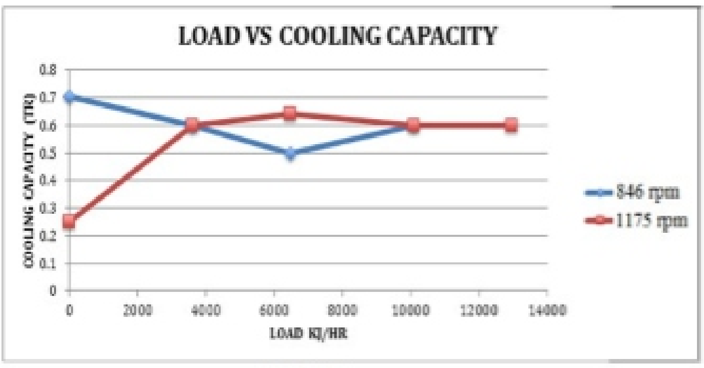
Graph 4.2



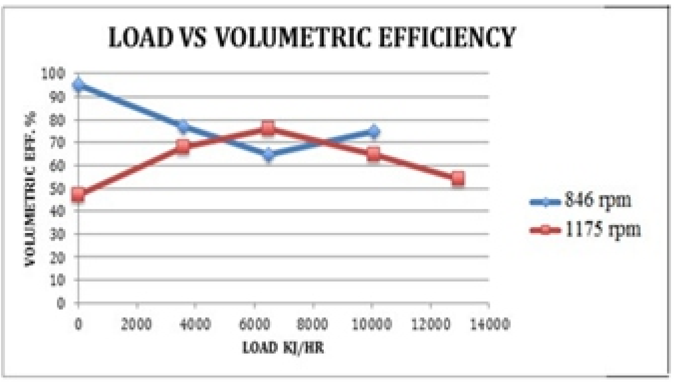
Graph 4.3



Graph 4.4

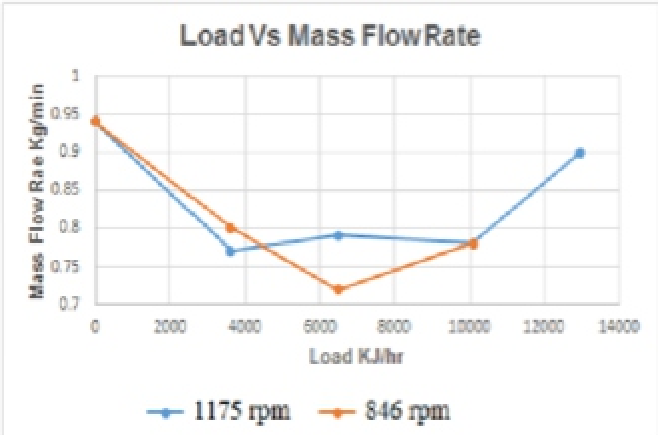


Graph 4.5

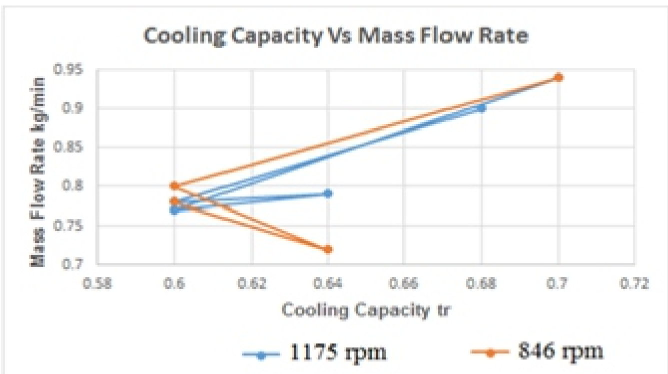


Graph 4.6

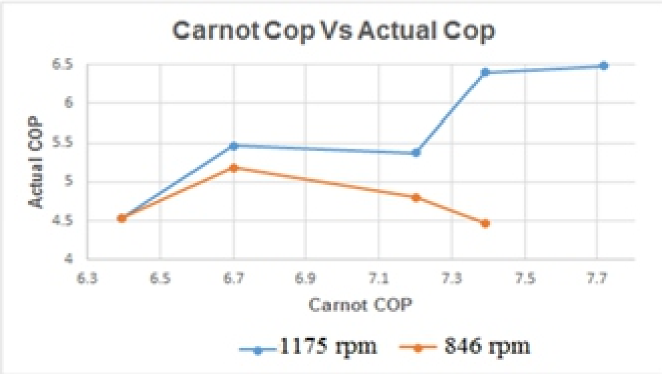
Graph 4.7



Graph 4.8



Graph 4.9



Graph 4.10

5. MODEL CALCULATION

Model Calculations ¾ th load value 1

From Psychometry:

Dry Bulb Temp. Ambient T_{d1}=27.7^{0}C Dry Bulb Temp. Inside the cabin T_{d2}=25.8^{0}C

Relative Humidity Φ_1=32% Relative Humidity Φ_2=26%

Wet bulb Temp. Tw_1=16.10C Wet Bulb Temp. Inside the cabin Tw_2=13.9^{0}C

Specific Humidity ω_1=0.007 KJ/KG of dry air Specific Humidity ω_2=0.005 KJ/KG of dry air

Cooling coil temp. i.e.; Suction temp T_{d6}=2^{0}C From Psychrometry Chart

Bulb Temp. at entry condition of air T_{d3}=26^{0}C By Pass Factor (BPF) =Length 4-6/Length 3-6=0.74Dry

Wet Bulb Temp.at entry condition of air Tw_3=14.5^{0}C

Room sensible Heat=10080 KJ/HR Room Latent Heat=504 KJ/HR

Room Sensible Heat Factor=R.S.H/R.S.H+L.S.H=0.95 from B.P.F=T_{d4}-T_{d6}/ T_{d3}-T_{d6}

DBT at exit condition of air=T_{d4}=19.2^{0}C WBT at exit condition of air Tw_4=12^{0}C

From Psychrometry Chart:

h_1=46 KJ/KG h_2=39 KJ/KG h_3=41 KJ/KG

h_4=34 KJ/KG h_5=20 KJ/KG h_6=13 KJ/KG

Total Mass of air flowing M_4=

Room Latent Heat/h^2-h_4=10584/39-34=2116.8 KJ/HR

Mass of fresh air m_r=5% of m_a=105.84 KG/HR

Theoretical Cooling Capacity= Practical Cooling Capacity=

Q=m_a(h_3-h_4)/ 60x120=1.17 tr Q=m_a(h_3-h_4)/60x210=0.35 tr

From Refrigerant Properties:-

$COP = h_1 - h_{f3} / h_2 - h_1 = 5$

$Q_{practical} = m_r(h_1 - h_{f3})/210$ mass flow of refrigherant mr=0.49 KG/MIN

Theoretical Power Consumption $P = m_r(h_2 - h_1)/60 = 245$ watts

Volumetric Efficiency of Compressor $\eta_v = m_r x V_1$/Displacement X $_{speed}$ = m_r x $V_1/2.591x10^{-5}x2800$ $0.49x0.07/2.591x10^{-5}x2800 = 47\%$

Carnot Efficiency $\eta_{carnot} = T_1/T_2 - T_1 = 6.25$

6. CONCLUSION

Experimental test have been carried out to investigate the performance improvement of room AC. For experimentation we have used R134a refrigerant which is eco-friendly and the properties of R-134a will satisfies the requirements of AC. Experiment were carried out at different load and at different condenser fan speed to investigate the performance of the room AC. The following conclusions were drawn based on experimental results.

1) Experimental results show that, at the 3/4th load we got the maximum cop of 6.4 which is very closer to the carnot cop.
2) We achieved the better cooling capacity of 0.7 tr at the utmost $3/4^{th}$ load.
3) The volumetric efficiency of the compressor is in between 75 % - 90% at all loads which is a better indication of working of a compressor and therefore the power consumption is just above 130 watts at the maximum load i.e., $3/4^{th}$ Load.
4) Experimental results shows that the cop of the refrigeration system is increasing with the load which indicates the rate of cooling capacity is also increasing proportionately with load.
5) Since the rate of cooling capacity in the conditioned space is high therefore the power consumption decreases per unit cooling.

From the results R134a achieves the required room temperature in very fast manner. It is very good advantage in R134a room AC.

Government of India and Supreme Court has ordered to replace the present refrigerant R22 because of ozone depletion. Based on our results we concluded that R134a is best alternative for R12 and it achieves all the properties of R22. So R134a becomes one of the alternatives in future. R22 refrigerant is a single hydrochlorofluorocarbon (HCFC) compound that contains hydrogen, chlorine, fluorine and carbon. R134 refrigerant is a single hydrofluorocarbon (HFC) refrigerant that contains hydrogen, fluorine and carbon. It does not contain chlorine, which makes it more environmentally-friendly than R22 refrigerant. R22 is less stable than R134 because, when the hydrogen compound breaks down in the atmosphere, it releases chlorine before it reaches the stratosphere. The chlorine then reacts with the oxygen molecules in the ozone to create new molecules that result in ozone depletion.

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