ICSD/14

GENERATION SCHEDULING AND POWER MANAGEMENT OF PEDALING SYSTEM WITH SOLAR PHOTOVOLTAIC SYSTEM

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Abstract

A clean and environment friendly electric power generation with consideration of pedal system and solar energy system is introduced in this paper. The villages, cities and towns grappling with the problems of electricity cut, outage and shortage. In this paper a simple system is proposed to generate electricity at a small level. A gym bicycle pedal system (GBPS) with solar photovoltaic (SPV) system is presented to solve the aforementioned problems. The system is being considered for the power system management to schedule energy output without any fuel consumption. It is a trouble-free approach to generate electricity and seems more helpful to those area/regions where no power connection is available; even in 21st century. The effectiveness of methodology presented here is experimentally verified on the GBPS and obtained energy output is integrated with SPV system to fulfill the power demand. For smooth operation of mechanism a 1:30, turn-ratio gear box is used. A 50 kWp SPV system with GBPS considered in this work. The predicted load is being managed by the energy management in peak hours and off-peak hours. The scheme presented here is a good alternative for the electric power generation with zero emission to the environment.

Keywords: Solar photovoltaic system, pedal system, generation schedule, energy management.

NOMENCLATURE

B	Magnetic field density in Weber/m^2
F	Force in Newton
l	Length in meter
e	emf in volt
I	Current in Ampere
v	Voltage in volt
emf	Electromotive force
KWp	Peak capacity in kilowatt
Kmph	Kilometer per hour
RPM	Revolution per minute
ALT	Alternator
Ah	Ampere hour
SPV	Solar photovoltaic
GBPS	Gym bicycle pedal system

1. Introduction

In present era electrical power demand is rising. Mostly populations in the world live a lavish life by using various electrical appliances, but have you any idea about the life without electricity. Several developing countries are ill with the power crisis. More than 75% populations living without electricity that is anticipated 1.2 billion people have no access to electricity (World Energy Outlook, 2015). Power cut, outage and shortage problems are not only in the rural areas but also in the urban areas. In the worldwide the maximum electricity generation depends on the fuels. Power produced from the fossil fuels may bring adverse environmental effects (such as SO_x, NO_x and CO_2) and emissions. An alternative is preferred for clean energy generation to meet load demand and targets to reduce carbon and green house gas emissions which are polluting environment. An approach is presented here which totally independent on fuels.

The main aim of this paper is to generate electricity by using Gym Bicycle Pedal System at the gym centre with solar photovoltaic system. In previous many researchers worked on the power generation by the pedal system. A bicycle lighting system in which pedal driven vehicles generated 4 Watt energy at 5 to 10 kmph [1]. For providing sufficient output voltage, a gear box was used with pedal system [2]. An exercise device introduced with pedal system for electricity generation [3]. In some developing countries the power generation and transmission is not affordable or it is too expensive. For these places local generation such as renewable energy sources or combination of the renewable sources is better alternative [4]-[5]. A human based power generation for rural and urban areas developed [6]-[7]. A power assisted pedal rickshaw was introduced to saving power consumption at Chittagong, Bangladesh [8]. A clean, ecological and reliable power generation is discussed in [9].

This paper paying attention gym centre where gym bicycle is concern and rooftop utilized for solar photovoltaic system. By integrating both systems would give electricity for the local areas at economical rate. An approach to short term resource scheduling for an integrated thermal and photovoltaic generation presented in [10]. The impact of grid connected PV/Battery system is introduced in [11].

The good amounts of work have been done by the previous authors to solve the energy generation problems as observed by the literature survey. However, among these works, some uncertain factors and renewable energy system were not considered fully in generation problem, there is a scope forever to do improvement. The paper targeted the emission and global warming problems which are major issues for the power engineers. In regards aforementioned problems a hybrid vehicle that can be powered by the human pedaling, electric and solar energy is invented [12].

The energy generation by the gym bicycle pedal system with solar PV system is considered fewer in the previous work, which is one of the better options for the areas where no electricity access and power cut is the major issue. The paper mainly focused the energy generation by the GBPS on daily, monthly and yearly and integrates with the solar photovoltaic system to fulfill the load demand. The main contributions of this work are:

(1) The energy generation and cost analysis of the GBPS.

(2) Energy management of solar PV system with or without GBPS.

(3) Economical cost analysis with on-site and off-site solar PV system.

(4) Energy management in peak and off-peak hours with both the system.

The paper is organized as follows. Section I is the introduction part of the paper. The enlightenment of the background information of GBPS and SPV system are given in section II. Section III presents implementation of work cost and energy evaluation. Section IV presents experimental results and discussion. Finally, section V concludes the work.

2. Background Information

The purpose of the work is to generate electricity from the human efforts with solar energy system and makes a station which is totally independent on fuels to overcome the issues of power cut, outage and shortage. The background theory of the work is discussing over here.

2.A. Gym Bicycle Pedal System (GBPS):

The gym bicycle pedal system consists of a gym bicycle, pedal system with spur gears. For speed up the rotation of the alternator a gear box arranged with 30 multi turn ratio. A convertor for converting alternator output into dc, battery bank and inverter for converting dc into ac to the end users. Fig. 1 shows the diagram of the GBPS.

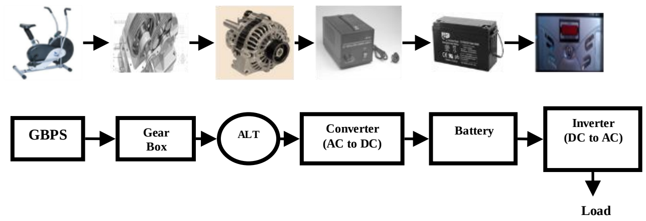

Fig. 1 Gym bicycle pedaling system.

The gym bicycle used in the exercise centre is rated as 90-110 rpm. The front wheel of the bicycle is connected with the axel and chain. This part further on connected with the gear box which have the 30 multi turn ratio, means one rotation of the pedal converts into 30 rotations by the gear box. The gear box is connected via a shaft with the alternator; basically we have considered a car alternator over here which will provide the better output voltage at lower speed. The particulars range and units show in Table I.

As practically pedal system speed is not constant so for maintaining the output powers a charge controller requisite for charging the battery at the constant value. It will increase the life of the battery and operates for a long time.

TABLE I
THE PARTICULARS OF THE GBPS

S. No.	Particulars	Values	Units
1	Gym bicycle	90-110	RPM
2	Gear Box	1:30	RPM
3	Alternator	12 V 50 A	Volt, Amp
4	Convertor (ac to dc)	12 V 10A	Volt, Amp
5	Battery	12 V 90Ah	Volt, Amp hour
6	Inverter (dc to ac)	1 KW	Kilowatt

The output capacity of the battery depends on the discharging time, a normal battery can be charged within 6-8 hours. So, a 1080 Watt-hour capacity battery has been used which will take around 8 hours to charge. The battery output now can be utilized by using an inverter. Inverter is converting the dc output of the battery into ac for the end users.

2.B. Solar photovoltaic System (SPV):

The solar photovoltaic (PV) modules are static devices that convert sunlight on the earth, directly into electricity without any rotating paraphernalia. A PV device has no moving parts, so it requires less maintenance and has a long life [13]. As the scarcity of land and available land is costly, the gym center's rooftop can be used for the solar photovoltaic system.

It is like a smaller power station where we can generate electricity by the human efforts and solar PV system. Fig. 2 shows solar PV system. A 50 kW solar PV system considered and can be installed on the rooftops of the gym center.

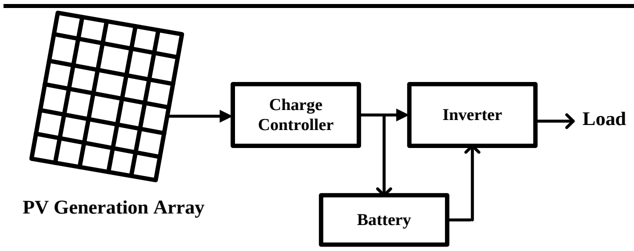

Fig. 2 Solar photovoltaic system

2.C. On-site and Off-site SPV power plant

In on-site solar photovoltaic power plant the land cost is considered while in off-site SPV plant there is no land cost. Off-site SPV power plants can be used without battery and land. In this work, the effects before and after installing the GBPS with SPV system are evaluated. Therefore, the digital meters connected to the exercise center to the distributor. A general switching room, data monitoring operator is required for the record of energy generation by the GBPS and SPV power station.

The generated power by the GBPS and SPV system can be used for the predicted load. In the night and weekends load may be low, but in the working days it must be higher. The power cut and outage can be possible in peak hours. Then this scheme works and better choice to fulfill the power demand without any fuel cost and at a cheap rate. The capacity of the SPV power plants and GBPS may be increase as per the load demand. Concerns the global warming and green house gas effect, it is the healthier alternative to generate electricity without emission along with no fuel cost. This power station can be fulfill the power demand where no electricity access and more power crisis.

3. Implementation

3.A. Speed analysis of GBPS

The pedal system smoothly runs by the human efforts. The characteristics between the pedal system and alternator speed (in rpm) shown in Fig. 3. The characteristic is linear, as the pedal speed increases the alternator speed also increases in the same manner via the gear box.

The alternator speed is around 3000 rpm at 100 rpm pedal speed, which is sufficient to generate the voltage to charge the battery. It may be increase by more pedaling as shown in Fig. 3. The speed of the system may be varying as this system is operated by the human. If a healthy person operates the pedal system, then he/she can acquire the maximum speed.

3.B. Voltage and Current analysis of GBPS

The voltage generated by the pedal system almost constant at different speed with smaller fluctuations. The battery charging time may be reduced by using the alternator at their maximum speed. The voltage and current characteristics in reverence of alternator speed shows in Fig. 4 and Fig. 5. The adequate voltage (say 10.5 volt) can be generated between 1000-2000 rpm to charge the battery as shown in Fig. 4. The current and speed curve indicated that with increase in speed current also increases exponentially.

The force developed and induced emf in an alternator is given by equation (1) and (2).

$$F = I \times l \times B \qquad (1)$$

$$e = B \times l \times v \qquad (2)$$

3.C. Generated power output of GBPS

The exercise centers have the gym bicycle. The set up installed with the pedal bicycle. Peoples come to the centre for exercise which starts early in the morning around 05:00 A. M. to 09:00 A. M., and in the evening from 05:00 P. M. to 09:00 P. M. It is approximately 8-hours enough to charge full of the battery. If we connected two batteries in series they will take almost same time to charge and power output would be just double. If utilizes these hours in morning (4-hours) and in evening (4-hours) the power will be generated by the GBPS.

The generated powers have to be used for next 24-hour time period for the local area when power supply is not available. The power generated by the GBPS is around 918 Watt or 0.918 kWh per day (Considering 15% is the loss of battery). If connected two batteries in series the power would be 1836 Watt hour per day or 1.836 kWh/day.

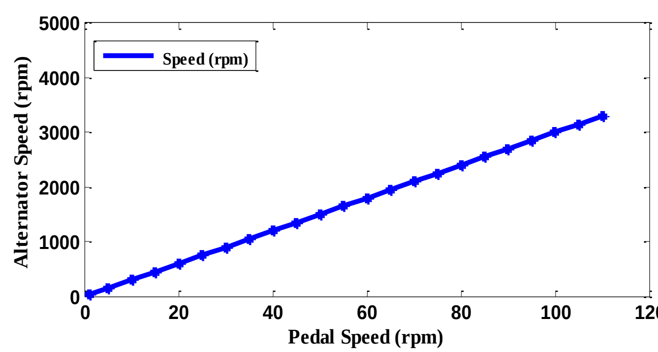

Fig. 3 Alternator speed against pedal system.

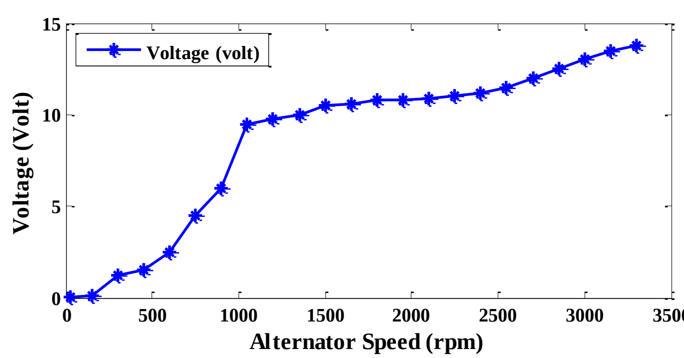

Fig.4 Induced voltage against alternator speed

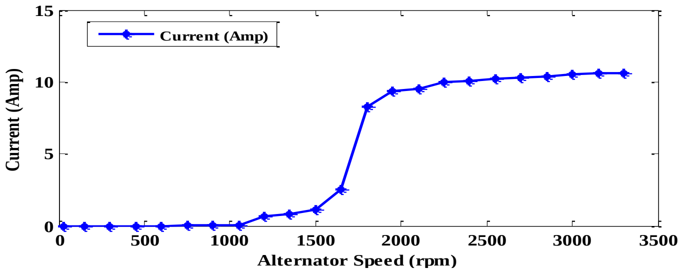

Fig.5 Current production from the alternator at different speed

This is the generated power from the one unit of GBPS and the total cost of the one unit is just about $ 900 with batteries and inverter. Table II shows the estimated energy generation from the GBPS for daily, monthly and yearly.

table II

ENERGY GENERATION FROM GBPS UNITS

S. No.	No. of Units	Energy (kWh/Day)	Energy (kWh/Month)	Energy (kWh/Year)
1.	5	9.18	275.4	3350.7
2.	10	18.36	550.8	6701.4
3.	20	36.72	1101.6	13402.8
4.	40	73.44	2203.2	26805.6
5.	60	110.16	3304.8	40208.4
6.	80	146.88	4406.4	53611.2
7.	100	183.60	5508.0	67014.0

D. Design of SPV power plant

To design of SPV power plant consists of PV modules, controllers, inverter size, batteries, land required and technical specifications. For developed a 50 kWp SPV power plant, the energy required from PV modules is 1560 kWh/day, total watt peak rating for PV modules 249.6 kW.

Tata Power Solar TP 250 Series Module (250 Watt) is selected for the PV power plant and the solar cell made of a thin Monocrystalline silicon wafer. Total numbers of PV modules required in the power plant are 998.

Inverter size in the PV power plant depends on the total peak watts requirement. Battery size depends on the total battery watt-hours used per day with 15% loss of battery. Total number of PV arrays used 53. The land required for the 50 kW SPV power plant is 3850 m^2 or 0.9515 acres (1 acre = 4047 m^2) [14]. The project cost for SPV 50 kWp capacities shown in Table III.

TABLE III

PROJECT COST FOR SOLAR PV 50 KWP CAPACITIES POWER PLANT

S. No.	Particulars	Cost ($)
1.	Module Cost	197255
2.	Array Structure	13774
3.	Inverters	8125
4.	Electrical Commodities	10000
5.	Installation labor cost	469
6.	Design & Management cost	313
7.	Hardware packing & freight	1719
	Total cost for off-site plant	**231655**
8.	Land Cost	240625
9.	Batteries	36125
	Total cost for on-site plant	**508405**

4. Result and Discussion

The main goal of the work is to produce electricity without fuels and best tried to fulfill the power demand where power cut, shortage and no power connections are the major issues. The power generated by the SPV and GBPS is evaluated and utilized for the end users. The load demand would be decrease after installing GBPS with the solar PV system. The Fig. 6 shows the energy scheduling diagram of the GBPS and SPV system.

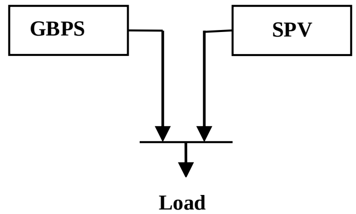

Fig. 6 The GBPS with SPV system to a common load.

The solar PV system 50 kWp with 20 GBPS units have been considered here. The load curve shown in Fig.7 is the predicted load for the power consumption of the area per day. The test is conducted for the load and SPV generation without GBPS.

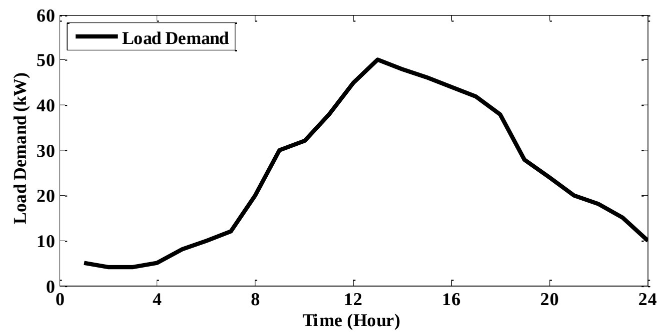

Fig. 7 Predicted load curve for the power consumption per day

The change in load demand has been found after integrating the GBPS with the Solar PV system. The energy manages mainly in the peak hours when the demand is higher. In this work two conditions have been discussed, first, the load and solar PV generation without GBPS and secondly, load change after adding GBPS with the solar PV system.

4.A. Load and solar PV generation without GBPS:

Fig.7 shows the actual load curve of the power consumption for the 24-hour time period. The peak load demand occurs at 1:00 P. M. and the value is 50 kW and the minimum load occurs at 4:00 A. M. along with the load demand value 4 kW. After installing the solar PV system the load demand is reduces at a certain level.

The 50 kWp capacity SPV system is better preference for the lower loads and smaller areas but for the bigger demands the capacity would be raise. Fig. 8 shows the load curve with the 50 kWp system for the 24-hour time period. It shows that in the noon the capacity of PV generation is better and almost near the power demand. The lowest PV generation is at 6:30 A. M. and highest at 1:00-2:00 P. M.

The power consumption is maximum at 1:00 P. M. The PV generation is more than the demand at 10:00 A. M., this surplus power can be stored by using battery energy storage system (BESS) for the future. To reduce the peak load demand GBPS system integrated with solar PV system.

4.B. Load and solar PV generation with GBPS:

After adding up the GBPS system in peak hours the power demand must be reduced. The energy generated by the GBPS can be stored in the energy storage system and used in the peak hours when demand is high. Fig. 9 shows the load curve when 50 kWp SPV generation systems added with the 20 GBPS units. The curve shows that the power generated by both the system is excessive and in surplus. In Fig. 9 when compared with the Fig. 8, the load demand decreases.

The surplus power can be used in the off peak hours. In both figures the demand decreases. The power demand can be decreases more if we have increased the power generation by the GBPS and SPV system. By using GBPS and SPV systems can accomplish the load power demand.

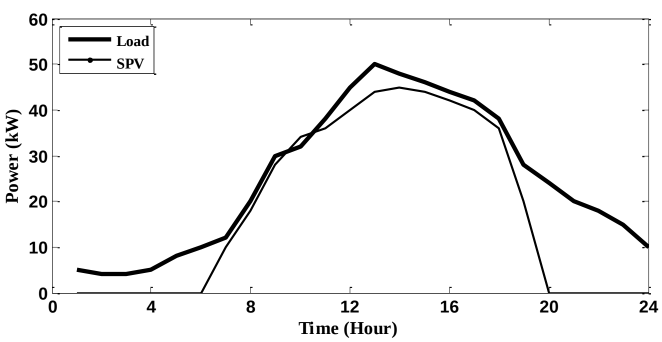

Fig. 8 Variation of predicted power generation of SPV and demand with time

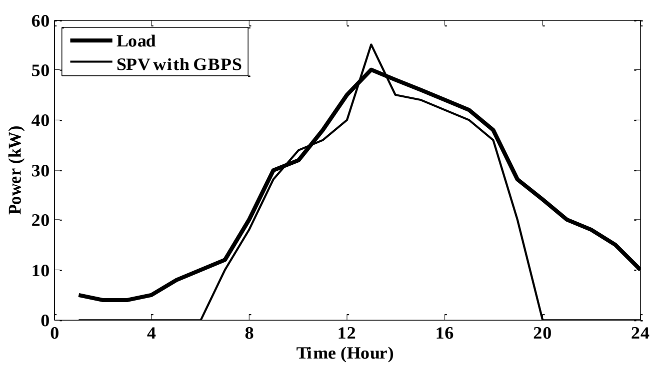

Fig. 9 Predicted power generation in peak hours and demand with time

4.C. Load and solar PV generation with GBPS in off-peak hours:

The sun is available in the day time between 7:00 A. M. to 6:30 P. M. in summer and 7:30 A. M. to 5:00 P.M in winter in North India. The sun light intensity is good in noon time. The solar PV generation is superior in noon. The drawback of the sun light is not available in the night, rainy season and cloudy season. Fig. 10 shows the load demand, solar PV and GBPS generation.

The load has been changed efficiently when added the GBPS in off-peak hours or when sun is not available. Fig. 10 shows the energy generation scheduling between GBPS and solar PV systems in off-peak hours. The demand would be diminish, if we increases energy by the gym bicycle pedal system and integrates with the solar PV systems. It would be possible if installed more GBPS (inside) with SPV system (at rooftop) on the gym center.

Fig. 11 shows the on line demand supply between 6:30 A. M. to 6:00 P. M., by the SPV system and remaining demand carried out by the GBPS in off peak hours (12:00 A. M. - 6:30 A.M. & 6:00 P. M. - 6:30 A. M.). The results are the variation of load and power consumption per day. This system used as a power station which can execute the local area's power demand such as town, cities, villages etc., it is like a mini power station and useful for the populations where power connection is not available. It is totally emission free means zero emission occurs in this scheme.

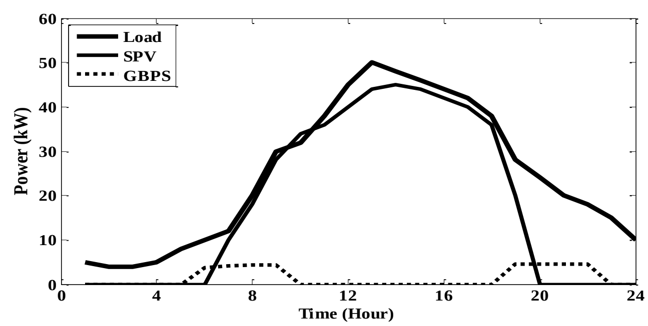

Fig. 10 Variation of predicted power generation and demand with time

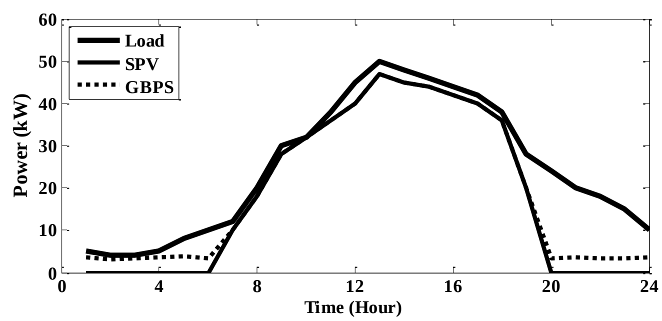

Fig. 11 Variations of the power in off-peak hours with time

By proposing this model in urban area electricity bill is reduced in a good amount of values by connecting this scheme in grid line system. In present time many villages have no choice for electricity, the students are not educating due to the lack of electricity. By making this type of the power stations it is not only give the electricity but also gives employment for these areas as the GBPS basically generate electricity by the human efforts.

5. CONCLUSIONS

This paper presents a scheme and implementation a pedal system with the photovoltaic system for power generation. It is being clean, safe and reliable power generation for the millions of peoples of the world. The GBPS and SPV system have been presented to solve the power crisis problems in rural areas. Solar PV systems 50 kWp with GBPS has been discussed. The predicted load managed by the energy management in peak hours and off-peak hours. The experimental results show that the use of renewable energy sources with GBPS is a preferable choice. The advantages of this system are totally emission free, clean and environment friendly. The arrangement is good for the rural areas. The hardware setup for the proposed work is developed at prototype stage.

References

[1] Edwin Schwaller, "*Bicycle lighting system and generator*", United States Patent, January 1999
[2] Richard Banfield Hicks, "*Electricity generation for pedalled vehicles"*, United States Patent, August 2000.
[3] James P. Gagne, "*Pedal operated power generating system",* United States Patent, May 2001.
[4] P. Bhusal, A. Zahnd, M. Eloholma and L. Halonen, "Energy efficient innovative lighting and energy supply solutions in developing countries", *International Review of Electrical Engineering,* Vol. 2, No. 5, pp 665-670, 2007.
[5] R Podmore, Ray Larsen, Henry Louie and Brian Waldron, "Affordable energy solutions for developing communities*", IEEE,* pp 1-8, 2011.
[6] S. C. Mok, "New village gadgets synergy of human-powered generation and ultra-efficient electrical appliances for poverty eradication*", IEEE Computer Society,* pp 25-29, 2011.
[7] Rajesh Kannan Megalingam, Lekshmi M Nair, Meera Viswanath and Shreeja Sugathan, "Pedalite: lighting up lives in un-electrified villages", *IEEE Global Humanitarian Technology Conference*, pp 12-17, 2012.
[8] Sujoy Barua and Md. Mahmudul Hasan, "Savings of electricity consumption through solar based recharging station for power assisted pedal rickshaw in *Chittagong",* pp 1-4, 2014
[9] Jitendra Kumar, Nikunj Garg and Aadil Ali, "Energy generation using paddling system with solar system", *MIT International Journal of Mechanical Engineering, ISSN 2230-7680*, Vol. 6, No. 1, pp. 5-8, January 2016.
[10] M. K. C. Marwali, Haili Ma, S. M. Shahidehpour and K. H. Abdul-Rahman, "Short term generation scheduling in photovoltaic-utility grid with battery storage*", IEEE Transactions on Power Systems*, Vol. 13, No. 3, pp 1057-1062, August 1998.
[11] Bo Lu, and Mohammad Shahidehpour, "Short-term scheduling of battery in a grid-connected pv/battery system", *IEEE Transactions on Power Systems*, Vol. 20, No. 2, pp 1053-1061, May 2005.
[12] Tai-Ran Hsu, Raymond K. Yee and Thuy T. Le, "Hybrid-powered zero-emission vehicle using human , *electric and solar power inputs", United States Patent*, July 2010.
[13] Soteris Kalogirou, "Solar energy engineering", *Library of Congress Cataloging in Publication Data*, 2009.
[14] M. Chandel, S. Mathur, A. Mathur and G. D. Aggarwal, "Techno-economic analysis of solar photovoltaic power plant for garment zone of Jaipur city", *Case Studies in Thermal Engineering*, pp 1-7, 2, 2014.