ISSN Application No. 21772

Journal of Advances in Electronic and Electric Engineering

Volume No. 12

Issue No. 2

May - August 2024

ENRICHED PUBLICATIONS PVT.LTD

JE - 18,Gupta Colony, Khirki Extn,
Malviya Nagar, New Delhi - 110017.
E- Mail: info@enrichedpublication.com
Phone :- +91-8877340707

ISSN Application No. 21772

Journal of Advances in Electronic and Electric Engineering

Aims and Scope

Advances in Electronic and Electric Engineering is a Journal that publishes original research papers in the fields of electronics and electrical engineering and the recent advances in these fields. It is open to all researchers from all kind of universities and organizations across the globe and aimed at the increasing important area of electronic and electrical engineering. The Journal policy is to publish high quality original scientific articles and reviews with permission from the Editorial Board. Papers must be written in English. They must not have been previously published and should not be under consideration for publication elsewhere. The principal aim of the journal is to bring together the latest research and development in various fields of science and technology such as electrical engineering, electrotechnics, electric machines modeling and design, control of electric drive systems, non-conventional energy conversion, sensors, electronics, communications, data transmission, energy converters, transducers modeling and design, electro-physics, nanotechnology, computer science, artificial intelligence, pattern recognition, knowledge engineering, process control theory and applications, distributed systems, computer networks and software engineering

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Interest Target Object Detection using Radio Frequency Identification (RFID) Technology

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ABSTRACT

RFID (radio frequency identification) is a technology that incorporates the use of electromagnetic or electrostatic coupling in the radio frequency (RF) portion of the electromagnetic spectrum to uniquely identify an object, animal, or person. RFID is coming into increasing use in industry as an alternative to the bar code. The advantage of RFID is that it does not require direct contact or line-of-sight scanning. An RFID system consists of three components: an antenna and transceiver (often combined into one reader) and a transponder (the tag). The antenna uses radio frequency waves to transmit a signal that activates the transponder. When activated, the tag transmits data back to the antenna. The data is used to notify a programmable logic controller that an action should occur. In this paper we are discussing the Radio frequency identification RFID technology as a solution to a problem in industry and other fields. This problem is detecting the position of objects with respect to a reference point (Target detection). In this work, it is needed basic skills in programming using Visual basic at the beginning, then C#. It is also required to know how to deal with database and connect it with C# using SQL Server. We required to make user requirement analysis in making the graphical user interface of this project. We needed to learn about different types of motors and their different operations. We needed also basic knowledge about antennas. All these problems were discussed the solution and the results with all the applications has been given.

Keywords: Radio Frequency Identification, RFID, Object detection, motor, database.

1. INTRODUCTION

1.1. Radio Frequency Identification (RFID) technology

Radio-frequency identification (RFID) uses electromagnetic fields to automatically identify and track tags attached to objects. The tags contain electronically stored information. Passive tags collect energy from a nearby RFID reader's interrogating radio waves. Active tags have a local power source such as a battery and may operate at hundreds of meters from the RFID reader. Unlike a barcode, the tag need not be within the line of sight of the reader, so it may be embedded in the tracked object. RFID is one method for Automatic Identification and Data Capture (AIDC).

RFID tags are used in many industries, for example, an RFID tag attached to an automobile during production can be used to track its progress through the assembly line; RFID-tagged pharmaceuticals can be tracked through warehouses; and implanting RFID microchips in livestock and pets allows positive identification of animals.

1.2. Tags

A radio-frequency identification system uses tags, or labels attached to the objects to be identified. Two-way radio transmitter-receivers called interrogators or readers send a signal to the tag and read its response. RFID tags can be either passive, active or battery-assisted passive. An active tag has an on-board battery and periodically transmits its ID signal. A battery-assisted passive (BAP) has a small battery on board and is activated when in the presence of an RFID reader. A passive tag is cheaper and smaller because it has no battery; instead, the tag uses the radio energy transmitted by the reader. However, to operate a passive tag, it must be illuminated with a power level roughly a thousand times stronger than for signal transmission. That makes a difference in interference and in exposure to radiation.

Tags may either be read-only, having a factory-assigned serial number that is used as a key into a database, or may be read/write, where object-specific data can be written into the tag by the system user. Field programmable tags may be write-once, read-multiple; "blank" tags may be written with an electronic product code by the user.

RFID tags contain at least two parts: an integrated circuit for storing and processing information, modulating and demodulating a radio-frequency (RF) signal, collecting DC power from the incident reader signal, and other specialized functions; and an antenna for receiving and transmitting the signal. The tag information is stored in a non-volatilememory. The RFID tag includes either fixed or programmable logic for processing the transmission and sensor data, respectively.

An RFID reader transmits an encoded radio signal to interrogate the tag. The RFID tag receives the message and then responds with its identification and other information. This may be only a unique tag serial number, or may be product-related information such as a stock number, lot or batch number, production date, or other specific information. Since tags have individual serial numbers, the RFID system design can discriminate among several tags that might be within the range of the RFID reader and read them simultaneously.

Since RFID tags can be attached to cash, clothing, and possessions, or implanted in animals and people, the possibility of reading personally-linked information without consent has raised serious privacy concerns. These concerns resulted in standard specifications development addressing privacy and security issues

1.3. Readers

RFID systems can be classified by the type of tag and reader. A Passive Reader Active Tag (PRAT) system has a passive reader which only receives radio signals from active tags (battery operated, transmit only). The reception range of a PRAT system reader can be adjusted from 1–2,000 feet (0–600 m), allowing flexibility in applications such as asset protection and supervision.

An Active Reader Passive Tag (ARPT) system has an active reader, which transmits interrogator signals and also receives authentication replies from passive tags.

An Active Reader Active Tag (ARAT) system uses active tags awoken with an interrogator signal from the active reader. A variation of this system could also use a Battery-Assisted Passive (BAP) tag which acts like a passive tag but has a small battery to power the tag's return reporting signal. Fixed readers are set up to create a specific interrogation zone which can be tightly controlled. This allows a highly defined reading area for when tags go in and out of the interrogation zone. Mobile readers may be hand-held or mounted on carts or vehicles.

2. RFID METHODOLOGY

2.1. Method

Radio Frequency Identification (RFID) is one of the most exciting technologies that revolutionize the working practices by increasing efficiencies, and improving profitability.

It is often presented as a replacement for today's barcodes, but the technology has much greater possibilities, such as the possibility to read the product information at a distance of several meters in addition to, RFID does not rely on the line- of-sight reading that bar code scanning requires to work. RFID system consists of ; Tag chips attached to products carrying identification information, Readers and Tags communicate information between one another via radio waves and finally the Controller connected to the reader can use that information for various purposes.

In this project, we are using the RFID technology in target detection. The target detection is needed in a lot of industrial applications. By making some changes on the readers and tags, the RFID technology can be used in the target detection.

The target detection will be detecting the location of the tag with respect to the reader. We can consider the two perpendicular axes, the abscissa and the ordinates. The reader will be in the origin and the tag is anywhere else. The location is defined by knowing the distance between the origin and the tag, and the angle between two lines: the ordinate, and the line passing between the reader and the tag. By knowing the distance and the angle, the location is detected accurately.

In order to make the RFID reader give us the capability of detecting the location of the tags, the reader antenna should be directional, with a very small beam angle. Since the farther the tag is, the weaker the field strength it receives, therefore, the field strength can be used in measuring the distance, after applying some calibrations to get the relation between the distance and the field strength practically.

To detect the angle, the reader with its antenna will be coupled on a rotating stepper motor with known number of steps. The initial position can be assumed with no constraints. The predicable case is that on the initial position, the reader won't be able to read the tag, as the beam is not directed towards the tag. The motor will be made to rotate until the reader reads the tag. When the reader reads the tag, the interface will display the position of the detected tag.

The angle will be detected by counting the steps that the motor took from the initial position until it stops, and by knowing the angle of the step, the required angle can be calculated. The distance can be known by knowing the field strength. In order to know the field strength, the reader should have a built-in field strength meter, or any later technology that makes the reader able to measure the distance.

2.2. Block diagram of the system

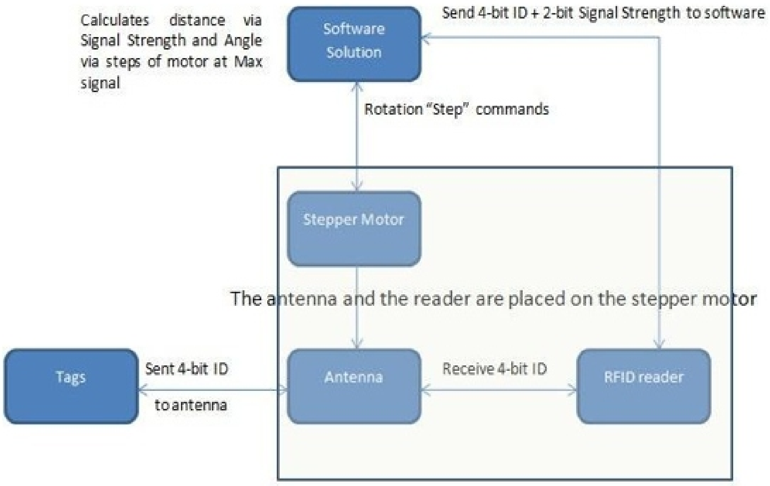
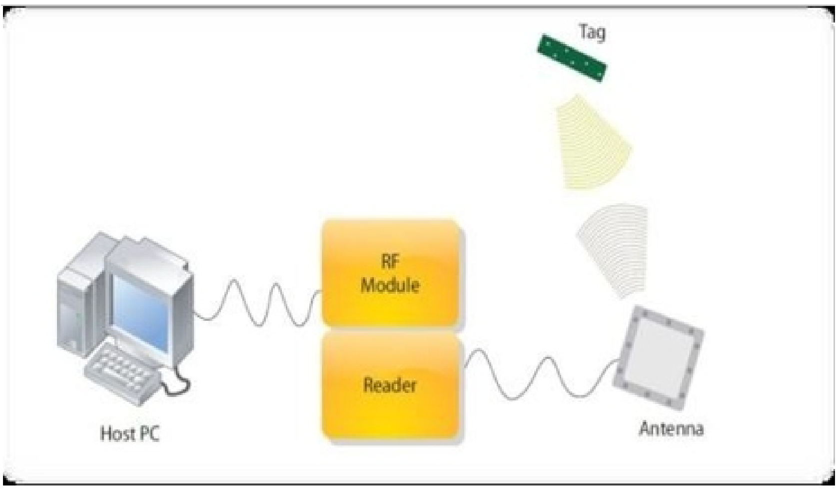


Figure 1: Block diagram of RFID

2.3. Working of RFID

Short for Radio Frequency Identification. The term RFID is used to describe various technologies that use radio waves to automatically identify people or objects. RFID technology is similar to the bar code identification systems we see in retail stores every day; however one big difference between RFID and bar code technology is that RFID does not rely on the line-of-sight reading that bar code scanning requires to work. Basically RFID is a wireless communication system which use RF signal to establish the communication between two ends. RFID system does this communication by using modulated RF signal which is sent between the two main components in the system; the reader and the tag.



2.4. Components of the RFID system

The main components are:

1- RFID Reader
2- RFID Tag or transceiver

Although that physically they are separated but the reader and the tag are inseparable for any applied application. The Reader main function is to read the ID stored in the tag this is done by receiving the modulated signal from the tag. Meanwhile the tag must be placed on the object which needs to be identified like book covers and cloth price tags that is why tags comes in different shapes and sizes in order to cope with the requirements of the application. Tags at least consists of a small antenna and a small silicon chip where data can be processed and stored in. one approach of RFID is that it was built to read one particular kind of tags but recently RFID systems are implemented to read different kinds of tags. RFID readers are also classified into two classes; the first class is the fixed RFID where the reader is fixed during the identification process while the tag is moving. The second class is the mobile RFID where the reader can be moving during the identification process while the tag can be in a stationary position or even moving as well. The two classes are successfully implemented in various numbers of applications by various major electronic manufactures.

2.5. Types of Tags

There are two differentiating factors between Tags

1. According to the on board Power Source
2. According to the Memory type

According to the on Board Power Source, there are three types of tags: 1- Active Tags

2- Passive Tags

3- Semi-Passive Tags

2.6. Advantages of RFID systems

- Reliable system and portable database Easy to use and tags can be simply installed
- Easy way to read tags therefore saving time and effort
- Line of sight is not needed between the reader & the tag unlike barcode system
- Wide reading range, the reader can be up to 10 meters away from the tag
- Anti-collision Identification (multiple access techniques - TDMA/SDMA/FDMA/CDMA)
- Implanted RFID tags
- RFID tags cannot be easily replicated
- RFID tags can stand to harsh environment
- RFID tags can store data up to 2KB
- RFID tags can be rewritable

2.7 Applications of RFID

- Access control in school and universities
- Airport baggage tracking
- Animal Identification and tracking
- Asset tracking
- Automatic vehicle location using RFID (AVL)
- Contactless payment (e-tolling)
- Libraries organization (replacing barcode) Race timing (used in Marathon)

CONCLUSION

An interface between the PC and the stepper motor, and a program that enables us to operate on the motor with the required rotating angle, and the required delay. Simulation to the rotation of the motor in both directions clockwise and anticlockwise. An interface between the RFID reader and the PC and recording the reading results in a database. Simulation of approximated results in detecting the target of the objects, which are the tags, according to the distance and the angle. A demo application of the readers and tags, besides target detection, which can be used in markets (Shopping carts) The RFID can be used as an indicator of objects and can be used in tracking, but not in a fully exact way, and needs development of up to date technology in order to reach full accurate results.

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Maximum Power Tracking for PV Systems

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ABSTRACT

In this paper photo voltaic (PV) electricity is one of the best options for most impartment and ecological future energy requirements of the world. Organic photovoltaic (OPV) cells are hopeful views for common renewable energy unpaid to light weight, low cost, and flexibility. An organic solar cell or organic photovoltaic (OPV) cell is a photovoltaic cell that uses organic electronics-a branch of electronics that deals with conductive organic polymers or small organic molecules for light absorption and charge transport. The plastic used in OPV cells has low production costs in high volumes. Combined with the flexibility of organic molecules, OPV cells are potentially cost-effective for photovoltaic applications. Solar photovoltaic (PV) panels are a great source of renewable energy generation. The biggest problem with solar systems is relatively low efficiency and high cost. In this research work hopes to alleviate this problem by using novel power electronic converter and control designs. An electronic DC/DC converter, called "Quasi- Double-Boost DC/DC Converter," is designed for a Solar PV system. A Maximum Power Point Tracking (MTTP) algorithm is implemented through this converter. This algorithm allows the PV system to work at its highest efficiency. Different current sensing and sensor less technologies used with the converter for the MPPT algorithm are offered and tested. Design aspects of the system and components will be discussed. Results from simulations and experiments will be presented. These results will show that the proposed converter and MPPT control algorithm improves overall PV system efficiency without adding much additional cost.

Keywords : Maximum Power, PV System, MPPT, DC, System Layout, PV panels, I-V Curves, CCM, DCM

1. INTRODUCTION

The past few years have been filled with news of fuel price hikes, oil spills, and concerns of global warming. One of the few positives that can be taken from this is that it is changing the average person's mind set towards renewable energy. People are finding the benefits of having their own renewable energy system more attractive than they ever have before. The biggest form of renewable energy to benefit from this is solar PV systems because of their many merits, such as cleanness and relative lack of noise or movement, as well as their ease of installation and integration when compared to wind turbines. However, the output power of a PV panel is largely determined by the solar irradiation and the temperature of the panel. At a certain weather condition, the output power of a PV panel depends on the terminal voltage of the system. To maximize the power output of the PV system, a high-efficiency, low-cost DC/DC converter with an appropriate maximum power point tracking (MPPT) algorithm is commonly employed to control the terminal voltage of the PV system at optimal values in various solar radiation conditions. There are three main DC/DC converter technologies used with most PV systems(Bernardo, 2009; Morales-Saldana, 2006; Mrabti, 2009; Nabulsi, 2009; Shanthi, 2007).The first of these converters is the buck converter (Bernardo, 2009; Mrabti, 2009). Buck converters are step-down converters that output a voltage lower than the voltage that is input to the converter. The standard buck converter has an output that is equivalent to the input voltage multiplied by the duty cycle or

$$V_{out} = D * V_{in} \text{ ....} 1.1$$

Buck converters work for low voltage applications. They can be implemented in MPPT algorithms (Bernardo, 2009), as long as the PV panels output voltage is greater than the voltage required by the load. To maximize the efficiency of the PV panel from near zero to the maximum output, the entire range of the duty cycle needs to be used for the implementation of the MPPT algorithm. The second commonly used converter in PV systems is a boost converter(Shanthi, 2007). Boost converters are step-up converters that output a voltage higher than the voltage that is input to the converter. The standard boost converter has an output that is equivalent to the input voltage divided by the duty cycle.

$$V_{out}= V_{in} / (1- D) \text{...........} 1.2$$

Basic boost converters work well with the MPPT control as long as the load can accept a voltage from the minimum output of the PV panel all the way up a certain value (e.g., 5 times) subject topractical limits of the duty cycle (e.g., 80%). However, in many applications, a high boost ratio is required for the DC/DC converter to connect the low-voltage PV panel to a relatively high- voltage load or power grid. This cannot be satisfied by using basic boost converters .The third commonly used converter in solar PV systems is a cascaded boost converter (Morales-Saldana, 2006; Nabulsi, 2009). Cascaded boost converters have an output that is equivalent to the input voltage divided by the duty cycle to the nth power, where n refers to the number of boost converters that are cascaded.

$$V_{out} = V_{in} / (1-D)n \qquad 1.3$$

Cascaded boost converters work well in applications that require high voltage boost ratios. One problem with both the boost and the cascaded boost converters is the oscillations and relative instability under changing and startup conditions as shown in (Rensburg, 2008).In order to utilize the potential with any of these converters in a PV system, the converter needs to be controlled by a MPPT algorithm. Various MPPT algorithms (Hua,1998; Hussein, 1995; Koutroulis, 2001; Pan, 1999) have been proposed based on power measurements, including the hill-climbing (HC) method (Koutroulis, 2001), perturb-and observe(P&O) method (Hua, 1998), and incremental conductance (Inc Cond) method(Hussein, 1995). The HC and P&O methods achieve the same fundamental thought indifferent ways (Salas, 2006). These two algorithms are widely used because of their simplicity; however they can fail under rapidly changing atmospheric conditions. The incremental conductance method can track the maximum power point (MPP) more accurately than the HC and P&O algorithms can, however it is relatively complicated to implement. Every addition, converter and MPPT algorithm add additional cost to the entire PV system. However the cost in minimal compared to the PV panels and can usually be offset by improved efficiency. Improving efficiency is the easiest way to cut cost with a PV system. A good MPPT algorithm and a high efficiency converter are a must to improve efficiency but should not be the only changes to the standard setup. One should also employ higher output voltages to lower line losses and allow for more efficient AC conversion. The second easiest way to improve overall system cost is in the components themselves. A higher and more stable line voltage will mean smaller AC inverters with grid tie systems that will not need any boosting capabilities at all. The removal of expensive components such as current sensors also helps to keep cost at a minimum and improves the system reliability. The system needs to be robust enough that when the consumer wants to expand their energy production by adding more panels, they don't need to replace their entire system. The DC/DC converter and MPPT control algorithm proposed in this work will implement all of these improvements in hopes creating a highly efficient, low-cost, and highly reliable solar PV system for clean and renewable power generation.

2. SYSTEM LAYOUT

The overall PV system layout can be seen in Figure 1. The system consists of a PV panel or panels, a quasi-double-boost DC/DC converter, a MPPT control algorithm and some sort of load.

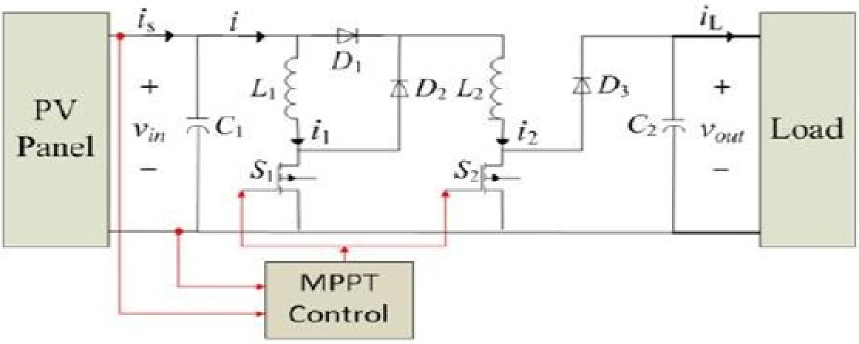

Figure 1.The layout of the overall PV System

2.1. The PV Panel

PV panels generate electricity through what is called the "Photovoltaic Effect"(Wenham, 2009). In the simplest form the Photovoltaic Effect can be described as follows: Light particles called photons are constantly emitted from the Sun. This can be seen by the brightness on a sunny day when many of these particles make it to earth's surface. The effect comes into play when these particles hit a PV material, such as a solar cell. When the photons impact this material it excites the atoms within the material, which causes an electron-hole pair to form. A band gap built into the material causes the electron to move along a certain predefined path. This electron-hole pair creation happens many times over, throughout the panel. All of these flowing electrons generate a current that is directed out of the panel to some type of load. Thus, the photovoltaic effect converts light into the more useful form of power, electricity. Solar cells output power in what is called an I-V curve. A typical I-V curve of a solar cell can be seen in Figure 2 (Wenham, 2009). This curve represents what the current output by the solar cell would be as the output voltage is varied and vise versa. Below the I-V curve, the P-V curve is alsoshown in Figure 2. This curve can be easily obtained from the I-V curve through the equation P = V x I.

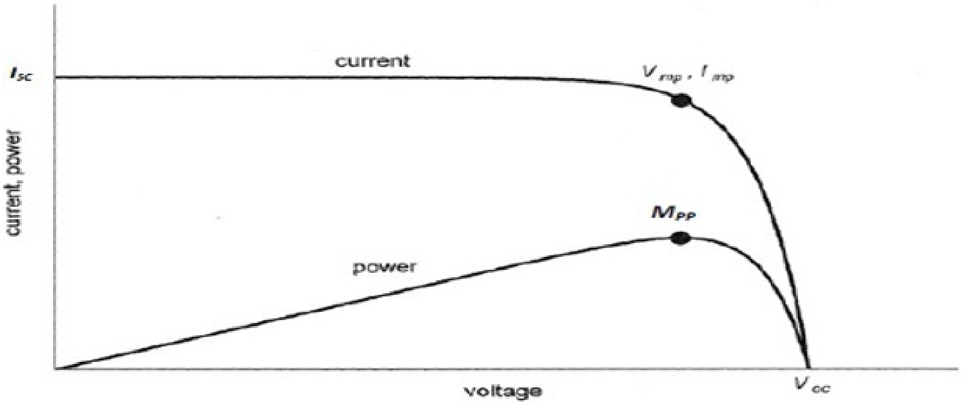

Figure2 : A rep I- V cure for a solar cell showing the MPP

There are three other important aspects of a solar cell also shown in Figure 2.The first two are the open circuit voltage (Voc) and the short circuit current (Isc) of the cell. The open circuit voltage is the voltage that is output to the cell terminals when the cell is exposed to light and there is no current flowing between the terminals. This is also the maximum voltage that can be produced by the cell, which makes knowing this number useful when designing a circuit or load to connect to the cell terminals. The short circuit current is the current that will flow when the cell is under light and the terminals are shorted together. This is the maximum current that can be output by the specific solar cell. The third important aspect of a solar cell is the MPP. This is the point where the cell is operating at maximum efficiency and outputting the highest power available. The MPP also has voltage at maximum power (Vmp) and current at maximum power (Imp) points associated with it. The way these points move and change with the environmental conditions around the cell will be discussed in more detail later.

Each individual cell is relatively little in size and can only produce a small amount of power. The Voc of an individual solar cell is usually approximately 0.6 V(Wenham,2009). The cells become much more useful when combined in an array to create a PV panel. When connected together the cells properties add together to create an I-V curve that has the same appearance as that of an individual cell but is larger in magnitude. The cells in an array are usually connected in series to obtain a higher and more appropriate terminal voltage. The PV panels used in this research are BP Solar model SX 3175 (Appendix 1).Each panel consists of 72 individual solar cells connected in series to obtain a rated power of 175 W, which corresponds to a maximum power current and voltage of 4.85 A and 36.1 V, respectively. The panel has an open circuit voltage of 43.6 V and a short circuit current of 5.3 A.

2.2. Modeling of the PV Panel

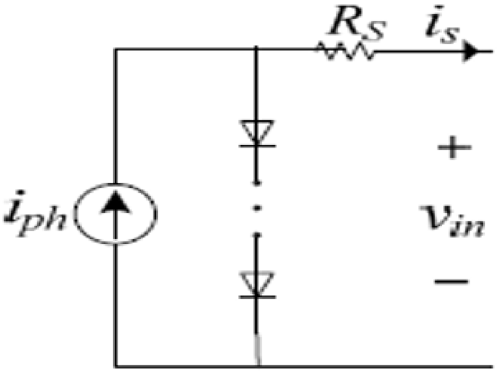

Figure 3: the PV Panel model

A PV panel model is developed using the work in (Tsai, 2008) as a starting point. The panel is modeled as a current source as shown in Figure 3 that follows equation 2-1

$$i = I_{ph} - I_S(T)(\exp\{q(V_{in} + i \cdot R_S)/kTA\} - 1) \quad \text{……….2.1}$$

where i is the PV panel output current; Iph is photocurrent; IS(T) is the reverse saturation current; q (= 1.6×10-19) is an electron charge; Vin is the terminal voltage of the PV panel; RS is the PV panel series resistance; A is the ideal factor of the PN junction of the PV diode, which varies in the range of [1, 2]; and k (= 1.38×10-23J/K) is the Boltzmann constant. The photo current is then found using equation 2-2.

$$I_{ph} = \left[I_{sc} + K_i(T - T_{ref})\right] \cdot \lambda \quad \text{…….2.2}$$

where ISC is the short circuit current provided by the PV panel at a reference temperature and an irradiance of 1kW/m2; Ki (= 3mA/℃) is the temperature coefficient, λ is the solar irradiance in kW/m2; and T and T_{ref} are measured temperature and reference temperature, respectively. The output current is then

$$I_S(T) = I_S(T_{ref})\exp\{K_S(T - T_{ref})\} \quad \text{………….2.3}$$

where IS(Tref) is the reverse saturation current (Tref = 295K) and Ks (≈ 0.072/℃) is the temperature coefficient of the PV panel.

2.3. The Quasi-Double-Boost DC/DC Converter

Many DC/DC converter topologies were considered prior to designing the system. Ultimately a double-boost DC/DC converter (Rensburg, 2008) was chosen because of the requirement for a high voltage regulation ratio (200/28) as well as the converter's output stability over the entire duty cycle range. As shown in Figure 1, the double-boost DC/DC converter consists of two inductors, two switches and three diodes. The boost function is achieved by switching the two switches simultaneously. However, the following analysis reveals that the voltage regulation ratio is not exactly double boost previously derived (Rensburg, 2008).

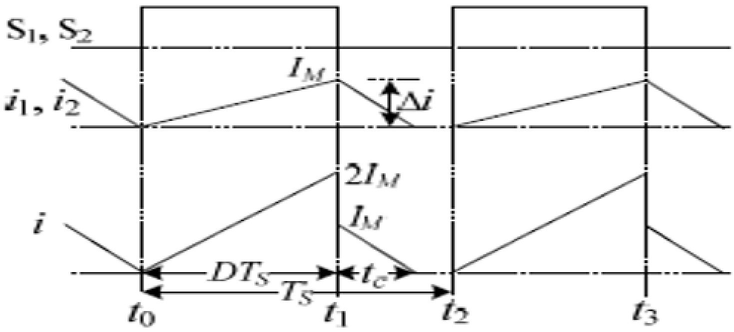

Figure 4.The current waveform in DCM mode.

The converter can work in a continuous current mode (CCM) or a discontinuous current mode (DCM). The DCM is studied since the CCM is a special case of the DCM. The waveforms in the DCM are shown in Figure 4, where S1 and S2 are the gate signals of the two switches; TS and D are the switching period and duty ratio of the DC/DC converter, respectively; tc is the duration that the inductor currents decrease to zero from the maximum value; and IM is the maximum inductor current. Neglecting the ripples of vin and vout, the following formula can be obtained for the switch on and off periods, respectively.

$$I_M = \frac{V_{in} D T_S}{L} \quad \ldots\ldots\ldots 2.4$$

$$V_{in} - V_{out} = -2L\frac{I_M}{t_c} \quad \ldots\ldots\ldots 2.5$$

where L1 = L2 = L; Vin and Vout are the average values of vin and vout, respectively. Then the voltage regulation ratio can be obtained from (2-4) and (2-5) as follows.

$$\frac{V_{out}}{V_{in}} = \frac{2DT + t_c}{t_c} \quad \ldots\ldots\ldots\ldots 2.6$$

The average value of the input current I in a period can be calculated as:

$$I = \left(D + \frac{t_c}{2T_S} \right) I_M$$

……….2.7

According to the power conservation law, Vin*I = Pout, then

$$\frac{V_{out} \times V_{out}}{R} = V_{in}\left(D + \frac{t_c}{2T_S}\right) I_M$$

……2.8

where R is the equivalent resistance of the load. Substituting (2-4) and (2-7) into (2-8), then

$$\frac{D + \frac{t_c}{2T_S}}{\frac{t_c}{2T_S} \times \frac{t_c}{2T_S}} = \frac{D \cdot T_S \cdot R}{L}$$

……2.9

The conduction time tc can be derived from (2-9).

$$t_c = \frac{1 + \sqrt{1 + 4D^2 T_S \left(\frac{R}{L}\right)}}{D\left(\frac{R}{L}\right)}$$

……. 2.10

Equation (2-10) indicates that the conduction time during the switch off period is related with R, L, T, and D. The following formula can be obtained by substituting (2-10)into (2-6).

$$\frac{V_{out}}{V_{in}} = \frac{1 + \sqrt{1 + 4D^2 T_S \left(\frac{R}{L}\right)}}{2}$$

……… 2.11

Equation (2-11) indicates that in the DCM, the voltage ratio is not only determined by the duty ratio, but also determined by the output current and the inductance value. If the equivalent load resistance varies from time to time, the duty ratio should be changed to sustain the desired voltage gain.

When tc = (1−D) TS, the converter works in the critical mode, substituting tcinto(2-9), then the critical inductance LC is:

$$L_C = \frac{D(1-D)^2}{(1+D)} \cdot \frac{RT_S}{2}$$

------2.12

Equation (2-12) indicates that the critical inductance depends on the duty cycle and load. Equation (2-12) also indicates that there exist a supremum (i.e., the least upper bound) value LM such that for any L > LM, the circuit will work in the CCM for any duty ratios. This unique maximal critical inductance can be derived by setting the first derivative of LC with respect to D as zero.

$$\frac{\partial L_C}{\partial D} = 0$$

………. 2.13

Then

$$L_M = 0.113 \cdot \frac{RT}{2} \quad \text{…..2.14}$$

Therefore, (2-14) can be used to design the inductor so that the circuit always works in the CCM when the load is fixed. On the other hand, if the inductance is fixed, then there exists a critical duty cycle (DC), when D < DC, the converter works in the DCM; otherwise, the converter works in the CCM, in which (2-6) can be further simplified as:

$$\frac{V_{out}}{V_{in}} = \frac{1+D}{1-D} \quad \text{…..2.15}$$

Equation (2-15) indicates that the voltage regulation ratio is not simply twice that of the basic boost converter as claimed in (Rensburg, 2008). Thus, the original double-boost converter named in (Rensburg, 2008) is called the quasi-double-boost converter from here on.

3. THE MAXIMUM POWER POINT TRACKING ALGORITHM

The P&O algorithm is a relatively simple yet powerful method for MPPT. The algorithm is an iteration based approach to MPPT (Salas, 2006). A flowchart of the method can be seen in Figure 5.The first step in the P&O algorithm is to sense the current and voltage presently being output by the PV panel and use these values to calculate the power being output by the panel. The algorithm then compares the current power against the power from the previous iteration that has been stored in memory. If the algorithm is just in the first iteration the current power will be compared against some constant placed in the algorithm during programming. The system compares the difference between current and previous powers against a predefined constant.

This constant is placed within the algorithm to ensure that when the method has found the MPP of the PV panel, the duty cycle will remain constant until the conditions change enough to change the location of the MPP. If this step is not included the algorithm would constantly change the duty cycle, causing the operating point of the panel to move back and forth across the MPP. The movement across the MPP is an unwanted oscillation that can be disruptive to power flow and could also cause unwanted loss from not having the operating point right over the MPP at all times. The next step in the algorithm is determining whether the current power is greater than or less than the previous power. The answer to this tells the algorithm which branch of the flowchart to take next. No matter which direction the algorithm takes, the next step is to compare the voltages in the current and previous iterations. The voltage comparison tells the algorithm which side of the MPP the operating point is at thereby allowing the algorithm to adjust the duty cycle in the right direction, either a positive or negative addition to the current duty cycle. The final step of the method is to actually change the duty cycle being output to the converter, and wait for the converter to stabilize before starting the process all over again.

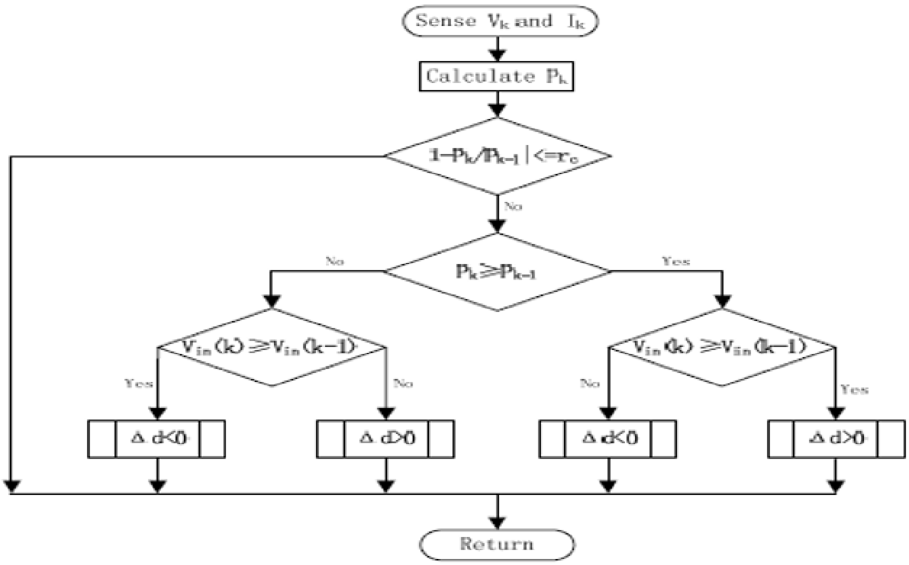

Figure 5.Flowchart

There are multiple ways to try to optimize the P&O algorithm. The first and most important is to choose the constants within the system carefully. The first constant (rc in the flowchart) that tells the algorithm whether or not the MPP has changed, needs to be sized just right. It needs to be big enough to stop the oscillation effect once the MPP has been found but small enough to ensure that the algorithm will move to the correct point when the MPP changes even slightly. Another important constant to optimize is the amount the duty cycle changes (Δd) with each perturb. Thisneeds to be small enough to allow for a sufficient number of steps within the full duty cycle range. It is also important to make this number small enough that when the MPP is reached one change won't be enough to throw it over the MPP causing the same oscillations that were avoided by sizing rc correctly. This also means that the amount of change in the duty cycle should be correlated with the first constant as well as. This all makes it sound as though it would be best to have Δd as small as possible, but this would also cause problems. The system needs to be able to respond to rapid changes in the environment, such as cloud cover. If a cloud suddenly shades part of the panel the algorithm should be able to quickly account for the change in MPP and move the operating point to the new MPP. Having the amount of change in the duty cycle per iteration very small would mean that it would take a great number of iterations to reach the new MPP. Every iteration where the panel is not operating at the MPP can be considered a loss in power. Therefore it is important to have Δd be large enough to allow the algorithm to converge to a new MPP quickly. This shows that there is a large trade off between speed and efficiency with this algorithm. The algorithm in use here increases or decreases the duty cycle by 0.125% per iteration. The last main way to optimize this algorithm is to change the time between when one iteration ends and the next one begins. There needs to be enough time between the iterations to be sure that the converter or panel has reached a steady state after a variation in duty cycle. If there is not enough time the power calculation may be being made from fluctuating voltage and currents. The fluctuations would cause the calculated power to be wrong, which could make the rest of the algorithm change the duty cycle in the wrong direction. Here again careful decisions need to be made though, because if the time between iterations is too long then there will be convergence issues with the system under rapidly changing conditions.

4. RESULTS

Simulation studies are carried out in MATLAB Simulink to validate the converter and MPPT control for a PV system as is presented in Appendix 2.

4.1. Validation of the PV Panel Model

The PV panel model is firstly tested to make sure it is accurate. The results from the first test can be seen in Figure 11. In this test the I-V curves are found after different levels of solar irradiance were applied to the model. It can be seen here that while the voltage remains nearly the same, the current changes greatly with varying irradiance. In the second test, simulations are performed for the PV panel model with different cell temperatures. The results are shown in Figure 7. These results from the model provide a great visual depiction of how small an effect a temperature change has when compared to a change in irradiance, shown in Figure 6.The Quasi-Double-Boost DC/DC Converter. The DC/DC converter is the next part of the system that needs to be tested. The converter tests are preformed with a constant voltage source of 36 volts.

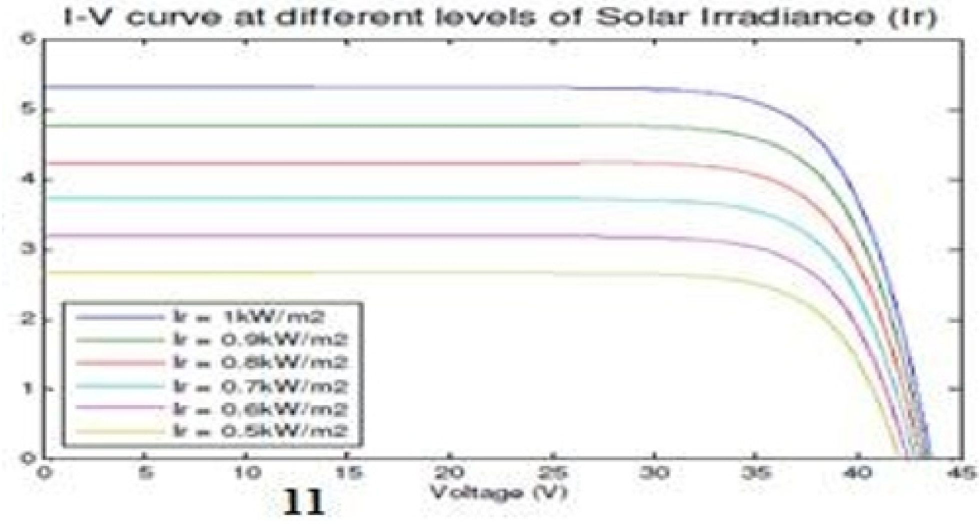

Figure 6. I-V curves at different levels of solar irradiance generated by the PV panel model.

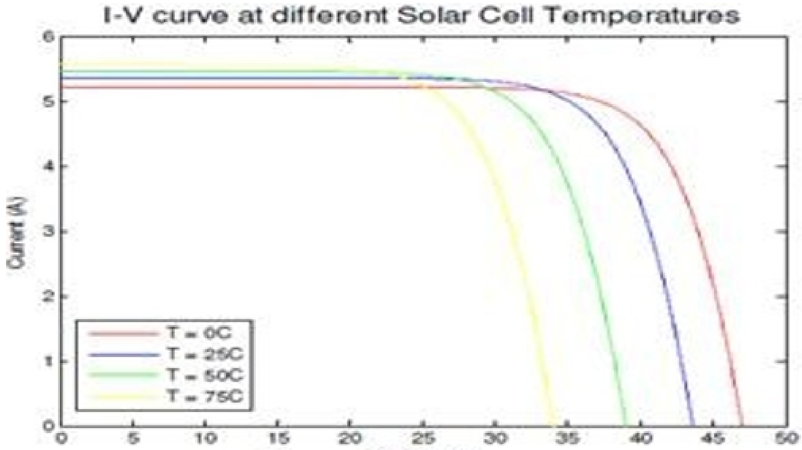

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Figure 7. I-V curves at different levels of solar cell temperatures generated by the PV panel model.

This is both for ease of testing and for the accuracy of the results. Other system parameters are set as follows: the switching period of the converter is 50 µs (20 kHz); the inductors are 560µH and the load resistance R is 330 Ω. The first aspect of the converter is its characteristics in different operating modes: CCM and DCM. This can be tested by looking at the inductor currents around the critical duty cycle found in equation (2-12). With the parameters set above and equation (2-12) it can be calculated that the critical duty cycle is 0.568. Figure 8 shows a converter duty cycle on each side of the critical value. From Figure 8 it is shown that when the duty cycle is 0.60, which is higher than the critical value the converter operates in CCM. The figure also shows that when the duty cycle is lower than the critical value at 0.50, the converter operates in DCM. At a duty cycle of 0.55 which is close to the critical value but still below it the converter is only ever so slightly acting in DCM.

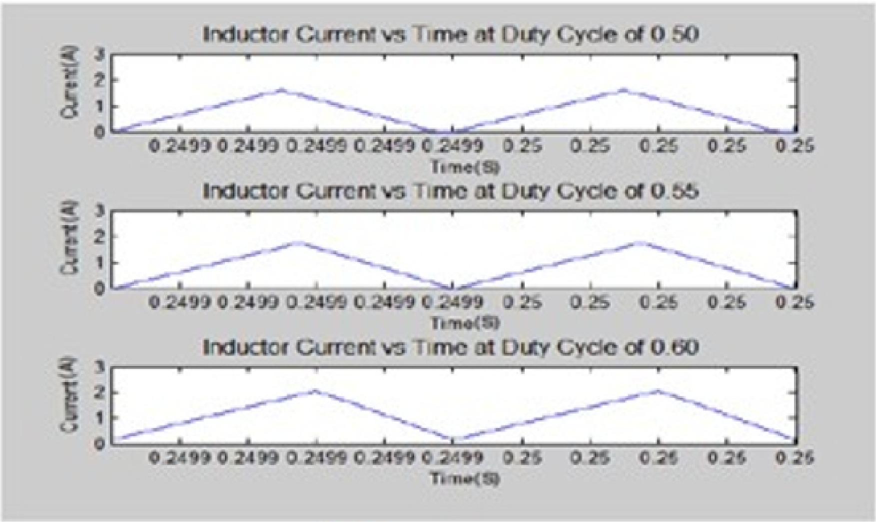

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Figure 8.The inductor current of the converter in DCM and CCM,

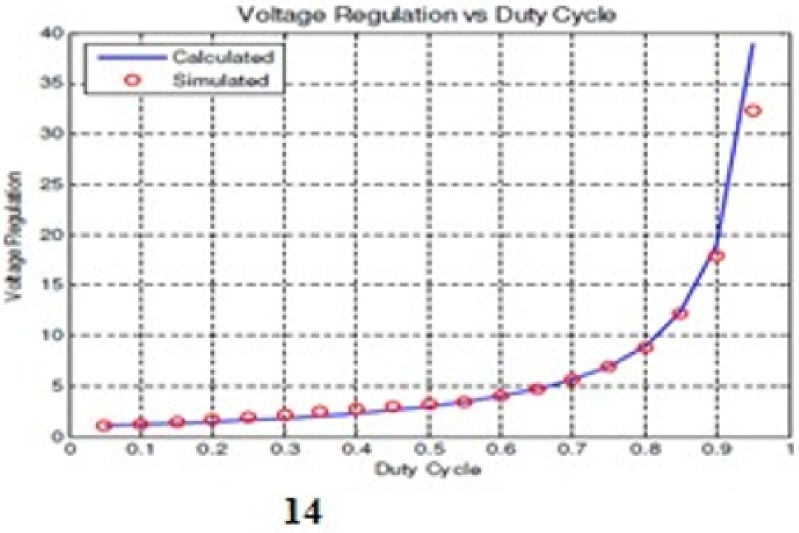

Figure 9. Comparison of the calculated and simulated results of voltage regulation for the DC/DC converter.

The next property of the converter to look at is the voltage regulation. To test voltage regulation the converter is ran at specific duty ratios while input and output voltages are measured. The regulation ratio is then compared to the ratio calculated by equation (2-15) in Figure 9. As is shown in the graph, the simulated results for the voltage regulation are close to what had been calculated. The one main difference is when the duty cycle is at 95%. At this point the simulated value is a gain of 32.4 while the calculated value is a gain of 39. This is believed to be due to the simulation being more accurate to real life where the higher voltage causes more losses though the components in the converter.

4.2. The MPPT Control

The P&O MPPT method is implemented in Simulink and added to the converter circuit and PV panel model. The MPPT control unit takes as its input voltage and current measurements from the PV panel simulation. The control unit then computes the power and sends the information along with the PV panel voltage value into the P&O algorithm. The algorithm then decides whether the duty cycle output to the circuit should be increased, decreased or kept the same. This new duty cycle is then output to the converter. The process is able to hold the PV panel at its maximum power output under changing conditions. In order to test the MPPT control algorithm the entire PV system has to be simulated. The best way to test the MPPT algorithm is by simulating the PV panel under various light conditions all while running the converter. This allows the tracking system to sense the changes in the panel output and correct for them using the duty cycle of the converter. Figure 10 shows the results of a 40 second simulation of the entire PV system. It can be seen that the irradiance was first increased from 0 to 1 kW/m2 and then decreased back down to 0 in a stair step fashion. In the second part of Figure 10 the algorithms reaction to the irradiance is shown in the form of the duty cycle it outputs. The third graph on Figure 10 shows the resulting solar power output from the panel.

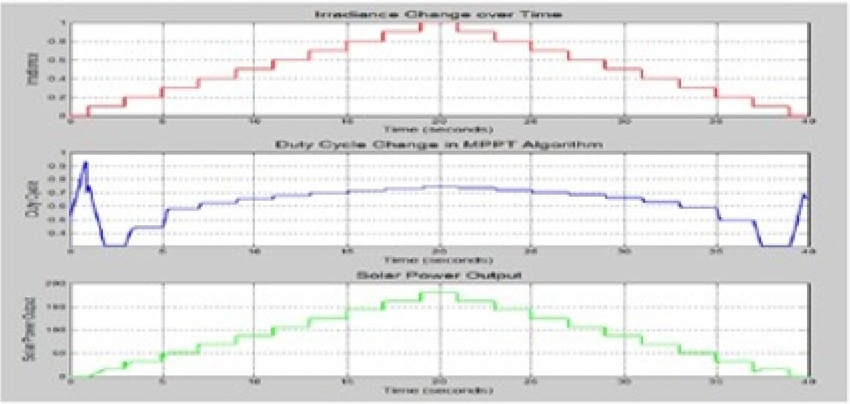

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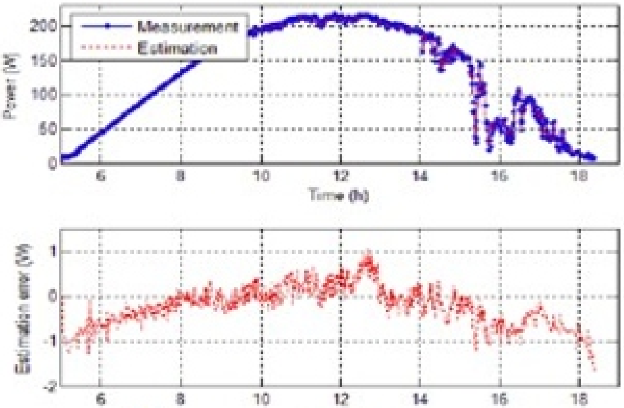
Figure 10. Simulation results of the MPPT control algorithm,



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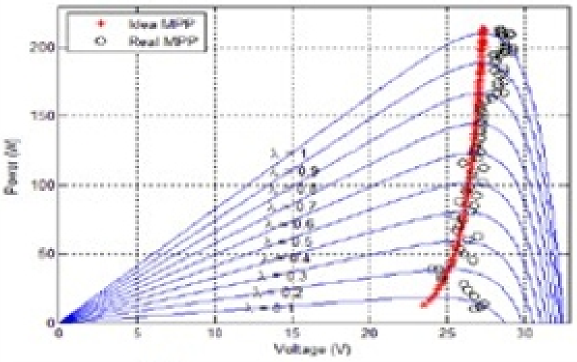

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Figure 11.The power estimation results,

Figure 12. The MPPT results of the PV system.

There are a few interesting outcomes worth noting from the results shown in Figure 10. The first thing that is noticed is the rapid increase in the duty cycle at the beginning of the simulation. This is something that will only be seen in a simulation and is a result of the PV panel model being so accurate to real life. When a PV panel is not given any light at all it can actually work in a reverse. This is best described while talking about a panel hooked up to a battery directly. The reverse leakage current through the diodes within a solar cell can actually take power away from the battery and emit it through the PV panel when no light is present. The same is true for this simulation where the capacitor starts with a slight charge on it. The algorithm is actually doing exactly what it is supposed to, just backwards. When there is 0 kW/m2 irradiance the PV panel model is actually taking power out of the capacitor and it is flowing backward s through the circuit. Even though the amount of power is very small (~-3e-30) the algorithm senses it and tries to compensate for it. This compensation is seen in Figure10 by the duty cycle rapidly increasing at both the beginning and end of the simulation. Here the algorithm is actually trying to completely shut off the switches within the converter in order to lessen the loss of power. Since the control algorithm only allows the converter to operate at a duty cycle from 5% to 95% when the duty cycle shown in Figure 10 increases to 95% it is reset at 72.5%. Shortly after this reset the irradiance increases to 0.1 kW/m2, which causes all backward power flow to cease. This allows the algorithm to settle at the duty cycle which allows the most power flow from the panel to the converter. There are two main reasons that the backward power flow seen in Figure 10 is only a simulation result. In the real system the controller will be powered from the PV panel in order to minimize losses when it is not needed. This means that when there is zero irradiance the controller will not be running and, therefore, the converter will already be in its off state, not allowing reverse power flow. The second reason this should not be seen in the real system is that there is almost never a time when there is absolutely no irradiance. At night the sun reflects off the moon, there are manmade lights everywhere and even the stars give off some irradiance that will be seen on the panel. While this isn't enough to see a usable amount of power, it is usually enough to stop the panel from allowing power to flow in reverse. The next thing to take notice of in Figure 10 is how good the system actually is at tracking the power output of the PV panel. At very low irradiance values the algorithm has a slight lag before it settles at the correct value since the duty cycle has to change so much. This can be seen both when the irradiance is increasing and when it is decreasing at values of 0.1 and 0.2 kW/m2. This is only seen at these low values and is almost completely eliminated at higher irradiance values. At the higher values of irradiance the algorithm is very quick at tracking to the new irradiance value once a change has occurred. With the simulation only being 40 seconds in total length and having irradiance changes in steps over the full range of values, the algorithm preformed even better than expected. This shows that the algorithm should have no problem adjusting for a quickly changing MPP on partly cloudy days. The next step is to simulate the other current-sensor less technologies.

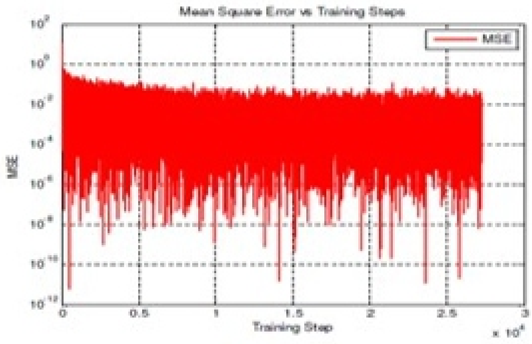
4.3. Current-Sensor less MPPT Control

Simulation studies are carried out in MATLAB Simulink to validate the proposed current- sensor less MPPT quasi-double-boost converter for the PV system. These simulations are completed by using real solar radiation data obtained from National Renewable Energy Laboratory (NREL) to validate the proposed system and control algorithm. The data was collected from the South Table Mountain site in Golden, Colorado, on May 31, 2010. During the simulation, the output power of the PV panel is estimated by the proposed current-sensor lessMPPT algorithm and is compared with the measured output power by using both voltage and current transducers, as shown in the Figure 11.The proposed current-sensor less algorithm estimates the real output power with good precision; the estimation errors are less than 1 W during most of the day. Without knowing the solar radiation, the proposed MPPT algorithm controls the PV system to track the MPP of the PV panel by using the estimated current and measured voltage. Figure 12 shows the operating points, i.e., the real MPPs, of the panel at various solar radiation conditions during the day, which are close to ideal MPPs.

Inductor Current Sensing Technology Simulation studies are also carried out to validate the inductor current sensing technology and the resulting MPPT control algorithm. These simulations were preformed within MATLAB's Simulink using the neural network laid out as in Figure 10.The code for the neural network design can be seen in Appendix 2. In order to gather data to train the system, the converter simulation presented above was run again. The simulation used a varying duty cycle incremented in small steps and the resulting inductor voltage drop along with the input voltage and current were recorded. These results were then used to train the artificial neural network. The resulting mean square error (MSE) output from training can be seen in Figure 13, where the MSE is calculated by

$$MSE = \frac{1}{2}E^2 \qquad \ldots\ldots 4.1$$

Where E is the error between the actual input current and the input current estimated by the artificial neural network.



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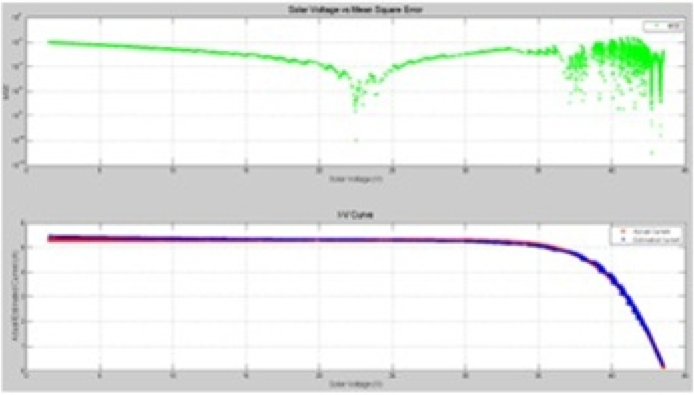

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Figure 13. Mean square error output during the neural network training,

Figure 14.Comparison of actual and estimated input current,

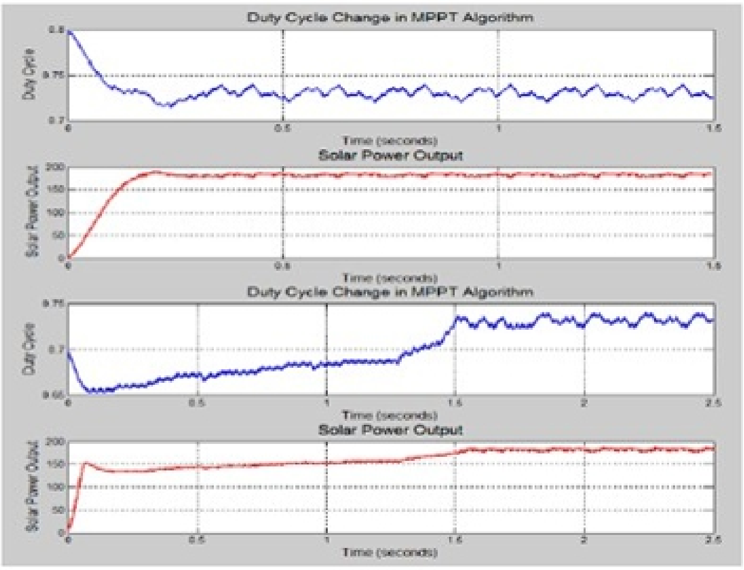

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Figure 15. Simulation results of the inductor sensing MPPT control algorithm.

Figure 13 shows that the mean square error stays below 10-1.5 for all inputs by the end of the training period. To obtain a better understanding of what this actually means the weights found in testing, the neural network is applied to the data set recorded through the converter simulation and the estimated input current is compared against the actual recorded input current. The results of this comparison are shown in Figure 14.

Figure 14 shows the I-V curve output for both the estimated and the actual PV panel current. It can be seen that the two curves are very similar. While the two curves do not exactly match they are close enough to run the MPPT system. The important aspect of the curve for the MPPT algorithm is not the exact current value, but that the current is linear in the movement throughout the curve. The algorithm only cares whether the current is increasing or decreasing. This can further be seen by simulating the MPPT system while using the artificial neural network to estimate the input current within the algorithm. Figure 15 shows the results of running the system with the estimated current as an input to the MPPT algorithm. The irradiance is set to 1 kW/m2and the duty cycle is began to different values, one higher (80%) than the value expected for the maximum power output and one lower (70%). The algorithm finds the MPP in both directions to be 184 W, at a duty cycle of 74% which are the same as the results seen in Figure 10. When comparing the results after the algorithm has reached the MPP in Figure 15 and in Figure 10, it is again seen that they are the same. This shows that the algorithm with the inductor current sensing technology is working as good as the algorithm with the standard sensing technology, though it may be slightly slower. The inductor current sensing algorithm still manages to find both new MPP within 1.6 seconds. This is quick enough for the system to work under any normal working conditions. The next step was to apply the results observed in the simulations to the actual system.

4.4. Sensing Technology Comparisons

All three of the sensing technologies work when simulated but each one has pros and cons when compared against each other. When comparing both current sensor less techniques there is not really one that stands out over the other. Both work in the lower power application presented here but do not improve on the traditional resistor sense technology. Where the biggest improvement would be seen is in high power, high current applications. This is where the resistor sense technology would incur the most losses. However at these higher powers and currents the current sensor less and inductor current sense designs would not have any extra losses when compared to a low power system. Being used in a higher power system may even improve the accuracy of both systems. The higher current in the current sensor less design would give the system a more defined voltage ripple to perform calculations off of, improving overall results. The inductor current sense system would also have a higher inductor voltage drop to read into the neural network which would allow the system to obtain better accuracy in the current estimation. This would be due to there being a higher inductor voltage change correlated to the higher current. The higher current would however require retraining of the neural network to ensure proper operation. In low power applications with low current the standard resistor sense technology is recommended, both for ease of use, cost effectiveness, and reliability. In applications where the power level may change overtime, such as modular systems where panels may be added and removed the traditional system is also recommended. This is because both current sensor less technologies would have to be modified each time the input power level changed. With the traditional sense technology as long as the voltage drop across the resistance does not exceed the input rating of the voltage transducer used to measure it the system will continue to work without any modification at any power level. In higher power applications that would cause large power losses across a resistive element it is recommended that both the current sensor less and the inductor current sense technology be evaluated for performance with the overall system. High power applications are where these systems will excel over the traditional current sense technology.

5. CONCLUSIONS

In order to maintain the highest power output from a PV panel at all times a high efficiency converter coupled with a MPPT system must be used. In this research a high efficiency quasi- double-boost DC/DC converter was designed and implemented. A fast reacting and accurate MPPT algorithm was implemented to control the converter and make sure the PV panel is always outputting the maximum power available at a given time. Results are presented showing the output power improvement over a standard panel with a fixed load. Three separate current sensing and sensor less methods are presented to ensure the entire system operates with the highest possible efficiency. In future work it is recommended that all three current sensing technologies be implemented with identical converters and PV panels, so they can truly be tested against one another.

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Assessment of Conceptual Understanding Through Auto-Electrical Engineering Circuit: Based on Conventional Instruction in a Cultural Laboratory with Inquiry Instruction

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ABSTRACT

Conventionally, in the curriculum of auto- electrical engineering circuit systems, using textbook instruction and hands-on lessons has been effective in teaching approaches for students in terms of definitions and the procedural use of formulas, and how to estimate current flows through the conceptual academic performance. However, students often lack the conceptual understanding especially in the subject under study. Therefore, based on the effectiveness of cultural laboratory under instructional inquiry, the students' conceptual understandings are enhanced

Keywords: Conventional and cultural investigations, instructional inquiry, conceptual understanding, auto- electrical circuit.

INTRODUCTION

Auto- electrical concepts are abstracts, hard to grasp. Automobile concepts are barely visible and universal in our lives. Many models and analogies for Auto-electrical systems have been used, but none of them fully explains all of its aspects [1]. Auto- electrical concepts are delicate in nature, causes many students even those who have completed auto-electrical system courses have incorrect ideas about it and about the behavior of the electrical systems.

Assessment responses from groups of university students who had completed a course on auto-introductory courses, including thermo-electrical, air-condition and refrigeration and thermodynamics Law, the students were presented with an exam question of simple auto-electrical systems. Although the students had the necessary mathematical skills and had previously used Ohm"s law and the thermodynamics Law to solve more complex transmission problems, only 10-15% of them answered the question correctly. [2] found that many students failed because they held misconceptions (i.e. “Current is used up by the bulbs in the electrical circuit”), misunderstood concepts (equivalent resistance and viscosity), used concepts incorrectly, or lacked conceptual ideas that would enable them to make qualitative predictions about the behavior of fluids and circuits.

In addition, [3] observed that many students have persistent conceptual difficulties with analyzing simple electrical circuits, such as inability to apply formal concepts related to voltages, viscosity, and resistance (e.g., a failure to distinguish between equivalent network and the resistance of individual elements).

Ideal conceptual understanding enables students to reason about potential differences, voltage at different locations within a circuit, and the flow and the intensity of current [4]. They argue that conceptual understanding in the engineering sciences includes both knowledge about quantities (such as current and potential difference) and knowledge about the relationships among these quantities (e.g., as expressed by Ohm‟s Law). Conceptual understanding is a critical element in the competence and expertise of engineering students and practicing professionals [4]. Yet a correct and deep conceptual understanding of electricity does not seem to emerge in traditional instruction. Before moving on towards possible solutions, the next section will first focus on current practices in traditional electricity instruction.

CONVENTIONAL INSTRUCTION ON ELECTRICAL CIRCUITS

Traditionally, in auto-engineering, curricula about electrical circuits have two components: textbook-based instruction and experiential, hands-on lessons. In the textbooks, the subject matter is often approached from a factual and calculus-based angle. Students are presented with facts, definitions, and laws, and they are taught equations (e.g., based on Ohm‟s Law, $I = V/R$) that can be used to solve standard circuit problems [5]; [6]. Therefore, Textbooks, and the exercises in the textbooks often emphasize procedural skill, which is "the ability to execute action sequences to solve problems" [7], and the reproduction of facts and definitions.

These textbooks-based lessons are often supplemented with experiential lessons in which students can build electrical circuits and carry out measurements. These experiential lessons are essential for developing skills and experience with working with real equipment and, through experimentation, a conceptual understanding of the domain. However, experiential lessons also have limitations that in general, keep students from developing a proper conceptual understanding. For example, in experiential lessons, students tend to focus on making their circuits work rather than on trying to understand the causal relations between variables and outcomes [8]). Furthermore, when working with real circuits, students must deal with all kinds of unexpected circumstances (dim bulbs misinterpreted as unlit [9] and deviations from what they have learned in the textbook-based lessons. For example, in reality equipment (circuits, resistors, wires, and batteries) is not ideal, and consequently the measurements in the circuits will show different outcomes than expected purely on the basis of formulas. Furthermore, students often do not engage in systematic experimentation and they rarely, if ever link their hands-on activities with what they have learned in the textbook lessons.

The observation that the acquisition of conceptual understanding of engineering program is problematic suggests that this combination of textbook-based instruction and practical lessons does not provide students with optimal conditions for acquiring proper conceptual understanding of electricity and electrical circuits. If engineering instruction is less than suitable for fostering the acquisition of conceptual understanding, adding learning opportunities that foster conceptual understanding of the curriculum seems a logical next step.

DEVELOPING THE ACQUISITION OF CONCEPTUAL UNDERSTANDING IN AUTOMOTIVE ELECTRICITY

[10] argued that the accumulation of experiences with natural phenomena through active exploration, investigation, and interpretation provides a basis for the development of conceptual understanding. The role of active experimentation by students in science learning was also emphasized by [11] opinion; there are at least two elements that appear to be critical in making science instruction successful.

First, successful instruction is based on understanding how students make sense of the subject matter. That is, the instruction must take into account the ideas and conceptions the students already have about the subject matter. As stated in the introduction, auto-electrical is an abstract and intangible concept; however, most people have conceptions, often pre-scientific and idiosyncratic ones, about what electricity is and how electricity “behaves”. Steinberg emphasizes the importance of instruction on helping students to “elicit” their own conceptions and using those conceptions as a starting point for the instruction.

Secondly, students must be actively engaged in finding out what is happening instead of just witnessing something being presented. They need to make predictions, design experiments, analyze and interpret the collected data, and formulate answers to their research questions; in other words, they must be engaged in a process of inquiry [12].

In inquiry learning, students learn through exploration and application of scientific reasoning. It has been found to be among the most effective methods for acquiring conceptual knowledge [13], and [14]. Computer technology can support inquiry learning by students and facilitate the inquiry learning process in many ways, such as by offering computer simulations for exploring, experimenting, and collecting empirical data [15]. Simulations contain models that are designed to simulate systems, processes, or phenomena. Students can change the values of variables in the simulation (e.g., the resistance in a virtual electrical circuit) and observe the effects of those changes on other variables (e.g., voltage or current). The simulations allow students to conduct experiments and collect experiential data quickly and easily. (In this sense the simulation could also be called a virtual laboratory, and therefore henceforth the term "virtual lab" will be used.) Building or adjusting experiential setups with real equipment can be laborious and time-consuming.

In a virtual lab, in contrast to a real lab as described above, the setup can be given and changes to the configuration can be made quickly and effortlessly, allowing students to focus and to stay focused on their inquiry processes without delay or disruption. By systematically changing variables and observing and interpreting the consequences of those changes, the students can explore the properties of the underlying model (e.g., Ohm‟s Law) [16], [17]. Furthermore, seeing what happens in reality can support students with testing the validity of their own mental model and with identifying aspects of their model that need to be refined. Eventually, this can help students to bring their mental models in line with the real phenomena [10].

The idea of using virtual laboratories in electricity instruction is not new. Previous studies have indicated that learning with virtual labs or computer simulations can have a positive effect on the acquisition of conceptual knowledge in the domain of electricity and simple electrical circuits when used as a substitute for real equipment [18]; [6]; [19]. These studies focused on university students.

In the current study, we focus on a different type of students, namely students from secondary vocational engineering education. Vocational education is more concrete in nature compared to general types of education. In vocational education students are trained for clearly defined professions or tasks (e.g., becoming mechanics, electricians). In the Netherlands, an achievement test known as the „CITO-test‟ (the Central Office for Standardized Testing) is administered to all pupils at the end of their primary education. On the basis of their test scores, the pupils are tracked into either pre-vocational education or general (higher or pre-university) education, and a little more than 60% of the students are tracked into pre-vocational education (12 to 16 year olds) and then secondary vocational education (16 to 20 year-olds) [20].

Inquiry learning is often assumed to be too demanding for the students, because it requires them to adopt a scientific approach. [20] characterized students in secondary vocational training as „doers‟, who have a visual orientation and who are mostly interested in the practical application of their knowledge. They learn by experience and have difficulty with abstract theoretical models and methods. In particular, these students find the domain of electricity tobe abstract. [21] Suggests that using realistic visualizations in computer simulations or practical labs can support these students in connecting reality and theoretical concepts. Working with real laboratories is also a necessity for these students, because they will work with similar equipment in their professional lives. Therefore, in the current study we did not replace the practical lesson with a real laboratory but instead gave students additional lessons in a virtual lab.

The main question addressed in the current study is: how can the acquisition of conceptual understanding be fostered in electricity instruction that occurs in the context of secondary vocational engineering education? The current study compares two experimental conditions: one condition in which students followed traditional instruction supplemented with inquiry learning within a virtual lab, and one condition in which students followed traditional instruction only (supplemented with additional traditional (computer-based) practice). The lessons involved were an integral part of a complete electricity curriculum (including both textbook and practical lessons) in the context of intermediate level vocational engineering training.

METHOD

PARTICIPANTS

In total, 126 students in auto-electrical engineering training participated, all boys, no female students were enrolled in the engineering courses. The study was approved by the school board and the participants‟ parents. As will be further explained in the next section there were two conditions, the conventional condition and the Cultural lab condition. Thirteen participants dropped out: four dropped out of school during the period in which the experiment took place (one in the traditional condition and three in the virtual lab condition); four missed more than half of the sessions (two in the traditional condition and two in the virtual lab condition); and five were unable to attend the post-test session (two in the conventional condition and three in the cultural lab condition). The ages of the 43 remaining students (23 on the traditional condition and 20 in the virtual lab condition) ranged from 16 to 22 years old (M = 19.17; SD = 1.39).

DESIGN

A between-subjects design was used in the experiment, with the Instructional method (conventional instruction plus extra computer-based practice (conventional condition) versus traditional instruction plus inquiry learning within a cultural lab (cultural lab condition)) as the independent variable. Participants were randomly assigned to either the conventional or the cultural lab condition. Students in both conditions followed the same curriculum, the full regular electricity curriculum. This curriculum in which the experiment was embedded contained the following courses: a textbook-based course, “Electricity Theory”, and two practical courses, “Measuring Electricity” and “Workshop Practice”. The courses in the curriculum lasted three months or more. The time span of the experiment was nine weeks, with one session every week. These nine sessions formed a relatively small part compared to the entire electricity curriculum, but the experiment only aimed to cover the period during which simple DC circuits were treated in the regular curriculum. In the conventional condition, the instruction was supplemented with additionalpractice based on conventional instruction on topics treated in the main curriculum. In the cultural lab condition, the conventional instruction was supplemented with inquiry learning in a cultural lab, also on the topics treated in the main curriculum. Except for these nine sessions, all courses and activities were the same for all participants.

LEARNING ENVIRONMENTS OF THE STUDY

The regular curriculum that the students follow includes topics such as energy sources, resistance, circuits, Ohm‟s Law, Kirchhoff‟s Laws, alternating current, and magnetic fields. In this curriculum, students have textbook and practical (lab) lessons. The emphasis on the textbook lessons is on facts, definitions, formulas, and procedural skills (calculating parameters such as voltage, current, resistance, and power); in the practical lessons students‟ practice building electrical circuits and performing electricity measurements in these circuits. Two books are used: a textbook of [22] in which facts, definitions, and formulas are presented and procedures are explained, and an exercise book with chapters that correspond to the chapters in the textbook. These chapters briefly repeat the topics treated in the textbook, provide more in-depth explanations of procedures, and offer questions (about facts and definitions) and assignments in which students are required to calculate the parameters. The experiment covered part of the topics treated in the regular curriculum, namely electrical circuits (series, parallel, and mixed connections), Ohm‟s Law, and some elements of Kirchhoff‟s Laws. Two computer-based learning environments were used in the experiment, one for each condition.

LEARNING ENVIRONMENT USED IN THE CONVENTIONAL CONDITION

The conventional condition included use of a computer-based learning environment that was developed and produced by the same company that published the textbook and exercise book described above. The software was meant as additional practice material, although the participating school did not use this software in the regular curriculum. The software offered a brief summary and a series of exercises for each chapter of the textbook and exercise book, mainly calculation exercises, but also some insight questions (measured by means of multiple choice items). After completion of each exercise, students received feedback about the correctness of their response as well as an explanation of the correct answer. At the end of each chapter the system informed the student about the percentage of correct responses for that chapter.

LEARNING ENVIRONMENT USED IN THE CULTURAL LAB CONDITION

Participants in the cultural lab condition were provided with a cultural lab-based inquiry learning environment. This was created by the authors with SIMQUEST authoring software [23]. The virtual lab environment presented photographic images of equipment used in the school‟s practical (lab) courses about electricity (Figure 1).

In the cultural lab environment, students were presented with electrical circuits (Figure 1). They could add or remove electrical components (e.g., light bulbs, resistors, LED‟s), adjust the voltage, and perform measurements using virtual measuring equipment to measure changes in voltage across components and the strength of the current flowing through different parts of the circuit. The images of real equipment made the virtual lab highly realistic.

As indicated in the introduction, students need instructional guidance in order to make inquiry learning within a virtual lab effective. In the current study, students were provided with assignments that were integrated within the cultural lab environment, and that were designed to structure their experimentation processes. Such assignments have been found to be a successful type of instructional guidance in inquiry learning [23]. In the current study, these assignments had the following structure: First, the students were asked to predict the outcome of a change in a circuit, e.g., "in a series connection there is one component, a light bulb (6V/3W). The voltage applied across this bulb is 6V. Suppose a second bulb is added to the connection. What will happen to the voltage across the first bulb (all else being equal)?" This part of the assignment was meant to activate prior knowledge and to have students articulate their own, idiosyncratic conceptions or misconceptions about the domain. Then the participants could use the cultural lab to experiment, that is, to collect empirical data, and make observations that would help them to find out what really happens in the situation described in the first step. After the second step, the participants were asked to reflect upon the correctness or incorrectness of their initial prediction and to draw conclusions on the basis of their observations in the virtual lab.

KNOWLEDGE MEASURES

Two knowledge tests were used in the experiment: a prior knowledge test and a post-test. The prior knowledge test was an entrance test that contained 27 items and aimed at measuring (possible differences) in the prior knowledge of the students. The post-test contained 19 items and was meant to measure the effects of instructional method on learning outcomes. The prior knowledge test contained 14 conceptual and 13 procedural items. The post-test contained 14 conceptual items and 5 procedural items. Because the depth of understanding required to answer problems depends on their level of complexity, we included both simple and complex items on the post-test.

CONCEPTUAL AND PROCEDURAL ITEMS

In the introduction it was argued that a proper conceptual understanding enables students to reason about potential differences and the flow and the intensity of current [4]. Therefore, the conceptual items on the test required participants to reason about the behavior of current and potential difference in various DC circuits, including series, parallel, and mixed connections. At this stage, the curriculum and the textbook treated resistance as a constant. In some conceptual items participants were given two circuits (e.g., one circuit with two light bulbs in a series connection, and one circuit with two light bulbs in parallel) and then they had to reason about how a specific variable (e.g., current) would behave in the different circuits. In other conceptual items participants were given a circuit in which a certain change took place (e.g., turning a switch on or off). Then they had to reason about how this change in one parameter would affect other parameters. An example of a conceptual item is shown in Figure 2.

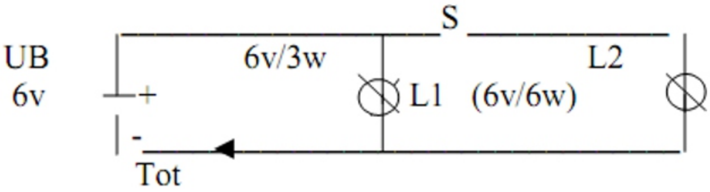


Figure 1. Post-test item (conceptual understanding)

Given the circuit displayed above. Light bulb L1 is shining. Peter is measuring the current at I TOT. When switch S is turned on, Peter notices that the current remains unchanged. Why is that?

Several principles need to be taken into account when solving the problem displayed in Figure 1, (a) when switch S is turned on, the simple connection actually becomes a parallel connection; furthermore, under normal conditions (b) the voltage across light bulb L Unchanged when the circuit switches from a simple to a parallel connection; (c) the voltage across the two parallel trajectories will be equal; (d) the total equivalent resistance will change; (e) therefore so will the current (Ohm‟s Law). The information that the current at I remains unchanged after switch S is turned on therefore, indicates that the circuit is not behaving normally. In fact, the circuit keeps behaving as it did when switch S was still turned off. Apparently, there is some blockage in the parallel trajectory; perhaps one of the components (e.g., switch S or light bulb L2.

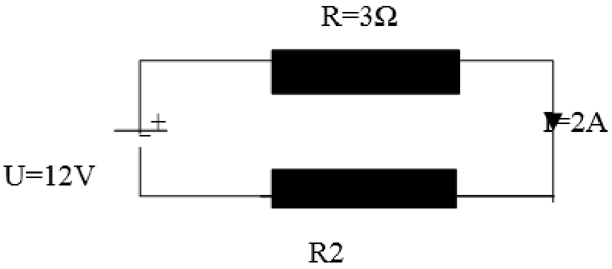


Figure 2

Given the circuit displayed above,
Calculate the resistance of R2 (in Ω).

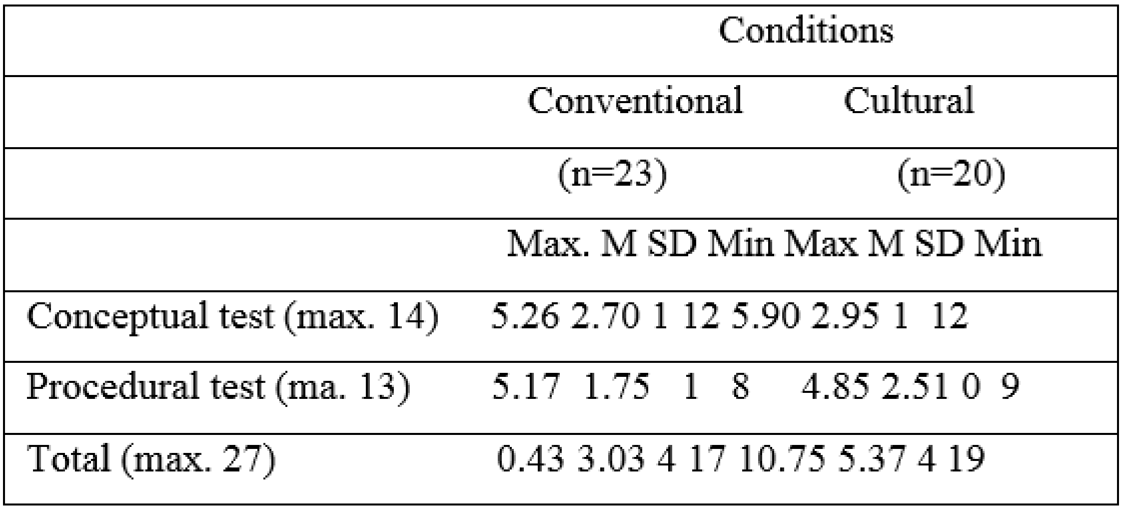
The procedural skills items on both the pretest knowledge and the post-test were based on test items designed and used by teachers in previous years in the Electricity Theory course. All procedural items presented to the participants with a given circuit and required them to calculate the value of a specific variable (e.g., resistance, voltage, or current).

Like the previous problem, the problem displayed in Figure 3 requires multiple principles to be applied in order to find the solution. One principle is Ohm‟s Law (I =V/R) to determine the total amount of resistance in the circuit. The total resistance is 12V/2A = 6O. There are two resistors in the circuit. The second principle that must be applied is the principle that in a series connection such as the given circuit, the resistances of different components (e.g., resistors) adds up. One resistor (R1) is 3 Ω, and therefore the resistance of the other (R2) must be the total resistance minus the resistance of R1,
6 Ω - 3 Ω = 3 Ω.

PROBLEM COMPLEXITY

Problems and solutions that involved two or more principles were considered complex problems. Problems that required the application of only one principle (e.g., Ohm‟s Law) were considered simple problems. Around 40 percent of the post-test items were complex, so that a differential effect of treatment in relation to the level of complexity could be assessed. The 2) must two items discussed in the previous section (see Figure 2 and Figure 3) both required the application of multiple principles in order to be solved. The distribution of post-test items over the different categories of knowledge type and complexity is displayed in Table 1.

Table 1 .Distribution of Post-Test Items by Knowledge Type (Conceptual or Procedural) and Complexity: Simple or Complex



	Conditions							
	Conventional				Cultural			
	(n=23)				(n=20)			
	Max.	M	SD	Min	Max	M	SD	Min
Conceptual test (max. 14)	5.26	2.70	1	12	5.90	2.95	1	12
Procedural test (ma. 13)	5.17	1.75	1	8	4.85	2.51	0	9
Total (max. 27)	0.43	3.03	4	17	10.75	5.37	4	19

EXPERIMENT RESULTS

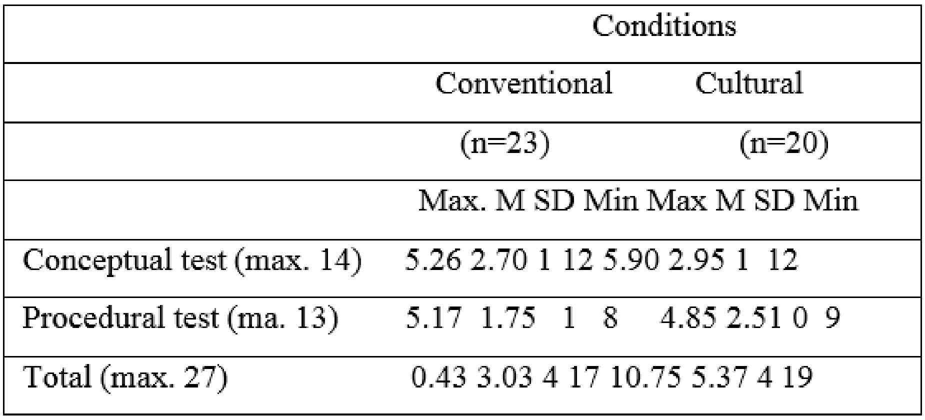
At the end of the semester, the school provided the experimenters with the participants' examination results in the following related curricular courses: Electricity Theory, Measuring Electricity, and workplace practice. In the course Electricity Theory, students were presented with facts, definitions, laws, and theories, and they were taught equations that could be used to solve standard circuit problems. In the practical course measuring electricity, the students had to put components in the electrical circuits following recipe-like instructions and had to perform measurements in those circuits. In the practical course Workplace Practice, students had to design and build electrical circuits.

PROCEDURE

The experiment was carried out in a real school setting. In both conditions, the time taken for the experimental sessions was in addition to that devoted to the regular curriculum. There were nine sessions in total, including a prior knowledge test session and a post-test session. The Sessions were separated by one-week intervals. In the first session, this took about 90 minutes; the students received some background information about the purpose of the study, the domain of interest, learning goals, and so on. This was followed by the prior knowledge test.

In the second session, participants were randomly assigned to one of the experimental conditions. After this, both groups were directed to separate classrooms. (The experimental instructional sessions all took place in two different classrooms: one for each condition). The rest of the second session was spent teaching participants how to operate their assigned learning environments. Following this introduction to the assigned learning environments, students in both conditions participated in six content-related instructional sessions, each lasting 45 minutes. Students felt this amount of time on the topic was sufficient. During these sessions the participants in both conditions worked on their own (one participant per computer) and at their own pace through the chapters and assignments in their learning environment. In the ninth, final session, the participants completed the post-test. The duration of this session was also 45 minutes; all students were able to finish the post-test within this time. APA standards for the ethical treatment of human participants were followed.

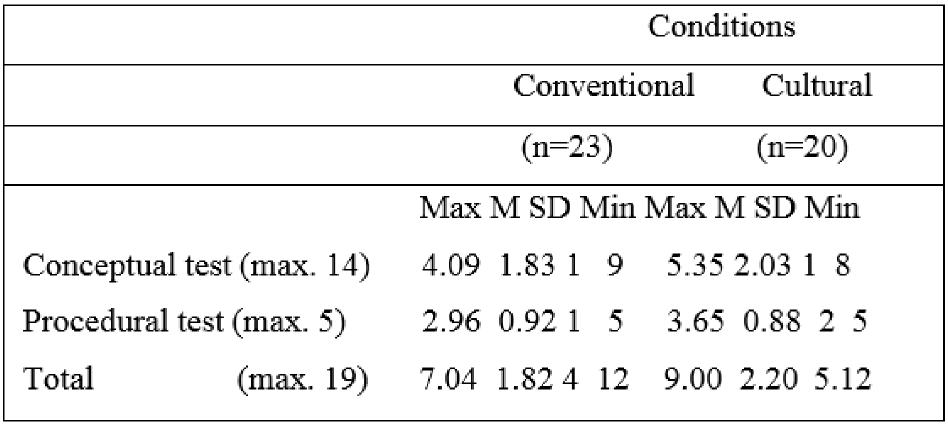
Table 2. Prior Knowledge Test Scores on Conceptual and Procedural Items



	Conditions							
	Conventional				Cultural			
	(n=23)				(n=20)			
	Max.	M	SD	Min	Max	M	SD	Min
Conceptual test (max. 14)	5.26	2.70	1	12	5.90	2.95	1	12
Procedural test (ma. 13)	5.17	1.75	1	8	4.85	2.51	0	9
Total (max. 27)	0.43	3.03	4	17	10.75	5.37	4	19

Independent samples T-tests performed on the prior knowledge test scores established that there were no significance differences between conditions: conceptual understanding, t (41) = - 0.74, n.s.; procedural skills, t (41) = 0.50, n.s.; total prior knowledge test score, t (41) = - 0.31, n.s. It can therefore be assumed that students in both conditions had comparable levels of prior knowledge.

Table 3. The post-test scores on conceptual and procedural Items



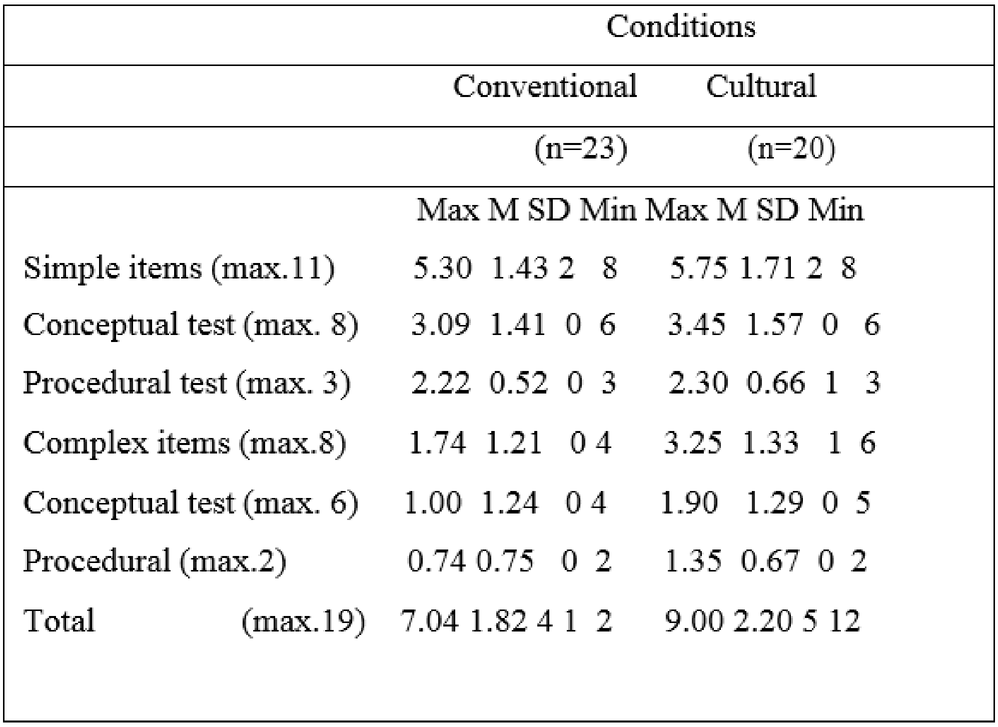
	Conditions							
	Conventional				Cultural			
	(n=23)				(n=20)			
	Max	M	SD	Min	Max	M	SD	Min
Conceptual test (max. 14)	4.09	1.83	1	9	5.35	2.03	1	8
Procedural test (max. 5)	2.96	0.92	1	5	3.65	0.88	2	5
Total (max. 19)	7.04	1.82	4	12	9.00	2.20	5.12	

Prior knowledge scores were entered as covariates in the analyses of post-test scores. It was found that students in the cultural lab condition obtained significantly higher overall scores (F (1, 40) = 9.82, p < 0.01) than participants in the conventional condition. The effect size (Cohen‟s d = 0.98) indicates that this is a strong effect. Participants in the cultural condition also scored significantly higher on conceptual items (F (1, 40) = 4.12, p < 0.05). The effect size (Cohen‟s d = 0.65) shows that this can be considered a medium effect. Participants in the cultural lab condition obtained significantly higher scores as well on the procedural items (F (1, 40) = 5.93, p < 0.05), the effect size (Cohen‟s d = 0.76) indicates that this is a large effect.

The procedural skills items were based on test items designed and used by teachers in previous years in the Electricity Theory course. Therefore, a correlation between scores on the post-test procedural skills items and examination grades for Electricity Theory was to be expected. This was confirmed by the data (r = .52, p < 0.01) (see also Table 5). The conceptual items were developed for the current study, and therefore their reliability still had to be established. The internal consistency measure, Cranach‟s alpha, for the conceptual knowledge scale was .43. This value suggests that conceptual understanding in this situation has many different facets, including understanding of different variables such as current and potential difference, along with knowledge about how each of these behaves in different circuits (e.g., in series, parallel, or mixed connections). If conceptual items about current are considered as one subscale and conceptual items about potential differences as another subscale, the internal consistency values rise to 0.57 and 0.67, respectively; however, these subscales are still estimates because they do not differentiate between types of circuits.

Besides the conceptual-procedural distinction, post-test items can also be distinguished on the basis of the complexity of their solutions. Problems that required the application of only one principle in solving them were considered simple problems, while those that required multiple principles for their solution were considered complex items. The data regarding scores on simple and complex items are presented in Table 4.

Table 4 Post-Test Scores on Simple and Complex Items



	Conditions							
	Conventional				Cultural			
	(n=23)				(n=20)			
	Max	M	SD	Min	Max	M	SD	Min
Simple items (max.11)	5.30	1.43	2	8	5.75	1.71	2	8
Conceptual test (max. 8)	3.09	1.41	0	6	3.45	1.57	0	6
Procedural test (max. 3)	2.22	0.52	0	3	2.30	0.66	1	3
Complex items (max.8)	1.74	1.21	0	4	3.25	1.33	1	6
Conceptual test (max. 6)	1.00	1.24	0	4	1.90	1.29	0	5
Procedural (max.2)	0.74	0.75	0	2	1.35	0.67	0	2
Total (max.19)	7.04	1.82	4	1 2	9.00	2.20	5	12

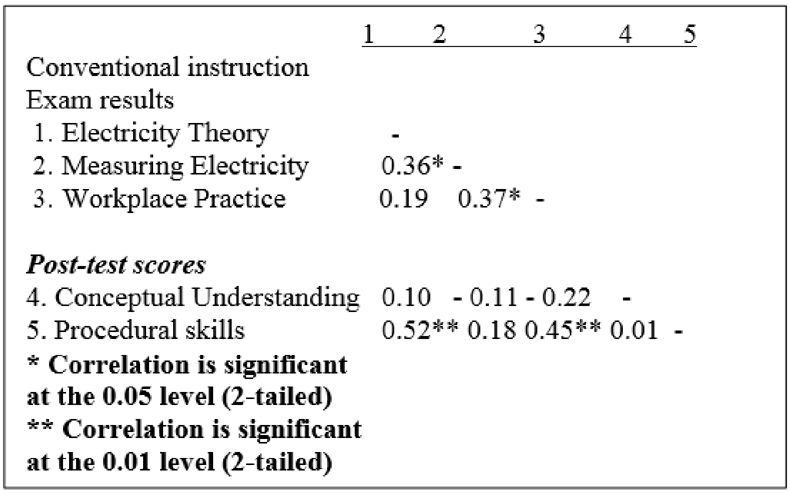
No differences between conditions were observed with regard to scores on simple problems t(41) = - 0.93, n.s.). However, with regard to complex items, a significant difference was found between conditions. Participants in the virtual lab condition were more successful in solving complex problems (t (41) = - 3.89, p < 0.0001). The effect size (Cohen‟s d = 1.19) shows that this is a large effect.

In Table 4 both the simple and complex item scores are also specified in terms of conceptual understanding and procedural skills. There were no differences between conditions with regard to scores on simple conceptual items (t (41) = - 0.80, n.s.) or simple procedural items (t (41) = - 0.46, n.s.). The participants in the virtual lab condition were more successful in solving complex conceptual problems (t (41) = - 2.32, p < 0.05). The effect size (Cohen‟s d = 0.71) indicates that this is a medium effect. The participants in the virtual lab condition were also more successful in solving complex procedural problems (t (41) = - 2.79, p < 0.01). This effect size was Cohen‟s d = 0.86, which is a large effect.

CONCEPTUAL KNOWLEDGE IN THE CURRICULUM

We began this article by stating that conventional instruction is not very well suited to helping students acquire conceptual understanding. In the following analyses we explore the relations among type of instruction, conceptual understanding, and procedural skills. The first analysis involves the correlations between post-test scores and other examination scores (Table 5). The correlations in the table are the total correlations. Correlation analyses were also run for each condition separately, but yielded results very similar to those in Table 5.

Table 5 Correlations between Post-Test Scores and Examination Results for the Other Curricular Activities

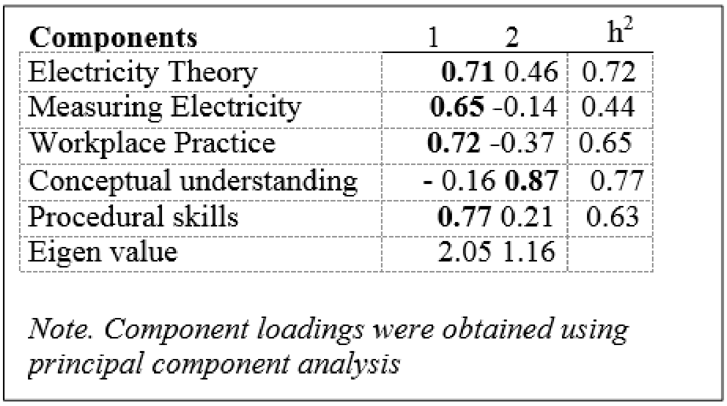


	1	2	3	4	5
Conventional instruction					
Exam results					
1. Electricity Theory	-				
2. Measuring Electricity	0.36*	-			
3. Workplace Practice	0.19	0.37*	-		
Post-test scores					
4. Conceptual Understanding	0.10	- 0.11	- 0.22	-	
5. Procedural skills	0.52**	0.18	0.45**	0.01	-

*** Correlation is significant at the 0.05 level (2-tailed)**
**** Correlation is significant at the 0.01 level (2-tailed)**

Of interest in Table 5 is that conceptual understanding as measured in the post-test turns out to be unrelated to the examination results obtained in the other curricular activities. Procedural skills as measured in the post-test are related to performance in the Electricity theory part of the curriculum (conventional instruction) and workplace practice. To further explore these relations, we ran a principal component analysis of post-test scores and examination results. The results are displayed in Table 6. Principal component analyses were run for each condition separately as well, but since they yielded very similar results, the analysis of the sample is discussed as a whole.

Table 6 Component Loadings



Components	1	2	h^2
Electricity Theory	**0.71**	0.46	0.72
Measuring Electricity	**0.65**	-0.14	0.44
Workplace Practice	**0.72**	-0.37	0.65
Conceptual understanding	- 0.16	**0.87**	0.77
Procedural skills	**0.77**	0.21	0.63
Eigen value	2.05	1.16	

Note. Component loadings were obtained using principal component analysis

As observed in Table 6, two components were detected. From these results, it becomes clear that conceptual understanding is a separate aspect of knowledge that is different from the knowledge acquired through the conventional curricular activities. The loadings on the first component showed that examination results for these traditional activities (Electricity Theory, Measuring Electricity and Workplace Practice) are intimately tied together, and largely belong to one and the same component. Scores on the procedural skill items, that all involved calculating basic parameters, such as voltage, current, and resistance, also loaded heavily on this first component. This component can therefore possibly be interpreted as a kind of (procedural) domain understanding that allows students to perform procedures and to solve computational problems. Conceptual understanding that was measured by items that all involved reasoning about the behavior of electrical circuits, loaded heavily on the second component. The emergence of this second distinct component confirmed that conceptual understanding as we operational zed it in this study is a unique, separate, element.

DISCUSSION AND CONCLUSIONS

The main question addressed in this study was: how can the acquisitions of conceptual Understanding about automobile electrical is fostered in the context of engineering Education? Two conditions were compared to each other in an experimental setup. In both conditions, students followed the same conventional electricity curriculum. In the conventional condition the traditional instruction was supplemented with additional, computer-based practice about topics treated in the basic curriculum.

In the other condition the traditional instruction was supplemented with inquiry learning within a cultural lab condition, again about the topics treated in the main curriculum. Post-test results showed that participants in the cultural lab condition outperformed participants in the conventional condition on conceptual understanding. One could argue that if participants in the conventional condition had had more time and practice, perhaps their conceptual understanding might finally have reached the level of understanding of their colleagues in the cultural lab condition.

However, the data indicate that the key does not seem to lie in extra time and practice. Principal component analysis of the scores on conceptual understanding, procedural skills, and the examination results of the other curricular activities showed that procedural skills scores and the examination results for the other curricular activities all loaded heavily on one component, indicating they are all largely co-determined.

The factor loading of conceptual understanding of this component was very low. And on the other way, conceptual knowledge loaded heavily upon a second component, whereas procedural skills scores and examination results showed only low factor loadings on this second component. This result indicates that conceptual understanding is fundamentally different from other knowledge and skills that the students acquire in the electricity curriculum.

Participants in the cultural lab condition also outperformed participants in the conventional condition with regard to procedural skills. This finding was unanticipated, because all assignments that were included in the cultural labaimed at making and testing qualitative predictions about the behavior of electrical circuits; none of those assignments targeted the acquisition or practice of procedural skills. The finding that also procedural skills improved, could be an indication that in the cultural lab condition bootstrapping[24] or iterative knowledge development [7] processes took place, that is, the idea that the acquisition of conceptual understanding and other forms of knowledge and skills (e.g., procedural skills) can mutually support and stimulate each other. An increase in one type of knowledge facilitates an increase in the other type of knowledge, which facilitates an increase in the first, and so on. The existence of interrelations between procedural and conceptual knowledge has been presumed for decades. For example, conceptual knowledge helps learners to recognize and identify key concepts when studying or diagnosing a problem.

As a result, a better conceptual understanding of the problem will increase the likelihood that the learner will select the appropriate problem solving procedure (enhancing procedural skills). In turn, reflecting on or self-explaining the conceptual basis of procedures can help learners to become aware of which concepts play a key role in a problem [7]. Some evidence for bootstrapping has been found in the domain of mathematics, but not so far in engineering education [4].

This interplay between conceptual and procedural knowledge will become most evident when solving complex problems. Items on our post-test that required the application of only one principle in solving them were considered simple problems; items that required multiple principles for their solution were considered complex items. It was found that participants in the cultural lab condition scored significantly better on solving complex problems, both complex conceptual and complex procedural problems. Students in the conventional condition had more difficulty when two or more principles had to be taken into account simultaneously. This could be an indication that learners in the virtual lab condition had better synthesized the basic electrical concepts into a coherent framework.

In the current study, we did not replace practical lessons with inquiry learning in a real laboratory, but gave students additional experimentation experience in a cultural lab. Handling real equipment in real laboratories is also necessary for these students, because they will work with similar equipment in their professional lives. An obvious question would be: can inquiry learning be integrated into the practical, real lab lessons; that is, can the cultural lab be replaced by the real lab? And conversely, could the cultural lab replace the real lab? In some studies comparing learning in real labs to learning in virtual labs, equivalent learning results were found [19].

In other studies, learning in cultural labs has been found to be more effective than learning in real labs [20]; [21]. However, we would not recommend choosing between real or cultural labs. Now that the beneficial effects of inquiry learning in a cultural lab have been established in the context of automobile engineering education, we would instead suggest as a next step to shift the focus towards supporting inquiry learning by using a combination or sequence of both cultural and real labs. Other empirical studies have shown that such a combination or sequence(e.g., first learning in a cultural lab, followed by learning in a real lab) can lead to better conceptual understanding than using a cultural lab or a real lab alone [6]; [12].

Second, one would suppose that muddying the effects because of mixing would lead to more equal post-test scores for both conditions. Therefore, if muddying took place in our study this would mean that the effects that were observed in this study are actually an underestimation of the „true‟ effects. Being an underestimation or not, the ecological validity helps to establish the value of inquiry learning within a cultural lab by showing that the beneficial effects can actually be observed in the daily practice of the school.

On the basis of the current study, we can recommend that teachers in engineering education about electricity who want to stimulate conceptual understanding should supplement or perhaps interweave their conventional approach with inquiry learning within a cultural lab. It is often assumed that this is too demanding for students of this level, but our study shows that if the inquiry component is well-supported it will also work in engineering training settings.

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Modeling of an Active Suspension System using State Space Approach

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ABSTRACT

Over the years, automobile market has experience significant growth due to increasing demand for more sophisticated luxurious vehicles that can give better comfortable ride. In order to improve the comfort experienced by the occupants of a vehicle, accurate modeling of an active suspension system with an intelligent control algorithm is paramount. In this paper, an overview of the vehicle suspension system was presented. The different classifications of the suspension system were discussed. The State Space approach was used to develop the mathematical model of an Active Suspension System from its block diagram representation.

Keywords: Suspension System, State Space representation, Mathematical Model, Road Profile

1.0. INTRODUCTION

Technological trend in automobile market has induced more research in developing intelligent approaches to vehicle suspension systems. The automobile suspension system includes all the components which are designed to work together in order to provide quality driving comfort, good handling characteristics and safety for the occupants of a vehicle while in motion. A good suspension system can provide this quality ride by preventing the road shocks from being transmitted to the vehicle frame, maintain stability during vehicle pithing or rolling, performing cornering and braking. A suspension system is basically made up of any of the types of springs, shock absorbers, control arms, linkages, camber, steering system, tire, and some other components. In suspension system, the shock absorbers and the springs suppresses the unpleasant force effect of the irregularities on the road. In the acceleration and retarding motions of the vehicle, the suspension system mitigates the adverse inertial force effects felt by the passengers. Figure 1 shows a unit of the vehicle suspension system.

Figure 1: A unit view of a suspension system

They are several classifications of the suspension system in the literature; suspension system can be classified from the mechanical point of view and as well from the control strategies point of view.

Viewing the suspension from its mechanical setup, the suspension systems are basically of three types(1); the dependent, semi-dependent and the independent suspension systems. In independent suspension system, the two opposite wheels do not have direct linkage to each other. The two wheels have the ability to independently move in vertically independent up and down motion while the vehicle is observing irregularities or uneven road surfaces. Dependent suspension system has a rigid linkage between the two wheels through a single axle. This direct linkage courses the force acting on one wheel to affect the opposite wheel. The semi-independence has the characteristics of both the independent and dependent suspension systems.

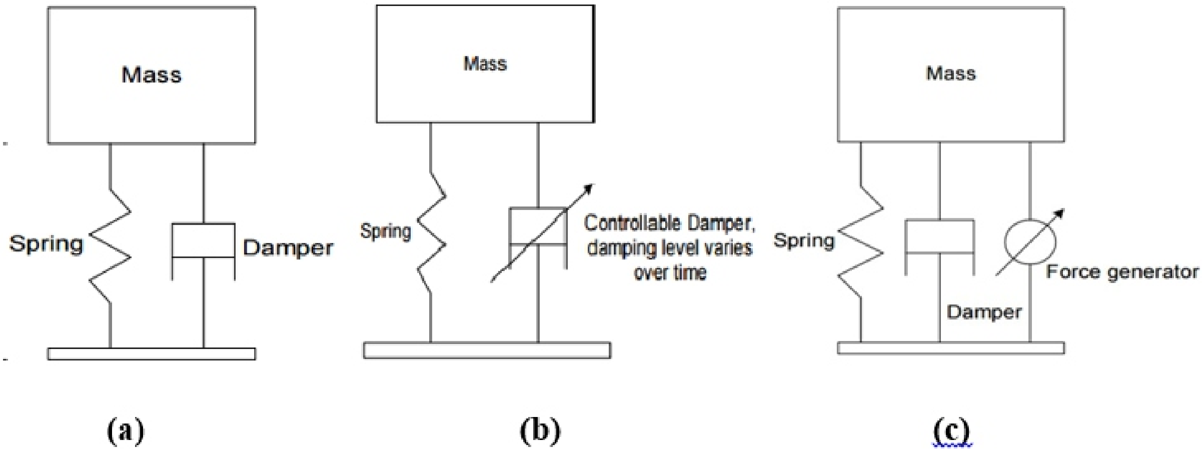
From the control approach, the suspension system can be passive, active, and semi-active suspension system (2).

A passive suspension system controls the relative motion of the vehicle chassis and the wheel through the use of the shock absorber dampers and springs to absorb and equally dissipate part of the force energy from the uneven surfaces. No energy is applied to the passive suspension from any actuator in order to cushion the force effect from uneven surfaces. Passive suspension is in the form of an open loop system since it has a fixed a characteristic which is determined by the designer according to the design goals, specifications and intended use.

Semi-active suspension system has a controllable shock absorber used in place of the non- controllable shock absorber. The controllable shock absorbers determines the damping level according to the control algorithm and automatically adjust the shock absorber's damping level. The road profile is observed through the sensor to select the appropriate control input.

The active suspension system has a sensor and an electrically activated actuator which is aligned parallel to the damper and springs in order to aid in dissipating the energy moving in or out of the suspension system. The active suspension provides smoother ride by using the actuator to add or absorbs energy in the system according to the control algorithm determined by the system designer. Active suspension is in the form of a closed loop system since the actuator can adjust the system dynamics as the road surface varies.

Figure 2 shows the block diagram representations of the passive and active, and semi-active suspension systems.



(a) (b) (c)

Figure 2: Schematic of (a) Passive (b) Semi-active, and (c) Active Suspension systems

In the work, a model of the active suspension system was presented using the state space approach. This was done in order to improve the comfort experienced by the occupants of a vehicle as the vehicle is driving through an uneven terrain.

2.0. MODELLING AND DESIGN OF SUSPENSION SYSTEM

Following the physical system modeling procedure stated in (3), the model of a passive suspension system considering the tire spring affect was derived as shown in figure 3.

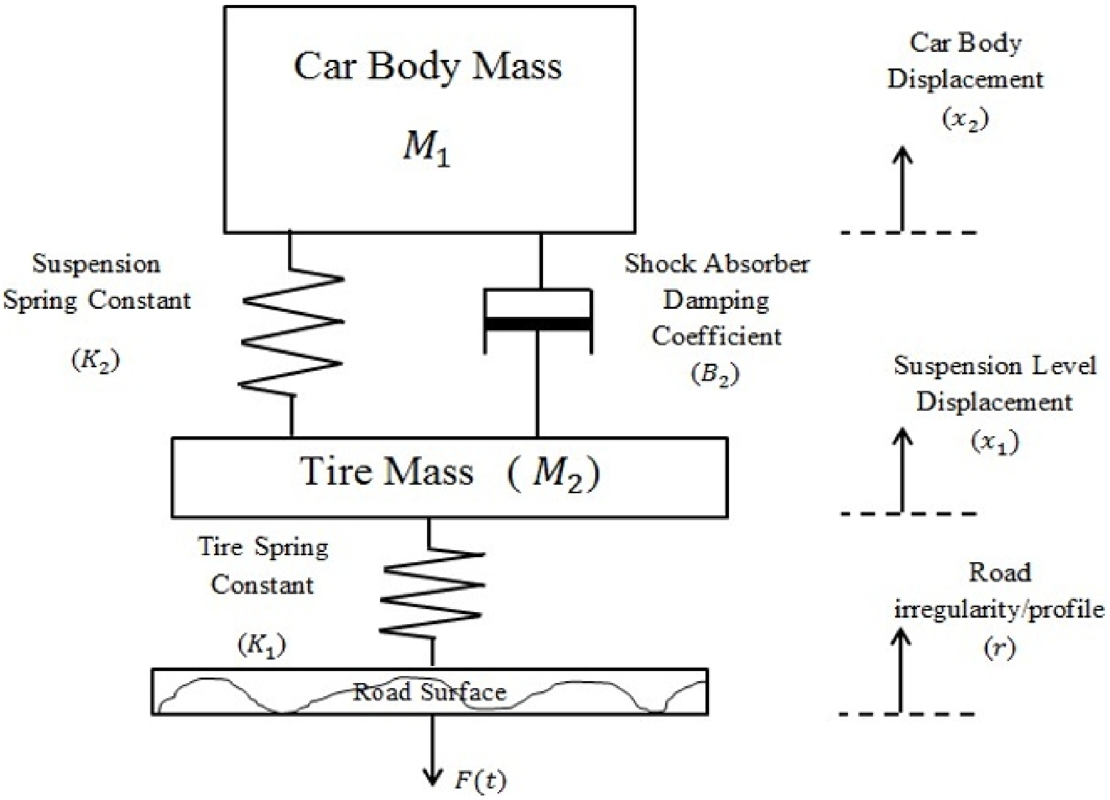


Figure 3: Block diagram model of a Passive Suspension System

From the model of the passive suspension in figure 3, the active components can be added to the system to achieve an active suspension system block diagram as shown in figure 4.

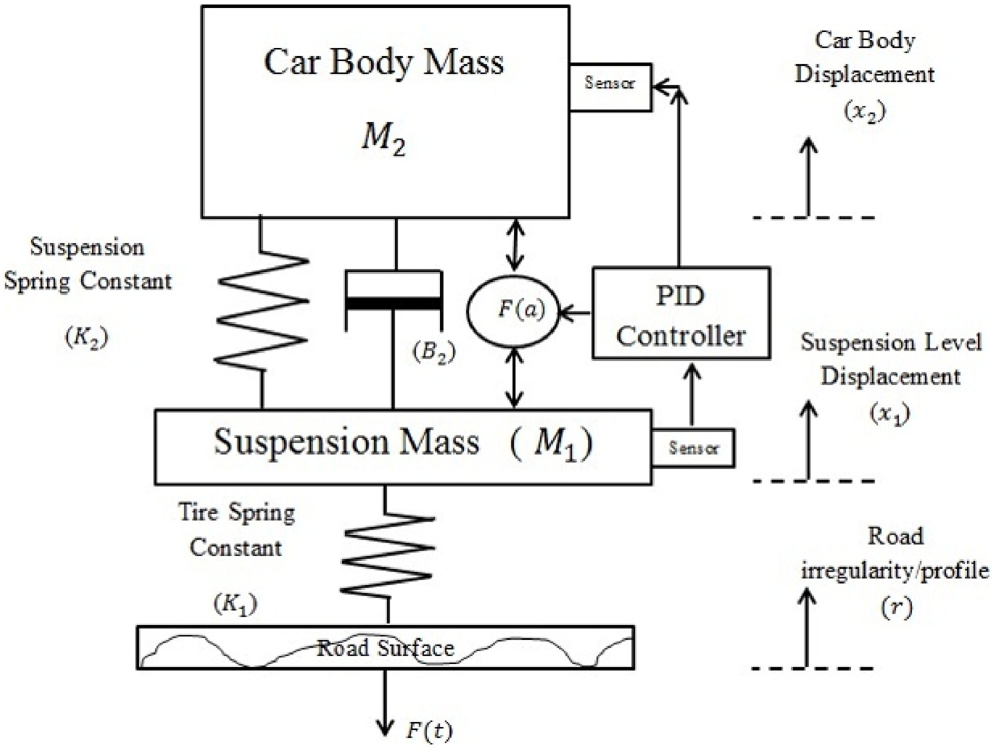


Figure 4: Block diagram model of an Active Suspension System with a PID Controller

The active suspension in figure 4 has an actuator (f_A) and sensors which are used for data collection. The actuator may be a hydraulic actuator or pneumatic actuator located parallel to the shock absorber and the spring. According to Newton's laws of motion, the free body diagram for the active suspension system is shown in figure 5.

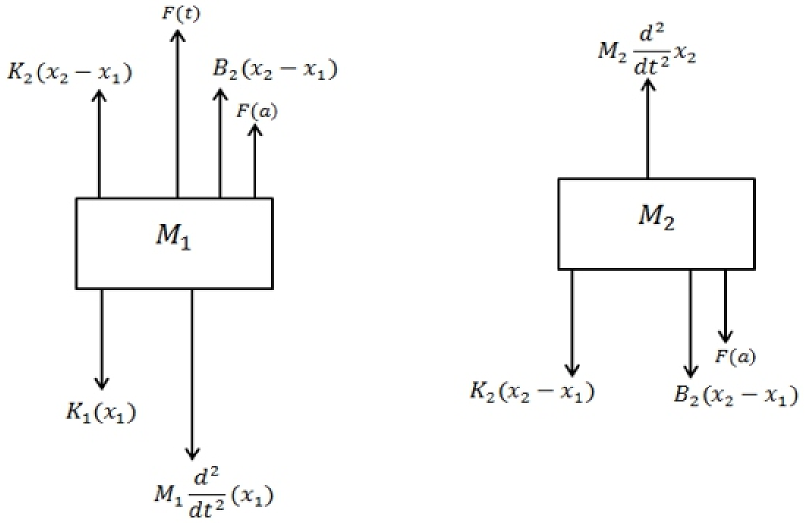


Figure 5: Free body diagram of the active suspension system.

Applying D'Alembert Principles (4) the differential equation for the suspension component total Mass (M_1);

The External forces = Total force of the system + Actuator force

$$= F\,t + F(a)$$

The Resisting forces = Inertial force + Damping force + Spring force

Where

Inertial force, $F_M = M_1 \frac{d}{dt^2}(x_1)$

Damping force, $F_D = B_2(x_2 - x_1)$

Spring force, $F_K = K_2\, x_2 - x_1 - K_1(x_1)$

Road profile, = r

Therefore, with the Newton's law,

$$F\,t + F\,a = F_M + F_D + F_K + r \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$F\,t + F\,a = M_1 \frac{d^2}{dt^2} x_2 + B_2\ x_2 - x_1 + K_2\ x_2 - x_1 - K_1\ x_1 + r \ldots\ldots (2)$$

$$-M_1 \frac{d^2}{dt^2} x_2 = B_2\ x_2 - x_1 + K_2\ x_2 - x_1 - K_1\ x_1 - F\,t - F\,a + r \ldots\ldots\ldots (3)$$

Similarly for vehicle body mass (M_2), the total upward forces = the total downward forces;

$$M_2 \frac{d^2}{dt^2} x_3 = B_2 \quad x_2 - x_1 \quad + K_2 \;\; x_2 - x_1 + F\,a \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . (4)$$

Rearranging equations (3) and (4) to get equation (5) and (6) respectively

$$-M_1 \frac{d^2}{dt^2} \;\; x_2 \quad = B_2 + K_2 \quad x_2 - \quad B_2 + K_1 + K_2 \;\; x_1 - F\,t \quad - F\,a + r \ldots \ldots \ldots \ldots . \;\; (5)$$

$$M_2 \frac{d^2}{dt^2} \;\; x_3 \quad = B_2 + K_2\, x_2 - B_2 + K_2\, x_1 + F\,a \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (6)$$

Where

M_1 = Mass of the suspension system

M_2 = Vehicle body mass

K_1 = Spring constant (stiffness) of the wheel

K_2 = Spring constant (stiffness) of the suspension spring

B_2 = Damping ratio of the damper

x_1 = Road profile

x_2 = Suspension displacement

r = Road profile

$F\,t$ = Resultant force

$F\,a$ = Actuator force

Let the state variables be selected as;

$$\begin{aligned} X_1 &= x_2 - x_1 \\ X_2 &= x_2 \\ X_3 &= x_1 - r \\ X_4 &= x_1 \end{aligned} \qquad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . . (7)$$

Where

Suspension travel = $x_2 - x_1$

Vehicle body velocity = x_2

Vehicle body acceleration = x_2

Wheel deflection = $x_1 - r$

Wheel velocity = x_1

Formulating the State Space representation of the active suspension system with the general form;

$$X\,t = Ax \;\; t \quad + f\,t \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . . (8)$$

$$X_1 = \frac{B_2 + K_1 + K_2}{M_1} . \quad \frac{B_2 + K_2}{M_1} X_1$$

$$X_2 = \frac{B_2 + K_2}{M_2} \quad \frac{B_2 + K_2}{M_2} X_2 + \frac{-F t + F a - r}{F a} \ldots\ldots. (9)$$

3.0. CONCLUSION

This paper presented the modeling of an active suspension system from the first principle using block diagram representation of the major components of a suspension system. The free body diagram was show and the mathematical model of the system was achieved using state space representation.

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Single Phase Seven Level Inverter with Less Number of Components for Grid Connection

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ABSTRACT

A new topology for cascaded seven level converters with pulse width modulation (PWM) and reduced number of switches for grid connection is presented in this paper. By increasing the number of voltage levels at the output in multilevel converters the power quality is improved. The proposed topology reduces the number of switches and reduces THD with increase in output voltage levels. Reduction in number of switches and number of voltage sources reduces losses, cost and complexity of the converter. Switching strategy and operation principal of proposed seven level cascaded multilevel converters are presented. The proposed inverter has been compared with the five-level PWM inverter. The effectiveness of the proposed inverter analysed using MATLAB/SIMULINK simulation program

Keywords-Seven level inverter, PWM techniques, reduced components, THD

I. INTRODUCTION

By using multilevel converters, the power quality is improved as the number of levels increase at the output voltage. However, it increases the number of switching devices and other components, and increases the cost and control complexity and tends to reduce the overall reliability and efficiency of the converter. It can be noticed that multilevel converters can sustain the operation in case of internal fault [9]. In the case of internal fault of one cell of FC converter, the maximum output voltage remains constant, but the number of levels decreases. On the other hand, when an internal fault is detected in the CHB converter, and the faulty cell is identified, it can be easily isolated through an external switch and replaced by a new operative cell.

Recently, renewable energy sources for grid connected applications are increased. Therefore, single phase multilevel inverters (MLI) become a good solution for these applications and have become more attractive for researchers due to their advantages over traditional inverters [1].

The research and development for these types of inverters gaining popularity especially for high power medium voltage applications.[2]

Conventional MLI include diode clamped converter, flying capacitors, cascaded H-bridge inverters. The cascaded H-bridge inverters are the most popularly hardware implemented topologies especially in the growing technological field of renewable energy[3].Unfortunately, one of the major disadvantages of MLI is large number of the required power semiconductor switches[4-6]. Although low voltage rate switches can be utilized, each switch requires a gate drive circuit. So, the system becomes expensive and complex. Therefore, it is necessary to reduce the number of switches in MLI to overcome the above disadvantage.[7-8]

II. CONVENTIONAL CASCADED MULTILEVEL INVERTER

A single phase full bridge inverter itself gives three levels therefore every module added in cascade to that extends the inverter with two more voltage levels. Conventional cascaded five level and seven level inverters are shown in figure 1 and figure 2. In figure 1 shown that five level inverter uses 8 switches and in figure 2 seven level inverter uses 12 switches, where as in proposed inverter these switches are reduced to give respective levels in the output waveform.

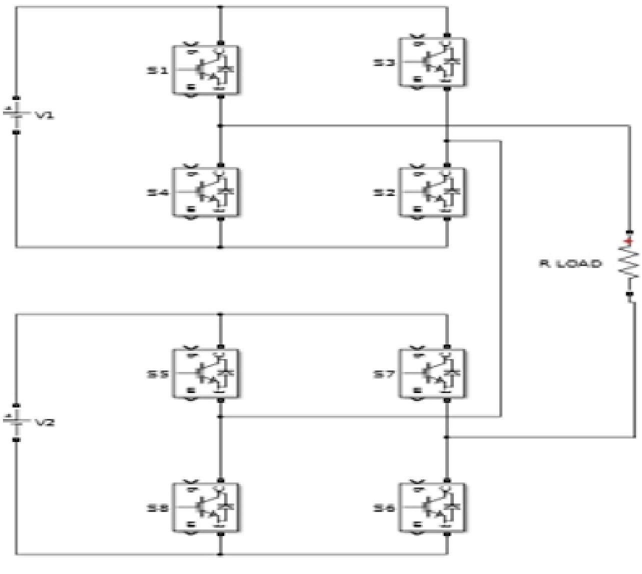


Figure1. Conventional 5-level cascaded inverter

III. OPERATIONAL PRINCIPLE AND SWITCHING ALGORITHM OF THE PROPOSED 5-LEVEL INVERTER

Figure 3 shows a proposed 5-level inverter with only 6 switches. Compared to conventional cascaded 5-level inverter two switches are reduced in the proposed inverter. The switching patterns employed in the proposed inverter are shown in fig 4.

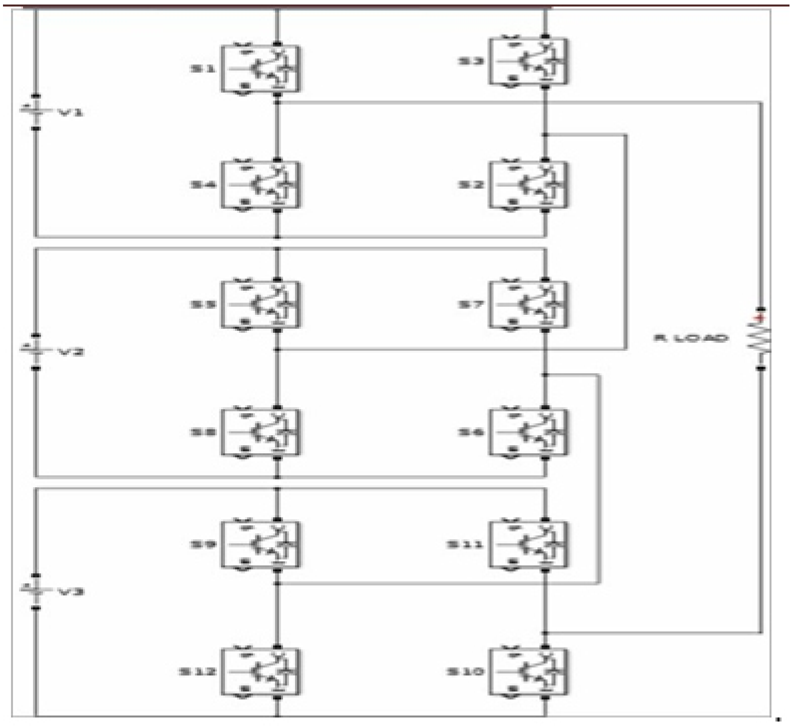


Figure 2.Conventional 7-level cascaded inverter

A reference signal of rectified sinusoidal wave is taken and by comparing this wave with two triangular carrier signals having the same frequency and phase angle, then the pulses obtained are given to the switches.

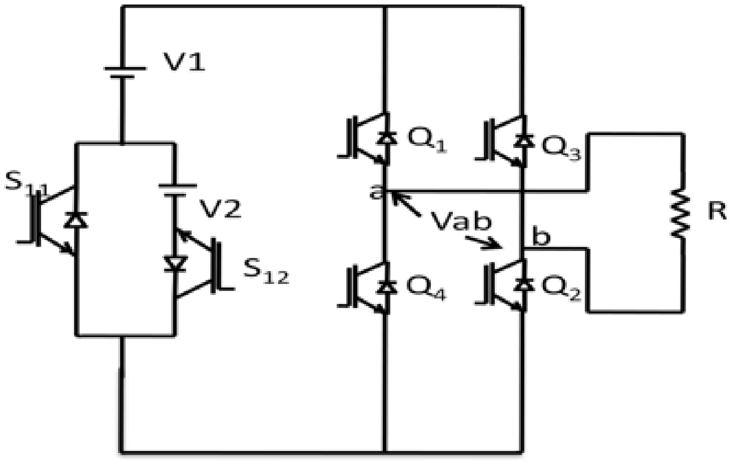


Figure 3. Proposed 5-level inverter.

Modulation index (MI)=Am/2Ac

Where,

Am= The peak value of reference signal

Ac= peak-to-peak value of carrier signal

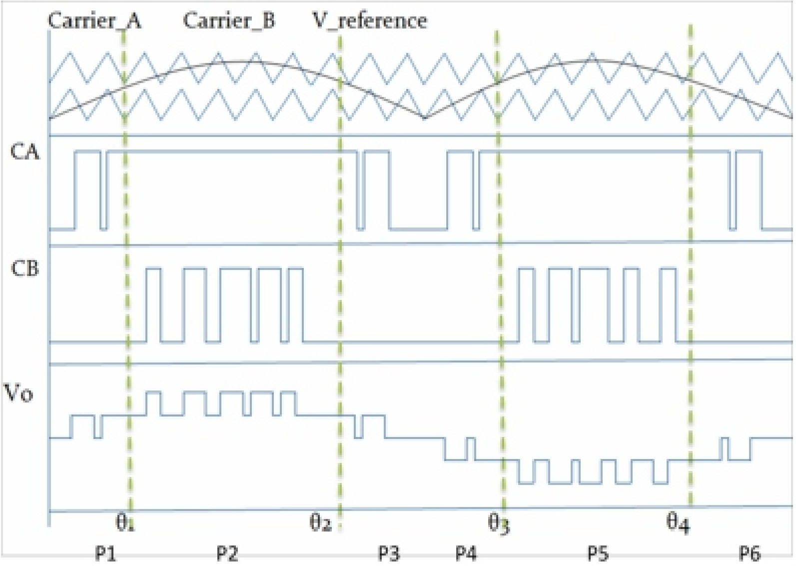
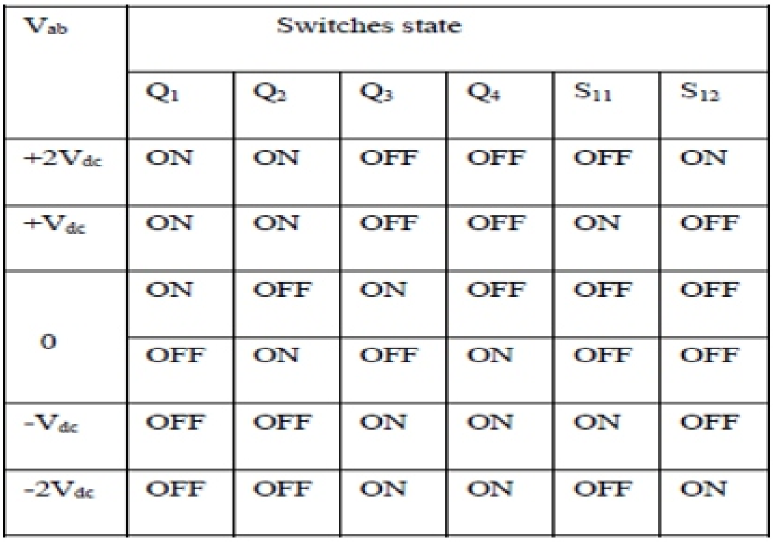


Figure 4. Switching patterns of the proposed 5-level inverter

Table: I Switching table for five level inverter



V_{ab}	Switches state					
	Q_1	Q_2	Q_3	Q_4	S_{11}	S_{12}
$+2V_{dc}$	ON	ON	OFF	OFF	OFF	ON
$+V_{dc}$	ON	ON	OFF	OFF	ON	OFF
0	ON	OFF	ON	OFF	OFF	OFF
	OFF	ON	OFF	ON	OFF	OFF
$-V_{dc}$	OFF	OFF	ON	ON	ON	OFF
$-2V_{dc}$	OFF	OFF	ON	ON	OFF	ON

The main six periods (P1 to P6) are shown in figure.4 can be calculated from the intersection of the reference waveform with the carrier signals. Then switch signals Q1-Q4, S11 and S12 can be formulated based on these six periods by below code.

CODE:

$$Q_1 = P_1 + P_2 + P_3$$

$$Q_2 = [(P_1 + P_2 + P_3).C_A] + [\ P_4 + P_6\ .\ C_A\ ]$$

$$Q_3 = \ \ P_1 + P_3\ .\ C_A \ \ + [\ P_4 + P_5 + P_6\ .\ C_A]$$

$$Q_4 = P_4 + P_5 + P_6$$

$$S_{11} = P_1 + P_3 + P_4 + P_6 . C_A + [\ P_2 + P_5 . C_B\ ]$$

$$S_{12} = P_2 + P_5 . C_B$$

II. OPERATIONAL PRINCIPLE AND SWITCHING ALGORITHM OF THE PROPOSED 7-LEVEL INVERTER

Figure 5 shows a proposed 7-level inverter with only 8 switches. Compared to conventional cascaded 7-level inverter four switches are reduced in the proposed inverter. The switching patterns employed in the proposed inverter are shown in fig 6.

A reference signal of rectified sinusoidal wave is taken and by comparing this wave with three triangular carrier signals having the same frequency and phase angle, then the pulses obtained are given to the switches.

Modulation index (MI)=Am/3Ac

Where,
Am= The peak value of reference signal
Ac= peak-to-peak value of carrier signal

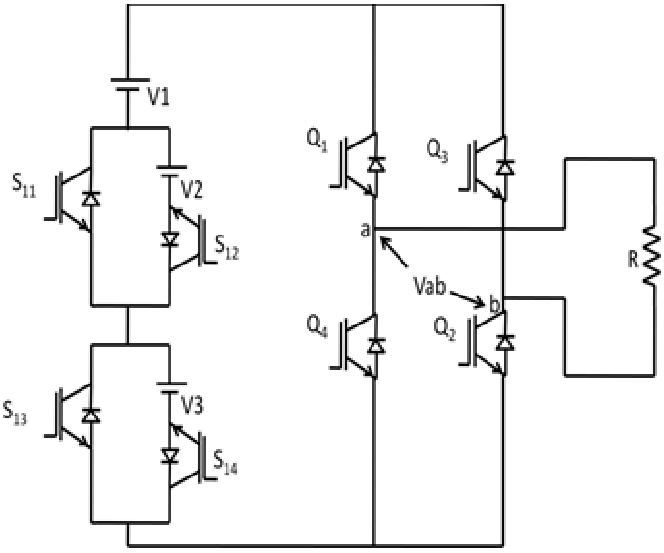


Figure 5. Proposed 7-level inverter

The main eight periods (P1 to P8) are shown in figure.6 can be calculated from the intersection of the reference waveform with the carrier signals. Then switch signals Q1-Q4, S11- S14 can be formulated based on these eight periods by below code.

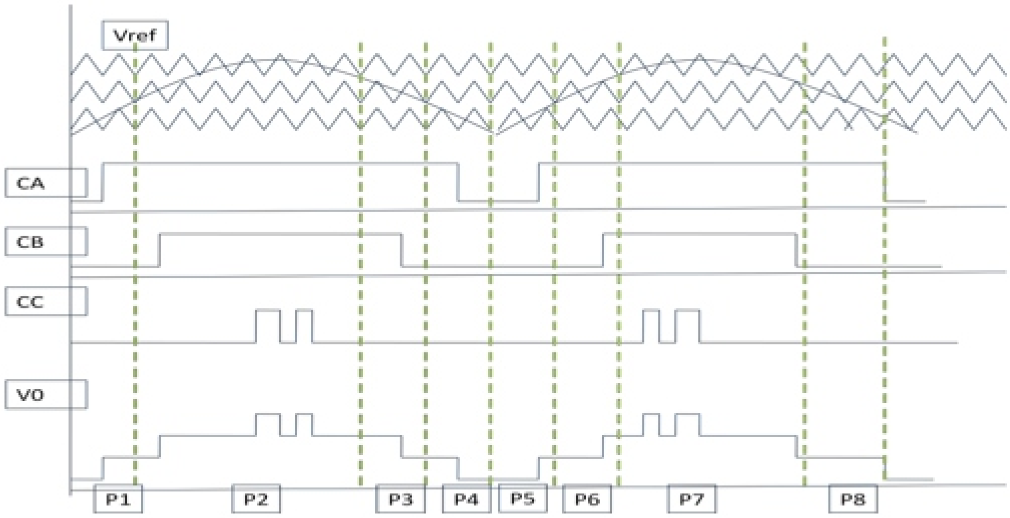


Figure 6. Switching patterns of the proposed 7-level inverter

Table: II Switching table for seven level inverter

V_{ab}	S_{11}	S_{12}	S_{13}	S_{14}	Q_1	Q_2	Q_3	Q_4
$+3V_{dc}$	OFF	ON	OFF	ON	ON	ON	OFF	OFF
$+2V_{dc}$	ON	OFF	OFF	ON	ON	ON	OFF	OFF
	OFF	ON	ON	OFF	ON	ON	OFF	OFF
$+V_{dc}$	ON	OFF	ON	OFF	ON	ON	OFF	OFF
0	OFF	OFF	OFF	OFF	ON	OFF	ON	OFF
	OFF	OFF	OFF	OFF	OFF	ON	OFF	ON
$-V_{dc}$	ON	OFF	ON	OFF	OFF	OFF	ON	ON
$-2V_{dc}$	ON	OFF	OFF	ON	OFF	OFF	ON	ON
	OFF	ON	ON	OFF	OFF	OFF	ON	ON
$-3V_{dc}$	OFF	ON	OFF	ON	OFF	OFF	ON	ON

CODE:

$$Q_1 = P_1 + P_2 + P_3 + P_4 + P_5$$

$$Q_2 = [(P_1 + P_2 + P_3 + P_4 + P_5).C_A] + [\ P_6 + P_{10}\ .C_A\ ]$$

$$Q_3 = \quad P_1 + P_5\ .C_A \quad + [\ P_6 + P_7 + P_8 + P_9 + P_{10}\ .C_A]$$

$$Q_4 = P_6 + P_7 + P_8 + P_9 + P_{10}$$

$$S_{11} = [(P_1 + P_5 + P_6 + P_{10}).C_A] + [P_2 + P_4 + P_7 + P_9 . C_B]$$

$$S_{12} = P_3 + P_8 . C_C$$

$$S_{13} = [(P_1 + P_5 + P_6 + P_{10}).C_A]$$

$$S_{14} = P_2 + P_4 + P_7 + P_9 . C_B + [P_3 + P_8 . C_C]$$

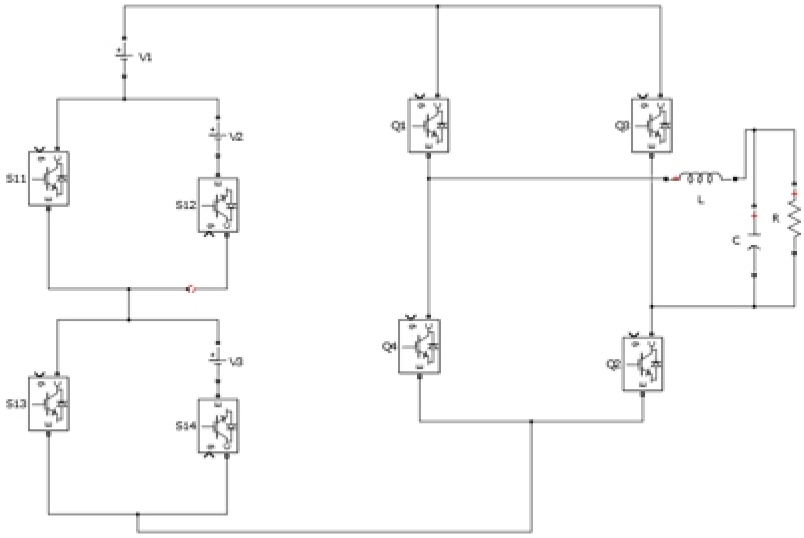
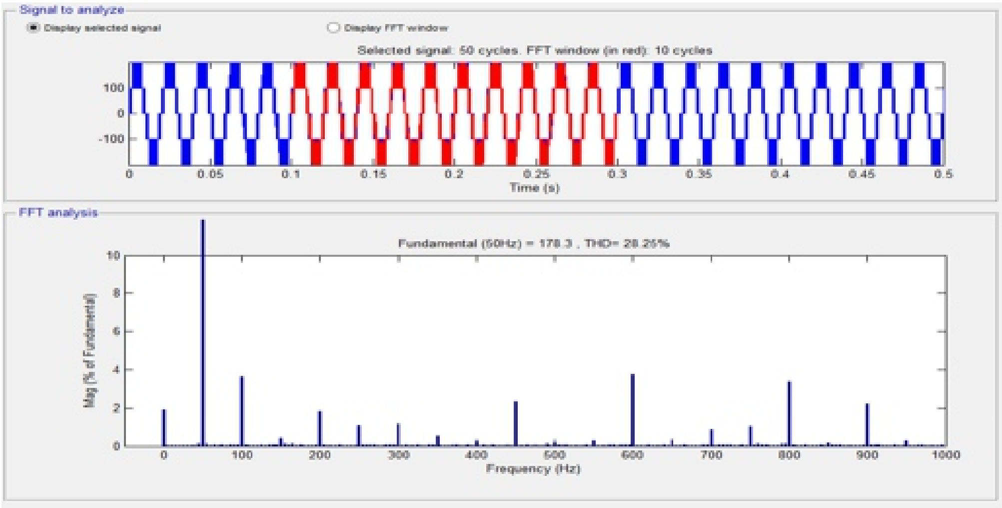


Figure 7. Proposed 7-level inverter with filter

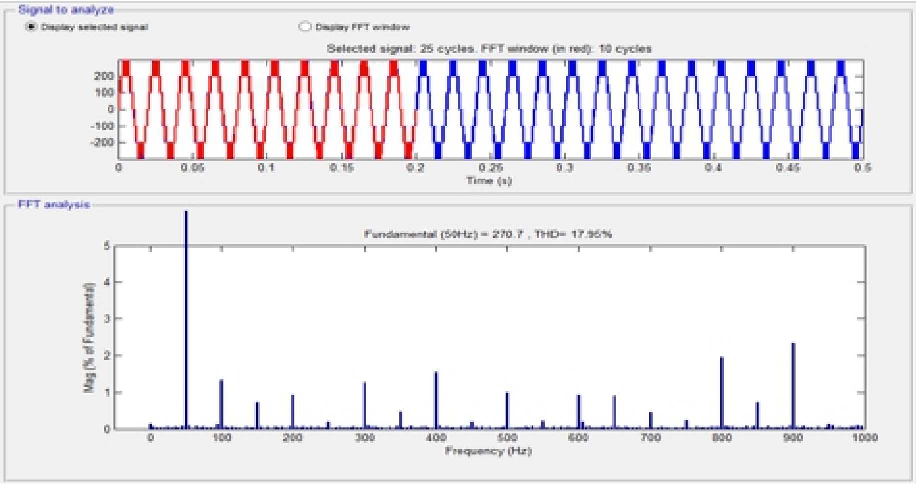
V. SIMULATION RESULTS



Selected signal: 50 cycles. FFT window (in red): 10 cycles

Fundamental (50Hz) = 178.3 , THD= 28.25%

Figure 8. output waveform of conventional 5-level inverter



Selected signal: 25 cycles. FFT window (in red): 10 cycles

Fundamental (50Hz) = 270.7 , THD= 17.95%

Figure 9. output waveform of conventional 7-level inverter

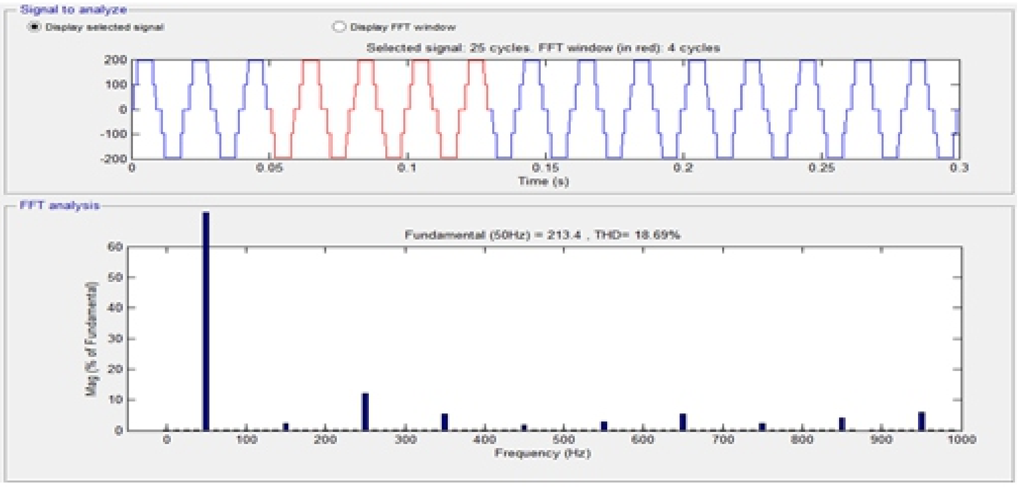


Figure 10.Output waveform of proposed 5-level inverter

Figure 7 shows a proposed 7-level inverter with a filter at output and the corresponding output waveform is shown in figure 12. A simple passive filter is used so that design of filter becomes easier in the proposed inverter.

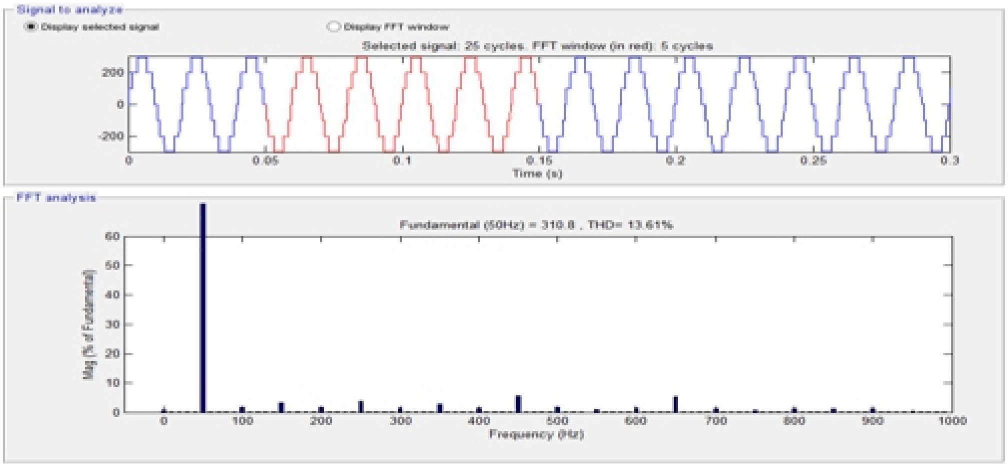


Figure 11. Output waveform of proposed 7-level inverter

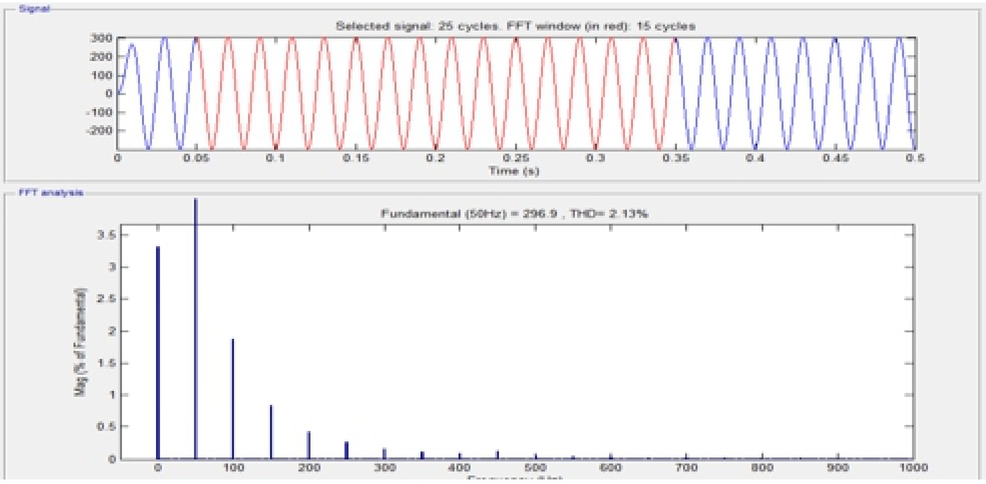
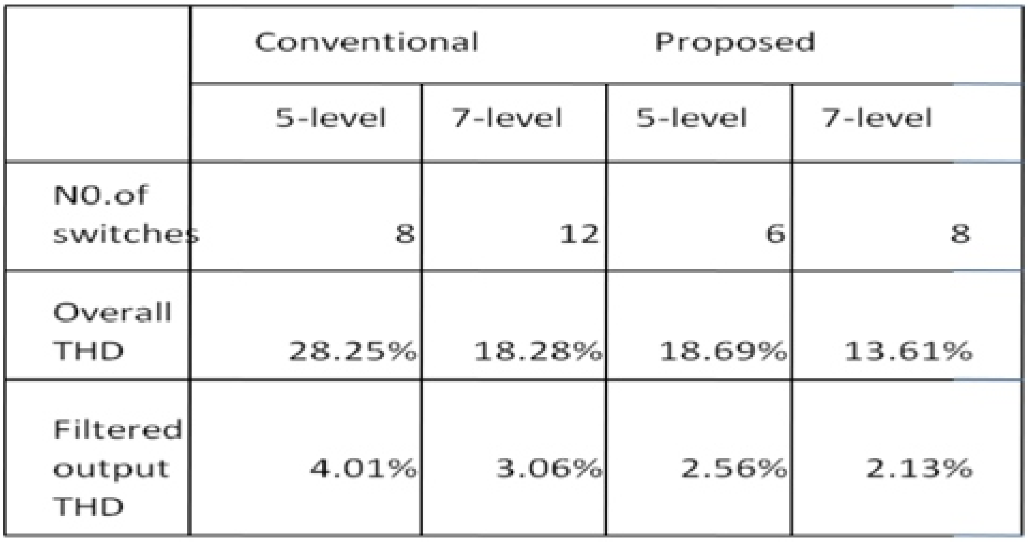


Figure 12. Proposed 7-level inverter with a filtered output

As this proposed inverter topology can be extended up to n level so that filter design becomes simpler compared to the conventional inverter. Comparison of harmonic content for five level as well as seven level inverters is given in below table.

Comparison table:



	Conventional		Proposed	
	5-level	7-level	5-level	7-level
N0.of switches	8	12	6	8
Overall THD	28.25%	18.28%	18.69%	13.61%
Filtered output THD	4.01%	3.06%	2.56%	2.13%

VI. CONCLUSION

In this paper a new topology of seven level inverter has been has been presented and compared with the conventional cascaded five level inverter. The proposed method results in the reduction of the number of switches, losses and cost of the converter. Based on the presented switching algorithm, the multilevel converter generates near-sinusoidal output voltage and as a result, it has very low harmonic content. This new topology as a advantages of smaller filter size, less circuit complexity, less number of switches and increased stepped output with less THD. Simulation results prove that proposed single phase seven level inverter has the less harmonic content with less number of switches compared with conventional inverter.

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