Application of Solar Energy for Lighting in Opencast Mines

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of

Master of Technology
In
Mining Engineering

By

Abhishek Kumar Tripathi
(Roll No. 212MN1424)

DEPARTMENT OF MINING ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA -769 008, INDIA
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CERTIFICATE

This is to certify that the thesis entitled "**Application of Solar Energy for Lighting in Opencast Mines**" submitted by Sri Abhishek Kumar Tripathi (Roll No. 212MN1424) in partial fulfillment of the requirements for the award of Master of Technology degree in Mining Engineering at the National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in this thesis has not formed the basis for the award of any Degree or Diploma or similar title of any University or Institution.

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Finally, I most gratefully thank my parents **Mr. Kali Dutt Tripathi** and **Grish Tripathi** for staying in my heart and their continuous guidance in each step of my life, without which it would have been impossible for me to reach this stage.

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CONTENTS

ABSTRACT

Proper illumination in mines is a major requirement for un-interrupted production and improved safety. Most of the mines currently use conventional lighting systems. The energy source for such lighting systems are either electric or diesel power. The price of fossil fuel and diesel are increasing rapidly, which is responsible for increased price of power generation and cost of illumination. Therefore an alternative source like solar energy is a necessary requirement. The illumination level of mines can be improved by increasing the power output of a solar panel, the light intensity of solar panel being directly proportional to power output of solar panel. Solar energy could be a good choice of power generation, since the cost of solar panels decreasing rapidly in the past few years. Moreover, solar energy has also become more efficient as compared to other source of energy.

The P-V and I-V characteristics of a solar cell for constant temperature, varying temperature & radiation, varying tilt angle and shading effect on solar cell were studied in the laboratory (figure 1&2). It was observed that solar power output is directly dependent on sun light intensity and as the tilt angle of solar cell increases sun light intensity decreases which results in reducing the solar output power. So for maintaining permissible temperature limit large variation in tilt angle is not desirable. For reducing heat loss of solar cell, it should be connected in parallel configuration, because it was observed that at same radiation parallel configuration generates less heat as compared to series configuration and also improves the power output of a solar cell.

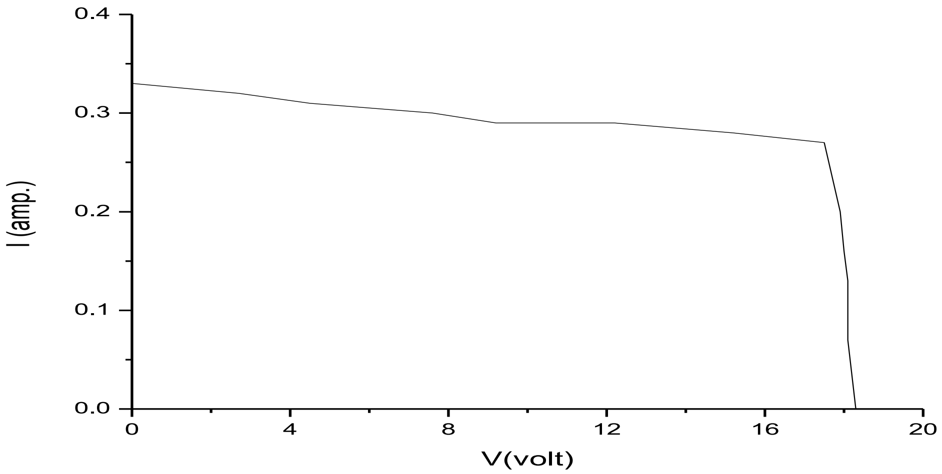

Figure1. I-V characteristics of PV module for varying temperature and radiation.

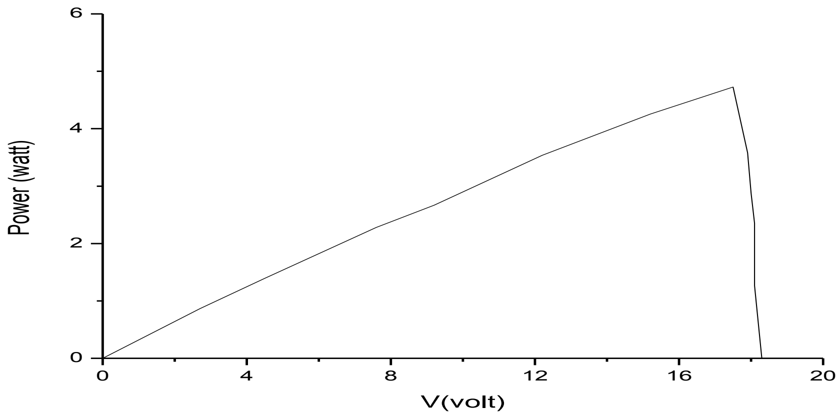

Figure2. P-V characteristics of PV module for varying temperature and radiation.

Illuminance measurements were carried out in two iron ore mine and a bauxite mine in the state of Odisha using a Metravi Lux Meter 1332. The lux meter was placed directly in front of the light source for observing the Vertical Illuminance of the source. The Metravi lux meter takes the reading into two units Lux and Foot-candela where 1 Foot-candela = 10.73691 lux. It was observed that in an iron ore mines placed at Sundergarh district for the location of excavator and haul roads were the illumination level of 25.50 lux, 0.80 lux and 0.5 lux respectively, which is below the standards presented by Directorate General of Mine and Safety. This illumination can be improved by using solar lighting lamps, which provides a better and uniform lighting for working place. For the Bauxite mine located in Koraput district, it was observed that the solar lamp produced uniform illumination as compared to the HPSV lamp even the pole height of solar lamp is high compared to HPSV lamp. It was also noticed that the solar lamp takes less power and produce better illu0mination as compared to HPSV lamp.

It was observed that with solar lighting system, an amount of Rs.15, 27,854, Rs.52, 41,950 and Rs.41, 32,590 per year can be saved by TRB iron ore mines (JSPL), Tensa, Panchpatmali Bauxite mines (NALCO), Damanjodi and Katamati mines (TATA Steel) respectively. Illumination of mine can improve by increasing solar output, which is directly dependent on sun light intensity. However for proper operation low tempera true in solar panel is desirable because PV module is made by semiconductor and at high temperature this module offer's high resistance leading to increase in resistance losses and decrease in efficiency. It was suggested that solar lighting system may be used in illuminating the mine and may be used CFl's in place with HPSV lamp. The power factor of lamp can be improved by connecting a capacitor in parallel with lamp circuit. There are three main fields where solar panel can be installed successfully, viz. haul road, pondage of mine and abandoned mine lands (AML).

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Chapter 1

INTRODUCTION

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1. Introduction

1.1 General

Lighting is a major requirement when we deal with working inside a mine whether it is Underground or Opencast mining. In opencast mining efficient lighting system is required while working during dark hours. In underground mining a very efficient lighting system is required when worked underground hours for whole day long. Lighting can influence the performance of people in the industrial workplace by way of different mechanisms that include visual performance, visual comfort, visual ambience, interpersonal relationships, job satisfaction, and problem solving. Poor lighting and reduced visual feedback decreases detection of slip trip fault (STF) hazards. There are several factors that affect the visual environment. These are:

- *Level of illumination*: It is the only one factor that determines the quality of light.
- *Mounting height of pole*: High mounting height of lighting pole represent the low level of illumination, so for proper illumination mounting height should be within the standard limit.
- *Reflectance of the surface*: High reflectance surface appears brighter than the low reflectance surface.
- Suspended dust and water vapor cause backscattering reducing apparent illuminance.
- *Spacing between the lighting pole*: Placed the two lighting pole in such manner that the illumination at the intermediate point is the sum of illuminations generated by source (lighting pole) 1 &2.
- *Nature of light:* High intensity of light provides good level of illumination. Light intensity and light temperature are two factors that directly affect the quality of light.
- *Glare:* Glare is a major problem in the coal mining industry. To decrease this, it is better to have lower powered lights with small distances between them than to have high-powered lights far apart.

In no lighting installation i.e. the zero illumination condition no mining operation can be performing during night hours, which limit the mining operation and slow down the frequency of production.

A good lighting installation is one which makes good visibility conditions. By creating better visual environment, a mining engineer can ensure safety and efficiency in underground. Lighting has important effect upon safety, health and productivity which influence the attitude of the workmen. Good lighting plays an important role in production as it encourages the worker to give their best performance.

Poor lighting discourages new entrants, slow down the rate of working, causes the industrial eye disease known as miners nystagmus and results in increase in fatigue and accidents. Thus, it is required that whatever lighting system is used should follow the mining rules and regulations given by Directorate Gernal of Mines Safety (DGMS). As per DGMS the minimum standard recommendation for open cast mines are given below:

Location	**Illumination level**
General working area as determined by the manager in writing	0.2 lux
Work place of heavy machinery	5 lux
Area where drilling rig works	10 lux
Area where bulldozer or other tractor mounted machines work	10 lux
Places where manual work is done	10 lux
Operators cabin of machines or mechanism	30 lux
At hand picking points along conveyor belt	50 lux
Truck, hauling road	0.5 to 0.3 lux

Low illumination not only affects the mine production but it also may cause a serious accident. Due to poor lighting Photoreceptors stressed and may cause a problem of headache. Working in poor lighting sends a mixed signal and confuse visual muscles which increases a human error rate.

The main power sources of mine lighting are the fossil fuels (gas, oil, coal) and due to the usage of fossil fuels, greenhouse gases (CFC, CH_4, O_3, but mainly CO_2) emit into the atmosphere which is responsible for global warming as well as the environmental pollution. On the other hand, there is an alarming energy crisis worldwide as fossil fuel reserves decrease and the ageing power plants are going to close in near future. From the aspect of global warming and shortage of natural gas, scientists and engineers are looking for clean, renewable energies. Solar energy is the one of the best options, because the earth receives 3.8 YJ [1YJ = 10^{24} J] of energy which is 6000 times greater than the worlds consumption.

Solar energy is readily available anywhere and everywhere in the earth. It can be used it to generate electricity at the point of consumption, so sometimes it is called a point power source. Solar powered building is based on this concept. Solar energy can be utilize by using sun light intensity, this energy can either be generated by using photovoltaic effect or by using concentrating phenomena of the sun light intensity.

According to Heinrich Hertz the photovoltaic effect is the phenomena in which electrons at the surface of any matter are emitted by absorbing energy from electromagnetic radiation such as visible light. A material used in photovoltaic effect (PV) known as PV cell, which are generally made by silicon semiconductor device. In PV cell, when sunlight strikes on the surface of PV cell it absorbed solar energy and if absorbed energy is greater than the band gap energy of the semiconductor, the electron from valence band jumps to the conduction band, Which is responsible for solar current.

Presently mostly conventional systems of lighting which are used inside the mines extract lots of power and deal with major maintenance problems. So a replacement to such methods is required by establishing an appropriate lighting system with may overcome all the flaws and improvements required in the current conventional lighting system. Solar energy is the best alternative of conventional lighting system. Solar lighting provides better illumination compared to the conventional lighting systems which are used in mining industry.

For good running performance of mining industry the efficiency of mining industry should be high. The efficiency of mining industry depends on several factors such as production output, mining method, cash inflow etc. for good production schedule the illumination level of mine should meet with standard one, increase illumination level directly increase the production output. For improving illumination inside the mine solar lighting systems is best choice, the solar energy not only improve the illumination level of mining industry but also minimize the cash inflow of mining industry in the form of reducing the cost of illumination system.

The costs of solar energy technologies have dropped substantially over the last 30 years. For example, the cost of high power band solar modules has decreased from about $27,000/kW in 1982 to about $4,000/kW in 2006; the installed cost of a PV system declined from $16,000/kW in 1992 to around $6,000/kW in 2008 (IEA-PVPS, 2007;

Lazard,2009). The rapid expansion of the solar energy market can be attributed to a number of supportive policy instruments, the increased volatility of fossil fuel prices and the environmental externalities of fossil fuels, particularly greenhouse gas (GHG) emissions.

Solar energy is clean and renewable. It doesn't emit carbon dioxide during operation. Solar energy is a renewable energy resource that does not generate pollution and has become an increasingly valuable way to diversify the nation's energy options. Spurred by technological advances, falling costs, and rising energy prices, solar energy projects are being developed across the country.

The major material of photovoltaic panel which is the most commonly used today is silicon, it is a semiconductor device with a positive temperature coefficient i.e. increase in temperature results in increase in resistance and power loss which decreases the efficiency of photovoltaic panel. So for proper operation solar panel should be operating within the reasonable temperature limit. The efficiency of PV system can be increases by using a suitable Maximum power point tracker (MPPT) device that provides a maximum current and voltage to the inverter circuit which enhance the efficiency of PV system.

1.2 Objectives

Keeping the above problems in mind, the present work has been designed with the following objectives:

1. Study of the existing illumination system in mines.
2. Evaluation of the merits and demerits of existing lighting system.
3. Assessment of the potential application of solar lighting system in mines.
4. Design considerations in solar lighting system.
5. Economic evaluation of solar lighting system.

Chapter 2

LITERATURE REVIEW

2. Literature review

Proper illumination is an important requirement in mining industry as it is directly related to production and safety in mines. The number of studies carried out by different researchers regarding illumination in mining is limited. A summary of the relevant work carried out by different researchers worldwide has been presented in this chapter.

Lewis (1971) studied the application of fiber optics technology to design of mine lighting system. Lewis observe that as the number of lighting installation increased more and more complaint were made by miner about lighting system causing impedance problem. Lewis examines that application fiber optics to design the mine lighting system offer a potential solution to most of the identified problem. Since the power to the light source is supplied through the electric cable and packing gland from main power supply or blast box, and electric cable may produce potential shock hazards and damage the system and if these cable replace by fiber optics cable than it reduce the potential shock hazard of conventional system and in even of damage the time consuming task of replacing the cable and repacking. Lewis observe that two major problem associate with fiber optics technology , inadequate light output and second overheating of light source both problem can be reduce by applying the new light source that will produce higher light output and at the same time generating less heat.

Van et al. (1971) studied the underground lighting of African gold mine. They make fleeting reference to the effect of underground lighting on productivity and accident rates. They make an accidental statics with carbide lamp and cap lamp, on a 12 month trial period in which 250,000 shift were worked with carbide lamp and 307,000 with cap lamp. They conclude that incidence of major accident was 115 accident per 1000 shift while the minor accident was 1152 per 1000 shift with carbide lamp and corresponding figure for men using cap lamp were 079 and 731 accident per 1000 shift respectively.

Lewin (1999) studied the lamp color and visibility to design the outdoor lighting system. In order to design the lighting system under outdoor lighting condition, the spectral distribution of light source has been shown to be an important factor in visibility. The spectral characteristic of light source is given by V (λ) curve. V-lamenda curve is the eye sensitivity curve, which relates the visual response to the wave length of light source. Lewin observe that V (λ) curve not applicable where viewing condition change i.e. in mesopic condition. Lewin observe that effective lumen increases for Metal Halide lamp as the light level reduces and eye shift toward blue/green peak sensitivity. So MH lamp is more effective than HPS lamp in mesopic condition. For calculating effective lumen rating

Lewin suggested a multiplier known as Lumen effective multiplier, as the lumen level fall the LEM value change more. Lewin observe that yellow region indicate high light level and blue/green level indicate low light level.

Bisketzis et al. (2004) studied the design of road lighting system from the point of view of mesopic vision. They observe that in mesopic vision condition the sensitivity of human eye moves toward the lower wavelength. Therefore some type of lamp which is widely used for road illumination is not as efficient as that they use to be in photopic vision. They examine the two type of model for mesopic vision which is based on Brightness matching and reaction time. They observe that the mesopic luminance value from commercially available Metal halide (MH) lamp higher than the High pressure sodium (HPS) lamp. They conduct the experiment for three type of road such as District distributor road, Residential major access road, and Local distributor road and they found that the reaction time for MH lamp always better than HPS lamp but the uniformity ratio for MH lamp was higher only for Residential major access road and for rest two road the uniformity ratio of MH lamp system poor as compare to HPS lamp system. Thus they suggested that the MH lamps are more efficient than HPS lamps in mesopic vision.

Saulius et al. (2005) studied the comparison of scale of spectral diffuse reflectance of Helsinki University of Technology (TKK) and the Singapore National Metrology Center (SPRING).They gave the reflectance factor measurement of diffuse reflectance characteristic of a sample under test. They examine the realization of absolute scale of spectral diffuse reflectance at TKK and SPRING is based on gonioreflectometer method. They conduct the comparison measurement which was held at TKK in 2004 and 2005 similarly at SPRING in 2004. They examine that the uncertainty of TKK and SPRING are constant at 0.2 and 0.3 for the wave length 480-780 nm.

Chen and Rincon (2006) designed an accurate, instinctual, and suitable electrical model to capture the dynamic characteristic of a solar battery from different linear nonlinear parameters of a PV system. They used a Ni-MH and polymer Li-ion batteries for designing the required electrical model. They found that the proposed electrical model accurately predicts battery run time with less than 0.4% error and voltage response within 30 mV for any load profile. The proposed model offers to improve system efficiency and prolong battery runtime by predicting both operation life and I-V performance accurately.

Denholma and Margolis (2007) were examined some of the limits to large-scale deployment of solar photovoltaic (PV) in traditional electric power systems. They compared the power output of PV panel to existing power generation and they found that for 50% fraction of PV panel generate high level of power compare to grid connected power system. They examine that this excess PV generation reducing the cost of power generation, when PV provides 10-20% of system energy then it not only reduces the cost of power generation but also reduces the environmental pollution at power generation site.

Esram and Chapman (2007) were discussed and compared the different available Maximum power point tracker (MPPT) techniques and explained about nineteen maximum power point tracker (MPPT) methods. They have given detail explanations of theses maximum power point technique and their implantation method which helps in selecting a right MPPT method for specific PV system. They found that the effect of shading on PV panel is major problem in photovoltaic system; it decreases the output of PV system and reduces the efficiency of PV system.

Xiao et al. (2007) studied the spatial relations and geometric properties of Photovoltaic (PV) system to optimize the operation of maximum power point tracker (MPPT). They proposed an individual power interface for each PV module and suggested a suitable structure for the PV system. They found that an individual power interface is to minimize the non- ideal condition and improve the performance of photovoltaic system that helps in enhancing the efficiency of PV power system.

Gules et al. (2008) studied and implemented a parallel connected MPPT system for a standalone photovoltaic (PV) power generation. They constructed a prototype board which showed a maximum 45 W power in practical test. They found that the parallel connection of Maximum power point tracking (MPPT) system reduces the negative influence of power converter losses in the overall efficiency during photovoltaic power generation.

Mills et al. (2008) they examined the impact of retail electricity rate design on the economic value of grid-connected photovoltaic (PV) systems, focusing on commercial customers in California. They used a 15-min interval building load and PV production data from a sample of 24 actual commercial PV installations, and they compare the value of the bill savings across 20 commercial-customer retail electricity rates currently offered in the state. Across all combinations of customers and rates, they found that the annual bill savings from PV, per kWh generated, ranges from $0.05 to $0.24/kWh. This sizable range in rate-reduction value reflects differences in rate structures, revenue requirements, the size of the PV system relative to building load, and customer load shape. They found that the commercial value of PV for most significant rate of design is to be the percentages of total utility bills recovered through demand charges, though a variety of other factors are also found to be of importance. They examine that the net value of metering is to be sustainable but only when energy from commercial PV system represents a sizable portion of annual customer load.

Campbell et al. (2009) studied the importance of PV power plant on large scale renewable energy power generation. They compared the cost of PV power generation with other power generation source. They suggest a levlized cost of energy (LCOE) for common means of comparing the relative cost of electricity from generating source. The LCOE equation allows alternative technologies to be compared when different scales of operation, investment or operating time periods exist. They conclude that on many dimension of cost and performance the LCOE for a solar power plant has high capacity factor and low cost of power generation. They suggest a high LCOE for lowest life cycle cost and highest lifetime's energy production.

Firth and Jacket (2009) carried out on site measurement of the reflective properties of a sample of the New Zealand pavements in order to review the standard of road lighting from safety point of view. They measured the road surface for two reflection parameter used in standard base design calculations for road safety lighting with the help of prototype reflect meter known as Memphis . These were Q_0, the weighted average surface reflectance and S1 the specula try index. A surface with high Q_0 is preferable as it would need less light to illuminate road. Similarly higher the S1 more mirror like is the surface. A surface with low S1 is generally preferable as it would require less laminate for the lighting. They found that the road surface had lower Q_0 value than the equivalent CIE standards, which imply that the roads would be lighted far lower levels than the design parameters suggested. The result of the study indicated that the New Zealand pavements are considerable less reflective and less safe than previously thought.

Sammarco et al. (2009) studied the effect of cap lamp lighting on postural control and stability. They observe that the strip, trip and falls (STFS) injuries occurred more frequently than any other category. Better lighting condition could reduce the risk of STFS injuries. They suggested that a cap lamp is an important piece of personal protection equipment in mining. The LED base cap lamp have been shown to improve STFS hazard and peripheral motion detection, but LED cap lamp show a significant decline in postural stability when moving from fully lit laboratory to an underground coal mine. They noted that visual change with age include the decline the ability to focus on near subject, and they suggested the deterioration of visual function may compensated by improving the quality of lighting.

Villalva et al. (2009) designed a method of modeling and simulation of photovoltaic (PV) array. They adjusted the I-V cure at three points i.e. open circuit, maximum power and short circuit and found the nonlinear parameter on I-V cure by nonlinear I-V equation. They proposed an effective and direct method to fit the mathematical I-V curve to three (V_{oc}- I_{oc}, V_m-I_m and V_{sc}-I_{sc}) remarkable point without need to guess and estimate any parameter except diode constant a. They suggested a close solution for the problem of finding the parameter of the single diode model equation of a practical PV array, theses solution always require visually fitting the mathematical curve to the I-V points and graphically extracting the slope of the I-V curve at given point or successively solving and adjusting the model in a trial and error process.

Lewin (2010) said that definition of lighting depends up on the luminous sensitivity curve of eye V (λ). Lewin observe that the V (λ) function does not apply in off axis and at low level of luminance. The author proposes the use of lumen effective multiplier (LEM) to convert normal photopic lamp lumen to the effective lumen for particular lighting design. The values of LEM for high light level are 1.0 for all sources and for low light level greater than 1. Lewin suggested that three parameter that select the LEM value that are first mesopic response function particularly based on Brightness matching data, second mesopic response function based on visual performance data and third data from visual performance experiment using commercial light source.

Yenchek and Sammarco (2010) examined the mining record compiled by the mine safety and health administration (MSHA) from 2002 to 2006 and observed that an average of 28 accidents involving light occurred annually within the U.S.A mining industry. These accidents could be separated in to three main group associated with operation and maintains/repair activities, cap lamp and auxiliary lighting. The greatest number of accident occur when employ maintain and repair lighting. They observed that LED in general exhibit a longer life and thus require less maintains with respect to light source replacement. LED do not typically fail catastrophically compare to incandescent light source, rather they gradually decrease light out over time. LED also use less electrical power than conventional incandescent and halogen light source. They were of the opinion that luminous using LED have the potential to significantly reduce to the frequency of accident caused during maintains and repair of lighting system. They observed that a number of accident in the mining accident occur because of the miner cap lamp cable and they gave the technology for the chord less LED cap lamp is viable and this could eliminated cable related accident. They found that Metal Halide (MH) lamp have an efficiency compare to commercial available LED and stated that the current state of LED technology would not enable a power reduction for mobile light plant because LED efficiency is approximately equal to MH lamp currently used for portable mine lighting.

Aruna and Jarakliar (2012) design a lighting system for surface mine projects. Using Mat lab software they developed software SURLUX for designing the surface mine illumination. The software is capable for calculating the illumination level at a grid point for any given set parameter, such as luminare type and its characteristic, location of pole, spacing of pole, mounting height and tilt angle etc. The software can directly take in to consideration the reflectance factor of the surface. It is capable of calculating minimum and maximum light level and uniformity ratio for deciding feasibility of an illumination system for an area. They considered a stretch of 1 km long haul road for comparison of five different types of luminaries. They also varied the lamp mounting height at 8,10,12,14 and 16 m. They observed that the lighting design under wet condition incurred and excess cost of 94% for mineral bench and 50% for overburden bench of haul road. The increase in cost of overburden bench was due to low reflectance of surface and also large difference between dry and wet surface reflectivity.

Pal et al. (2012) studied the lighting system for haul road using compact fluorescent lamp (CFL) with standalone solar lighting system. They constructed a proto type board which showed a fairly constant lumen output over varying input voltage. They decrease the inverter operating frequency to maintain the constant lumen output, and observe that when the battery was fully charged the voltage was 14.21 volts. The inverter efficiency was found to be above 94% for 9 WCFL. They suggested that low electrical consumption by the CFL makes it an ideal choice for solar photovoltaic standalone lighting system for a surface mine haul road.

Simon et al. (2013) studied the analysis of the important of modeling of solar data. They observed that solar irradiation can be measure by geostationary satellite but satellite method have special problem with snow on ground, strong varying area like mountain at high latitude in winter when sun is very low , so an accurate solar model are mandatory for many application including forecasting. They classify many different models to predict solar irradiation in two main groups, first from predicting irradiation from other climate variables and second for space interpolation. They suggested two indicators for calculating the accuracy of each models, first mean bias error and second root mean squire error. The RMSE value is better to analyze the model.

Chapter 3

Lighting System used in Opencast Mines

Power source used inside the mines

Types of lamps used inside the mines

Drawback of current lighting systems

Technological development in the field of lighting system in open cast mines

3. Lighting System used in Opencast Mines

The lighting systems used in open cast mines can be characterized in two parts, viz. power source used inside in the mines and type of lamps used inside the mines.

3.1 Power Source used inside the Mines

There are two types of power source used inside the mines, which are discussed below:

Power from GRID: An electrical grid (also referred to as an electricity grid or electric grid) is an interconnected network for delivering electricity from suppliers to consumers. It consists of generating stations that produce electrical power, high-voltage transmission lines that carry power from distant sources to demand centers, and distribution lines that connect individual customers. Now a day many generating station generate electricity from fossil fuel which not only pollute the environment but the cost of fossil fuel increases day by day.

Figure3.1 Grid connected power system.

Power from D-G set: A diesel generator is the combination of a diesel engine with an electric generator (often an alternator) to generate electrical energy. This is a specific case of engine-generator. Diesel generating sets are used in places without connection to the power grid, as emergency power-supply if the grid fails, as well as for more complex applications such as peak-lopping, grid support and export to the power grid. Sizing of diesel generators is critical to avoid low-load or a shortage of power and is complicated by modern electronics, specifically non-linear loads.

Figure3.2 Diesel Generator set in an iron ore mine

Disadvantage of power from D-G set:

1. Efficiency of D-G set depends on D-G size.
2. Maximum efficiency obtained for less than 70% loading.
3. Large load fluctuations.
4. Harmonic distortion.

3.2 Type of Lamps used inside the Mines

There are various kind of lighting lamps currently used in mines, viz. Incandescent, Tungsten halogen, Metal halide, High pressure sodium, High intensity discharge, L.E.D lamp, Which are (Bisketzis et al., 2004; Dishna et al., 2009; Yenchek and Sammarco, 2010; Pal et al.2012;)

Incandescent lamp: Incandescent light, which is likewise called general lighting administration (GIS), light, is prepare by heading present through a tungsten wire. The working temperature of tungsten fibers in brilliant lights is something like 2700k.therefore the principle discharge happens in infrared locale. The run of the mill brilliant productivity of diverse sorts of glowing light is in the extent between 5 and 15 lm/W.

Advantage of incandescent lamp:

1. Inexpensive.
2. Easy to utilize, little and does not require assistant supplies.
3. Easy to lower by changing the voltage.
4. Excellent shade rendering properties.
5. Directly work at force supplies with altered voltage. s
6. Free of poisonous remarks.
7. Instant exchanging.

Disadvantage of incandescent lamp:

1. Short light life (1000hr).
2. Low glowing effectiveness.
3. Heat era is high.
4. Lamp life and other trademark firmly subject to supply voltage.
5. The aggregate expenses are high because of high operation cost.

Tungsten halogen lamp: Tungsten incandescent lights are inferred from brilliant lights. Inside the lamp, halogen gas restricts the dissipation of the fiber, and store's the vanished tungsten over to the fiber through the supposed halogen cycle. Contrasted with glowing light the working temperature is higher, and thusly the color temperature is additionally higher, which implies that the light is whiter. Shade rendering record is near 100 as with radiant lights. Additionally, lumen devaluation is irrelevant. Their lifetime compasses from 2000 to 4000 hours, and brilliant adequacy is 12-35 lm/W. The most recent advancement in incandescent lights has been arrived at by presenting particular IR-mirror-coatings in the globule. The infrared covering redirects infrared radiations again to the fiber. This expands the glowing adequacy by 40–60% contrasted with different plans and light life is dependent upon 4000 hour

Advantages of tungsten halogen lamps:

1. Small size.
2. Directional light with a few models.
3. Low voltage elective.
4. Easy to lower.
5. Instant exchanging and full light yield.

6. Excellent shade rendering properties.

Disadvantages of tungsten halogen lamps:

1. Low glowing effectiveness.
2. Surface temperature is high.
3. Lamp life and other trademark firmly subject to supply voltage.

Compact fluorescent lamps (CFL): The CFL is a minimized variant of the fluorescent light. The general length is abbreviated and the tubular release tube is frequently collapsed into two to six fingers or a winding. For an immediate substitution of tungsten fiber lights, such minimal lights will be outfitted with interior weights and screw or pike tops. There are additionally stick base CFLs, which require an outside balance and starter for operation. The iridescent adequacy of CFL will be about four times higher than that of brilliant lights. Along these lines, it is conceivable to spare vitality and expenses in lighting by supplanting brilliant lights with CFLs.

Advantages of compact fluorescent lamps:

1. Good brilliant effectiveness.
2. Long light life 6000-12000 hr.
3. The lessened cooling burden when supplant with the radiant light.

Disadvantages of compact fluorescent lamps:

1. Expensive.
2. Light yield deteriorated with age.
3. Short smoldering cycle.
4. The current waveform of CFLs with inward electronic counterbalance is misshaped.
5. Contain mercury.

Metal halide lamps: To increment the brilliant adequacy and CRI of mercury high weight lights, it will be valuable to add mixtures of metal parts to the filling of the release tube. These added substances transmit their line spectra in the circular segment release, prompting an gigantic differing qualities of light color. For sufficient vapor weight, it is better to use metal halides (mixes with iodine or bromine) rather of essential metals. At the point when the vapor enters the high temperature locale of the release, particles separate, metal molecules are energized and radiation is emitted. The provisions of metal halide lights arrive at from electric lights (10miniature variants) to assorted purposes in indoor and open air lighting (wattages up to 20 kw). The lights are accessible with brilliant viability regularly from 50 to 100 lm/W. CCT esteem from 3000 to 6000 K and CRI from 70 to in excess of 90. The light life is normally from 6000 h to 12000 h.

Advantages of metal Halide lamps:

1. Good brilliant proficiency.
2. Alternatives with great color rendering accessible.
3. Different color temperature accessible.

Disadvantages of metal Halide lamps:

1. Expensive.
2. Starting and restarting time 2-5 min.

High pressure sodium lamps: In high weight sodium light is processed by sodium vapor, the gas weight being something like 15 kpa. The brilliant yellowish discharge range applies to wide parts of the unmistakable zone. The CRI is low (≈ 20), however the iridescent viability is high. The most widely recognized requisition today is in road and way lighting. Glowing viability of the lights is 80-100 lm/W, and light life is 12 000 h (16 000 h). The CCT is 2000 K. A change of the CRI is conceivable by beat operation or hoisted weight yet this decreases the radiant adequacy. Color enhanced high weight sodium lights have CRI of something like 65 and white high weight sodium lights of more than 80. Their CCT is 2200 and 2700, individual

Advantages of high pressure sodium lamp:

1. Very great iridescent productivity.
2. Long life 12000-16000 hr.
3. High iridescent flux from one unit for road and territory lighting.

Disadvantages of high pressure sodium lamp:

1. Low CCT (Correlated shade temperature) something like 2200k.
2. Low CRI (Color rendering record) something like 20.
3. Starting and restarting time 2-5 min.

High intensity discharge lamps: Without any temperature impediments (illustration softening point of tungsten) it is conceivable to use gas releases (plasmas) to create optical radiation. These lines may be utilized straightforwardly or after phantom transformation by phosphors for outflow of light. Release lights create light of diverse shade quality, as per how the phantom lines are dispersed in the noticeable extent. To forestall runaway current and guarantee stable operation from a consistent voltage supply, the negative current voltage aspects of gas release lights must be offset by a circuit component such as ordinary attractive or electronic stabilizer. In all Cases, higher voltages are required for lighting the release. The force change for every unit volume in high weight circular segment release lights is 100 to 1000 times higher than that of low weight lights.

Light-emitting diodes (LEDs) lamps: A LED light is a light-discharging diode (LED) item that is gathered into a light (or light)) for utilization in lighting apparatuses. Headed lights offer relatively long life contrasted with radiant lights and some fluorescent, in spite of the fact that at a higher starting cost. Research into natural LED’s and polymer light-emanating diodes is pointed at decreasing the creation expense of lighting items. Diode engineering presently enhances at a rate. Some LED lights are made to be a specifically good drop-in substitution for glowing or fluorescent lights. A LED light bundling may demonstrate the lumen yield, power utilization in watts, color temperature and at times a comparable wattage of a glowing light it will supplant. Adequacy of LED gadgets keeps on improving, with a few chips ready to emanate more than 100 lumens for every watt. The adequacy of LED lights is for the most part fundamentally higher than that of incandescent lights.

3.3 Drawbacks of Current Lighting Systems

Current lighting system used conventional electric power for lighting the mines. Conventional power system consist thermal power plant, diesel power plant, steam power plant and etc. That consist various drawbacks such that:

1. **Fuel Cost:** Existing lighting system require fuel, and the cost of fuel continuously increasing day by day, this is a huge disadvantage over solar lighting system, and costs of fuels are increasing at a drastic rate every year. Due to this Electricity prices are

increasingly rapidly in most parts of the world much faster than general inflation. Price shocks due to high fuel costs are a big risk with fossil fuel energy these days.

2. **Material Handling problem:** Primary material required for generation of electricity by thermal power plant is coal, ash is a part of coal which produces after burning the coal and ash handling is a big problem also it require an additional cost.
3. Not economical in areas which are remote from coal fields.
4. It pollutes the atmosphere due to production of large amount of smoke and fumes.
5. High running cost.
6. More raw materials require.
7. Manpower required is more.
8. For large units, the capital cost is more.
9. Diesel plants do not work satisfactorily for over loads.
10. The cost of diesel is high.
11. The plant capacity is limited.
12. The life of diesel plants is less compared to the steam plan.
13. Some lighting lamps require more input power and produce less out power compares to other lamp; therefore it should be necessary to replace these lamps with more efficient lamps.

3.4 Technological Development in the Field of Lighting in Opencast Mines

Significant advancement has been made in the area of mine illumination over the last few decades. Some of the advances in mine illumination are:

Light-emitting-diode or LED (Yenchek and Sammarco, 2010):

A light transmitting diode (LED) is a semiconductor light source. LED’s are utilized as marker lights as a part of numerous gadgets, and are progressively utilized for lighting. Early LED's emitted low power red light, however current adaptations are accessible over the unmistakable, ultraviolet and infrared wavelengths, with high splendor. The LED is focused around the semiconductor diode. At the point when a diode is forward predisposition (exchanged on), electrons can recombine with gaps inside the gadget, discharging vitality as photons. This impact is called electroluminescence and the color of the light (comparing to the vitality of the photon) is dictated by the vitality hole of the semiconductor. Leds present numerous focal points over radiant light sources including easier vitality utilization, longer lifetime, enhanced heartiness, more modest size, quicker exchanging, and more stupendous sturdiness and dependability. Notwithstanding, they are moderately unmanageable and require more exact current and hotness administration than customary light sources. Current LED items for general lighting are more unreasonable to purchase than fluorescent light wellsprings of equivalent yield. As indicated by Yenchek and Sammarco (2010) most extreme number of mishap in mining industry happened because of upkeep and repair of lighting framework since LED's require less support and repair so LED's altogether lessens the recurrence of mischance brought about throughout upkeep and repair.

Figure 3.3 Lighting Emitting Diode (LEDs) lamps

Metal Halide (MH) Lamp (Bisketzis et al., 2004):

The provision of metal halide lights arrive at from electric lights (10 W little variants) to differing reason in indoor and open air lighting (wattage up to 20kw). The light are accessible with radiant effectiveness regularly from 50 to 100 lm/W, CCT esteem from 3000 to 6000k and CRI structure 70 to in excess of 90. The light life is regularly from 6000 to 12000 hr. Metal halide light likewise exceptionally effective in mesopic vision approach, street lighting by and large think about under mesopic vision condition on the grounds that the luminance level on streets of low or medium activity, fall beneath the easier furthest reaches of photopic vision. In this district the utilization of Metal halide light is more effective than high weight sodium light.

Hybrid lighting

An integrated lighting system utilizing both daylight and electrical lighting is called hybrid lighting system. A hybrid lighting system usually consists of the following major elements:

1. A day lighting framework (give characteristic light to the half breed lighting framework).
2. An electrical lighting framework (give fake light on the off chance that it is needed).
3. A lighting control framework (improve the fiery execution).
4. Hybrid illuminating presences (coordinated lighting conveyance framework for both light and electrical lighting).
5. Transportation module (in unique case).

Hybrid solar lighting (HSL)

Sun oriented lighting frameworks catch light from the sun and behavior it towards a room utilizing optical filaments. They utilize roof authorities, extensive reflected dishes that track the sun. The gatherers conform to point the daylight onto 127 optical filaments which are directed into a solitary harmony. The optical filaments are adaptable and might be joined into mixture light installations that are joined to diffusing bars that scatter the light. A solitary authority can power up to eight crossovers light installations coating 1,000 square feet (93m^2).daylight is gathered by a heliostat (sun following light gatherer). A transportation framework (here optical filaments) is utilized to circulate the gathered daylight all around the building inner parts.

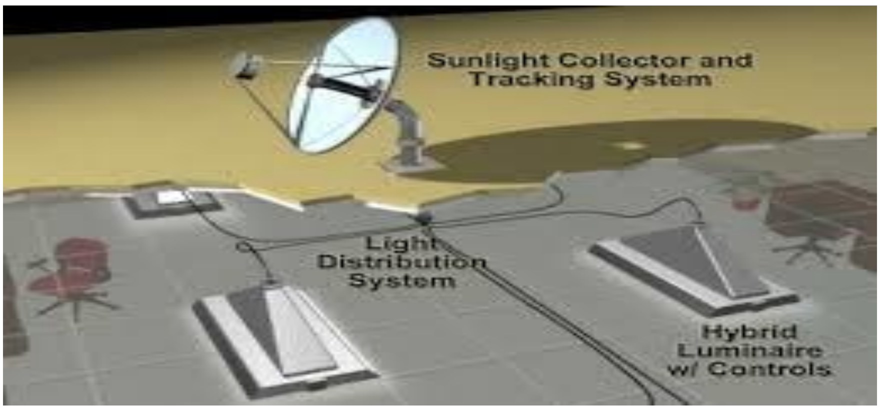

Figure3.4 Hybrid Solar Lighting System

Chapter 4

Solar Lighting and Current Status of Solar Energy Technology

Solar lighting system

Positive feature of solar lighting system

Limitation of solar lighting system

Implementation of solar lighting system in open cast mines

Current status of solar energy technologies and markets

4. Solar Lighting and Current Status of Solar Energy Technology

Solar energy is the sun light oriented energy which can be generated by the help of sun light intensity. When sun light strike on the photovoltaic panels, it generates a photo current that is in dc form, which can be converted to ac form by inverter circuit, and this can be easily utilize by any kind of lighting load.

Working of Solar Lighting Systems

A photovoltaic panel is an electric device that convert energy of light directly in to electric current. When a sun light (photo) strikes on PV panel then it generate a photo current in the form of DC. A charge controller is used to maintain the charge of PV panel, it maintain the charge of PV panel in such a way that it generates a maximum charge. An inverter circuit is used to convert DC load current in to AC load current, this AC load current feed in to a load circuit (Figure 4.1).

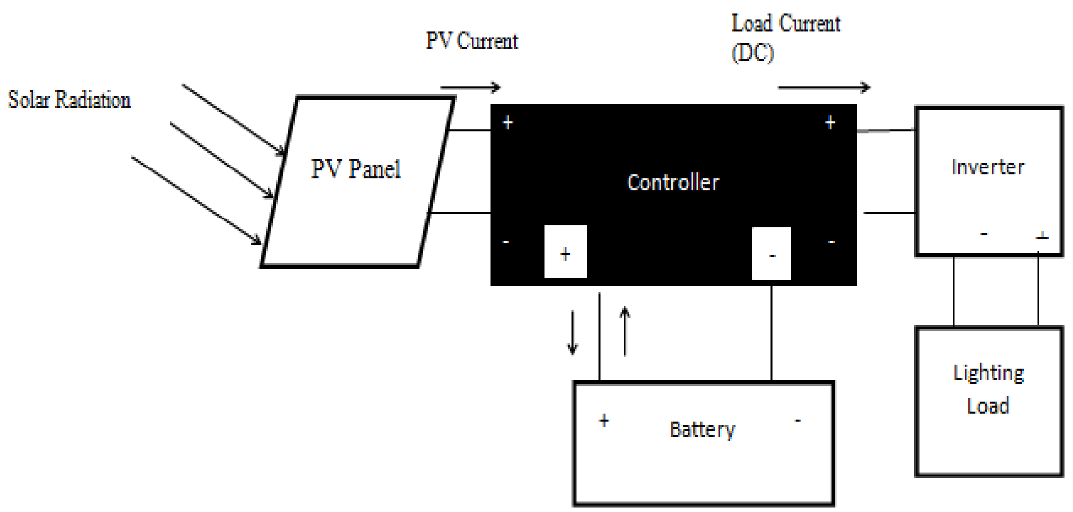

Figure 4.1 Block diagram of solar lighting system

The photo current can't be directly use because of its fluctuating nature that's why a battery is used to store the charge of charge controller. The primary functions of solar battery are:

1. *Energy Storage Capacity and Autonomy*: To store energy when there is an excess is available and to provide it when required.

2. *Voltage and Current Stabilization:* To provide stable current and voltage by eradicating transients.
3. *Supply Surge Currents:* to provide surge currents to loads like motors when required.

4.1 Positive Features of the Solar Lighting Systems

Some of the positive features of the solar systems are:

1. Owners of solar systems do not wait for political decisions or global change, they just act.
2. Solar system is easily recognized sign of high responsibility, environmental awareness and commitment.
3. Owners of solar collectors are happy with every sun beam and have bigger environmental knowledge.
4. Solar energy system makes them more independent from rising of energy bills.
5. Solar energy systems for swimming pools are economical and investment can be regained in a short time.
6. Throughout life, solar systems produce 13 times more energy than the energy used in their manufacture.
7. Solar systems have low maintenance requirements, and their energy is constantly available.
8. Solar technology creates lasting jobs in the manufacturing, design, training, installation, servicing and maintenance.
9. Solar system is easily recognized sign of high responsibility, environmental awareness and commitment.
10. No utility line extensions required.
11. Fast and Simple Installations.
12. Standalone independent systems.
13. Decentralized street lighting solutions.
14. Small in size compared with other lamps of same output.
15. Long life; an estimated 50,000 + hours operation.
16. Robust; can withstand vibration from transport & rough weather.
17. Good efficiency comparable with fluorescent lamp.
18. 2 year system warranty.
19. 25 years Solar Module warranty.
20. Reduced maintenance cost due to long life.

4.2 Limitation of Solar Lighting System

1. *Availability:* Solar energy's greatest confinement is its sporadic accessibility. Since mists and, obviously, dusk intrude on the gathering of sunlight based energy, numerous sun powered plants really are crossover plants that likewise require an auxiliary fossil fuel source, for example, common gas, to continue preparing energy.
2. *Intensity:* Solar energy does not always provide the level of power necessary to fulfill energy needs of a business or area. In those cases, a secondary energy source must supplement the solar energy.
3. *Cost:* With technology to harness solar energy still under development, panels and other units that collect and store the energy still remain prohibitively expensive for some regions.
4. *Transmission:* Because sunny deserts are the ideal spot for solar energy collection, plants there do not have easy access to major energy grids. The plants require some method of transmission to compensate for the lack of power lines in the desert.
5. *Enviourmental impact:* While solar energy is kind to the environment, not all of the facilities needed to harness it are. Some of the higher capacity solar energy plants take up large amounts of land, and building a large number of those plants could displace animal populations.

4.3 Implementation/Location of Solar Lighting System in Opencast Mines

There are three main fields where solar panel can be installed successfully:

1. *Haul Road:* Haul roads inside the pit are one of the discriminating areas in surface mines where lighting installations are not permanent because of customary progression of the working face. Because of this reason it is extremely troublesome to keep up the lighting standards, as specified by various administrative bodies. Lighting in mines presents special problems because of the dim surroundings and low surface reflectance. Henceforth, scientific design of fake lighting is exceptionally vital to accomplish the base obliged lighting standards. Solar lighting is a standout amongst the most compelling methods to attain the base obliged lighting standards. Standalone lighting system with CFL's light can enhance the lighting standards of open cast mines.

A Standalone power system also known as a remote zone power supply (RAPS), is an off network power system for area that are not fitted with a power distribution system. Because of this reason a standalone PV system could be actualized in pull road for better brightening.

Figure 4.2 Stand- alone PV Lighting System

2. *Pondage of mine:* Solar panel can be located on pondage of mines. In evening time due to sun ray shadow of one solar cell made on other and the shadow of other surrounding objects (tree, pole dust zone) on the solar panel decreases the output power of solar panel.

Figure 4.3 Pondage of Mines

3. *Abandoned Mine Lands (AML):* Abandoned Mine Lands (AMLs) are those lands, waters, and surrounding watersheds where extraction, beneficiation, or processing of ores and minerals (excluding coal) has occurred. These lands also include areas where mining or processing activity is temporarily inactive. So this land can be utilized by installing the solar panel for solar energy production.

Figure 4.4 Abandoned mine land

4.4 Current Status of Solar Energy Technologies and Markets

Technologies and resources: Sun based energy is a source of energy that might be specifically credited to the light of the sun or the hotness that daylight produces (Bradford, 2006). Sun powered vitality advances might be grouped along the accompanying continuum: 1) uninvolved and dynamic; 2) warm and photovoltaic; and 3) concentrating and non-focusing. Detached sun oriented vitality engineering simply gathers the vitality without changing over the hotness or light into different structures. It incorporates, for instance, expanding the utilization of light or hotness through building configuration (Bradford, 2006).

Interestingly, dynamic sunlight based energy engineering alludes to the bridling of sun powered energy to store it or believer it for different requisitions and could be comprehensively arranged into two gatherings: (i) photovoltaic (PV) and (ii) sun oriented warm. The PV engineering proselytes brilliant vitality held in light quanta into electrical energy when light falls upon a semiconductor material, bringing about electron excitation and firmly upgrading conductivity. Two sorts of PV innovation are now available in the business: (a) crystalline silicon-based PV cells and (b) slight film innovations made out of a reach of diverse semi-conductor materials, including nebulous silicon, cadmium telluride and copper indium gallium diselenide1.

Solar based warm innovation utilizes sun powered hotness, which could be utilized specifically for either warm or warming provision or power era. Likewise, it might be partitioned into two classifications: (i) sun based warm non-electric and (ii) sun powered warm electric. The previous incorporates requisitions as horticultural drying, sun powered water warmers, sun oriented air radiators, sunlight based cooling frameworks and sun powered cookers2 (e.g. Weiss et al., 2007); the recent alludes to utilization of sun based hotness to transform steam for power era, otherwise called concentrated sun powered force (CSP). Four sorts of CSP innovations are as of now accessible in the business: Illustrative Trough, Fresnel Mirror, Force Tower and Sun oriented Dish Gatherer (Wolff et al., 2008). Sunlight based energy speaks to our biggest wellspring of renewable energy supply. Compelling sunlight based irradiance arriving at the world's surface extents from about $0.06kw/m^2$ at the most noteworthy scopes to $0.25kw/m^2$ at low scopes. Beneath figure analyzes the actually achievable capability of distinctive renewable energy alternatives utilizing the present change efficiencies of accessible advances. Actually when assessed on a territorial premise, the specialized capability of sun oriented energy in most areas of the world is ordinarily more terrific than current aggregate essential energy utilization in those districts (de Vries et al. 2007).

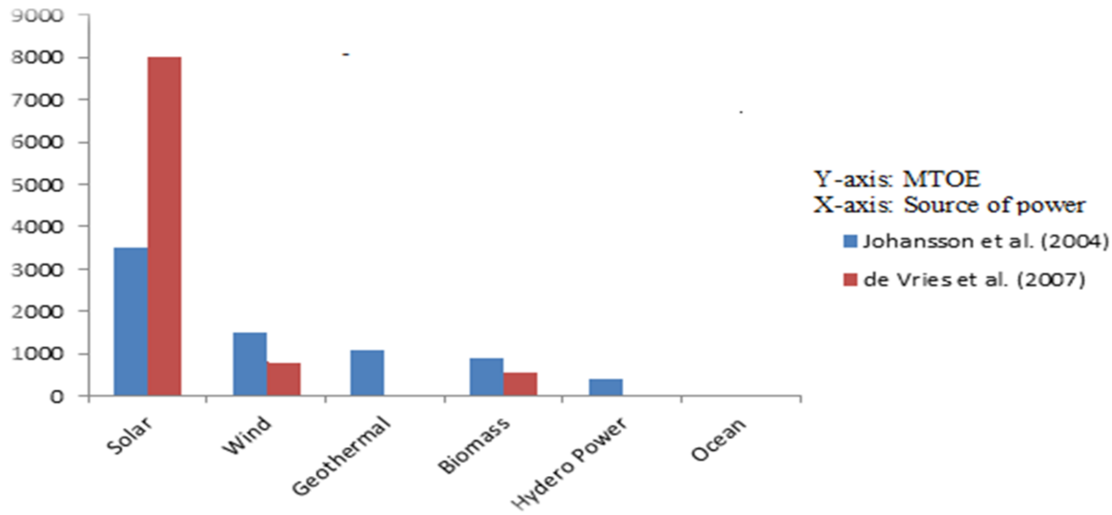

Figure4.5 Technical potential of renewable energy technologies

MTOE= Million Tonnes of Oil Equivalent

Current market status

The establishment of solar energy advances has become exponentially at the worldwide level in the course of the most recent decade. For instance, as delineated in Figure 4.5, worldwide introduced limit PV (both framework and off-matrix) expanded from 1.4 GW in 2000 to give or take 40 GW in 2010 with a normal yearly development rate of around 49%. So also, the introduced limit of CSP multiplied throughout the most recent decade to achieve 1,095mw before the end of 2010. Non-electric sunlight based warm engineering expanded very nearly 5 times from 40 GW in 2000 to 185 GW in 2010. The driving force behind the late development of sun oriented advances is credited to supported strategy help in nations, for example, Germany, Italy United States, Japan and China.

Solar PV: By December 2010, worldwide introduced limit for PV had arrived at around 40 GW of which 85% lattice associated and staying 15% off-network. This business sector is at present commanded by crystalline silicon-based PV cells, which represented more than 80% of the business sector in 2010. The rest of the business sector very nearly totally comprises of flimsy film advances that utilization cells made by specifically keeping a photovoltaic layer on a supporting substrate. Two sorts of PV frameworks exist in the business sectors: network associated or incorporated frameworks and off-matrix or decentralized frameworks. The late pattern is solid development in concentrated PV improvement with establishments that are in excess of 200 kW, working as brought together power plants. The heading markets for these requisitions incorporate Germany, Italy, Spain and the United States. In the wake of displaying poor development for various years, yearly establishments in the Spanish business sector have developed from something like 4.8 MW in 2000 to more or less 950 MW at the end of 2007 (PVRES 2007) preceding dropping to 17 MW in 2009 and skipping over to around 370 MW in 2010 (EPIA, 2011). The off-matrix provisions (e.g., sunlight based home frameworks) commenced a prior wave of PV commercialization in the 1970s, yet as of late, this business has been overwhelmed by network associated frameworks. While matrix associated frameworks overwhelm in the OECD nations, creating nation markets, headed by India and China, without further ado support off-framework frameworks. This pattern could be an impression of their extensive rustic populaces, with creating nations embracing a methodology to sun powered PV that accentuates PV to satisfy fundamental requests for power that are unmet by the expected matrix.

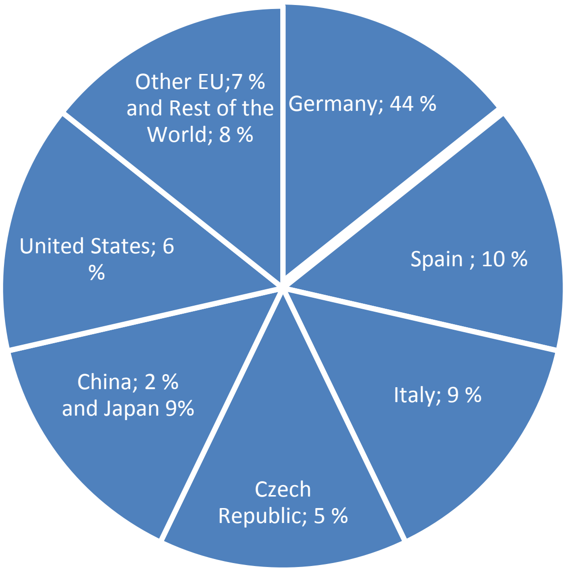

Figure 4.6 Total Installed Capacity of PV at the Global Level in 2010
Source: REN21, 2011

Concentrated Solar Power (CSP): The CSP showcase initially rose in the early 1980s however lost pace without government help in the United States. Then again, a late solid restoration of this business sector is clear with 14.5 GW in different phases of advancement over 20 nations and 740 MW of included CSP limit between 2007 and 2010 While numerous districts of the world, case in point, Southwestern United States, Spain, Algeria, Morocco, South Africa, Israel, India and China, give suitable conditions to the arrangement of CSP, business movement is principally focused Southwestern United States and Spain, both of which are backed with good arrangements, financing expense credits and food in taxes (Wolff et al. 2008). As of now, a few activities around the globe are either under development, in the arranging stages, or experiencing achievability studies6 and the business sector is required to continue developing at a noteworthy pace (Ren21, 2011).

Chapter 5

Experimental Investigation

Experimental Study on Behavior of Solar Panel

Result

5. Experimental Investigation

Incident sunlight can be converted into electricity by photovoltaic conversion using a solar panel. A solar panel comprises of unique cells that are substantial zone semiconductor diodes, developed so light can infiltrate into the district of the p-n intersection. The intersection structured between the n-sort silicon wafer and the p-sort surface layer oversees the diode attributes and in addition the photovoltaic impact. Light is ingested in the silicon, producing both overabundance gaps and electrons. These abundance charges can course through an outside circuit to process power.

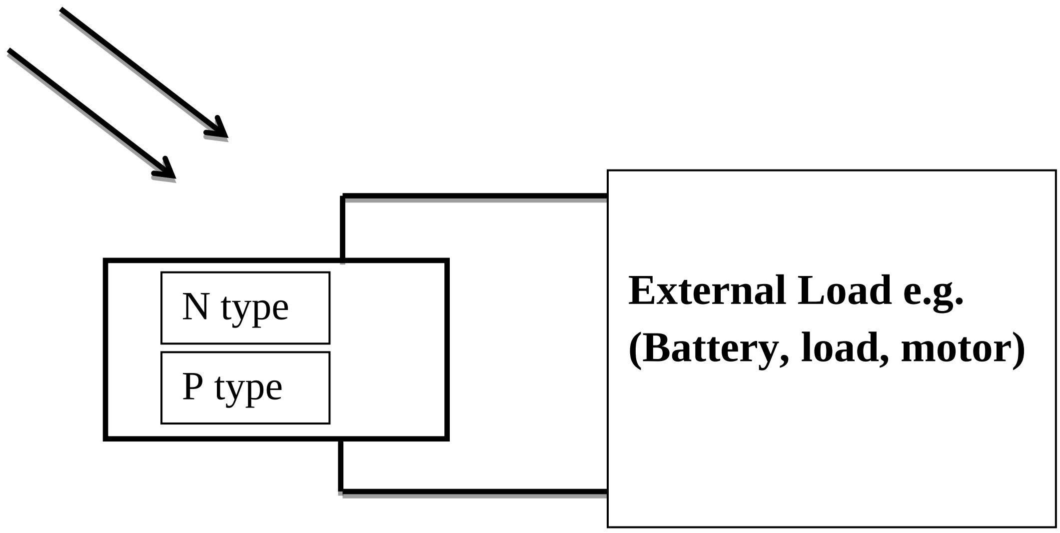

Figure 5.1 Equivalent Circuit of a Solar Cell

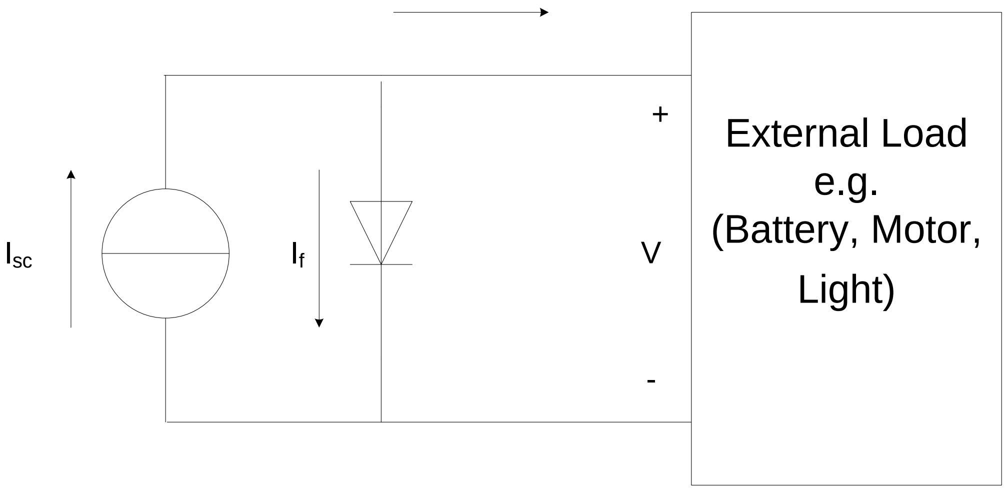

Figure5.2 Modified Equivalent Circuit of a Solar Cell

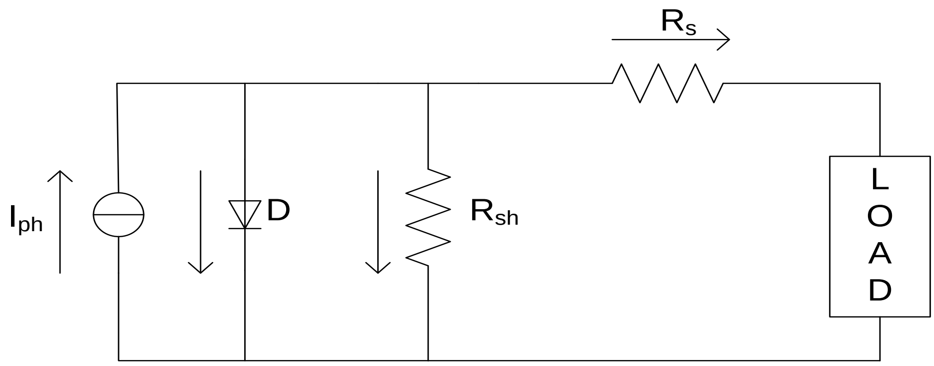

Figure 5.3 Electric circuit of solar panel

5.1 Experimental Study on Behavior of Solar Panel

The parameters of solar panel like resistance, losses, fill Factor, maximum voltage; maximum current and maximum power varies with changes in temperature, solar radiation and solar configuration. An experiment was conducted to know the behavior of solar panel with the change in specific parameters. The specific objectives of the experiments were:

a. To learn the properties of a photovoltaic cell including its equivalent circuit;
b. To test I-V and P-V characteristics for a photovoltaic module;
c. To determine the optimal conditions for operating a PV panel in a circuit with a known load and understand MPPT (maximum power point tracking);
d. To investigate the effects of solar insolation, shading, and tilting angle of a solar panel on an I-V characteristic.

Experimental Procedure

The experiment was conducted on three commercial photovoltaic cells with resistive load. First the circuit connection was setup as shown in Figure 5.4 and then the light source was setup directly above the PV panel. The resistance was set to zero in order to measure the shot circuit current. The current and voltage were recorded. The current and voltage were recorded. The effect of decrease in illumination on short circuit current was observed by turning off the light source. The resistance was increased until the current is very close to zero which corresponded to the open circuit voltage. Then I_{max} and V_{max} were recorded. Voltage and current reading were recorded for different tilt angle and shading of the PV panel. The temperature was varied by turning on or off the light source and the V and I reading were noted. Also, voltage and current reading were recorded by series and parallel connection of the PV panel.

Figure 5.4 Experimental setup of PV panel.

Results:

1) I-V characteristic for constant temperature

Initial temperature = 33.5 ^{0}C

Table 5.1 I-V characteristic for constant temperature

Current (I) Amp.	Voltage (V) Volt	Power=V*I Watt
0.32	0.1	0.032
0.31	5.2	1.612
0.30	5.1	1.53
0.27	10.8	2.916
0.25	13.1	3.275
0.22	**16.1**	**3.542**
0.19	17.2	3.268
0.16	17.4	2.784
0.13	17.5	2.275
0.11	17.6	1.936
0.09	17.7	1.593
0.08	17.7	1.416
0.06	17.7	1.062
0.05	17.7	0.885

Maximum voltage=16.1 volt

Maximum current=0.22 amp.

Maximum power = 3.542 watt

Final temperature = 47 ^{0}C

Constant Temperature = $\frac{33.5+47}{2}$ =40.25 ^{0}C

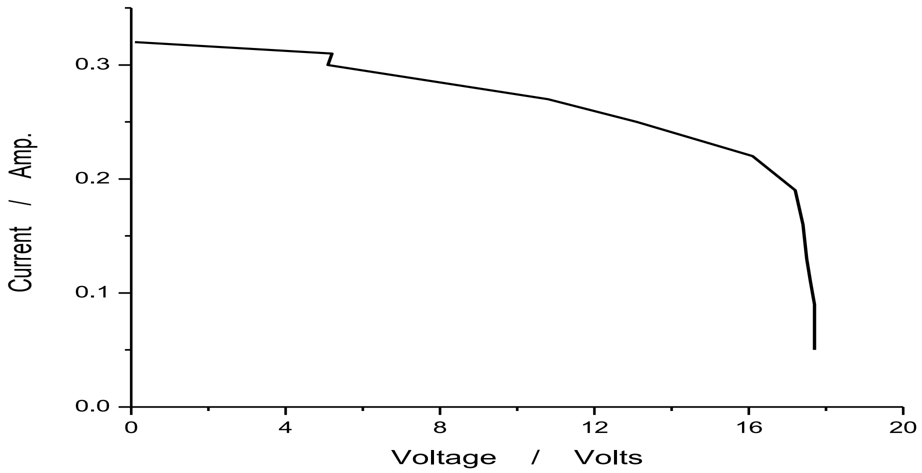

Figure 5.5 I-V characteristics of PV module for constant temperature

Constant Temperature= 40.25 ^{0}C

Intensity of light in our solar cell
At center= 800 W/m^2
At corner= 160 W/m^2

It may be observed from table 5.1 and Figure 5.5 that a large increment in PV voltage very small decrement in PV current but after maximum power point a small increment in PV voltage results a large decrement in PV current.

2) Effect of variation in tilt angle on PV module power (load and temperature fixed)

Table 5.2 Effect of variation in tilt angle on PV module power

Tilt angle (degree)	Radiation (W/m^2)	Voltage (Volt)	Current (Amp)	Power (Watt)
0	415	17.8	0.2	3.56
5	411.4	17.6	0.19	3.344
10	373.6	17.1	01.9	3.249
15	353.8	12.3	0.13	1.599
20	336.6	10	0.11	1.1
25	318	7.8	0.09	0.702
30	288	6.4	0.08	0.512

Contd…

35	230	5.2	0.05	0.26
40	186	3.2	0.033	0.1056
45	124	2.1	0.01	0.021

It may be observed from table 5.2 that due to tilt angle effect output of PV panel decreases which reduce the efficiency of PV panel.

3) Effect of shading angle on PV module power

Table 5.3 Effect of shading angle on PV module power

No of shaded Cells	Voltage (Volt)	Current (Amp)	Power(Watt)
0	17.2	0.27	4.644
1	7.6	0.11	0.836
2	2.9	0.04	0.116
3	2.5	0.03	0.075
4	1.7	0.02	0.034
5	1.1	0.01	0.011
6	1.1	0.01	0.011
7	0.8	0	0
36	0	0	0

It may be observed from table 5.3 that if solar cell shaded one by one due to environmental reason then we can see from observation table the output power of solar panel continuously decreases.

4) **I-V and PV characteristics of PV module with varying radiation and temperature level**

Table 5.4 I-V and PV characteristics of PV module with varying radiation and temperature levels

Radiation W/m^2	Temperature(^0C)	Voltage (Volt)	Current (Amp)	Power (Watt)
350	31.7	0	0.33	0
356	37.9	2.7	0.32	0.864
357	38.8	4.5	0.31	1.395
359	39.8	7.6	0.3	2.28
361	41.7	9.2	0.29	2.668
365	42.3	12.2	0.29	3.538
366	44.6	15.2	0.28	4.256
368	**45.4**	**17.5**	**0.27**	**4.725**
370	46.7	17.9	0.2	3.58
371	47.4	18	0.16	2.88

Contd…

371	48.3	18.1	0.13	2.353
372	49.3	18.1	0.08	1.448
374	49.9	18.1	0.07	1.267
375	52.1	18.3	0	0

I-V curve

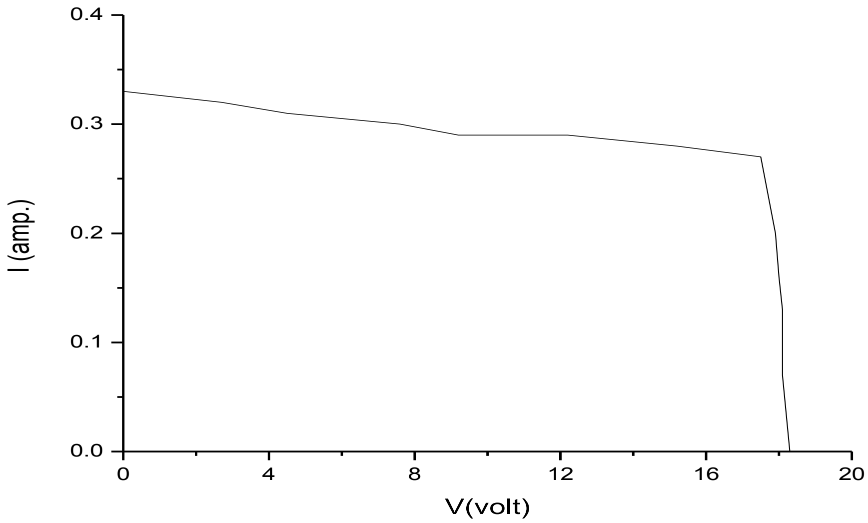

Figure 5.6 I-V characteristics of PV module for varying temperature and radiation.

P-V curve:

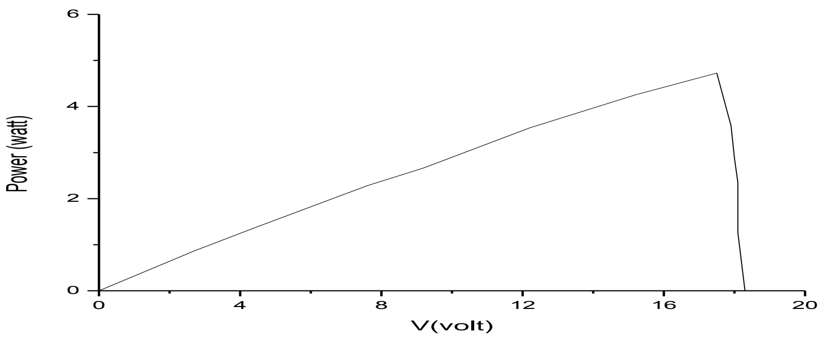

Figure 5.7 P-V characteristics of PV module for varying temperature and radiation.

It may be observed from table 5.4 and Figures 5.6 and 5.7 that since PV module made by semiconductor so at higher temperature PV module offer high resistance, due to increase in resistance losses increases and efficiency decreases. So for proper operation low temperature in solar is acceptable.

5) **I-V and PV characteristics of series and parallel connected PV modules**

a) For parallel connected modules

Table 5.5 Effect of solar radiation on PV panel for parallel connection

Radiation (W/m^2)	Temperature(^0C)	Voltage (Volt)	Current (Amp)	Power (Watt)
380	35.8	0	0.63	0
382	36.4	9.9	0.56	5.544
385	37.2	15.1	0.52	7.852
390	**37.8**	**18.5**	**0.46**	**8.51**
392	38.6	18.7	0.35	6.545
395	39.4	18.8	0.27	5.076
396	40.2	18.8	0.23	4.324
399	41.3	18.8	0.2	3.76
403	42.4	18.8	0.14	2.632
405	43.2	18.8	0.12	2.256
409	44	18.8	0.1	1.88
411	44.7	18.8	0.09	1.692
412	45.6	18.8	0.08	1.504
414	46.3	18.8	0.07	1.316
416	48.6	18.8	0	0

I-V curve:

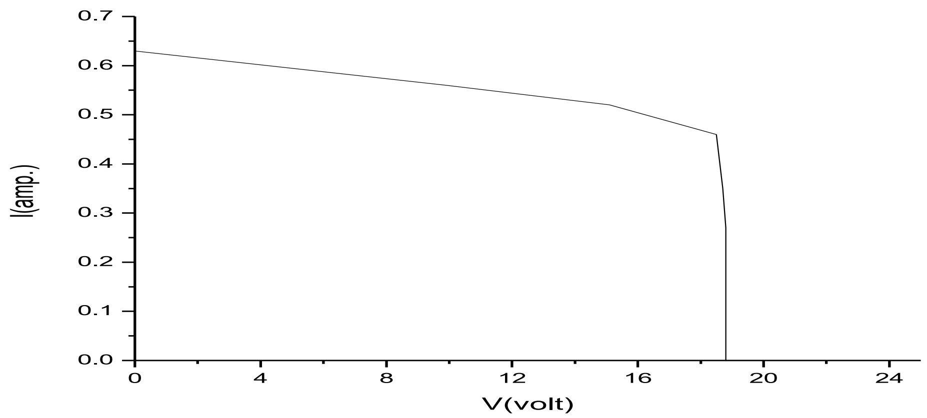

Figure 5.8 I-V characteristics of PV module for shunt connection.

P -V curve:

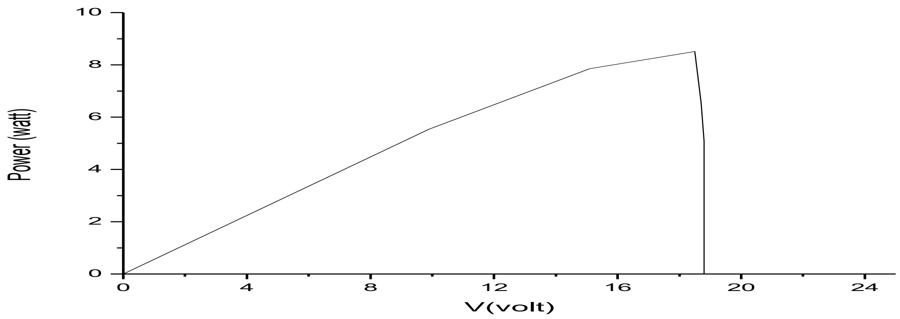

Figure 5.9 P-V characteristics of PV module for shunt connection.

It may be observed from table 5.5 Figures 5.8 and 5.9 that in shunt configuration maximum power occurs only in high load connection. Shunt connection require high sun radiation as compared to other connection, and Open circuit voltage of shunt connection is very low.

b) For series connected modules

Table 5.6 Effect of radiation on of solar cell for series connection

Radiation W/m^2	Temperature(^{0}C)	Voltage (volt)	Current (Amp)	Power (Watt)
360	36	0	0.3	0
366	39.5	2.6	0.3	0.78
368	41.3	6.3	0.29	1.827
371	42.5	8.5	0.29	2.465
375	43.8	13	0.29	3.77
378	45.1	17.5	0.28	4.9
380	46.1	20.4	0.28	5.712
381	47.8	25.3	0.26	6.578
382	48.8	26.7	0.25	6.675
385	49.6	28.3	0.24	6.792
386	50.4	30.4	0.23	6.992
389	**51.1**	**33.2**	**0.22**	**7.304**
390	52	35.8	0.18	6.444
391	52.8	35.9	0.16	5.744
394	53.1	39.1	0	0

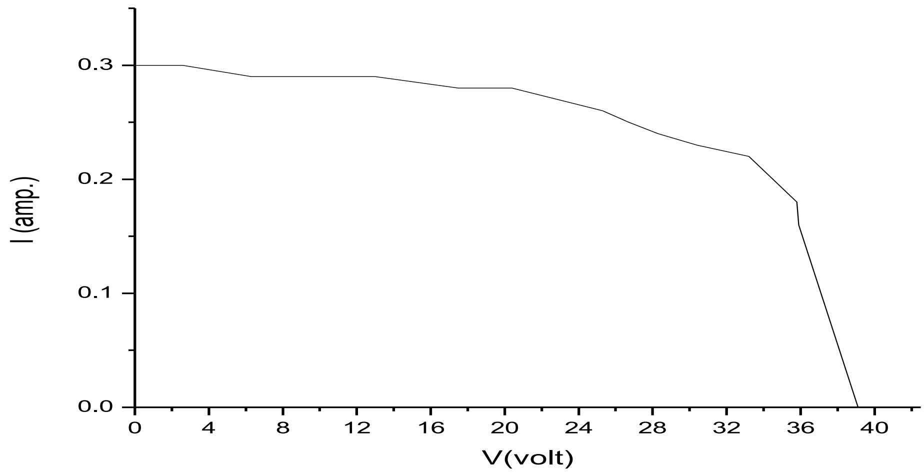

Figure 5.10 I-V characteristics of PV module for series connected modules

P-V curve:

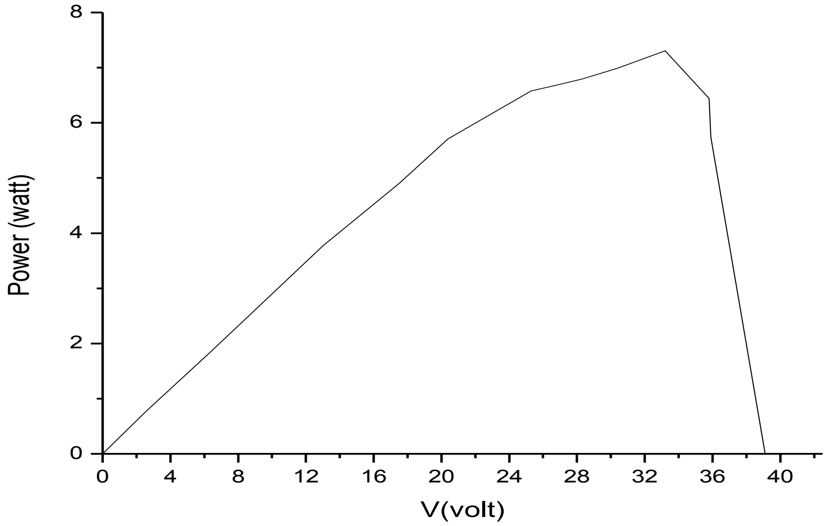

Figure 5.11 P-V characteristics of PV module for series connection

It may be observed from table 5.6 and Figures 5.10 and 5.11 that in series connection maximum power occur in low region. Series configuration requires low sun radiation, and Open circuit voltage for series connection is high. For same radiation series connection generate high heat as compared to shunt connection.

Chapter 6

Field Study on Application of Solar Lighting

Experimental Technique for Measuring Illuminance

Field Analysis

6. Field Study on Application of Solar Lighting

Field observations were carried out to identify the type of lighting lamps that are used in mines, and observed its illumination level. For determining a substitute power source it is necessary to know about existing power source, in mines in generally two types of power source are used for illumination purpose. Since the solar power is best substitute of existing power source so it is necessary to compared the cost of solar lighting with existing lighting system.

6.1 Experimental Technique for Measuring Illuminance

For measuring Illuminance for the though study of Illuminance in the mines, Digital Lux meters (Metravi 1332 and Metravi 1330) were used. The lux meter was placed directly in front of the light source for observing the Vertical Illuminance of the source. The Metravi lux meter takes the reading into two units Lux and Foot-candela. Where 1 Foot-candela = 10.73691 lux.

Figure 6.1 Digital Lux Meter (Metravi 1332)

Figure 6.2 Digital Lux meter (Metravi 1330)

The different features and Specifications of metravi 1332 lux meter are:

Features

1. Community of European society (CE) Approval.
2. Two unit options- Lux and Foot-Candela.
3. With PEAK /HOLD data function.
4. Cosine corrected: f'2 <3%.
5. Backlight Display.

General Specifications

1. Display	3 1/2 digit liquid display (LCD) with maximum reading of 1999
2. Indication for Low battery	A warning is displayed if the battery voltage is drop down below the operating level
3. Measurement Range	2.5 times per second, nominal
4. Operating Environment	0°C to 50°C (32°F to 122°F) at < 70% relative humidity
5. Accuracy	Stated accuracy at 23°C ± 5°C (73°F ± 9°F) <70% relative humidity
6. Battery	Standard 9V battery (NEDA 1604, IEC 6F22 006P)
7. Battery life	200 hours typical with carbon zinc battery
8. Dimensions	190mm (H) x 65.5mm (W) x 35mm (D)

9. Weight   210 gm. including battery

Technical Specifications

1. Photometric Formulas	10.764 foot candles = lux (lumens/m^2) 0.0929.lux = foot candles (lumens /foot^2)
2. Range	200lux, 2000lux, 20klux, 200klux, 200fc, 2000fc, 20kfc, 200kfc
3. Resolution	0.1lux, 0.1fc
4. Spectral Response:	Metravi photopic (The Metravi photopic curve is an international standard for the color response of the average human eye)
5. Acceptance Angle	f2 < 3% cosine corrected (150°)
6. Temperature Coefficient	0.1x (specified accuracy) / °C (<18°C or > 28°C), 0.056x (specified accuracy) / F° (<64.4°F or 82.4° F)
7. Peak hold response time	<50mS pulse light
8. Sensor	Silicon photodiode and filter

Procedure

First the carrying case was opened to take out the digital lux meter for measuring illuminance. The power button was pressed to run the power on or off. The cap of the light sensor was removed and the light sensor was put at the spot where the testing of light source was to be conducted. Auto testing will then be conducted by the meter, and the testing values were read. When “OL” was shown at the highest position at the left lateral side, overload was indicated, and then another range was chosen which was located at a comparatively higher position. (1332). After testing the recorded values were kept on the LCD by pressing D-H key. After testing, the cover of the light sensor was put back to its former position, and the switch was turned off. After testing was completed, the indication value should be 000 after putting the cap of the light sensor back to its former position. Then 0 ADJ was adjusted to enable LCD to indicate 000 if zero cannot be recovered. If zero still cannot be recovered, it means that the meter breaks down. (1332). Press the ZERO buttons for the zero adjustment if any digits is appear (1332A).

6.2 TRB Iron Ore Mine (JSPL), Tensa

About the mines: Tensa is vast some piece of SAIL On account of Iron Mineral Mines and is arranged close to Real Urban communities Joda, Barbils& Rourkela which is joined with Capital City Bhubaneswar in Eastern India. Tensa is encompassed by Green Timberland with mineral store. Tensa is celebrated for Winter Season. Tensa is placed 100 kilometers from the Rourkela. Tensa was created by SAIL & Jspl. JSPL'S iron metal mines, at Tensa valley in region Sundargarh, Odisha, 100 km from Rourkela somewhat satisfy the organization's prerequisite of iron mineral for preparing wipe iron. Handled as a feature of JSPL's regressive joining arrangements to make the organization independent, iron metal from Tensa mines guarantees consistency in the nature of crude material utilized as a part of wipe iron furnaces. Operational since 1990, these mines are prevalently known as TRB (Tantra, Raikela, and Bandhal) Mines.

Production Capacity: The mines at Tensa meet a piece of the organization's iron metal prerequisite for the wipe iron plant. Furnished with completely automated strategies, it as of now processes about 3.11 MTPA of wipe evaluation iron metal. An extra portable screening unit has been introduced to guarantee the accessibility of high-review iron metal/ fines for its sinter plant at Raigarh (Chhattisgarh).

Observations:

Table 6.1 Illumination survey on Bench Number 1 (Main Pit Floor)

Location (Coordinate point)	Vertical illumination (Lux)	Horizontal illumination (Lux)	Minimum standards for Horizontal (lux)	Remarks
21º52′14.04″N 85º08′58.76″E	0.4	1.3	1.5	Unsatisfactory
21º52′13.05″N 85º08′57.46″E	0.6	1.2	1.5	Unsatisfactory
21º52′13.46″N 85º08′56.58″E	0.6	1.1	1.5	Unsatisfactory
21º52′14.64″N 85º08′56.92″E	0.5	0.9	1.5	Unsatisfactory
21º52′16.37″N 85º08′57.67″E	0.5	1.1	1.5	Unsatisfactory

Average Horizontal Illumination 1.12 lux
Maximum Horizontal Illumination 1.3 lux
Minimum Horizontal Illumination 0.9 lux

Table 6.2 Illumination survey of excavator machine (Operator's Cabin)

Location (Coordinate point)	Vertical illumination (lux)	Horizontal illumination (lux)	Minimum standard of Horizontal (lux)	Remarks
21º52′18.84″N 85º08′58.70″E	10.8	25.5	30	Unsatisfactory
21º52′18.91″N 85º08′58.84″E	14	40	30	Satisfactory
21º52′18.62″N 85º08′58.52″E	11.1	27.3	30	Unsatisfactory

Average Horizontal Illumination 30.93 lux
Maximum Horizontal Illumination 40 lux
Minimum Horizontal Illumination 25.5 lux

Table 6.3 Illumination survey bench no.7 (Haul Road)

Location (Coordinate point)	Vertical illumination (lux)	Horizontal illumination (lux)	Minimum standard of Horizontal (lux)	Remarks
21º52′19.85″N 85º08′53.41″E	24.7	18.7 (near light source)	3.0	Satisfactory
21º52′18.89″N 85º08′53.23″E	8.3	3	3.0	Satisfactory
21º52′18.31″N 85º08′52.71″E	6.2	1.7	3.0	Unsatisfactory
21º52′18.09″N 85º08′52.12″E	2.9	3.5	3.0	Satisfactory
21º52′17.13″N 85º08′51.81″E	2.3	0.8	3.0	Unsatisfactory
21º52′16.25″N 85º08′51.31″E	0.7	1.5	3.0	Unsatisfactory

Measurement interval = 20 meter

Average Horizontal Illumination 4.86 lux
Maximum Horizontal Illumination 18.7 lux
Minimum Horizontal Illumination 1.5 lux

6.2.1 Illumination cost by existing lighting systems in the mines

The cost for mine illumination comprises of three costs viz., Fixed cost, Energy cost and Lamp and maintenance cost.

1) *Fixed cost:* It comprises of two types of costs.
- Diesel-Generator (D-G) cost.
- High mast tower cost.

Fixed Cost:

Diesel-Generator (D-G) cost	
Number of D-G set in mines	3
Capacity of D-G set	7KVA, 0.6 power factor, 7*0.6=4.2KW
Total capacity of D-G set	4.2*3=12.6KW
Cost of one D-G set	Rs.7,50,000
Cost of 3 D-G set	3*7,50,000= Rs.22,50,000
Life span of one D-G set	3 years
Cost of D-G set for 25 years	22,50,000*8= **Rs.1,80,00,000**
High mast tower cost	
Number of high mast tower	5
High Mast tower cost	Rs 2,10,000
Total cost of high mast tower	2,10,000*5= **Rs.10,50,000**
Fixed Cost	**Rs1,90,50,000**

2) *Energy cost:* It consist power consumption cost and D-G operational cost.

Power consumption cost	
Total power consumption for illumination	42KW
Power taken from GRID	42-12.6=29.4KW
Per unit charge of GRID	Rs 5.7
Usage hour	12hr.
Total power cost per day	5.7*29.4*12=Rs.2010.96
Total power cost per annum	Rs.7,34,000.4
Total power cost for 25 years	**Rs.1,83,50,010**
D-G operational cost.	
Diesel cost per annum	Rs.3,50,000

Diesel cost for 25 years	Rs.**87,50,000**
Energy cost	**Rs.2,71,00,010**

Since the cost of diesel always varies and increases day by day it become so an additional factor is multiply by operational cost and this multiplication factor becomes greater than 1.

Total energy cost for 25 years = 1,83,50,010+87,50,000=Rs.2,71,00,010

3) *Lamp and Maintenance cost:*

- Transport cost of diesel.
- Light Maintenance cost.

Transport cost of diesel	
Transport cost per day	Rs.3,000
Transport cost for 25 years.	Rs.**2,73,75,500**
Light maintenance cost	
Light maintenance cost per years	Rs.2,10,576
Light maintenance cost for 25 years	Rs.52,64,400
Total Lamp and Maintenance cost	2,73,75,000+52,64,400=Rs.**3,26,39,400**

Total illumination cost by existing lighting system	=1,90,50,000+2,71,00,010+3,26,39,400 =**Rs.7,87,89,410**

6.2.2 Illumination cost by solar lighting systems in the mines

It consist three types of cost such as:

1) Inverter cost.
2) Panel cost.
3) Battery cost.

1) *Inverter cost:* Cost of inverter is a function of peak power required. As determined by surveying current market prices for inverters, the costs of an inverter are about $ 0.14 per watt, or Rs 8.68 per watt. So the cost of inverter for 1KW will be Rs 8680.

Inverter cost	
In Tensa JSPL mines peak power required for mine illumination.	42 KW
Peak power usage in Tensa JSPL mines	12 hr.
Cost of inverter per Kw	Rs.8010
Total cost of inverter	Rs.8010*42=Rs.**3,36,420**

2) *Panel cost:* It is a function of energy used. The peak power produced by solar panels is determined by the type and number of solar panels uses.

Panel cost	
Average hours of sunshine	7 hr.
Cost of panel per Kw	Rs.2,50,000
Peak power produce by the panel	42*12/7=72KW
Cost of panel	**Rs.1,80,00,000**

3) *Battery cost:* The cost of batteries is a function of energy used. The number of kilowatt-hours we can store will be determined by the number and type of batteries we have.

Battery cost	
Assume the discharging factor of battery	50% or 0.5
Stored energy	2*used energy=2*42*12= 1008Kwh
Cost of battery per Kwh	Rs.5520
Total cost of battery	Rs.5520*1008= Rs.55,64,160
Life span of battery	6 years
Cost of battery for 25 years	Rs.**2,22,56,640**

Total illumination cost of mines by Solar lighting system	=3,36,42+1,80,00,000+2,22,56,640 =Rs.**4,05,93,060**

Saving in cost = illumination cost by existing lighting system-illumination cost by solar lighting system

= Rs.7,87,89,410-Rs.4,05,93,060

= Rs.**3,81,96,350**

6.3 Panchpatmali Bauxite Mines (NALCO), Damanjodi

About the mines: National Aluminum Organization Ltd. (NALCO) was set up to adventure Bauxite holds at Panchpatmali digs in Damanjodi for processing of Alumina. Damanjodi is a residential area in the Koraput region in the Indian state of Odisha. It is basically an uneven region with a meager populace. The greater part of the number of inhabitants in Damanjodi is made up of the representatives of National Aluminum Organization (NALCO), Asia's biggest, and the world's seventh biggest, maker of aluminum. The populace is cosmopolitan as the representatives originate from all parts of the nation. NALCO's bauxite mine, spread in excess of 18kms, is placed at Panchpatmali mounds in Koraput Region of Odisha.

Production Capacity: The First mining limit of 4.8 million tons for every year (MTPY) is constantly moved up to 6.3 MTPY under the second stage development, which will be further moved up to 6.8 MTPY under the up degree undertaking of mines & refinery. More or less 90% of the bauxite from the mine speaks to Gibbsitic Alumina, additionally called Tri-hydrate Alumina, a property which permits it to be processed at a generally low temperature and at barometrical weight throughout the alumina refining procedure.

<u>Illumination Survey</u>

Location	Water distribution pump house.
Specification	LED lamp, 12 volt DC.
Power consumption	36W
Lumen output of lamp	3240 lumen.
Type of lighting	Solar lighting.
Pole height	7 meter.
Number of pole	10
Minimum distance between poles	35 meter.
Installation cost	Rs 81,600 each pole.

1) Illumination survey at pole 1.

Table 6.4 Illumination survey at pole 1(water distribution pump house)

Location (Coordinate point	Measure Value (lux)	Minimum Standards (lux)	Remarks
18º46′15.15″N 82º54′51.55″E	7.3	6.5	Satisfactory
18º46′14.97″N 82º54′52.04″E	5.1	6.5	Unsatisfactory
18º46′14.72″N 82º54′52.16″E	10.5	6.5	Satisfactory
18º46′14.48″N 82º54′52.20″E	8.1	6.5	Satisfactory

Average Horizontal Illumination	7.75 lux
Maximum Horizontal Illumination	10.5 lux
Minimum Horizontal Illumination	5.1 lux

Table 6.5 Comparison of illumination between solar lamp (LED lamp) and HPSV lamp.

Sl.NO.	Parameter of comparison	Solar lamp	HPSV lamp
1.	Location	Water distribution pump house	Entrance of Haul Road
2.	Power Consumption	36 Watt	250 Watt
3.	Type of lamp	LED	HPSV
4.	Minimum distance between pole	25 meter	30 meter
5.	Number of Pole	10	10
6.	Pole Height	7 meter	4 meter
7.	Lux measurement	8.1 lux	9.2 lux
		7.2 lux	8.4 lux
		8.3 lux	7.0 lux
		8.7 lux	6.1 lux
		8.9 lux	4.4 lux
8.	Variation in lux with distance	Low variation	High variation
9.	Source of Power	Solar	Grid
10.	Color of light	White	Yellow

2) Illumination survey at pole 3.

Table 6.6 Illumination survey at pole 3 (water distribution pump house)

Location (Coordinate point	Measure Value (lux)	Minimum Standards (lux)	Remarks
18º46′15.88″N 82º54′51.41″E	6.7	6.5	Satisfactory
18º46′16.07″N 82º54′51.49″E	5.0	6.5	Unsatisfactory
18º46′16.62″N 82º54′51.43″E	7.5	6.5	Satisfactory
18º46′16.68″N 82º54′51.50″E	7.9	6.5	Satisfactory

Average Horizontal Illumination 6.78 lux

Maximum Horizontal Illumination 7.9 lux

Minimum Horizontal Illumination 5.0 lux

6.3.1 Illumination cost by existing lighting systems in the mines

The cost for mine illumination comprises of three costs viz., Fixed cost, Energy cost and Lamp and maintenance cost.

1) *Fixed cost:* It consist two types of costs.
   - Diesel-Generator (D-G) cost.
   - High mast tower cost.

Fixed Cost

Diesel-Generator (D-G) cost	
Number of D-G set in mines	12
Capacity of D-G set	11.66KVA, 0.6 power factor, 11.66*0.6=7KW
Total capacity of D-G set	7*12=84KW
Cost of one D-G set	Rs 20,50,000
Cost of 3 D-G set	12*20,50,000= Rs.2,46,00,000
Life span of one D-G set	3 years
Cost of D-G set for 25 years	2,46,00,000*8= Rs.19,68,00,000
High mast tower cost.	
Number of high mast tower	11
High Mast tower cost	Rs.1,90,000
Total cost of high mast tower	1,90,000*12= Rs.22,80,000
Fixed cost	19,68,00,000+22,80,000=**Rs.19,90,80,000**

2) *Energy cost:* It consist power consumption cost and D-G operational cost.

Power consumption cost	
Total power consumption for illumination	229.3KW
Power taken from GRID	229.3-84=145.78KW
Per unit charge of GRID	Rs.4
Usage hour	12hr.
Total power cost per day	4*145.78*12=Rs.6,997.44
Total power cost per annum	Rs.25,54,065.6
Total power cost for 25 years	**Rs.6,38,51,640**
D-G operational cost	
Diesel requirement per day	50 liter
Diesel cost per liter	Rs.53.2
Diesel cost per day	50*53.2=Rs.2660
Cost of diesel for 25 years	Rs.2,42,72,500

Total energy cost for 25 years	6,38,51,640+2,4272,500=**Rs.8,81,24,140**

3) *Maintenance cost:*

Maintenance cost	
Transport cost per day	Rs.4200
Transport cost for 25 years	**Rs.3,83,25,000**

Total illumination cost by existing lighting system	=19,90,80,000+8,81,24,140+3,83,25,000 =**Rs.32,55,29,140**

6.3.2 Illumination cost by solar lighting systems in the mines

It consist three types of cost such as:

1) Inverter cost.
2) Panel cost.
3) Battery cost.

1) *Inverter cost:* Cost of inverter is a function of peak power required. As determined by surveying current market prices for inverters, the costs of an inverter are about $ 0.14 per watt, or Rs 8.68 per watt. So the cost of inverter for 1KW will be Rs 8680.

Inverter cost	
In NALCO Damanjodi mines peak power required for mine illumination.	229.3 KW
Peak power usage in Tensa JSPL mines	12 hr.
Cost of inverter per Kw	Rs.8010
Total cost of inverter	Rs.8010*229.3=**Rs.18,36,693**

2) *Panel cost:* It is a function of energy used.

Panel cost	
Average hours of sunshine	7 hr.
Cost of panel per Kw	Rs.2,50,000
Peak power produce by the panel	229.3*12/7=393.08KW
Cost of panel	**Rs.9,82,70,000**

3) *Battery cost:* The cost of batteries is a function of energy used.

Battery cost	
Assume the discharging factor of battery	50% or 0.5
Stored energy	2*used energy=2*229.3*12= 5503.2Kwh
Cost of battery per Kwh	Rs.5520
Total cost of battery	Rs.5520*5503.2= Rs.3,03,77,664
Life span of battery	6 years
Cost of battery for 25 years	**Rs.12,15,10,656**

Total illumination cost by Solar lighting system =Rs.32,55,29,140+9,82,70,000+12,15,10,656 =**Rs.22,16,17,343**

Saving in cost = illumination cost by existing lighting system-illumination cost by solar lighting system

= Rs.32,55,29,140-Rs.22,16,17,343

= **Rs.10,39,11,791**

If unit charge is Rs 5.7 then saving = **Rs.13, 10, 48,738**

6.4 Katamati Iron Ore Mines, Tata Steel, Keonjhar

About the Mines

Katamati mines located in Keonjhar district of Orissa, The Katamati lease held by the Organization is the southern augmentation of Noamundi Iron Mine in Jharkhand. The mine was prior worked by manual opencast system. Consequently, in 2003, the mining operations were automated by an arrangement of 6m high seats. The run-of-mine metal is transported to the Noamundi Iron Mine, and handled at the LRP Plant for Wet Handling. Around 25 staff is occupied with this mine.

6.4.1 Illumination cost by existing lighting systems in the mines

The cost for mine illumination comprises of three costs viz., Fixed cost, Energy cost and Lamp and maintenance cost.

1) *Fixed cost:* It consists of costs Diesel-Generator (D-G) cost.

Diesel-Generator (D-G) cost	
Number of D-G set in mines	7 small and 3 big
Capacity of D-G set	7.5KVA,8KVA and 65 KVA 0.6 power factor,
Total capacity of three 7.5KVA D-G set	7.5*0.6*3=13.5 KW
Total capacity of four 8KVA D-G set	8*0.6*4=19.2KW
Total capacity of three 65 KVA D-G set	65*0.6*4=117 KW
Total power	149.7Kw
Cost of small D-G set	Rs.18,00,000
Cost of big D-G set	Rs.22,00,000
Total cost of D-G set	Rs.40,00,000
Life span of one D-G set	3 years
Cost of D-G set for 25 years	40,00,000*8= Rs.3,20,00,000
Fixed cost	**Rs.3,20,00,000**

2) *Energy cost:*

Energy cost	
Diesel requirement per month	12,000 liter
Diesel cost per liter	Rs.60
Cost of diesel for 25 years	Rs.21,60,00,000
Total Energy cost	**Rs.21,60,00,000**

Total illumination cost by existing lighting system	**= Rs.24,80,00,000**

6.4.2 Illumination cost by solar lighting systems in the mines

It consist three types of cost such as:

- Inverter cost.
- Panel cost.
- Battery cost.

Inverter cost: Cost of inverter is a function of peak power required. As determined by surveying current market prices for inverters, the costs of an inverter are about $ 0.14 per watt, or Rs.8.68 per watt. So the cost of inverter for 1KW will be Rs.8680.

Inverter cost	
In NALCO Damanjodi mines peak power required for mine illumination.	149.7 KW
Peak power usage in Tensa JSPL mines	12 hr.
Cost of inverter per Kw	Rs.8010
Total cost of inverter	Rs.8010*1499.7=**Rs.18,36,693**

Panel cost: It is a function of energy used.

Panel cost	
Average hours of sunshine	7 hr.
Cost of panel per Kw	Rs.2,50,000
Peak power produce by the panel	149.7*12/7=256.62KW
Cost of panel	**Rs.6,41,57,142.86**

Battery cost: The cost of batteries is a function of energy used.

Battery cost	
Assume the discharging factor of battery	50% or 0.5
Stored energy	2*used energy=2*149.7*12= 3592.8Kwh
Cost of battery per Kwh	Rs.5520
Total cost of battery	Rs.5520*3592.8= Rs.1,98,32,256
Life span of battery	6 years
Cost of battery for 25 years	**Rs.7,93,29,024**

Total illumination cost by Solar lighting system =Rs.11,99,097+6,41,57,142.86+7,93,29,024 =**Rs.14,46,85,263**

Saving in cost = illumination cost by existing lighting system-illumination cost by solar lighting system

= Rs.24,80,00,000 –Rs.14,46,85,263

= **Rs.10,33,14,737**

Chapter 7

DISCUSSION AND CONCLUSION

Discussion

Conclusion

7.1 Discussion

Solar panels have seen a steady drop in costs over the last three decades, and in the last few years that drop has been transient. In the most recent 35 years costs have gone from $75/watt to around $.14/watt. Since 2008, the expense of coal has climbed 13 percent. In a few parts of the business, sun powered has officially arrived at equality with coal. So for mine light sun based vitality is best decision, it lessens the expense of mine brightening as well as it enhances the enlightenment level by expanding its energy yield. The light intensity of solar panel is directly proportional to the power output. For a long time period solar energy is best choice for mine illumination it reduces the illumination cost and provide a safe and healthy environment, solar energy not produce any toxic gasses to the environment.

The P-V and I-V characteristics of a solar cell for constant temperature, varying temperature & radiation, varying tilt angle and shading effect on solar cell were studied in the laboratory. It was observed that for reducing I^2R loss (Heat loss) the temperature of solar cell should be within permissible limit.

Sl. No.	Configuration	Temperature (^0C)	Maximum voltage (Volt)	Maximum power (Watt)	Maximum current (Amp.)	Radiation (W/m^2)
1.	Normal connection of PV module	45.4	17.5	4.725	0.27	380
2.	Parallel connection of PV module	37.8	18.5	8.51	0.46	390
3.	Series connection of PV module	51.1	33.2	7.304	0.22	389

The Power-voltage and current-voltage characteristics of a solar cell for constant temperature, varying temperature & radiation, varying tilt angle and shading effect on solar cell were studied in the laboratory. It was observed that for reducing I^2R loss (Heat loss), the temperature of solar cell should be within permissible limit, since with increase in temperature, the heat loss of solar cell increases, which results in reduced efficiency of solar cell. For same radiation level, parallel configuration of solar module generates less temperature as compared to other connection (Table 5.4 to 5.6). Therefore, it is recommended that solar panel in parallel configuration is the best choice among all the configurations.

Solar power output is directly dependent on sun light intensity and as the tilt angle of solar cell increases, sun light intensity decreases. This results in reducing the solar output power. Therefore, for avoiding tilt angle effect of solar module, reflectors should be used which will reflect a portion of sun light to the solar panel.

From the illumination survey carried out at different mines it was observed that in TRB iron ore mine the illumination level of main pit floor (1.12 lux), operator's cabin (27.3 lux) and haul road in bench no.7 (1.7 lux) were below the standard levels of 1.5 lux, 30 lux and 3 lux respectively. Similarly, in Panchpatmali bauxite mines the illumination level of water distribution pump house (pole no.1) was 5.1 lux which was below the standard level of 6.5 lux. The reason of the poor illumination levels may be attributed to the high absorbance levels in the mines and improper location of the luminaires. Moreover, HPSV lamps are widely used for mine illuminations, but the intensity in such luminaires is less as compared to solar lamps. Therefore, to have better lightings at different mine locations, HPSV lamps can be replaced by solar lamps wherever feasible.

For different iron ore and bauxite mines it was observed that the illumination cost by solar lighting system is lower than the existing lighting system as discussed in section 6.4.2. Also solar lighting system improves the illumination level inside the mines. From the illumination survey and cost comparison of existing lighting system with solar lighting system, it was observed that with implementation of solar lighting system, the saving in lighting cost gradually increase with peak power required for mine illumination as shown in Figure 7.1.

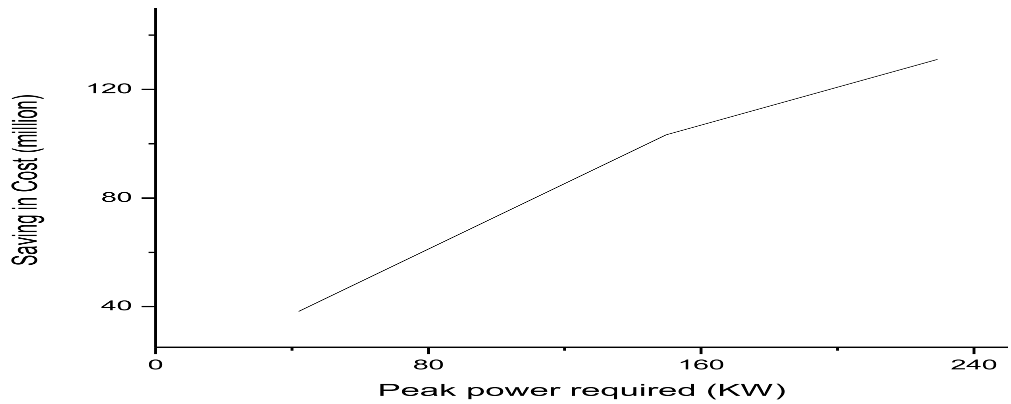

Figure 7.1 Relation between saving in cost and peak power required for mine illumination

From the cost analysis of the three case study mines, it was observed that cost of solar lighting system linearly increases with the peak power required for mine illumination. Both parameters can be related to each other by a linear equation C=MP, where C is the cost of solar panel, P is peak power required for mine illumination, and M is the slope of straight line. Figure 7.2 represents the relation between peak power required and cost of solar lighting system for mine illumination.

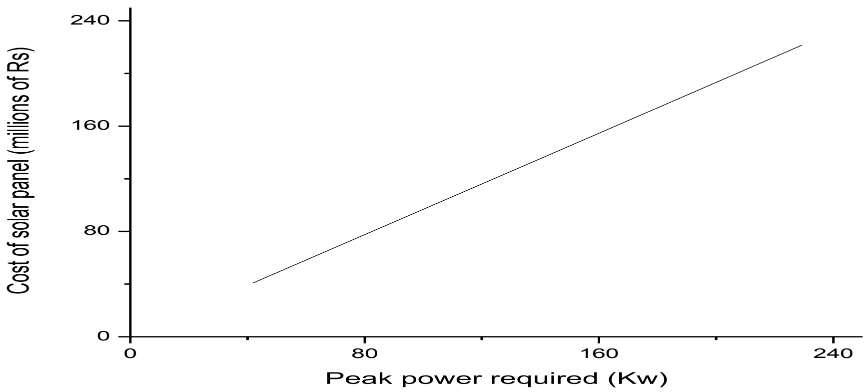

Figure 7.2 Relation between Peak power required and cost of solar lighting system

The cost of mine illumination depends upon the production capacity of mines. Different mines have a different fixed and energy cost as per it requirement. The comparison of fixed and energy cost of two iron ore and bauxite mines have been presented in Figure 7.3.

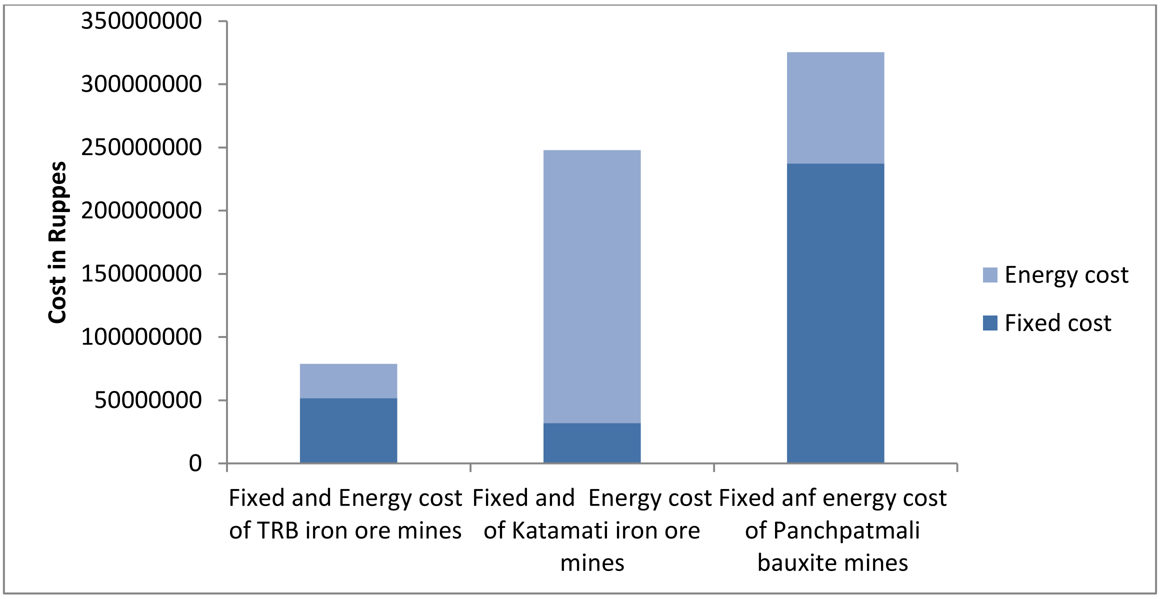

Figure 7.3 Comparison of fixed and energy cost of different mines

The cost comparison between existing lighting and solar lighting systems for TRB and Katamati iron ore mines and Panchpatmali bauxite mines are as presented in Figure 7.4. They require 42,149.7 and 229 Kw peak power for mine illumination respectively.

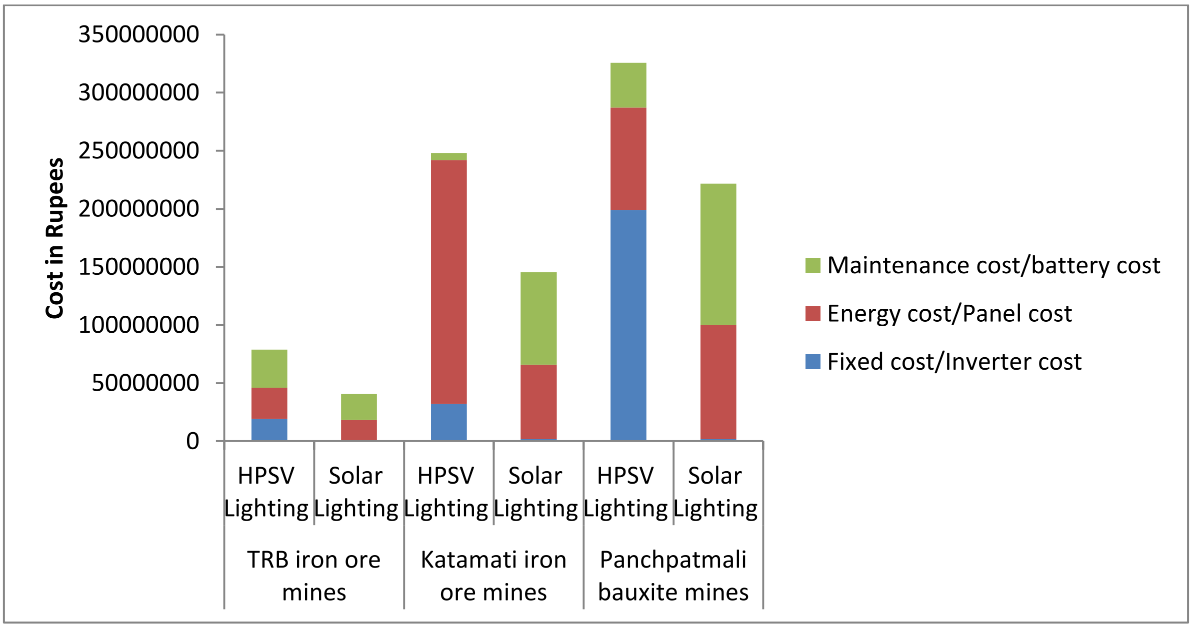

Figure 7.4 Cost comparisons between existing and solar lighting systems of three different mines

The illumination level of mines can be improved by solar lamps (LED lamps). Table 7.1 represents a comparison of solar lamp with HPSV lamps. :

Table 7.1 Comparison of solar lamps with HPSV lamps

Solar Lamps	HPSV Lamps
Power consumption 36 Watt	Power consumption 250 Watt
Distance between pole 35 meter	Distance between pole 30 meter
Number of pole 10	Number of pole 10
Pole height 7 meter	Pole height 4 meter
Lux measurement	Lux measurement
9.1 lux	9.2 lux
10.1 lux	8.4 lux
9.2 lux	7.0 lux
8.7 lux	6.1 lux
Very low variation in lux	High variation in lux

It may be observed that solar lamps with high pole height produces better and uniform lighting than the HPSV lamp. Solar lamp consumes less power than the conventional lamps. More over the poles could be placed at greater distance and height. The power consumption is also less in case of solar lamps compared to HPSV lamps.

Demerits

Solar power is used to charge battery banks so that solar powered devices can be energized as per the requirement. However, the batteries are large and heavy and need adequate storage space. The average life of the batteries varies from 5 to 6 years (Yago, 2004). Therefore these are to be discarded after their life is over. The used battery and battery parts should be store in separate chamber, because it comprises of toxic materials and can have serious health and environmental implications. They also pose safety hazards to the miners. The batteries should be stored in the designated chamber until an approved recycling agency is permitted to take them out for recycling.

7.2. Conclusion

Renewable energy alternatives such as solar power for illuminating the mine in remote mining areas are becoming more and more attractive as fossil fuel prices are increasing. These carbon free technologies could not only help mining companies save money but also to improve their public perception in an era of heightened environmental consciousness.

After analysis of the illumination data and cost comparison of the solar lighting with existing lighting system following conclusions are drawn:

- Solar lamps (LED) produce better illumination as compared to conventional lamps.
- Solar lamps consume less power.
- Solar lighting have several advantageous feature over conventional lighting system such as light weight, more rated life, more working hours, less charging time, no use of harmful electrolyte, low input power required, and low maintenance.
- Solar module with parallel configuration generates less heat compared to series and normal configuration for same radiation and power level.
- A substantial amount can be saved by the mine management by adopting solar lighting system.
- With the reduction of cost of solar panels, it is now feasible to adopt these lighting systems in mines.
- Since it is a form of green and renewable energy, there is no release of green house gases into the atmosphere and has minimum adverse environmental impact.

Chapter 8

Reference

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