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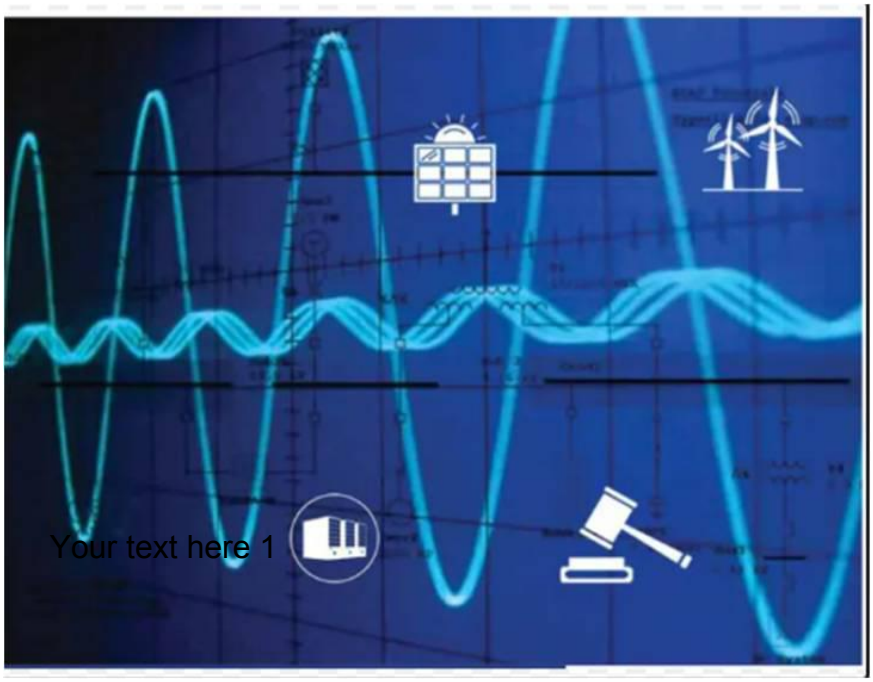

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CORONA's APPLICATION AS NITROGEN LASER

[1]KRISHNA DHONDDEV, [2]P.P.MAHAJAN, [3]V.P. KURALKAR

[1,2,3]Department of Electrical Engineering, AISSM's Institute of Information Technology, Pune, India
E-mail: [1]krishnadhonddev@gmail.com, [2]ppmahajan@gmail.com, [3]vaishali.kuralkar@gmail.com

Abstract - Corona discharge is the phenomenon which occurs on high voltage transmission lines. Because of corona there is much loss occurs in the transmission system. We can also identify corona discharge on lines by means of blue color spark and hissing sound. Also it is very harmful to system. But by using this discharge we can work on different applications such as we can manufacture Nitrogen Laser and so, we can use it in photocopying, also in tissue culture and in sanitization of pool water, etc. there is much use of applications of corona discharge in day to day life as well as in research field. For example, we use Xerox which is nothing but photocopying. Also in tissue culture and so on. By this we can make use of wasting energy by using in different applications in our life.

Keywords - Corona Discharge, Critical Disruptive Voltage, Nitrogen Laser.

I. INTRODUCTION

A corona discharge is an electrical discharge. Corona has also a typical sound called hissing sound, by which we can identify corona discharge. Corona discharges generally occur in high voltage transmission system. Corona is one type of loss. It is very harmful for transmission system, because as it is loss it losses energy flowing in the system. Corona takes place in a HT line when neutral atom or molecule in a strong electric field is ionized. Happening so positive ion and free electron created around the conductor and the conduction takes place through air between conductors of HT line. It causes the power loss in line, audible noise, electromagnetic interference, purple glow, and ozone production and insulation damage of the insulating medium. They also represent a power loss, and their action on atmospheric particulates, along with associated ozone and NOx production, can also be disadvantageous to human health where power lines run through built-up areas. Therefore, power transmission equipment is designed to minimize the formation of corona discharge. But there are some applications which are based on this corona discharge which are very useful in day to day life as well as in research field.

Power loss due to corona

Formation of corona is always accompanied by energy loss

Which is dissipated in the form of light, heat, sound and chemical action? When disruptive voltage is exceeded, the power loss due to corona is given by

$$P = 242 \cdot 2 \left(\frac{f+25}{\delta} \right) \sqrt{\frac{r}{d}} \left(V - V_c \right)^2 \times 10^{-5} \text{ kW / km / phase}$$

Where,

$$P = 242 \cdot 2 \left(\frac{f+25}{\delta} \right) \sqrt{\frac{r}{d}} \left(V - V_c \right)^2 \times 10^{-5} \text{ kW / km / phase}$$

f = supply frequency in Hz

V = phase-neutral voltage (*r.m.s.*)

V_c = disruptive voltage (*r.m.s.*) per phase

some ionization is always present in air due to cosmic rays, ultra-violet radiations and radioactivity. Therefore, under normal conditions, the air around the conductors contains some ionized particles (i.e., free electrons and +vet ions) and neutral Molecules. Corona Formation. Corona discharge on insulator string of a 500 kV overhead power line. Corona discharges represent a significant power loss for electric utilities.

When p.d.is applied between the conductors, potential gradient is set up in the air which will have maximum value at the conductor surfaces. Under the influence of potential gradient, the existing free electrons acquire greater velocities. The greater the applied voltage, the greater the potential gradient and more is the velocity of frees electrons.

When the potential gradient at the conductor surface reaches about 30 kV per cm (max. value), the velocity acquired by the free electrons is sufficient to strike a neutral molecule with enough force to dislodge one or more electrons from it. This produces another ion and one or more free electrons, which are turn, are accelerated until they collide with other neutral molecules, thus producing other ions. Thus, the process of ionization is cumulative. The result of this ionization is that either corona is formed or spark takes place between the conductors. But using this discharge we can travel in wide of application world.

II. CORONA DISCHARGE

A corona discharge is an electrical discharge brought on by ionization of a fluid such as surrounding a conductor that is electrically charged. Corona discharges generally occur in high voltage system. Basically the corona discharge observed at the surface of a conductor is due to formation of electron avalanches which occur when the intensity of the electric field at the conductor surface exceeds a certain critical value.

A corona will occur when the strength of electric field around a conductor is high enough to form a conductive region. But it doesn't cause break down. In many high voltage application corona is an unwanted side effect corona discharge from high voltage electric power transmission lines constitutes an economically significant waste of energy for utilities.

In high voltage equipment like televisions, radio transmitters, X-ray machines & partial accelerators the current leakage by coronas can constitute unwanted load on the circuit. Also in air corona generates gases such as ozone (o_3), nitric oxide (NO), & in turn nitrogen dioxide (NO_2), & thus nitric oxide (HNO_3) if water vapors are present.

These gases are corrosive & can degrade & brittle nearby materials, &are also toxic to people. Controlled corona discharges uses as application like air filtration, photocopiers & ozone generators. Corona is visible in the form of light. also it observes at the surface of the conductor are due to the formation of dectron avalanches which occur when the intensity of the electric field at the conductor surface exceeds a certain critical value which can be given by

$$\therefore \text{Critical disruptive voltage, } V_c = m_o g_o \delta r \log_e \frac{d}{r} \text{ kV/phase}$$

where m_o = 1 for polished conductors
= 0·98 to 0·92 for dirty conductors
= 0·87 to 0·8 for stranded conductors

$$Critical\ disruptive\ voltage\ V_c = mgr\delta ln(\frac{d}{r})\ kV/phase$$

$$Critical\ disruptive\ voltage\ V_c = 1 \times 21 \times 1 \times 1 \times ln(\frac{0.5 \times 10^2}{1})$$

$$Critical\ disruptive\ voltage\ V_c = 82.15\ kV/phase$$

It is the minimum phase-neutral voltage at which corona occurs.

The corona discharge is also used for doing corona treatment which is invented by the Danish Engineer Verner Eisby in 1951. Coronas may be positive or negative.

An important reason for considering coronas is the production of ozone around the conductor's underling corona processes in air. A negative corona generates much ozone than the corresponding positive coronas. Corona also can generate audible & radio-frequency noise, probably near electric power transmission lines.

Corona discharge constitutes of following steps
1) Discharge Initiation
2) Electrical Breakdown
3) Recombination & up keep of the discharge

Advantages and disadvantage of corona:-

Corona has many advantages and disadvantages. In the correct design of high voltage overhead line, a balance should be struck between the advantages and disadvantage.

Advantages: -

1- Due to corona formation, the air surrounding the conductor becomes conducting and hence virtual diameter of the conductor is increased. The increased diameter reduces the electro static stress between the conductors.

2- Corona reduces the effect of transient produced by surges.

Disadvantages:-

1- Corona is an accompanied by a loss of energy. This affects the transmission efficiency of the line.

2- Ozona is produced by corona and may cause corrosion of the conductor due to chemical action.

3- The current drawn by the line due to corona is non-sinusoidal and hence non- sinusoidal voltage drop occurs in the line. This may cause inductive interference with neighboring communication lines.

Microscope, surface profiler and laser desorption/ionization mass spectrometry

Optical micrographs and surface profile of the trace stained with discharge on the plate were obtained by using a BX51 optical microscope (OLYMPUS, Tokyo, Japan) and an Alpha-Step IQ surface profiler(KLA-Tencor, San Jose, CA, USA), respectively. LDI mass spectra were acquired on an AXIMA-CFR instrument (Shimadzu Corp, Kyoto, Japan).

A nitrogen laser (337 nm) was used to irradiate and ionize the components of the trace stained with discharge on the plate. The laser beam profile on the target was 200 μm in diameter. The mass spectra were obtained with negative-ion reflectron mode. The acceleration potential was set to 20 kV using a gridless-type electrode. The ion source and analyzer were maintained at 10-5 Pa.

Most important part of every subject is applications like wise; Corona discharge has a number of commercial and industrial applications

1) Drag reduction over a flat surface
2) Manufacture of ozone
3) Sanitization of pool water
4) Photocopying
5) Air ionizer
6) EHD thrusters, lifters
7) Nitrogen laser
8) Surface treatment for tissue culture
9) Stabilizer of Van de Graff generators
10) Static charge neutralization , as applied through antistatic device like ionization bars

Corona discharge widely used in

1) Nitrogen laser
2) Air ionizers

III. NITROGEN LASER

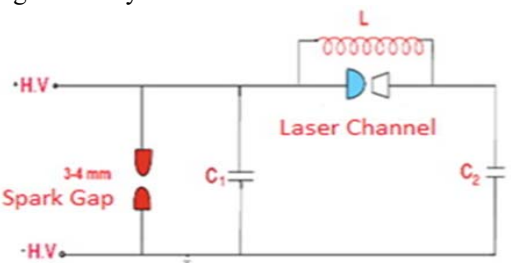
What are nitrogen laser and its use?

A laser which operates in the ultraviolet region using molecular nitrogen & its gain medium pumped by electric discharge. Nitrogen laser is one of the laser sources which

Can be fabricated without much difficulty. Basically nitrogen laser uses electricity to excite nitrogen.

A historical survey on the various designs of nitrogen lasers are briefly outlined followed by an overview of the theoretical analysis of laser action in nitrogen gas. It is known that very fast excitation of nitrogen molecules is a pre-requisite for population inversion. This is accomplished by a fast electrical discharge which dictates a very low impedance pulse circuit.

A Blumlein circuit with transverse excitation is ideal for this, since with a moderate voltage it is possible to excite the gas at high pressures. Necessary theory of the Blumlein circuit which is incorporated with the nitrogen laser system



The working principal of nitrogen laser is wall plug efficiency and nitrogen laser gives it very low, typically 0.1%. The laser constitutes mainly of plasma tube, spark gap, Blumlein capacitors, and high voltage power supply, trigger circuit and gas flow system.

The wall plug efficiency is product of

1) Electrical tea laser
2) Gain medium- This is same for all nitrogen lasers & thus has to be at least 3%.
3) Inversion by electron impact is 10 to 1 due to frank Condon principal
4) Energy loss in lower level -40%
5) Optical – more induced emission than spontaneous

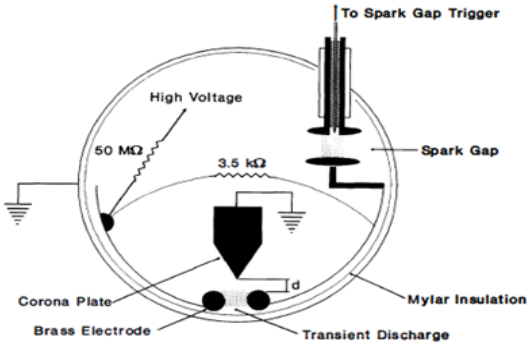
Nitrogen laser is a three level laser. In some applications it is of four layers also which are directly pumped, imposing no limits on pump. The range of it is to 100ev per tore-cm pressure of nitrogen.

Nitrogen lasers are manufactured by using different excitations of nitrogen molecules such as, the nitrogen laser medium can be excited by electron beams or electric discharges. Transverse electric discharge excitation is perhaps the simplest and most commonly used Excitation technique for nitrogen lasers.

Again there are some techniques which are used to excite the nitrogen molecule they are

1) Electron beam excitation

Electron beams from field emission cathodes are accelerated by potentials of 50-60 kV to produce a longitudinal traveling wave type of excitation. Laser beam energy to electron beam energy conversion efficiency was 0.15% and overall laser energy to electrical input energy efficiency was 0.03%. Electron beam excitation is, however, rarely used because of the complexity of excitation technique and it does not have any significant advantage over the electric discharge technique.



CROSS SECTIONAL VIEW OF NITROGEN LASER

2) Longitudinal electric discharge excitation

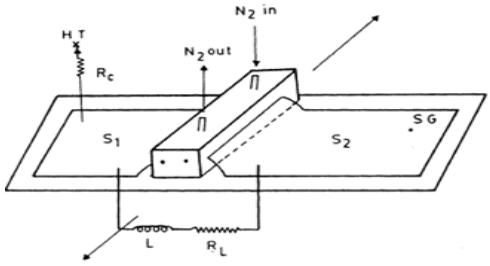
A charged coaxial cable used as the energy storage device is discharged across electrodes kept at

Either end. This causes a high current step function discharge in the nitrogen gas contained inside the cable creating high inversion. This type of laser has worked with and without mirrors.

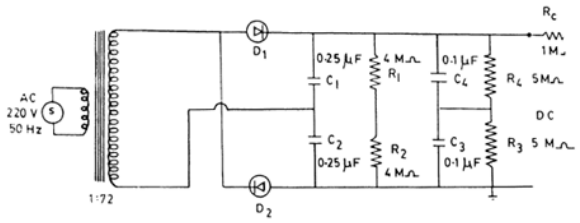
The main advantage is the almost complete suppression of electromagnetic noise since the discharge is contained inside the coaxial cable. One gets a power output of about 200 to 300 kW at 337.1 nm for an applied voltage of 20 to 30 kV.

3) Transverse electric discharge excitation

This is the most commonly used excitation technique in nitrogen lasers. The electrodes run along the entire length of the laser channel and the discharge can be accomplished with comparatively low voltages. One can get high powers of about 1 MW for a discharge length of about 1 m and for an applied voltage of about 20 kV. The efficiency of this type of excitation is rather high compared to other methods and is about 0.05 to 0.1%. The laser we have constructed as a pump for the study of amino coumarin dyes is a transverse electric discharge type nitrogen laser with a double parallel plate transmission line.



SCHEMATIC DIAGRAM FOR TRANSVERSE EXCITATION NITROGEN LASER

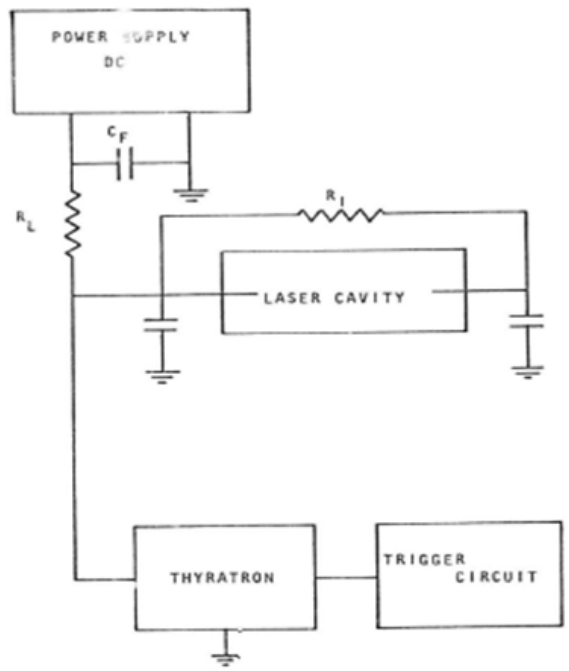


D. C. POWER SUPPLY IS USED FOR NITROGEN LASER

Construction of nitrogen laser:-

The block diagram of nitrogen laser is-

NITROGEN LASER BLOCK DIAGRAM



Specifications:-

The nitrogen laser is housed in a box which has the dimensions 60" long by 12" high by 12" wide. It is constructed of aluminum. An inner frame of welded aluminum angle supports the walls and allows for maximum rf shielding. Measurements were made of laser output as a function of voltage. The output is in terms of power per pulse. Measurements were made by focusing the beam into a Moll's thermopile. The thermopile has an output of. 16 volts per watt input. The average power was then calculated by the formula

$P_A = V/.16$ (1)

Where P_A is the average power in watts and V is the voltage in volts.

Energy per pulse can be calculated by

$E = P_A / f$ (2)

Where E is the energy per pulse and f is the pulse frequency in units of sec^{-1}. Since the entire energy and power output occurs during the pulse, the average power per pulse can be calculated by

$P_P = El\ f$ (3)

Where Pp is the power per pulse and it is the duration of the pulse in seconds. Combining the three equations:

$Pp = V / tf(O.\ 16)$ (4)

Almost the entire pulse occurs within a 5 nsec period so

$Pp = V / f(8 \times 10\text{-}\ 10)$ (5)

For the data on Figure 4, a repetition rate of 10 pulses per second was

Used so the formula simplifies to

$Pp = V /8 \times 10^{-9}$ (6)

Figure shows the effect of increasing the voltage at different flow rates. The output line designated P was measured at the maximum pumping speed for the vacuum.

To obtain P 1/ 2, the inlet was closed until the pressure read 25 torr. Then the pumping speed was slowed until the pressure l-e turned to 50 torr, giving approximately 1/ 2 the flow rate of the gas.

Note the two- fold increase in lase r output with the doubled flow rate. When excitation and emission occur, the nitrogen is left in a metastable B3 "g state. These metastable molecules must be removed before the next firing cycle or power is lost.

Therefore, the slower the gas flow rate, the lower the power. The leveling off at higher voltages occurs because the system saturates. All available N_2 molecules are excited with each pulse.

There is 40 ns upper limit of laser life time at low pressures & the lifetime becomes shorter when it increases. The strongest lines are at 337.1 nm wavelength in the ultraviolet. As this is gas laser so one should make care about gas pressure, the gas pressure in a nitrogen laser ranges from mbar to as much as several bars.

The metastable the lower level life time 40ns, thus the laser self terminates. This type of self-termination is known as “bottlenecking in the lower level”. This the thumb rules for majority lasers. The present thesis reports the work carried out by the author on the design, fabrication and parametric studies of a high-power nitrogen laser system and its use to study the fluorescence characteristics of certain doped phosphor samples.

As we have already mentioned the TEA laser which is when the pressure is at 1013 mbar configuration is TEA laser (Transverse electrical discharge in gas at atmospheric pressure). The basic property of nitrogen laser is in the gaseous form.

N_2 laser finds important applications in Spectroscopy, Solid State Physics, Chemical Physics and Biomedical Engineering.

The main part of each & every subject is applications i.e. whatever device or concept which we are using that where it is applicable or used likewise for nitrogen laser.

1) It can be easily coupled to a microscope for carrying out experiments in life science lab.

2) They are also efficient sources for laser induced fluorescence & photochemistry & general spectroscopy.

3) In measurement of air pollution

4) In treatment of non-healing wounds, pulmonary tuberculosis
5) Transverse optical pumping of dye laser
Also nitrogen laser uses in microscopic description of a fast discharge that the spark uses a high density of gas molecule and a low density of initial electrons to fever streamers. Electrons are removed by a slowly rising voltage. A high density gas increases the breakdown field thus shorter the electrical arcs.
Thus gas lasers use a low density gas molecules and high density of initial electrons to prevent streamers. Also wide avalanches can excite more nitrogen molecules.
Again in electrodynamics, this nitrogen laser uses as the electronic circuit is composed of a spark gap, a capacitor & the discharge through the nitrogen. The spark gap then discharges itself & the voltage is applied to the nitrogen. Now, the spark gap is stated by the Paschen's law which states that the length of the spark gap is inversely proportional to the pressure.

Also there are various types of nitrogen laser present in the market they are

- MNL 100 nitrogen laser
- MNL 100-hp nitrogen laser
- MNL 300 nitrogen laser
- MNL 330 nitrogen laser Nitrogen & Dye Laser Systems

Advantages of the nitrogen laser as a pumping source:
The nitrogen laser is chosen as the pump source for studying the gain characteristics of the coumarin dyes for the following reasons:
I. The nitrogen laser output at 337.1 nm is absorbed well by all the coumarin dyes.
ii. The nitrogen laser pulse has time duration of only about 10 nanoseconds and this helps to avoid triplet state effects.
iii. The nitrogen laser gives a rectangular beam of almost uniform intensity distribution.
iv. The fast rise time (3-5 ns) of the nitrogen laser pulse helps in efficiently populating the short lived (5-10 ns) excited singlet states of the dyes.
v. The dye does not show any detectable decomposition due to photochemical reactions when pumped by the nitrogen laser.

CONCLUSION

As we all know corona is a major discharge which occurs on high voltage transmission line and by that much amount of energy is wasted. So by this topic we learned to use this corona discharge by means of its various applications, Such as nitrogen laser. In that it is clear that nitrogen laser is very useful and efficient in many more applications.

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SIMULATION & HARDWARE IMPLEMENTATION OF SINGLE PHASE CASCADED FIVE LEVEL INVERTER

1. Mrs.S.M.Shaikh (Assistant Professor)
2. Nikita Bhosale, 3. Shubham Wale, 4. Devendra Patil; (UG Students)
AISSMS'S INSTITUTE OF INFORMATION TECHNOLOGY, Pune, Maharashtra, India. 411001.

***Abstract*— Multilevel inverters are employed mainly due to their high power transfer capabilities. The primary objective of designing the multilevel inverter is to implement this inverter in the field of domestic appliances aiming to lower output harmonics, proving it an enhanced version of inverter over conventional inverter. The paper presents a topology of multilevel inverter with features like lower Total Harmonic Distortion (THD) with reduced commutation losses. The single unit of this topology gives five-level output. The analysis is done based on parameters of the construction i.e. number of switches, DC voltage source, capacitor and diode requirements. The THD analysis of single phase cascaded five level inverter is done in Fast Fourier Transform (FFT) window, in order to get practical realization. The analysis of output voltage harmonics is carried out in MATLAB, the proposed multilevel inverter topology is modeled using MATLAB. From the results output is verified.**

***Keywords*— multilevel inverters; cascaded H-bridge;**

I. INTRODUCTION

For the applications ranging from medium voltage to Extra High Voltage high power applications, Power electronic converters are employed which have capability of DC to AC conversion such as multilevel inverters [1,2,3]. The current problems encountered while designing and implementing the power electronic converters are the complexity of circuit resulted due to large number of operational switching devices and large number of passive components such as capacitors which are used for voltage balancing in inverters. The inverters which use three or more than three voltage levels are multilevel inverters. There are three mains stream multilevel VSI topologies: 1) Neutral-point clamped inverter (i.e. Diode Clamped), 2) Flying capacitor (capacitor-clamped), and 3) Cascaded H-bridge multilevel inverter [4,5]. Wide range of other topologies has been invented and have successfully implemented in industrial applications. The Cascaded multilevel inverter has been proved the most trustworthy due to its feature of being operable even after failure of battery cells at potential lower than that of rated.[6,7] The Cascaded multilevel inverter consists of various identical H-bridge arms which are connected in series at the output side. This paper deals with such configuration of cascaded multilevel inverter for five level implementation. The Cascaded inverter consists of DC voltage for each H-bridge and four switching devices in a single arm resulting in overall 9 switching devices for implementing five levels. The general block diagram for a single unit of H-bridge is shown in fig.1 and general configuration of cascaded multilevel inverter is shown in fig.2.

II. PROPOSED INVERTER CONFIGURATION

The Cascaded inverter consists of DC voltage for each H-bridge and four switching devices in a single arm resulting in overall 9 switching devices for implementing five levels. The general block diagram for a single unit of H-bridge is shown in fig.1 and general configuration of cascaded multilevel inverter is shown in fig.2.

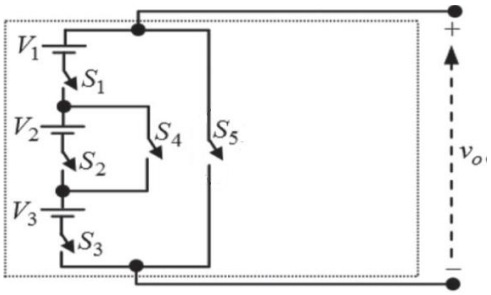

Fig. 1.: Single unit of H-bridge basic unit [1]

The configuration consists of a regular H-bridge, like a single phase full bridge 180° conduction mode inverter. But it is supplied through additional 5 auxiliary switching devices for the sake of providing 5 levels of the input to get 5 levels of corresponding output.[8]

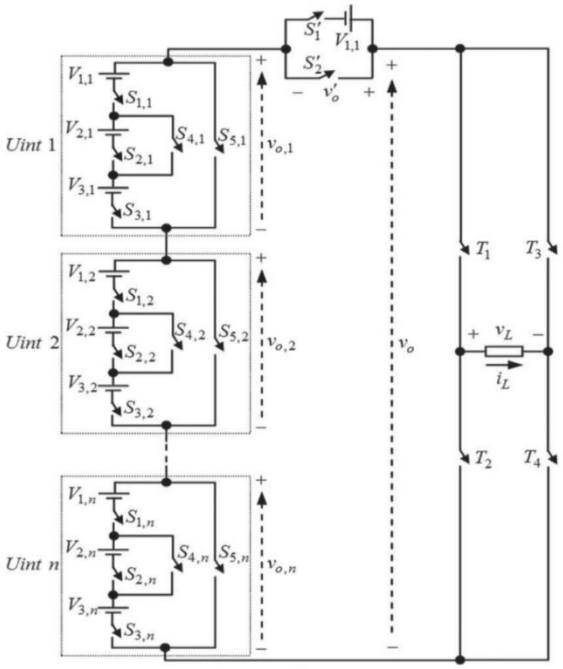

Fig. 2.: Cascaded multilevel inverter [1]

The switches T1, T2, T3, T4 forms the main H-bridge and remaining switches (S1,1), (S2,1), (S3,1), (S'1), (S'2) are the controlling auxiliary switches.

III. Comparison Of Conventional Five Level Inverter And Proposed Topology Of Inverter

PARAMETER	NPCMLI	FCMLI	PROPOSED TOPOLOGY
NUMBER OF SWITCHES	16	16	9
DC VOLTAGE SOURCE	1	1	3
CAPACITOR	4	16	0
MAIN DIODE	24	16	0

Table.1 comparison of different inverter topologies [Source: "Power Electronics circuits, devices and applications", by M.H.Rashid]

IV. Operation Of Proposed Inverter Topology

The working of 5 level cascaded multilevel inverter can be explained through following points:
1) The peak positive output voltage that can be produced i.e. 2Vdc is obtained when switches S1, S2, S3 and T1, T4 conducts simultaneously provided remaining switches are off.
2) The peak negative output voltage that can be produced i.e. -2Vdc is obtained when switches S1, S2, S3 and T2, T3 conducts simultaneously provided remaining switches are off.

The in depth operation of this inverter can also be understood through the look-up table which is provided in Table 2. The values 0 and 1 corresponds to switch state being OFF state and ON state respectively. The look-up table for five level operations given in table given below:

S1	S2	S3	S4	S5	S7	S8	S9	S10	OUTPUT (Volts)
0	0	0	0	1	1	1	0	0	0
1	0	1	1	0	1	1	0	0	40
1	1	1	0	0	1	1	0	0	60
1	1	1	0	0	1	1	0	0	60
1	0	1	1	0	1	1	0	0	40
0	0	0	0	1	1	1	0	0	0
0	0	0	0	1	0	0	1	1	0
1	0	1	1	0	0	0	1	1	-40
1	1	1	0	0	0	0	1	1	-60
1	1	1	0	0	0	0	1	1	-60
1	0	1	1	0	0	0	1	1	-40
0	0	0	0	1	0	0	1	1	0

Table .2. Switching configuration for proposed five level inverter

V. MATLAB Simulation Of Single Phase Cascaded Five Level Inverter

MATLAB Simulink software is used for software implementation of single phase cascaded multilevel inerter.

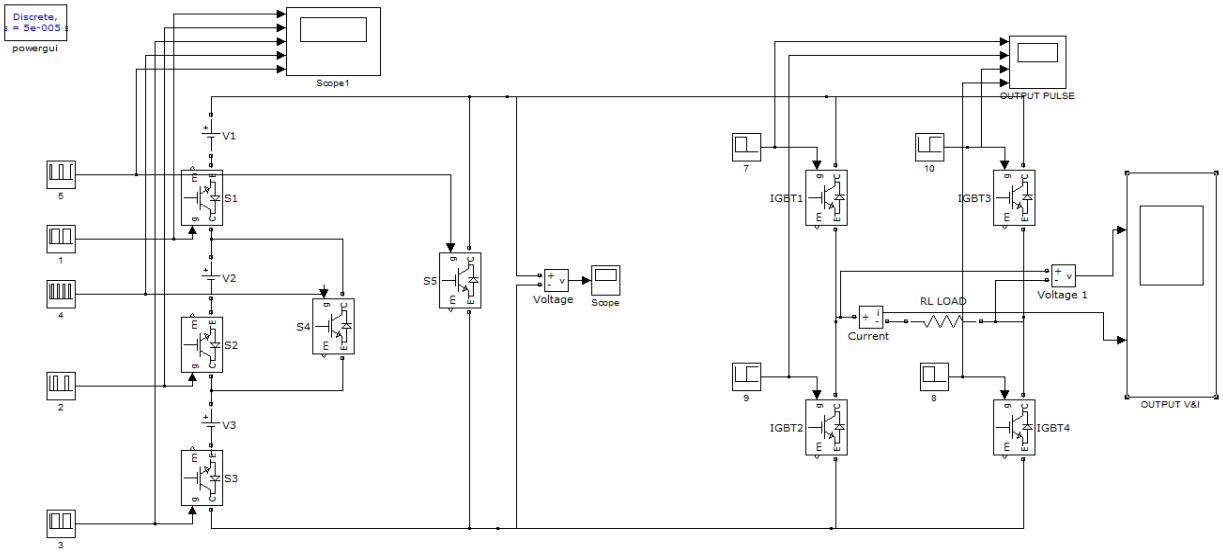

Fig.3.: MATLAB simulation of proposed single phase cascaded five level inverter

To generate gate pulse to IGBT in MATLAB the block called repeating sequence stair is used in which switching pulse to each IGBT is given as per table 2. When pulse is 1 the IGBT is on and when pulse is 0, it is off. According to the output,

voltage level required gate pulse is given to IGBT to turn on and off. In five-level as all dc input voltages are set to 20V, steps of +60V, +40V,0V, -40V, -60V are obtained.

VI. MATLAB Simulation Results Of Single Phase Cascaded Five Level Inverter

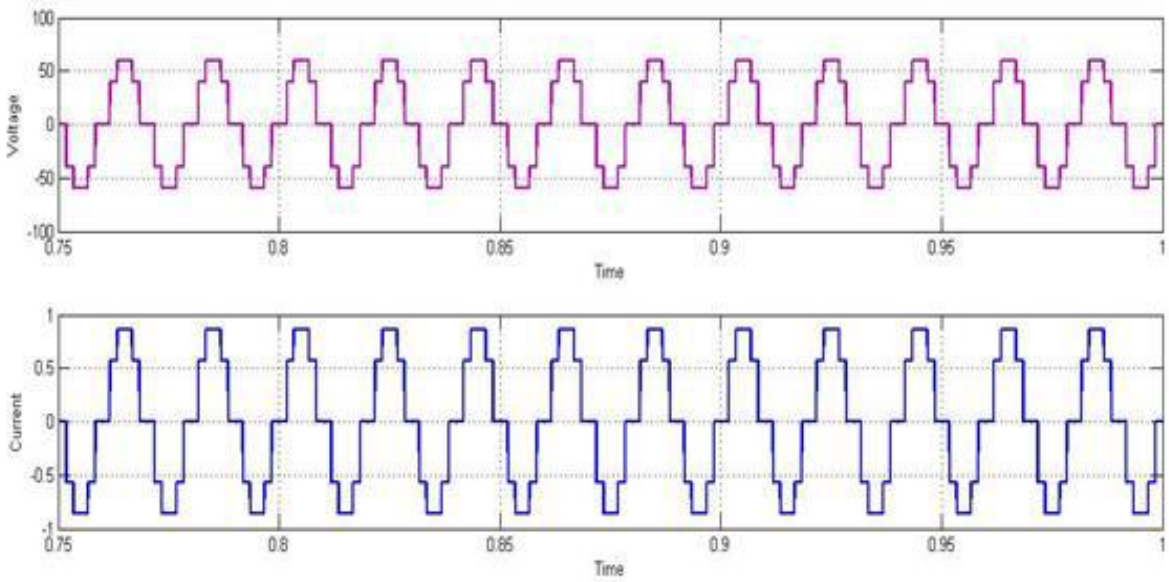

Fig.4: Ouitput of single phase cascaded five level inverter

VII. THD Analysis Of Single Phase Cascaded Five Level Inverter

Using MATLAB's SimPower system simulation is done for five-level, seven level and fifteen level and results are obtained. The THD calculate for five-level in MATLAB is 27% and 17% for fifteen-level inverter (from simulation result).

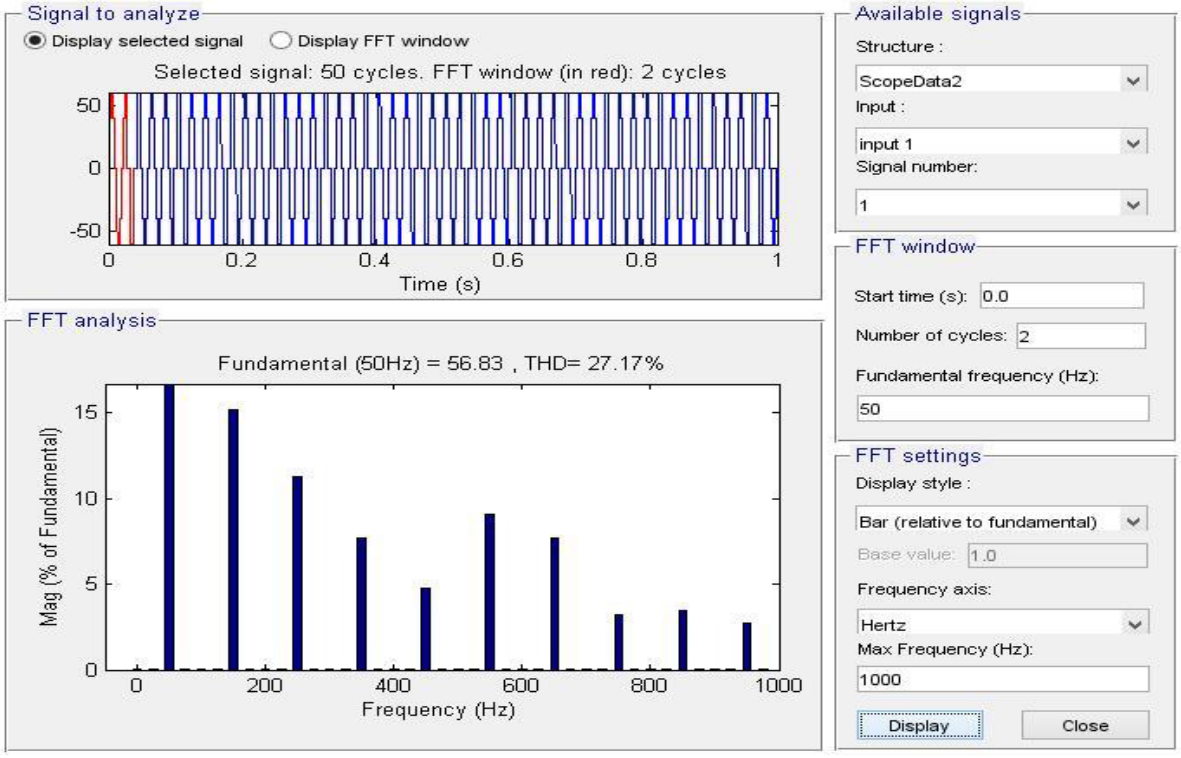

Fig.5: THD analysis of single phase cascaded five level inverter

VIII. HARDWARE IMPLEMENTATION

In this dissertation work a new basic unit for a cascaded multilevel inverter is proposed. By the series connection of several basic units, a cascaded multilevel inverter that only generates positive levels at the output is proposed. Therefore, an H-bridge is added to the proposed inverter to generate all voltage levels. This inverter is called the developed cascaded multilevel inverter.

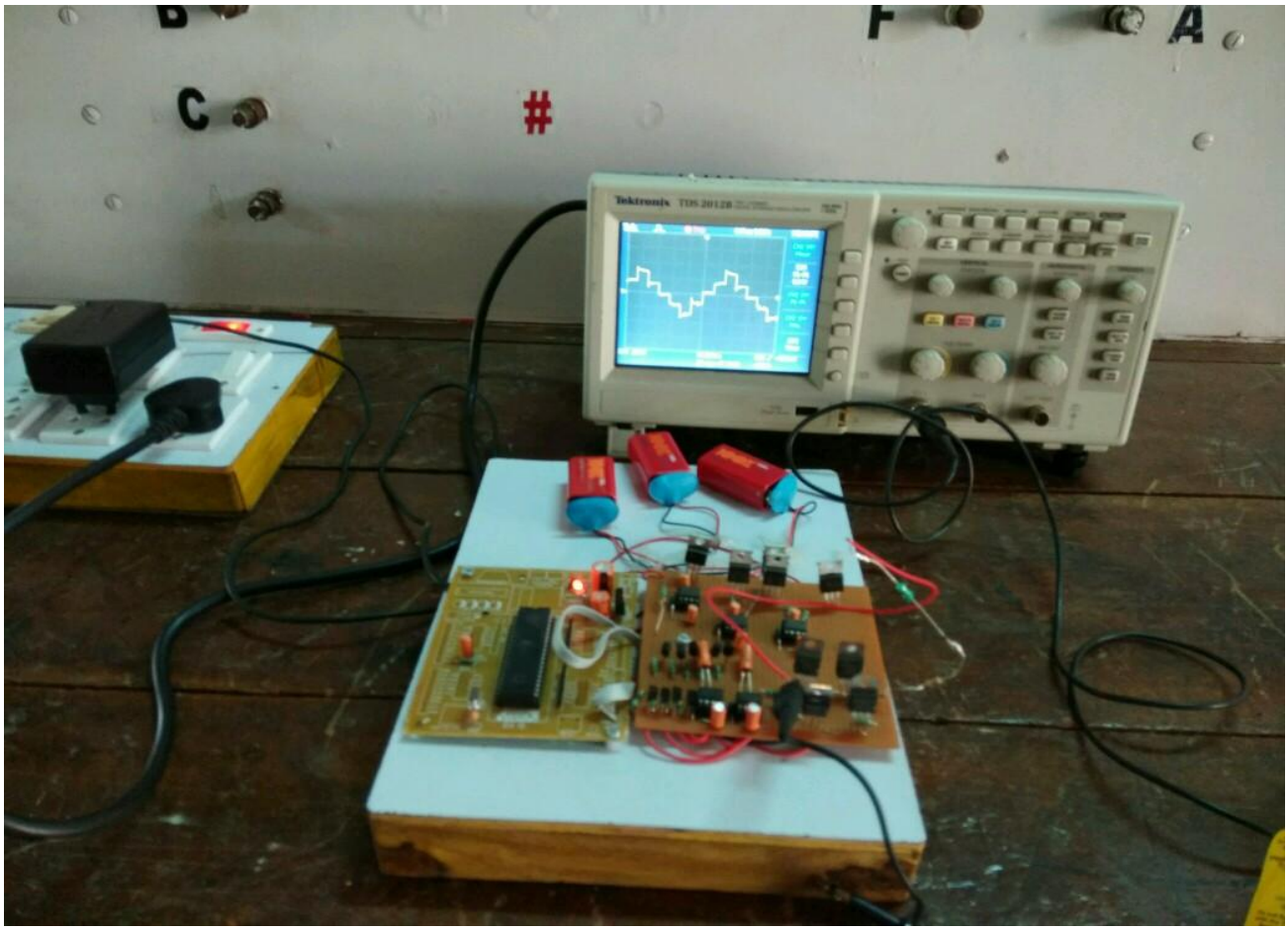

Fig 5.: Hardware implementation of cascaded 5 level multilevel inverter (with output measured on CRO)

IX. CONCLUSION

The proposed single phase five level multilevel inverter topology is very much superior over conventional multilevel inverters in terms of number of output voltage levels, magnitude of voltage and Total Harmonic Distortion (THD) [9, 10]. The FFT analysis is proving the fact of maximum presence of fundamental frequency components in the output along with very high frequency harmonics present in the output which can be easily filtered out with the help of passive filters tuned to particular frequency if required. With increase in level the sinusoidal like waveform can be generated at the output. As a result: THD decreases; Output waveform quality increases; Also lower switching losses; Lower voltage stress of dv/dt on switches; betters' electromagnetic interference.

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Power Quality Audit and Compliance As Per IEEE519-2014 Steering Manufacturing Industry (India)

[1]Mrs.Saba Shaikh,[2]Omkar Zanje, [3]Rohan Koli, [4]AbhishekEkal,[5]AartiDhotare,[6]ShwetaliJamadar,

[7]KirteeKamthe

Electrical Department, AISSMS IOIT, Savitribai Phule Pune University

[1]saba.shaikh@aissmsioit.org
[2]omkar.zanje1@gmail.com
[3]rohankoli101@gmail.com
[4]abhishekekal8898@gmail.com
[5]aratidhotare12@gmail.com
[6]shwetalijamadar12@gmail.com
[7]kamthekirtee14@gmail.com

***Abstract*: This paper presents the power quality audit of electrical installations and their loads for Steering Manufacturing Industry. Large inductive loads such as furnace, various manufacturing machines and short blasting machines etc., cause increase in losses, increase in neutral current, maloperation of sensitive electronic equipment's etc. Some of the major power quality issues are voltage sag, harmonics, poor power factor, unbalancing etc. Fluke 435-II power quality analyzer is used to conduct the power quality audit. Measurements were takenwith and without APFC.**

Keywords:Power Quality, Harmonic, Energy losses, Power Analyzer, THD

INTRODUCTION

Power quality is the important factor because most of power related problems that occurs in voltage, current, or frequency deviationsresult in failure of customer devices. Differentpower quality related problems are: frequency deviations, powersystemharmonics (in voltage, current, power and energy etc.),distortion of harmonics, transients in power system, poor power factor, etc. Power frequency deviations are low-frequencyphenomenonthat results in voltage sags or swells. These may besource or load generated caused due to faults or switching operations. Some of the major power quality issues are voltage sag, harmonics, poor powerfactor, unbalancing etc. Harmonics are integer multiple offundamental frequency. The frequency of each harmoniccomponent is called as harmonic frequency.The Power Quality Audit is an effective tool to reduce energy losses, helps in preventive maintenance and gives us quality control methods.The main objective of Energy Auditis to determine ways to reduce energy consumptionper unit of product output and/or to lower operating costs.Energy Audit provides a "benchmark" for managing energy in the companyandalso provides the basis for planning more efficient use of energy throughout the company. In this company there are three transformers and one solar panel. Fluke 435-II Power analyser is used for measuring power quality compliances.

TECHNICAL DETAILS OF ELECTRICAL INSTALLATIONS

Transformer1

Make-Crompton Greaves; 2000kVA, 3 Phase, Δ/Y Frequency-50 Hz, Type of cooling- ONAN, Line Current HV-52.5 A, Line current LV-2667 A, No load voltage ratio-22/0.433 kV, No. of taps-8, Percentage impedance-6.48%, Vector group-DY,n11, No OLTC.

Transformer 2

Make-CromptonGreaves; 2000kVA, 3 Phase, Δ/Y Frequency-50 Hz, Type of cooling- ONAN, Line Current HV-52.5 A, Line current LV-2667 A, No load voltage ratio-22/0.433 kV, No. of taps-9 , Percentage impedance-6.48%, Vector group-DY,n11, With OLTC

Solar Grid

Make- Kalpa Power; DC side- 487.05 kWp, AC Side- 450 kW, Solar inverter-14 AC Side- 50kW, DC Side-61.75kWp

FLUKE 435-II POWER ANALYZER

Figure 1 Fluke 435-II power analyzer

Fig.1 shows Fluke 435-II power analyzer with current and voltage probes.

Features of Fluke 435-II power analyzer are as follows:

Logger- used to store multiple readings with extreme resolution in a long memory.

Phase voltages- Should be close to the nominal value. Voltage waveforms must be a sine wave and free from distortion. Use Scope Waveform to check the waveform shape.Use Transients mode to capture voltage anomalies. Use Dips & Swells to record sudden voltage changes.

Crest Factor- A CF of 1.41 or higher means high waveform distortion. Use Scope Waveform to check waveform distortion. Use Harmonics mode to check harmonics and THD (Total Harmonic Distortion).

Harmonics-Use Harmonics mode to check for voltage and current harmonics and THD per phase. Dips & Swells- Use Dips & Swells to record sudden voltage changes as short as half a cycle.

Phase currents-Use Volts/Amps/Hertz and Dips and Swells to check current/voltage relations.

Unbalance- Each phase voltage should not differ more than 1 % from the average of the three. Current unbalance should not go beyond 10 %.

MEASUREMENT OF HARMONICS

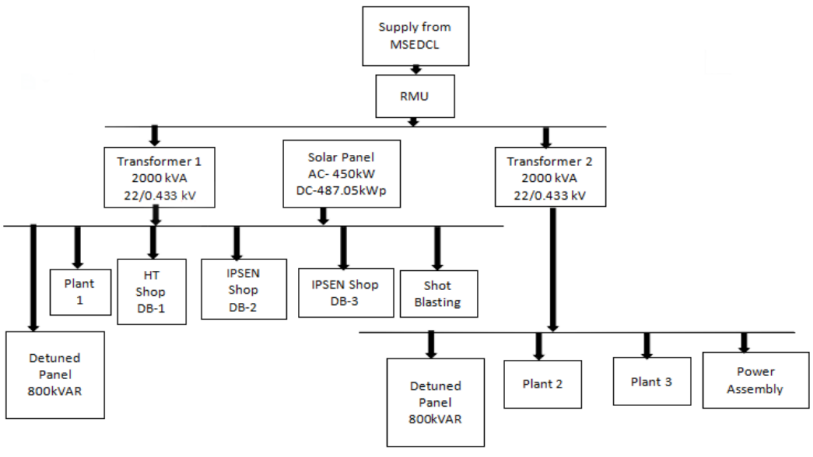

Figure 2 Sample Block diagram for case study

Sample block diagram for case studyis as shown in fig.2. Power analyzer Fluke 435-II was connected at Transformer 1, 2, solar panel and load of IPSENshop, plant 3.The connections of one of such process in shown in fig.3. Readings for half hourwas taken for eachmachine. After that, this data used for analysis purpose.

Figure 3 Connections of power analyzer

OBSERVATIONS

PowerLog software is used for analysis of data. From the collected data, current harmonics summary is plotted with IEEE limit. In fig.4 and fig.5such summary for IPSEN shop and transformer 1 is shown respectively.

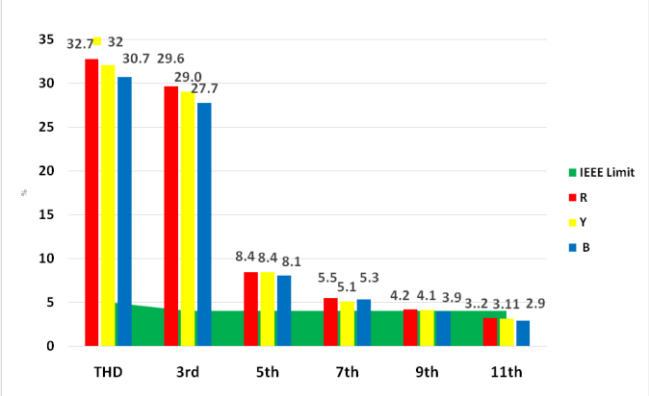

Figure 4 IPSEN Shop Current Summary

From this chart, it is observed that the 3rd harmonic is more dominant as 28.76% which is not within the limit as per IEEE limit shown in table no.1.

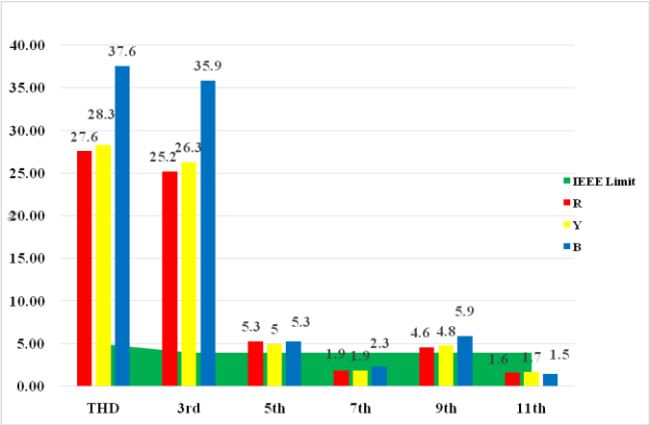

Figure 5. Transformer 1 Current Summary

From this chart, it is observed that the 3rd harmonic is more dominant as 29.13% which is not within the limit as per IEEE limit shown in table no.1

COMPARISON

IEEE 519-2014 HARMONICS LIMIT:

For the system under consideration as the PCC voltage is 0.433 kV applicable voltage harmonic limits are:

Individual harmonics (%)	Total Harmonic Distortion (%)
5.0	8.0

Table 1 IEEE 519-2014 Current Harmonics Limit

Bus Voltage at PCC	Individual harmonics (%)	Total Harmonic Distortion (%)
V≤1.0kV	5.0	8.0
1.0 KV ≤V ≤69kV	3.0	8.0
69kV ≤V≤ 161kV	1.5	8.0
161KV ≤V	1.0	8.0

Table 2IEEE 519-2014 Voltage harmonics Limit

By comparing the data with above standards, we noticed following points:

Transformer 1:

- Power factor of transformer 1 is slightly less (0.95).
- THD and 3rd, 5th and 9th harmonics are not within range as per IEEE limit.
- The total energy loss in rupeesfor transformer 1 for one year is ₹ 127059.75.

IPSEN shop:

- Power factor is poor (0.89).
- Due to APFC off THD and 3rd harmonics are dominated and are out of limit .

Transformer2:

- Power factor is poor(0.89).
- Harmonics and THD are not within the limit.
- The total energy loss in rupees for transformer 2 for a year is ₹212209.31

Plant3:

- Power factor is very poor (0.85).
- Harmonics and THD are within the limit.

Solar Panel:

- Power factor is unity.
- Harmonics and THD are within the limit.
- The total energy loss in rupees for solar panel in one year is₹432551.10

CONCLUSION

In the industry, power quality problems are major issues. They are causing dominant losses in the company. It is observed that harmonics of order 3^{rd}, 5^{th} are not within IEEE limit. So, corrective actions must be taken. Harmonic filter is suggested to filter out the harmonics.

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Fabrication of maximum power point tracking solar charge controller

Vijaykumar Kamble ,Ankush Deore, Nikhil Gole,Yashovardhan
Department of Electrical Engineering, AISSM'S Institute of Information Technology, Pune
[1]vskamble76@gmail.com
[2]ankushdeore18@gmail.com
[3]yashovardhanm@yahoo.com
[4]nikhilgole007@gmail.com

Abstract- **There are inherent power losses that occur when the solar is connected directly to a load/battery without matching their internal impedances. In addition to the non-linear (I-V) operating characteristics of a PV module associate degreed variations in its output power with star insolation and in operation temperature . MPPT charge controller is employed in most alternative energy harvest home systems to ensure that maximum rated power is drawn from the solar panel and is delivered to the battery while charging it in a healthy mode to increase its lifespan and for efficiency purposes under varying atmospheric conditions.**

Keywords- **Arduino, MPPT, Solar panel, Batttery.**

I. INTRODUCTION

Renewable energy sources are becoming an alternative to traditional fossil fuels due to their advantages of being clean and inexhaustible mainly. Solar power is one of the renewable energy sources and although it has a high potential its generation efficiency (conversion of solar energy to electricity) is low with most commercial solar panels having efficiencies of less than 30%. With this already low power generation efficiency of solar panels it is only necessary that the maximum power is sourced from that generated by solar panels to ensure high efficiency in delivering power to the load to make solar power an effective alternative and justify its high installation costs too. Since the I-V characteristics of solar panels vary with atmospheric conditions such as irradiance, more power can be received out of solar panels by direct methods e.g. solar tracking (panel mounted on frame and rotated with help of motors) to track the sun as it moves across the sky or by indirect methods e.g. Maximum power point tracking the latter being in the purview of this project. Using MPPT charge controllers reduces variety |the amount |the quantity} of PV modules that require to be put in to get a definite power by increasing the facility generated from the important number of PV modules needed to generate the power at high efficiency. Using MPPT charge controllers we actually find or track the exact value of voltage and current to obtain the maximum power. This is done by MPPT algorithms. There are various methods to make these charge controllers like P&O Technique , Open circuit voltage (OCV) technique ,Short Circuit Current(SCC) Technique Incremental conductance method.

II. METHODS

Charge controllers aim to supply the proper voltage and current ratings for a rechargeable battery by observation and control the electrical device output voltage to match the batteries. This output voltage regulation is very important in battery charging because batteries require a specific charging method with various voltage and current levels for each specific stage, these charging methods are required to prolong battery life and performance. Some common charge controller protection options to stop battery harms are undercharge and overcharge protection. Undercharge protection entails disconnecting the battery when the charge is too low to continue powering connected loads and battery is connected to charging via controllers .Similarly the charge controller stops providing energy to the battery when it is fully charged to prevent overcharge. This is where the charge controller does most of the work .Simple charge controllers disconnect the battery once the battery surpasses a threshold level and reconnect it once the battery level falls below a certain preset charge level. Implementing a DC to DC converter rather than a linear regulator (or just connecting the battery directly to the solar panel) ensures considerably higher power efficiency.

There are various types of solar charge controllers –

1. On / Off – This type of controller continuously monitor the charging level of battery, when it achieves a certain value then it disconnects the circuit from charging.

2. Pulse Width Modulation- In this Method we use the algorithm for Switching of MOSFET to vary the current and keeping the voltage level constant . This is done by setting the duty cycle of the Mosfet.
   The circuit disconnects after the battery voltage reaches the threshold value.

3. Maximum Power Point Tracking (MPPT) Solar Charge Controller- This has the highest efficiency of all the other methods . There are various ways to track the Maximum Power Point. Few of them are illustrated below :-
   a) Perturb and Observe Method- We have used this method in implementing our project. This is most simplest method and is used in most of the cases. It keeps on perturbing on both sides of Maximum Power Point along the P-V curve to obtain highest power from solar panel. The drawback of this method is that when the irradiance level changes rapidly then it gives false MPP point.

   b) Incremental Conductance Method- In this method we use current and voltage sensors on both sides towards the input and output. This works on principle that the slope dp/dv is zero at the maximum power point. Now Power= V*I , hence we are sensing both current and power. This reduces the error due to change in irradiance . But the system complexity increases. Also cost is high.

   c) Open Circuit Voltage Method- The relation between the open circuit voltage and Vmpp of the PV array is defined in this method.

   $$Vmpp = k1*Voc$$

   Now the k1 depends on the P-V characteristics of the solar panel used. Hence it has to be calculated before its implementation. The relationship between the Voc and Vmpp at different temperature and irradiance levels.

   d) Short Circuit Current- This methods works on the principle that the short circuit current and maximum power current are linearly related

   $$Impp = k2*Isc$$

   Where K2 is proportionality constant. It's value ranges from 0.78 to 0.92 .There is a switch provided to the converter to short the PV array after small durations to measure the short circuit current with help of current sensors.

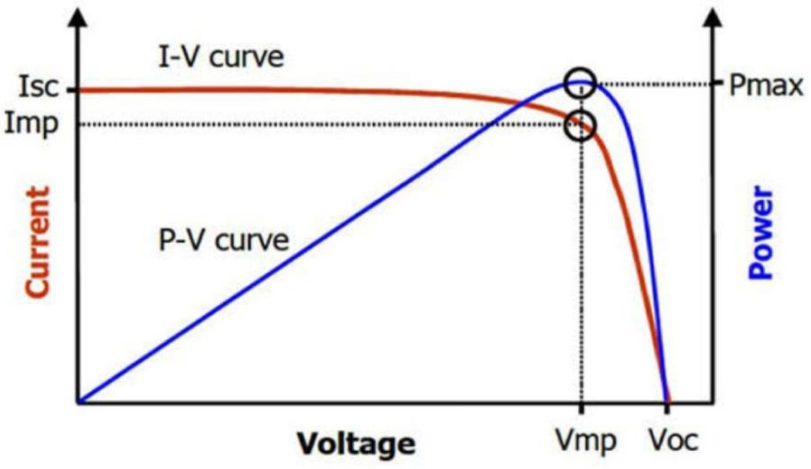


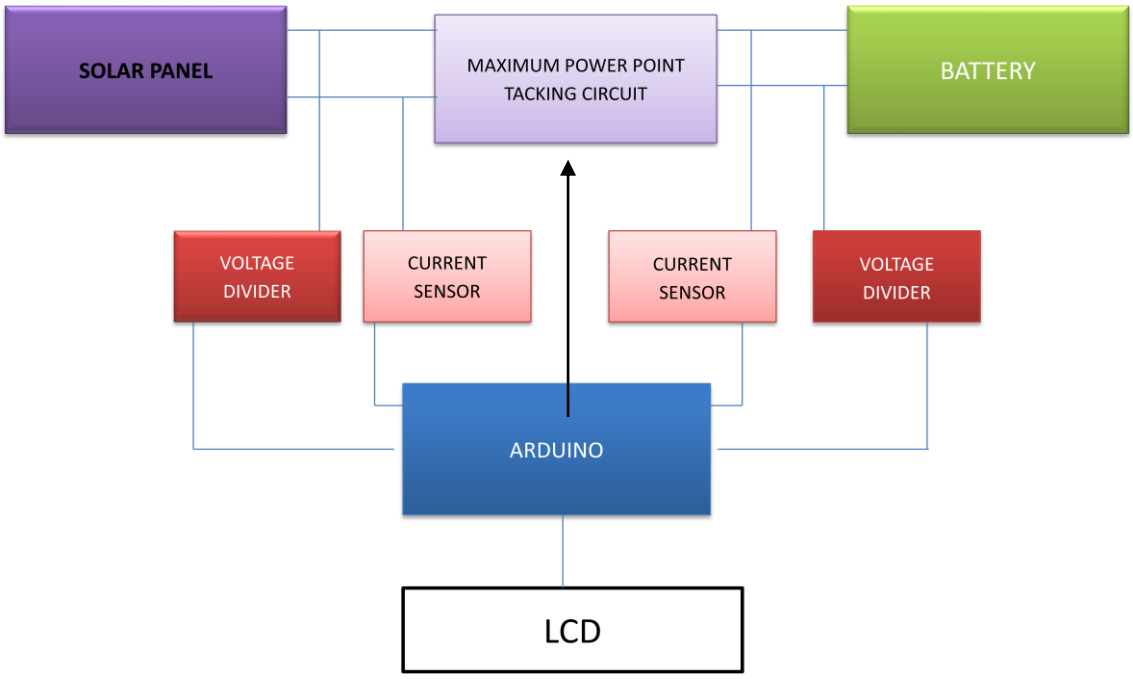
Figure shows the I-V Characteristics and Corresponding Power of Solar Panel.

III. WORKING

In this particular prototype of MPPT in solar system, solar panel is connected to the a battery through a Maximum Power Point Tracking (MPPT) circuit .MPPT circuit consists of DC-DC converter .Current sensors (ACS712) and voltage sensors(voltage divider) are connected between solar panel and MPPT circuit to sense the input voltage and current of the solar panel and same function is of the sensors between MPPT circuit and battery to sense battery voltage and battery current. For the different instances throughout the day the output of solar panel is different which depends on temperature and the irradiance level .So different V-I curves are drawn for different values throughout the day. So peak point or the knee point on that curve is the point of maximum power or Maximum Power Point .Let us consider a solar panel of 10 watt with 21 v open circuit voltage , whose current is 0.47 amps,directly connected to a battery of 12 volt ,as the impedances of storage and source do not match voltage at source comes to the level of voltage at storage , where current is fixed at 0.47 amps. So the current is actuated by the sunlight at that instance.Now the power,

$$P = V \times I = 12 \times 0.47 = 5.64W.$$

Here panel acts like a 6 watt panel. Efficiency becomes 10W-5.64W = 4.36W (42.36%).Here, we need proposed the controller. So the proposed controller comprises the DC-DC converter use to boost the voltage with the corresponding change in duty cycle. and it's duty cycle or gate pulse to the switch (here MOSFET) is controlled by arduino. The values of current and votages are displayed on a 16x2 LCD. The method we used is P&O method which compares the power at different voltages to obtain the maximum power. The output Power oscillates near the maximum power point.



BLOCK DIAGRAM OF THE SYSTEM

IV. ADVANTAGES

Using MPPT charge controller we can avoid harms to the battery like overcharge and undercharge condition which reduces battery life .It has capacity to utilize higher output voltage to deliver more power .The need for more power generally followed by the costly purchase of extra solar panels can be reduced at least to some extent by increasing the efficiency in the existing system.

V. FUTURE SCOPE

For more stability while obtaining the maximum power point more complex but effective methods like incremental conductance can be implemented in near future .One could power the DC-DC converter along with the arduino directly through the solar panel ,hence no need to use the power adapter .Also in near future AC loads can also be supplied using some techniques . As the efficiency will increase existing panels will be able to supply more load than without using controllers. Also it will prevent over charging and under charging.

VI. Conclusion

This paper explains the a model of a solar system with MPPT charge controller, along with the storage system. So, by this we are introducing a prototype model showing the design for the solar charge controller controlled by PWM. We focused to give the solution which will be on the basics of the current and voltage sensors and microcontroller as Arduino and the dc-dc converter controlled by arduino.We aimed to increase the efficiency of solar power transfer from solar panel to battery .We tried to reduce the need of the manual monitoring of solar system .

VII. Acknowledgement

The authors are thankful to All India Shri Shivaji Memorial Society and Principal Dr. P. B. Mane for providing healthy Teaching-Learning atmosphere at the institute. Also the authors are thankful to the teaching and non-teaching staff for their guidance and help in completion of the project.

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Design Implementation and Analysis of Energy Efficient Illumination Scheme for AISSMS IOIT, Pune

Sayali Paraye
Electrical Engineering
AISSMS IOIT, Pune,India

Aishwarya. S. Dhaigude
Electrical Engineering
AISSMS IOIT, Pune,India

Sayali Ghodke
Electrical Engineering
AISSMS IOIT, Pune,India

Pragati .W.Sontakke
Electrical Engineering
AISSMS IOIT, Pune,India

S. M. Chaudhari
Assistant Professor
AISSMS IOIT, Pune,India

***Abstract*— Lighting load is a major component of electrical load in an educational institute. Almost 20% of load is lighting load thus it is the major area of concern related to energy conservation. An attempt is made in this project to analyze the existing lighting illumination scheme of particular sections in an educational institute. Illumination level is quantified using standard measurement technique. The light pack software is used for detailed analysis. The calculations as per conventional method related to illumination scheme design are also included. Revised illumination scheme is proposed taking into consideration the energy conservation and energy efficiency. The revised illumination scheme provides improvement in quality of illumination and energy efficiency. The payback calculations are also included to justify the economics of revised illumination scheme.**

Keywords*— Illumination, power quality, power consumption, LITE PACK, LUX meter.

I. INTRODUCTION

The illumination should provide favorable visual performance, visual comfort, ease of seeing and safety. Most of the academic activity involves good visual performance which can be achieved with proper illumination. Educational institute comprise of different occupancies like classroom, library, laboratory, corridor, washrooms, multipurpose hall, administrative office.

Since lot of work requires clear visibility illumination is an important aspect. Average illumination as per standard is as follows;

Table no. 1

Sr no.	Occupancies	Standard average illumination (LUX)
1.	Classroom	250
2.	Library	300
3.	Laboratory	300
4.	Multipurpose hall	500
5.	Administrative office	500
6.	Corridor	100
7.	Washroom	100

The quality of existing illumination scheme is studied by standard measurement, calculation and by the use of software. Revised illumination scheme is proposed which gives better quality of education and better energy efficiency. All the measurements are carried out by using LUX meter Measuring range : 0-50000 lux .

A sample of payback period calculation for respective luminaries is also presented.

But modern luminaries like CFL's and LED's produce harmonics as electronic circuits are used for their ignition. Due to use of power electronic circuitry the load becomes nonlinear, which in turn impacts on the power quality of consumer side low voltage grids and ultimately on utility and generation sides .The concern for the quality of power is increasing amongst both electric utilities as well as end users of electric power. Hence maintaining proper illumination without compromising the power quality is the main focus of this project.

II. OBJECTIVES

These are the objectives which are obtained by project analysis:

1. To study the existing lighting scheme of the institute.
2. To analyze the existing system by carrying out various steps.
3. To work out the replacement of fluorescent bulbs with the LEDs for improving illumination and attain maximum efficiency and to maintain power quality.
4. To carry out payback period calculations and suggest the most economical combination of luminaries.

III. METHODOLOGY

Indian standard was adopted by the Indian Standards Institutions on 19 march 1984.This standard has been prepared to deal with the special aspect of lighting for educational institutes and shall be read in conjunction with

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IS :3646(PART I)-1966*, IS : 3646(PART II)-1966* and IS :3646(PART III)-1968*

This standard covers the principles and the practices governing good lighting in educational institutes and stresses on the importance of good visual environment for education. It also recommends the level of illumination and quality requirements to be achieved by general principles of lighting.

a) EQUIPMENTS REQUIRED

For the analysis purpose the following instruments-

Table no. 2

LUX meter	It is an analog or digital electronic device that measures the illumination level of the area.
LITE pack software	It is a tool for visually designing. Havel's LITE pack version 3.00. The parameters are entered in the software and the illumination distribution is obtained.

b) COLLECTION OF DATA

The area of respective occupancies is measured .The illumination at different points in respective areas is measured and average illumination is calculated.

c) OBTAINING AVERAGE LUMENS BY USE OF LITE PACK:

The existing illumination scheme performance is analyzed using LITE PACK software. Different parameters and physical dimensions are given as input to carry out the analysis. The report generated through this software contains-3D ISO LUX diagram, Gray scale pattern, Light distribution, Illumination distribution in tabular form giving maximum ,minimum, average values along with the different ratios of these quantities.

d) COMPARING THE DATA FOUND OUT BY MANUAL METHOD AND SOFTWARE

The data obtained from the manual interpretation and software is compared and the accordingly the suggestions are provided.

e) SUGGESTIONS

Suggesting replacement of fluorescent bulbs with LEDs for maximum efficiency and maximum power output. Table no. 3

IV. ANALYSIS OF EXISTING ILLUMINATION SCHEME

Table no. 3

LOCATION	EXISTING AVERAGE ILLUMINATION LEVEL (Measured by Lux-meter)	AVERAGE ILUMINATION LEVEL AS PER LITE PACK SOFTWARE	Illumination required as per the Indian Standards	REMARK
108-B Meeting Room	55.9	58.8	250	Not sufficient
010-A Physics Laboratory	154.57	105	300	Not sufficient
010-B Mechanical Laboratory	61.62	105	300	Not sufficient
010-C Civil Laboratory	91.6	55	300	Not sufficient

V. POINT-BY-POINT LAYOUT- 3D LUX WEB

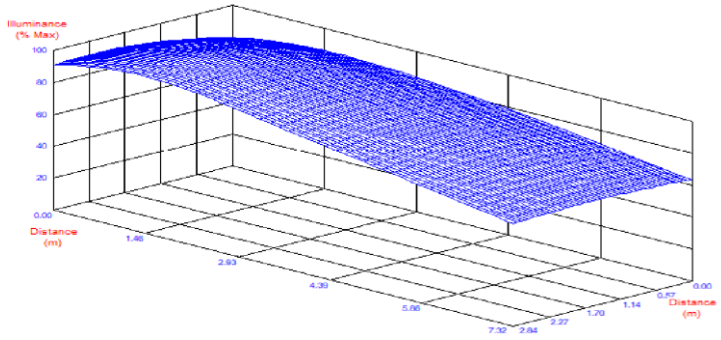

Fig.1. Room No. 108 B

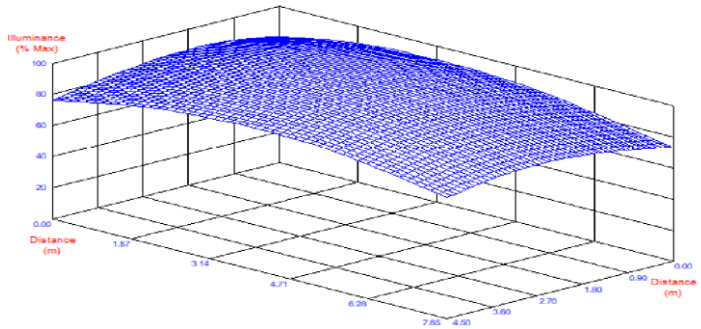

Fig.2. Room No.010. A

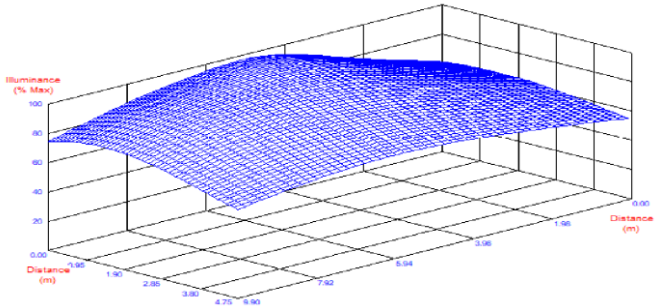

Fig.3. Room No. 010 B

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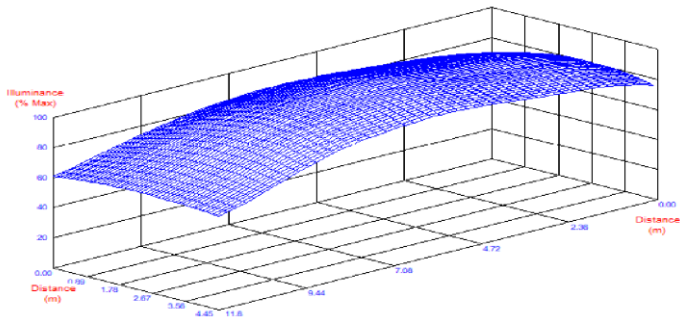

Fig.4. Room No. 010 C

VI. PAYBACK PERIOD CALCULATIONS

Payback period is the time taken by a business investment to recover its initial outlay in terms of profits or savings.

Payback period=Initial investment/annual payback.
Example.

For Room No. 108 (B)-

(a) Determination of the type, number and operational schedule of the lamps currently installed.
This will require a room inspection, in order to determine the characteristic of current installation. Following results are obtained:
Lamp type – 40 watt, T12 fluorescent, 4ft 1200mm
No. of lamps -12, Total Lumen output= 2300Lumes
Operation schedule – 7 hrs.

(b) Estimate demand in kilowatt and energy consumption in kWh:
The demand and consumption can be calculated by
Demand (kW) = [no. of lamps x power per lamp (w)]/1000
= [12x40/1000]
= 0.48kW
Energy kWh = [Demand (kW) x operational hours]
= [0.48x 7]/30
= 0.112kWh

(c) Estimate demand and consumption with the energy efficient alternative and compare
Consider a LED alternative is available which replaces the current lamps:
Type of LED – 16 watt, T8 equivalent LED Tube, Total Lumen output= 2300 Lumens
No. of equivalent LED – 12
Demand (kW) = [12x16]/1000
= 0.192
Energy (kWh) = [Demand (kWh) x operational hours]
= [0.192 x 7]/30
= 0.0448
Comparison:
Demand reduction = 0.48Kw - 0.192kW
= 0.288
Consumption reduction = 0.112 kWh/mo - 0.448 kWh/mo
= 0.336 kWh/mo

MSEDCL Charges=14.8 Rs/kWh
Total saving
= 14.8x0.336 Rs /mo
=4.972 Rs /mo.
Additional investment in LED
= (LED bulb cost) - (Fluorescent bulb cost)
= (200-50) Rs
=150Rs
Payback Period
=Additional investment / total saving
=150/4.972 Months
=30.168 Months
=2.51 Years.

In this scenario energy need of the lighting system is reduced by 40%, however this only considers direct energy savings from the lighting upgrade and it has a payback period of 2.51 years.

On the similar basis the calculation is carried out for the remaining occupancies.
The saving is 4.972Rs per month.
The payback period is 2.51 years.

Summarization of savings per month and payback period:

Table no.4

Sr.no	Room No.	No. of lights	kWh (fluorescent)	kWh (LED)	Total saving (Rs/mo)	Payback period (Years)
1.	108 B	12	0.112	0.0448	4.972	2.51
2.	10 A	8	0.074	0.029	0.666	1.8
3.	10 B	20	0.186	0.074	1.657	3.4
4.	10 C	6	0.056	0.0224	0.497	2.09

The average of the payback period is 2.45 years.

IV CONCLUSION

- We can conclude that the existing illumination system is not enough to provide an optimum visual environment for both students as well as faculties.
- In addition to the data mentioned in –IV and in table no. 4, the analysis of other occupancies is also carried out on similar basis. The existing and expected average illumination for these occupancies is summarized in following table:

Table no. 5

Sr no.	Occupancies	Existing average illumination (lumens)	Required average illumination (lumens)
1.	Classroom	170	250
2.	Library	250	300
3.	Laboratory	150	300
4.	Multipurpose hall	250	500
5.	Administrative office	300	500
6.	Corridor	70	100
12	Washroom	50	100

- It can be seen from the above table that the average illumination of the existing system is not sufficient and changes in luminaries is to be done.

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- Replacement of fluorescent bulb with the CFLs for maximum efficiency and to meet the required average illumination.
- After replacement the payback period is of 2.45 years, which means it will require 2.45 years to recover the initial expenses that were required to install all the LEDs. The life of LED luminaire is about 6 years.

ACKNOWLEDGMENT

This paper on “design implementation and analysis of energy efficient illumination scheme for educational institute” is outcome of guidance, moral support and devotion bestowed on us throughout our work. For this we acknowledge on profound sense of gratitude and thank everyone who has inspired us throughout the preparation of this paper.

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Earth Leakage Protection of Various Equipment using Arduino

Akanksha Kumar[1], Harshal Vanjari[2], Akash Salunkhe[3], Prashant Mahajan[4]
[1, 2, 3]*Student, AISSM's Institute of Information Technology, Pune.*
[4]*Assistant professor, AISSM's Institute of Information Technology, Pune*

Abstract: ***An earth fault protection of various equipment using Arduino is proposed in this paper, Construction of this circuit is done on the basis of ground fault circuit interrupter. The circuit trip on the tiniest difference in the current of the supply and return path. The leakage is detected by this difference which may damage a device and human operator. Both hardware and software are introduced in this circuit.***
Index Terms - 3 winding transformer, Arduino, relay, leakage current, fault protection.

I. INTRODUCTION

Nowadays, the leakage protection is very important technology in the various low-power rating field, this leakage current may damage the equipment also get hazardous for human being from electrical shock so, in protection of various electrical equipment we are going to construct circuit on the basis of ground fault circuit interrupter. Whenever any fault occurred in the equipment ground fault circuit interrupter (GFCI) is going to disconnect the circuit. whenever it detects the leakage current, that Causes electric current Unbalance between the energized conductor and the return neutral conductor. This unbalance indicates current leakage through the unwanted path of the circuit, which is grounded and accidentally touching the energized part of the circuit may get hazardous shock. So, to protect specific equipment's it is necessary to switch off the supply. In view of above situation this paper provides information about the protection from earth leakage current by designing protection circuit based on Arduino programming kit which helps us to give specific threshold value for the specific equipment's so that when any fault occurs and this cross the threshold value then Arduino going to trip that equipment only and other equipment's are safe for operation.

II. OBJECTIVES

A device is design to detect the leakage current in the circuit, the leakage current is given to op-amp to get the voltage waveform and by adjusting the gain we can adjust the value. and then further we give output of op-amp to rectifier which are used to get dc for Arduino programming. By designing the protection device with the help of the Arduino we can achieve so many benefits as well as the flexible operation for various power ratting equipment. Where we are designing this device so that we can achieve following objective. To protect the various equipment.

III. METHODOLOGY

Methodology is the process to find the suitable project, make the researching and study all of the project information, choose the suitable method for design this project, planning the time and selecting the equipment such as material is needed and computer software program. After selection of the topic it is very essential to separate the whole work in different phases so to make work suitable and more efficient, we divide the work in four different phases.

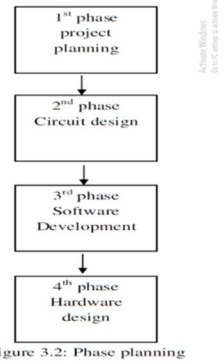

Figure 3.2: Phase planning

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IV. PROJECT PLANNING

To Develop any project the main thing requires which is to collect information. In the 1st phase the all the information regarding the hardware and software is collected by reading various papers and doing literature survey, in which the selection of proper method for earth leakage current sensing device is decided then to perform the various experiment to collect the required ranges and set a proper sensing method for that equipment and the material require for designing, there ranges to sustain that leakage current also in software which type of software is going to use, there ranges all these information is collected in the project planning.

V. HARDWARE DESIGN

The main part in this project is to build the hardware, to detect the earth leakage current. The detection of earth leakage current is main problem. With the help of the literature survey and performing various experiment for the earth leakage protection device the final conclusion is to go for 3 winding transformers to detect the earth leakage current.

A. Construction

In 3 winding transformers, 3 windings are placed on transformer core where the primary and secondary windings are having same number of turns also have same current rating but they placed are opposite to each other such that their flux cancel each other. Here the tertiary winding (tripping winding) having a large number of turns than primary and secondary where their turns ratio is 1:1:10. The test button is used to test the equipment is working or not.

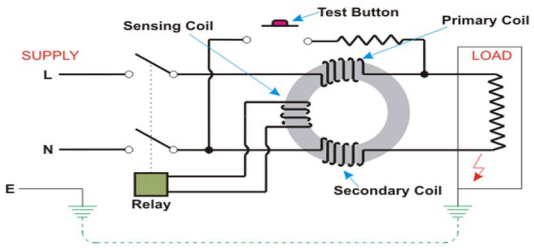

Fig. 3 Basic circuit diagram

B. Working

As show in Fig. 3 winding are placed on transformer core. In normal condition the same current pass through primary winding, and return back through secondary winding. Both primary and secondary winding are placed in such a way that the magnetic flux produced is in opposite direction so in healthy condition the same current pass through both winding so this will cancel each other's magnetic flux. In faulty condition the leakage pass to anywhere in circuit so the current returning through secondary winding is reduced. So, the magnetic flux present inside the transformer core is not equal anymore. So, the periodically changing magnetic flux inside the transformer core cut the tertiary winding conductors, this action will induce the electromotive force(emf) across the tertiary winding. Where it is an alternating in nature. The induced voltage across the tertiary winding produces a current in the (trip circuit). This current is sensed by the relay (Arduino) and it will give the command to the C.B. to operate.

C. Winding Transformer Design

In 3 winding CT we have to convert the current into the voltage because voltage is sensed by the Arduino easily. For this conversion we have to put a resistor. This resistor causes the burden on the CT. The main reason to go for 3 winding transformers instead of current transformer (CT) is because of problems arrive due to burden on CT. During the Fault condition the unbalance current derive is very small so due to burden this value get negligible. Due to this in the tertiary winding it fails to maintain CT ratio so it is better to design 3 winding transformers rather than current transformer (CT).

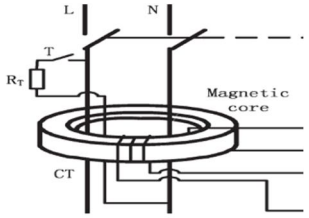

Fig. 3 Winding Transformer

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To design the 3 winding Transformer, the turns ratio for primary and secondary winding are kept to be equal which is 40 turns and 2 amp. current rating is to be calculated by practical performance and tertiary winding has 400 number of turns are calculated through practical performance where 3 tapping are to be given to tertiary for identification of magnitude of fault current. This three tapping are given at 120, 280, 400 number of turns. Where current ranging for tertiary winding has 50-100 m amp. These are on the basis of 1:10 turns ratio which can be calculated as above.

VI. SOFTWARE DESIGN

After hardware designing, we step forward toward the software designing. In this we are going to use Arduino for giving command to the circuit for protection. And protection is as per the threshold value given for operation to the Arduino. whereas Arduino is an open source hardware & software device. Arduino consist of variety of microprocessor and controller. The Arduino board consist of set of digital and analog input and output (i/o). Arduino has many benefits such as easy programming, flexible operation and inexpensive. the main task of circuit is to detect the leakage current and calculate the valid value, calculating variation in leakage current, judging and processing for the protection

The software system mainly consists of main program, data processing sub program, and leakage protection program. the main program will be carried as top-down infinite loop, the interruption in system will respond according to as per priority as given by software as interruption occur it will return to the main program and continue the execution after being completed.

A. Main Programming Design

The main function of main program to conduct the program flow & connecting each sub program. the main program provide initialization, data processing, failure treatment and interrupt handling and also timer & commutation interruption.

B. Data Processing Sub Program Design

The timing detection of current and digital filter is realized by data processing. the adjustment of the threshold value by adaptive adjusting is done by calculating the average value of data as per the tripping circuit. the variation of the leakage current should be greater than that of threshold leakage value set as per circuit. And the time duration must be greater than the set relay time.

C. Earth Leakage Protection Sub Program Design

The leakage current protection is detected by the circuit accordingly to compare between the leakage current value and setting value, the delay time as per provided in the circuit and also as per given by user. The value of leakage variation is less than rated value then the action would be normally operated. if the time duration is more than action should be relatively adjusted.

VII. TESTING

Testing phase are divided into two level first level is unit step, where the system is tested part by part and error is to be measured. Second level is integration test where the complete combine system between hardware and software part is examined. As per practical performance the error occurred are eliminated through changing the Arduino programming. The timer is to be set as if small fault come then the circuit is trip for only small period of time. And after this time the circuit again come in on condition.

VIII. PROBLEM STATEMENT

When the earth fault occurs and someone barely touched it they may get hazardous shock. so, there we use elcb (earth leakage circuit breaker) but this device trip all the system so if sometimes some small fault occur and this breaker sense this fault and trip all compartment. it requires time to erase this fault and due to such small fault, we could not use our other equipment and in industries it gets huge loss. So, we are going to develop an equipment which can trip only faulty part and others equipment remains healthy.

We are going to develop this equipment by using Arduino which is used to give separately command to circuit breaker to trip only faulty equipment and secure the other part also secure from fault occurring to all other compartment.

IX. ADVANTAGES

EARTH leakage circuit breaker has one major advantage over RCDs that they are less sensitive to fault conditions, and therefore have fewer nuisance trips. There is situation in which an ELCB can nuisance trip because the voltage and current on the earth line is usually fault current from live wire. While voltage and current on the earth line is usually fault current from a live wire, this is not always the case.

As the high current lightning strike would cause a voltage gradient in the soil, presenting the earth leakage circuit breaker sense coil with enough voltage to cause it trip this is only because of an installation has two connections to earth.
Also, this device is cost efficient device which has minimum the required cost as compare to other equipment's.
This equipment can also be used in AC as well as DC. but for DC we have to modify the transformer design as per the requirement.
By using Arduino, we can use this devise for wide range for equipment in which we only have to change the programming as per the equipment.
And this devise can also be used for commercial as well as industrial purpose, only due use of Arduino we can modify programming as per our requirement.

X. DISADVANTAGES

They do not detect faults that don't pass current through the CPC to the earth rods. They do not allow a single building system to be easily split into multiple sections with independent fault protection, because earthing systems are usually use common earth Rod.
We can assume that the earth leakage fault protection device is the ***brain for the shock protection***, and the grounding as the backbone. Therefore, without a functional grounding (Proper Earthing of Electrical System) there is totally no protection against electrical shocks in your house even if You have installed ELCB and its TEST switch show proper result. Looking after the ELCB alone is not enough. The electrical Earthing system must also be in good working order for the shock protection system to work. The qualified electrician had done the routine inspection, to check the grounding system should be inspected regularly at shorter intervals by homeowner and need to pour water in Earthing Pit to minimize the earth resistance at regular basis.
This brings us or alarming us to think over second basic requirement for earth protection. The second requirement for the proper operation of a home shock protection system is electrical grounding.

XI. CONCLUSION

The main focus of the project is to develop the device in cost efficient way. the device is use for safety of industries, residential & commercial etc. one single device will give wide range of control over equipment. As device is programmable, new firmware will unleash new intelligence and advance feature in the device. Protection and control of equipment play very important role in today's era. where protection is provided to eliminate the leakage in the system. so, we are using Arduino programming for various benefits.

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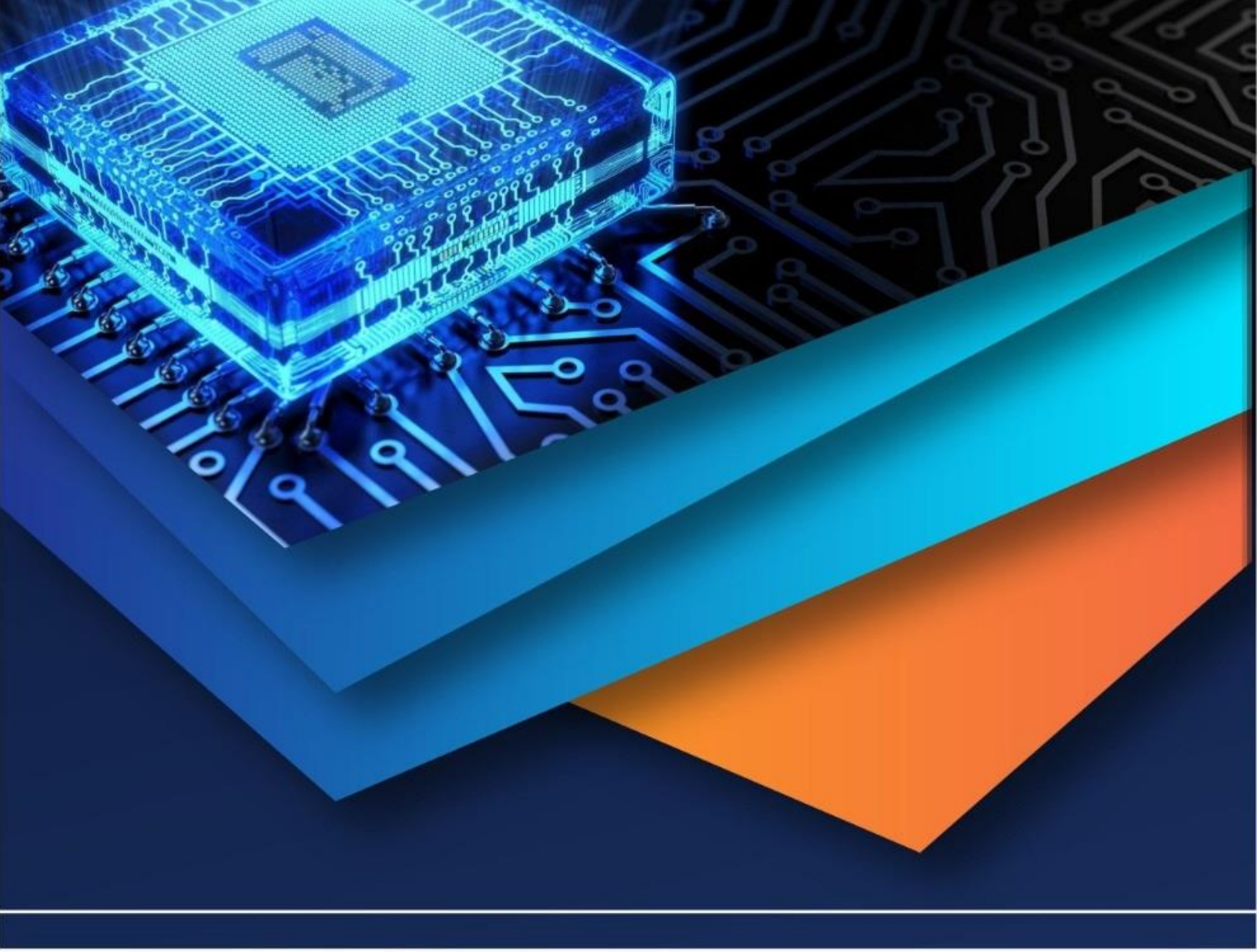

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IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Integrated Wind, Solar And Energy Storage

Mrs. V.A Yawale , Asst. Professor , AISSMS IOIT , PUNE

ABSTRACT :

Energy is the golden thread, a crucial factor that is connecting economic growth, social equity and develops a environment that allows world to thrive. Integrated wind, solar and energy storage is co-locating renewable energy source of wind and solar and thus integrating them into a single plant. The recent state of art hybrid energy system technological development is the result of activities in a number of research areas, such as Advances in electrical power conversion through the availability of new power electronic semiconductor devices, have led to improved efficiency, system quality and reliability. Development of versatile hybrid energy system simulation software; continuing advances in the manufacturing process and improve efficiency of photovoltaic modules. The task for the hybrid energy system controller is to control the interaction of various system components and control power flow within the system to provide a stable and reliable source of energy.

Keywords : **e**nergy , Integrated , efficiency , electronic semiconductor devices

INTRODUCTION

COLOCATING WIND AND SOLAR GENERATION with battery energy storage is a concept garnering much attention lately. An integrated wind, solar, and energy storage(IWSES) plant has a far better generation profile than standalone wind or solar plants .It results in better use of transmission evacuation system, which , in turn ,provides a lower overall plant cost compared to standalone wind and solar plants of same generating capacity. These plants are particularly suitable for regions that have set high targets for wind and solar generation but have limited land available for project development.

Renewable energy sources, such as photovoltaic, wind energy, or small scale hydro provide a realistic alternative to engine-driven generators for electricity generation in remote areas . It has been demonstrated that IWSES systems can significantly reduce the total lifecycle cost of standalone power supplies in many situations, while at the same time providing a more reliable supply of electricity through the combination of energy sources.

Separate wind and solar plants connected to same point of interconnection do not constitute an integrated wind and solar plant. In an IWSES plant , wind turbines, (PV)solar arrays , and a battery energy storage system(BESS) are integrated into a single plant using state-of-the-art controls, These integration can be performed at different levels.

The aim of this paper is to review the current state of design and operation of integrated energy system ,and to present future developments , which will allow a future expansion of markets, both in industrialized and developing countries.

NEED OF INTEGRATING RESOURCES

According to renewable energy experts, a small IWSES electric system that combines wind electric and solar electric (photovoltaic or PV) technologies offers several advantages over either single system. In much of the United States, wind speeds are low in the summer when the sun shines brightest and longest. The wind is strong in the winter when less sunlight is available. Because the peak operating times for wind and solar systems occur at different times of the day and year, hybrid systems are more likely to produce power when you need it. They are Complementary to each other. Intermittent in nature. For the times when neither the wind nor the solar system is producing, IWSES provide power through batteries and/or an engine generator powered by conventional fuels, such as diesel. If the batteries run low, the engine generator can provide power and recharge the batteries. The solar and wind both require robust electrical and power evacuation infrastructure. The storage

capacity of these systems must be large enough to supply electrical needs during non-charging periods. Battery banks are typically sized to supply the electric load for one to three days. Thus combining these resources is more convenient as they complement each other, requirements such as for land, equipments, machinery labor and skill sets required is almost the same .As well as there is reduction in cost which is elaborated further.

WORKING

The IWSES as stated earlier does not have wind and solar plant connected to the same point of interconnection .In IWSES plant; wind turbines, photovoltaic solar arrays, and battery energy storage system (BESS) are integrated into a single plant using state-of-art controls.

This integration is carried out in two ways

1. Wind turbine/PV array level.
2. Farm level.

- In farm level integration, balance-of-plant(BOP)equipment such as transformers and switchgears ,as well as the upstream transmission evacuation system ,is shared by wind, solar and BESS. In turbine level integration, each converter may be potentially shared by a wind, solar and BESS resource.

Thus in favorable conditions these plants generate energy. The electric energy generated from wind needs to be converted from AC to DC ,for purpose of transmission .The PV panel already generate DC supply where as the stored energy in batteries is chopped into favorable DC. This DC output's from all the sources is connected to a DC bus from where it is converted into AC supply for regular household and industrial applications.

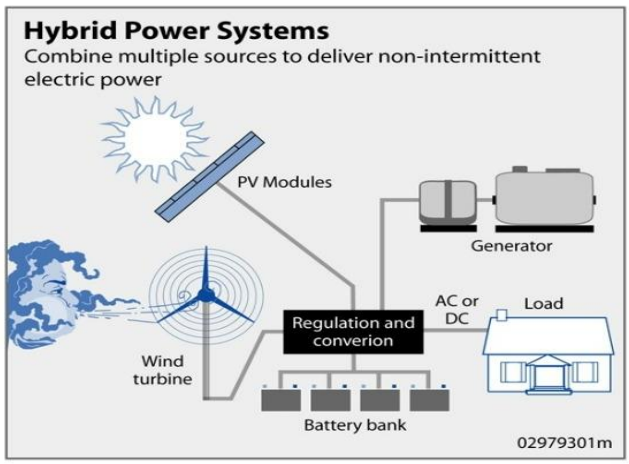

Figure.1:Block diagram of integrated system

DESIGN

According to the IEEE references ,a techno-economic feasibility study for IWSES plants was completed for two sites in India i.e. in Anathpur, Andhra pradesh; and Kutch, Gujrat.This study was performed for the Infrastructure Leasing & Financial Services Energy Development Company Limited,a developer and financier of renewable projects in India under a technical assistance grant from the U.S. Trade and development agency.

The deliverables of this study were as follows:

✓ Developing the technical design of the IWSES plant ,including the transmission evacuation plan

✓ Developing use cases for integrated energy storage appropriate for the Indian system

✓ Sizing energy storage to provide multiple plant and system-level services

✓ Performing cost-benefit analyses of IWSES plants under existing and proposed regulations

✓Preparing high-level environmental and social impact analysis guidelines

✓ Outlining the financing plan for the projects using viability gap funding and other incentives to supporting infrastructure projects that are economically justified but fall short of financial viability

✓ Recommending regulatory and policy changes required to integrate energy storage in India

✓ Conducting a reverse trade mission for Indian regulators and policy makers to learn about the energy storage business in the United States.

DESIGNING CONSIDERATIONS FOR AN INTEGRATED WIND-SOLAR PLANT

When designing an integrated plant, it is important to ensure that the interaction between the wind and solar plants is captured and taken into consideration. There are two principal types of interactions that must be modeled: 1)The effect of the turbines on the PV arrays . 2) The effect of the PV arrays on the wind-flow field.

The siting of the turbines was carried out first because the wind resource was more variable across the site than the solar resource; therefore, the optimum configuration of wind turbines is more sensitive to their siting than that of the solar array.

The presence of the PV panels can impact the surface roughness and affect the wind flow through the turbine array. An array of solar panels can be similar to other topographic or locational features (trees, buildings, etc.) ,in that it alters the surface roughness and affects wind flow through the array. Increased surface roughness changes the profile of the atmospheric boundary layer as it flows across the array, increasing the shear effect.

The approach for roughness modeling, turbine wakes, and the impact on wind flow is based on a theory advanced by Sten Frandsen. Frandsen stipulates that an infinite array of wind turbines is represented as a region of uniform high-surface roughness. The roughness imposes drag on the atmosphere, causing both a downstream change in the structure of the boundary layer and a reduction in the free-stream wind speed at the turbine hub height. At the project sites, the effect was comparable to that of the local vegetation.

Figure.2:Site favourable for IWSES (only for reference purpose)

BENEFITS OF IWSES

- ***Benefits from Integrating Wind and Solar Generation:***

The key benefits of an integrated wind-solar plant relative to standalone wind and solar plants with the same cumulative capacity are as follows:

1. Decrease in Project development cost:

Many factors are to be considered while designing solar or wind , like its impacts on markets , impact on environment , also some legal factors are to be considered. Which are as follows;

- Licence /permits
- Power purchase agreements
- Land lease
- Construction permits

Thus effective decrease in the cost is possible due to integration because tje legal procedures for both plants is the same.

2. Better use of available land:

- Collocating wind and solar power plants conserves space and increases the energy density (i.e., the amount of energy produced per acre of land).
- In many wind plants, the land between the turbines is often left unused. To make better use of space, wind and solar plants can be collocated, provided that conditions for both wind and solar power generation are favorable at the same location. Alternatively, if wind and solar plants can be sited adjacent to one another, they can share the same transmission evacuation infrastructure.

3. Complementary generation profile:

A further benefit of integrating wind and solar generation stems from the complementary nature of both the diurnal and seasonal patterns of their generation.

- the average hourly generation during selected months for a wind-solar plant made up of roughly 500-MW each of wind and solar generation capacity.

wind generation dips during the day and increases late in the evening. On the other hand, solar generation follows the sun and is highest during the middle of the day. Combining wind with solar reduces the difference between the generation levels during daytime and night time periods.

4 .Potential savings in transmission evacuation costs:

- An integrated wind-solar plant also has the potential for savings in evacuation and transmission upgrade costs.
- Typically, in a wind or solar plant, the collector system is designed to carry the maximum output of the plant. For example, standalone 100-MW wind or solar plants would each have 100 MW of evacuation capability.
- However, an integrated plant can make do with an evacuation capability lower than 200 MW because wind and solar generation will not peak at the same time. a range of cumulative hourly generation during selected months for a 1,000-MW wind-solar plant. Here the average cumulative hourly generation bounds within which the cumulative generation for each hour would occur 95% of the time.
- It is, thus, possible to design the evacuation system with a rating lower than the sum of the maximum capacities of the wind and solar plants.

CONCLUSION:

With increasing demand for energy and hikes in prices of non-conventional energy resource ,a future perspective should be considered .Even though the initial cost of set up is high ,long term savings and energy conservation is achieved.

It also supplies continuous power to the load with optimum design to control cost.

The IWSES energy systems are recognized as a viable alternative to grid supply or conventional, fuel-based, remote area power supplies all over the world. The literature review reveals that, renewable energy based low emission hybrid systems are not cost competitive against conventional fossil fuel power systems .However, the need for cleaner power and improvements in alternative energy technologies bear good potential for widespread use of such systems. Moreover, the rural households in industrialized and less developed countries attach high value to a reliable, limited supply of electricity. Community facilities such as rural hospitals, schools, telecommunication and water pumping stations can contribute significantly to the welfare of people and rural development. While it is recognized that technology can only be one aspect of community development, the renewable energy systems have demonstrated the potential to provide support in some of the basic infrastructure needs in remote and urban areas for different application.

Next steps for IWSES in India

The Ministry of New & Renewable Energy in India plans to add yet another record-breaking project in its portfolio .

Mega project capacity :160MW

Area:1000 acres

Investment:1000 crore(155 million $)

Developed by: Solar Energy Corporation of India (SECI), the renewable energy agency of Andhra Pradesh, Andhra Pradesh Transco.

120MW solar and 40MW wind power

Future of IWSES in other countries,

FORT HOOD, Texas (Jan. 28, 2016) -- Fort Hood, federal and local officials broke ground here during a ceremony for a massive energy project for the installation, Jan. 28.

The project, the largest and first of its kind, will include both an on-post solar farm and an off-site wind turbine farm, which has the capacity to generate 65 megawatts of electricity for the installation, saving taxpayer money during the duration of the contract. The upstart capital of the project will be $100 million.

Its main objective is to free up money to be able to make better Soldiers here on Fort Hood. So, if it's cheaper energy, it gives us more money to the military to spend on training up the best warriors in world.

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Astrosat - (India's first dedicated space observatory)

- **Astrosat** was launched on Monday at 10 am from the spaceport of Sriharikota in Andhra Pradesh. It is aimed at studying celestial objects. PSLV-C30 is carrying Astrosat, along with six other co-passengers, one satellite each from Indonesia and Canada, and four nanosatellites from the US.
- With the successful launch of Astrosat, India gained an entry into the select club of nations having its own space observatory after the US, Japan, Russia and Europe.
- Indian Space Research Organisation Chairman AS Kiran Kumar had recently said, "What it means for India is this: it is one of the first scientific missions which will be available to the Indian researcher community as an observation opportunity. This is a starting point for such things." India's ASTROSAT's life span is five years.
- Astrosat is India's first dedicated multi-wavelength space observatory. This scientific satellite mission endeavours for a more detailed understanding of our universe.
- One of the unique features of Astrosat mission is that it enables the simultaneous multi-wavelength observations of various astronomical objects with a single satellite, ISRO said.
- Astrosat will observe the universe in optical, ultraviolet, low and high energy X-ray regions of the electromagnetic spectrum whereas most other scientific satellites are capable of observing a narrow range of wavelength band.
- According to ISRO, after injection into Orbit, the two solar panels of ASTROSAT will automatically deployed in quick succession. The spacecraft control centre at Mission Operations Complex (MOX) of ISRO Telemetry, Tracking and Command Network (ISTRAC) at Bengaluru will manage the satellite during its mission life.

Conserve water, conserve life!

Energy conservation… (A little less now.. A little more for the future.)

ALAPPUZHA school initiative

Deore Ankush

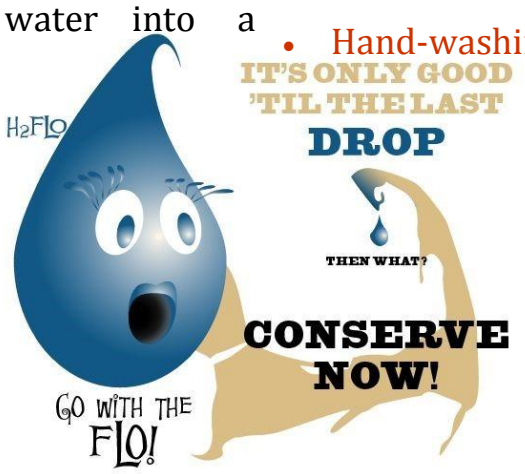
(BE Electrical)

Home remedies for water saving.

- Shower Bucket - Stick a bucket under the faucet while you wait for your shower water to heat up.

  You can use the water for flushing the toilet or watering your plants.

- Turn off the tap while brushing your teeth and washing your hands.
- Fix your leaks - Hire a plumber, fixing leaky faucets can mean big water savings.
- Re-use your cooking liquid - Instead of dumping that water down the drain, try draining your cooking water into a large pot. Once it cools, you can use it to water your plants.



- Cut your showers short - Older shower heads can use as much as 5 gallons of water per minute. Speed things up in the shower for some serious water savings.
- Choose efficient fixtures - Aerating your faucets, investing in a low-flow toilet, choosing efficient shower heads, and opting for a Water Sense rated dishwasher and washing machine can add up to big water savings.
- Don't run the dishwasher or washing machine until they're full- Those half-loads add up to gallons and gallons of wasted water.
- Keep an eye on your bill to spot leaks
- Install a rain barrel - Rainwater harvesting is a great way to keep your plants hydrated without turning on the hose or sprinkler.
- Water in the early morning -You'll need less water, since cooler morning temperatures mean losing less water to evaporation. It's not a great idea to water in the evenings.
- Hand-washing a lot of dishes?- Fill up your sink with water, instead of letting it run the whole time that you're scrubbing .
- Use less electricity - Power plants use thousands of gallons of water to cool. Do your part to conserve power, and you're indirectly saving water, too!
- Re-use grey water - Check to make sure that this is legal where you live, but in some areas you can do things like re-route the runoff from your clothes washer and use that water for things like flushing the toilet.

- As many as 50 schools in Alappuzha education district in Kerala have joined the Smart Energy Programme (SEP) of the government.
- The programme is being implemented by the Energy Management Centre (EMC)
- It is the State designated agency to implement energy conservation and education programmes.
- The programme aims at inculcating habits among children to save energy.
- The children are encouraged to innovate on energy conservation methods.
- 'Catching them young' in the energy management techniques is expected to make a long-term impact among the younger generation in adopting practices that could help develop a culture of energy saving and innovation.
- Simple practices such as replacement of incandescent lamps with compact fluorescent lamps havemade considerable impact in saving energy.
- The arrival of LED lamps has opened the doors further for energy conservation.
- Energy efficiency rating for electrical appliances through star labels has been adopted by the government with a view to reducing power consumption.

Awareness campaign

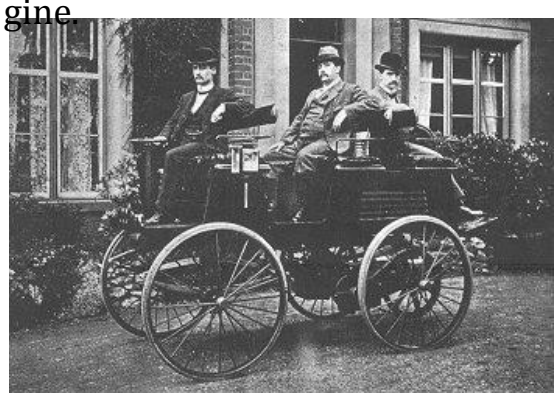
- The EMC intends to make inroads into the awareness campaign through schoolchildren.
- Under the SEP ,
- at least 50 schools are to be enrolled in an education district. Schools in categories of government, aided, unaided, CBSE, and ICSE are included in the list, with government schools being given priority.
- Each school would have to enrol a minimum of 50 students to the programme, according to EMC officials.
- Each school has to make a committee of principal/ headmaster to implement the programme.
- Each school will have to prepare a project to be presented at the education district level. Topic for the project for 2015-16 is 'Energy and Environment.
- A committee, consisting of District Education Officer, headmaster or principal and other nominees, formed at the education district-level, will monitor the programme.
- The projects presented by each school will be examined at the district-level and winners will be permitted to compete at the State-level.
- The State-level programme, titled Kerala State Students Energy Congress (KSSEC).
- A regional-level committee will evaluate the performance of the schools.
- A State-level judging panel will select the best schools.

E — Cars

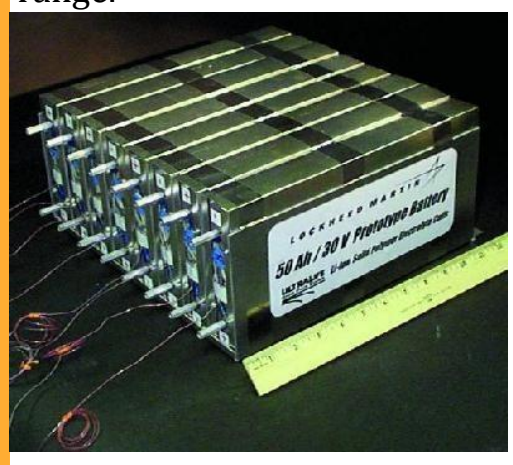
History and Future

Bokil Ruturaj (BE Electrical)

An **electric car** is an automobile that is propelled by one or more electric motors, using electrical energy stored in rechargeable batteries or another energy storage device. Electric motors give electric cars instant torque, creating strong and smooth acceleration. They are also around three times as efficient as cars with an Internal combustion engine.



The first electric cars were produced in the 1880s.Electric cars were popular in the late 19th century and early 20th century, until advances in internal combustion engines and mass production of cheaper gasoline vehicles led to a decline in the use of electric drive vehicles. The energy crises of the 1970s and 1980s brought a short-lived interest in electric cars; although, those cars did not reach the mass marketing stage, as is the case in the 21st century. Since 2008, a renaissance in electric vehicle manufacturing has occurred due to advances in batteries and energy management, concerns about increasing oil prices, and the need to reduce greenhouse gas emissions. Several national and local governments have established tax credits, subsidies, and other incentives to promote the introduction and adoption in the mass market of new electric vehicles depending on battery size and their all-electric range.



Electric cars are typically easy to drive, perform well, and are significantly quieter than conventional internal combustion engine automobiles. They also do not emit tailpipe pollutants,giving a large reduction of local air pollution, and, in many cases, a large reduction in total greenhouse gas and other emissions (dependent on the method used for electricity generation).They also provide for independence from foreign oil, which in several countries is cause for concern about vulnerability to oil price volatility and supply disruption.But widespread adoption of electric cars faces several hurdles and limitations, including their current higher purchase cost, patchy recharging infrastructure (other than home charging) and range anxiety (drivers' fear that electric energy stored in the batteries will run out before reaching their destination, due to limited range of most existing electric cars). Recharging can take a long time; however, for long distance driving, many cars support fast charging that can give around 80% charge in half an hour, using public

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Comparison of fuel efficiency and costs for all the electric cars rated by the EPA for the U.S. market as of August 2015 against EPA rated most fuel efficient plug-in hybrid, hybrid electric vehicle and 2013 average gasoline-powered car in the U.S.

Vehicle	Model year	EPA rated Combined fuel economy	EPA rated City fuel economy	EPA rated Highway fuel economy	Cost to drive 25 miles	Annual fuel cost
BMW i3	2014	124 mpg-e (27 kW-hrs/100 mi)	137 mpg-e (25 kW-hrs/100 mi)	111 mpg-e (30 kW-hrs/100 mi)	$0.81	$500
Scion iQ EV	2013	121 mpg-e (28 kW-hrs/100 mi)	138 mpg-e (24 kW-hrs/100 mi)	105 mpg-e (32 kW-hrs/100 mi)	$0.84	$500
Chevrolet Spark EV	2014	119 mpg-e (28 kW-hrs/100 mi)	128 mpg-e (26 kW-hrs/100 mi)	109 mpg-e (31 kW-hrs/100 mi)	$0.84	$500
Honda Fit EV	2013	118 mpg-e (29 kW-hrs/100 mi)	132 mpg-e (26 kW-hrs/100 mi)	105 mpg-e (32 kW-hrs/100 mi)	$0.87	$500
Fiat 500e	2013/14	116 mpg-e (29 kW-hrs/100 mi)	122 mpg-e (28 kW-hrs/100 mi)	108 mpg-e (31 kW-hrs/100 mi)	$0.87	$500

(Refrence : Wikipedia)

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Magazine Editor:

Akshay Walke
(Student-B. E. Electrical)

Magazine Editor:

Mr. S. A. Asarkar
(Assistant Professor)