Solar Photovoltaic Electricity for Irrigation under Bangladeshi Climate

K.A.Khan[1] and Salman Rahman Rasel[2]

[1]*Department of Physics, Jagannath University, Dhaka-1100, Bangladesh*
E-mail: kakhan01@yahoo.com , Phone Number: +8801911357447
[2]*Local Government Engineering Department (LGED), Fulbaria, Mymensing, Bangladesh*
E-mail: salman_rasel80@yahoo.com,Phone Number: +8801731722377

Abstract

In order to optimize the performance of SPV (Solar Photovoltaic) systems, one must first define what the system to be optimized is and what performance indicators should be used. Various indicators are used in the industry including Fill Factor(FF), Conversion Efficiency (ηc), specific yield (kWh/kWp), performance ratio (actual performance/theoretical performance), Levelized Cost of Energy (LCOE),Payback Period(PP) and internal rate of return (IRR). The fundamentals of SPV systems and how their performance can be measured are described throughout this chapter. Solar cells may be manufactured using a number of different semiconductors and techniques. The cell types used in this project were selected on the basis of being widely commercially available for terrestrial installations.

Keywords: *SPV, Crystalline Cell, Climatic condition, Conversion efficiency (η_c) ,Practical applications, Irrigation, Maximum power point (MPP)*

I Introduction

There are two main types of solar photovoltaic (PV) cell - thin film and crystalline. Crystalline cells make up over 90% of grid connected PV systems worldwide (including solar farms and building mounted systems) [30,65]. Whilst crystalline cells are more expensive than thin films, they are generally more efficient and have longer performance warranties. Silicon cells are mostly produced by doping a thin top layer with Boron and the thicker lower layer with Phosphorous (Fig. 1). These doped layers create an intermediate 'depletion zone' between them and a resulting electric field. When photons falling on the device transfer their energy to electrons, the latter are promoted to the conduction band and gain mobility.

II. Methods and Materials

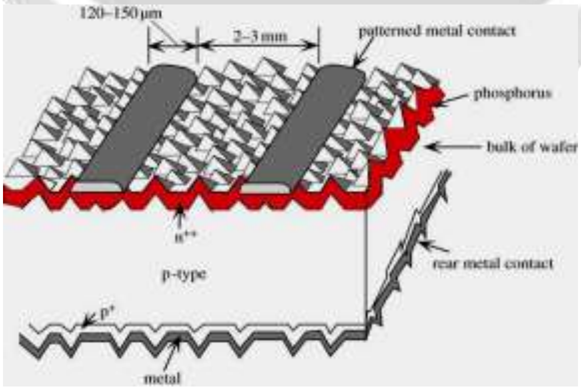

Fig.1: Cutaway section of a solar PV cell, showing doped layers, courtesy of [35].

Diffusing to the depletion zone, the field causes a net movement of electrons from the p-type layer to the n-type layer; if the cell is connected in a circuit power can then be extracted [31-34].

II. A. Define different Parameters:

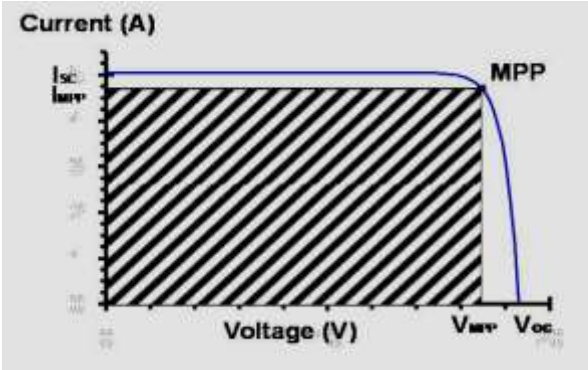

Fig.2 IV curve for a solar PV cell

The key points on the IV curve are:
(i) Open circuit voltage Voc: The maximum voltage of the cell or module, Connected to an infinite resistance, with no current flowing. The voltage of a solar cell Varies inversely with temperature.

(ii) Short Circuit Current (Isc): The maximum current of the cell or module at zero volts. Current varies proportionally with solar irradiance, but in datasheets is usually given for 1000W/m2 (STC1).

(iii) Maximum power point (MPP):
Note that at Isc and Voc no power can be generated because P= IV. On a graph of current against voltage, power is represented by the area under the box formed by the operating point. The ‘Maximum Power Point (MPP)’ is at the ‘knee’ of the IV curve where this is greatest. To maximize the output from a solar cell or an array of cells, a Maximum Power Point Tracking (MPPT) circuit is employed in the inverter or battery charger to optimize the current draw to operate the system at MPP.

(iv) Maximum power point voltage (VMPP):
Maximum power point voltage (VMPP) is the voltage corresponding to the MPP.

(v) Maximum power point current (IMPP):
Maximum power point current (IMPP) is the current corresponding to the MPP.

(vi) Crystalline silicon cells:
Crystalline (as opposed to thin film) silicon cells were historically believed to have better longevity than thin film, however recent research has found that this may not be the case [36]

(vii) Poly-crystalline silicon (mcSi):
The silicon is grown into multiple crystals, giving it a crazed appearance, like galvanized steel. Molten silicon is cooled in moulds to form ingots from which wafers are cut.

(vii) Mono-crystalline (scSi):
The silicon is grown into a large single crystal from a seed crystal. This crystal is sawn into an ingot from which wafers are cut. The mcSi or mSi wafers are doped, etched, and screen printed to create a working solar cell.

II.B. [46-49]: Description of solar module:

A module is consists of more than one unit of solar cell. The unit cells are fabricated by connecting silicon or germanium diode through series connection. But in a module, the solar cells are connected both in series and in parallel as per requirement. Generally, the solar cells are imported from other countries. Because, there is no industry in our country for making solar cell. Production of solar cell needs a furnace where it produces high temperature. So, modules are fabricated in our country by those imported solar cells. In Fig.3 shown below:

Fig.3 Solar Panel set up for irrigation at Savar, Dhaka, Bangladesh

II.C Connecting materials for producing solar module [24, 50-58]:

The Fig.4 shows the wafers for connecting solar cells to form solar modules. It is very sensitive to form a module by thin wafers. In the figure, it is not connected properly, then the I-V characteristics of the curve will not be ideal. The fill-factor (FF) will be less than the ideal value e.g. 0.7. Due to this reason, it is very important to use this wafer to form a module.

Fig.5 Method of measurement of I-V characteristics

The environmental conditions vary from time to time during the day period of the sun. That is why the efficiency and fill factor varies with the same change of environment [66,67]. Solar cell tester helps us to measure the performance of the solar cell instantly. Generally, solar cell is set up on the solar tester connecting with a calibrated computer. Finally, we get the value of all parameters with time including I-V curves. Before constructing a solar module, solar cell tester is very important whether those cells are ideal or not.

II D: I-V characteristics of a solar cell:

The solar cell is made by semi-conductor materials. These solar cells have I-V characteristics diode, transistors, FED and SCR. For any solar cell, firstly it has to measure the I-V characteristics. Because the I-V characteristics is wide different between ideal and non-ideal cell. The I-V characteristics is drawn by collecting the current and the voltage, we change the load resistor. Now it has to draw the variation of useful power with the variation of time in presence of sunlight. The following solar light also varies with time. So, the efficiency and FF also varies with time. From the I-V curve, it has to measure two important parameters, efficiency and FF of any solar cell. In that sense, I-V is the heart of a solar cell.

II E Standard solar cell condition:

The climatic condition of any country varies with their longitudinal and latitudinal earth location. That is why, the climatic condition of the countries are not the same. Bangladesh is a tropical country. The solar radiation here, during the consecutive eight months of the year remain sunlight favorable for solar cell for electricity production. Because for those eight months of the year, the sky condition remains clear. And the rest four months, the sky condition sometimes remains sunlight favorable, sometimes semi-favorable and sometimes cloudy, sometimes semi-cloudy and sometimes foggy or hazy. So, the performance during these four months (July, August, September and October) are low in comparison of the eight months. So, scientists determine the standard state condition for the solar cell, V_{oc}= 0.5 volt and Isc= 0.5 amp. The state conditions are, solar radiation is 1000 watt/m^2, cell temperature is 25^0C and atmospheric pressure is 760 mmHg.

II F Practical application of solar cell for irrigation:

For the practical application of the solar cell electricity, research was conducted at Savar in Dhaka. The Fig.6 shows the stand alone photovoltaic system for solar irrigation. The solar pump system is used during the season of paddy cultivation. Besides this, the local farmers are supposed to use the solar pump for the cultivation of various vegetables, greens after the end of the paddy cultivation.

Fig.6 Application of solar electricity for irrigation purposes using water pump collecting water from the lake.

III. Results and Discussion with Graphical Analysis:

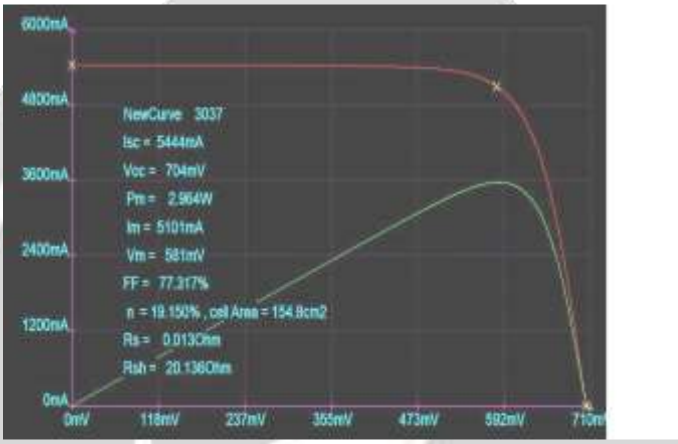

Fig.7 Ideal I-V curve for ideal solar cell-1

Fig.7 shows the I-V curve for a solar cell under Bangladeshi climatic condition. It is shown the following experimental result:

Short circuit current, I_{sc} = 5444mA,
Open circuit voltage, V_{oc} = 704 mV,
Maximum useful power, P_m=2.964W,
Maximum useful current, I_m = 5101mA,
Maximum useful voltage, V_m= 581 mV,
Fill Factor, FF= 77.317% ,
Conversion efficiency, η_c = 19.15% ,
Cell Area = 154.8cm^2,
Diode Series resistance, R_s = 0.013 ohm,
Shunt resistance, R_{sh} = 20.136 ohm.

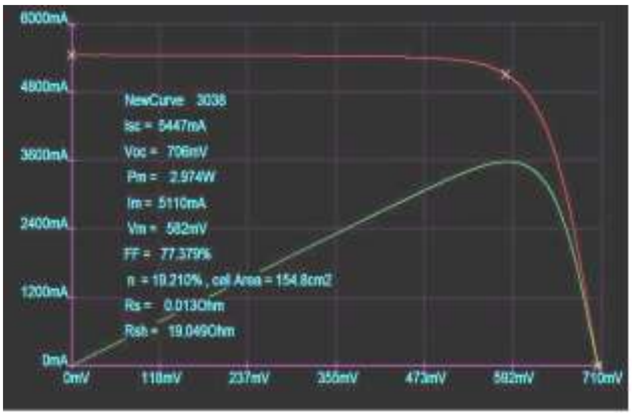

Fig.8 Ideal I-V curve for ideal solar cell-2

Fig.8 shows the I-V curve for a solar cell under Bangladeshi climatic condition. It is shown the following experimental result:
Short circuit current, I_{sc} = 5447mA,
Open circuit voltage, V_{oc} = 706 mV,
Maximum useful power, P_m = 2.974 W, Maximum useful current, I_m = 5110 mA, Maximum useful voltage, V_m= 582 mV,
Fill Factor, FF = 77.379% ,
Conversion efficiency, η_c = 19.210% ,
Cell Area = 154.8cm^2,
Diode Series resistance, R_s = 0.013 ohm,
Shunt resistance, R_{sh} = 19.049 ohm.

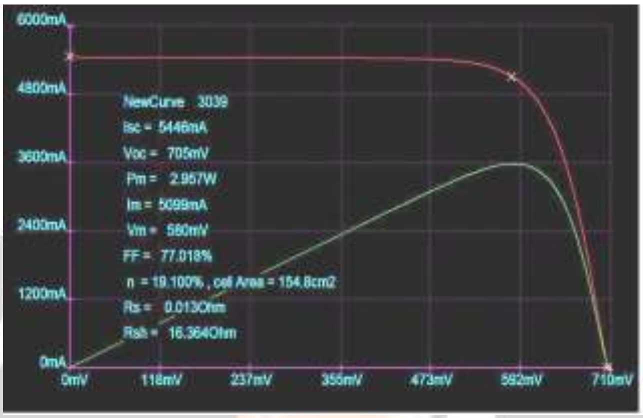

Fig.9 Ideal I-V curve for ideal solar cell-2

Fig.9 shows the I-V curve for a solar cell under Bangladeshi climatic condition. It is shown the following experimental result:
Short circuit current, I_{sc} = 5446 mA,
Open circuit voltage, V_{oc} = 705 mV,
Maximum useful power, P_m = 2.957 W, Maximum useful current, I_m = 5099 mA, Maximum useful voltage, V_m= 580 mV,
Fill Factor, FF = 77.379% ,
Conversion efficiency, η_c = 19.100 % ,
Cell Area = 154.8cm^2,
Diode Series resistance, R_s = 0.013 ohm,
Shunt resistance, R_{sh} = 16.364 ohm.

Finally, it is shown that where FF increases, the conversion efficiency also increases. Therefore it can be said that FF and conversion efficiency (η_c) is almost proportional.

IV. Conclusion

The Fig.6 shows that the water is extracted from a river which meets up the demands for cultivation in the whole months of the year. So, the farmers are very happy for having this solar irrigation pumping system. It is mentioned that this solar pumping irrigation project is installed by BADC to help the farmers when there is no water in the dry season as well to enhance paddy production. It is very happy system that in solar pumping system, no oil/fuel is required. It saves the environment and cost simultaneously which we may call environment friendly cheap cultivation system for Bangladesh and this is one of the main objective of my research work.

Acknowledgement

The authors are grateful to the PKL electricity research group named Md. Abdus Samad (Ex-Joint Secretary, GoB), Dr. M A Latif, Dr. Md. Sajjad Hossain, Dr. Md. Fakrul Islam, Dr. Bapy Guha, Md. Mehdi Hassan, Md. Shamsul Alam and Dr. Jesmin Sultana for their valuable suggestions and whole hearted cooperation during research work.

References

[1] K.A.Khan, Lovelu Hassan, A K M Obaydullah, S. M. Azharul Islam, M.A. Mamun, Tanjila Akter, Mehedi Hasan, Md. Shamsul Alam,M. Ibrahim, M Mizanur Rahman and M. Shahjahan , Bioelectricity: A new approach to provide the electrical power from vegetative and fruits at off-grid region, Published in the journal of Microsystem Technologies of Springer, manuscript number: 2018MITE-D-17-00623R2, Received: 14 August 2017/Accepted: 3 February 2018, Volumes-24,Issues-3, Impact Factor: 1.195, ISSN: 0946-7076 (Print) 1432-1858 (Online), Springer-Verlag GmbH Germany, Part of Springer Nature, DOI: 10.1007/s00542-018-3808-3, 2018.

[2] Mehedi Hasan and K A Khan, Dynamic Model of Bryophyllum pinnatum Leaf Fueled BPL Cell: A Possible Alternate Source of Electricity at the Off-grid Region in Bangladesh, Published in the Microsystem Technologies (2018), Springer, manuscript number, MITE-D-18-00800R1, DOI: https://doi.org/10.1007/s00542-018-4149-y, Publisher Name: Springer Berlin Heidelberg,Print ISSN: 0946-7076,Online ISSN: 1432-1858, First Online: 28 September 2018

[3] K A Khan, M.S.Bhuyan,M. A. Mamun, M. Ibrahim, Lovelu Hassan and M A Wadud, Organic Electricity from Zn/Cu-PKL Electrochemical Cell, Published in the Springer Nature, Series Title: Advs in Intelligent Syst., Computing, Volume Number:812, Book Title: Contemporary Advances in Innovative and Applicable Information Technology,ISBN:978-981-13-1539-8, https://doi.org/10.1007/978-981-13-1540-4, 2018

[4] K A Khan, A. Rahman, M. S. Rahman, A. Tahsin, K. M. Jubyer, and S. Paul, "Performance analysis of electrical parameters of PKL electricity (An experimental analysis on discharge rates, capacity & discharge time, pulse performance and cycle life & deep discharge of PathorKuchi Leaf (PKL) electricity cell)," In Innovative Smart Grid Technologies-Asia (ISGT-Asia), 2016 IEEE, pp. 540-544. IEEE, 2016.

[5] M. K. A. Khan, S. Paul, M. S. Rahman, R. K. Kundu, M. M. Hasan, M.Moniruzzaman, and M. A. Mamun, "A study of performance analysis of PKL electricity generation parameters:(An experimental analysis on voltage regulation, capacity and energy efficiency of pathorkuchi leaf (PKL) electricity cell)," In Power India International Conference (PIICON), 2016 IEEE 7th, pp. 1-6. IEEE, 2016.

[6] M. K. A. Khan, M. S. Rahman, T. Das, M. N. Ahmed, K. N. Saha, and S. Paul,"Investigation on Parameters performance of Zn/Cu Electrodes of PKL, AVL, Tomato and Lemon juice based Electrochemical Cells: A Comparative Study,"In Electrical Information and Communication Technology (EICT), 2015 3rd International Conference on, pp. 1-6. IEEE, 2017.

[7] K A Khan, Akhlaqur Rahman, Md Siddikur Rahman, Aniqa Tahsin, Kazi Md Jubyer, and Shuva Paul. "Performance analysis of electrical parameters of PKL electricity (An experimental analysis on discharge rates, capacity & discharge time, pulse performance and cycle life & deep discharge of Pathor Kuchi Leaf (PKL) electricity cell)." In Innovative Smart Grid Technologies-Asia (ISGT-Asia), 2016 IEEE, pp. 540-544. IEEE, 2016.

[8] M K A Khan, Shuva Paul, Md Siddikur Rahman, Ripon Kumar Kundu, Md Mahmudul Hasan, Mohammad Moniruzzaman, and Mohammad Al Mamun. "A study of performance analysis of PKL electricity generation parameters:(An experimental analysis on voltage regulation, capacity and energy efficiency of pathor kuchi leaf (PKL) electricity cell)." In Power India International Conference (PIICON), 2016 IEEE 7th, pp. 1-6. IEEE, 2016.

[9] M K Alam Khan, "Copper Oxide Coating for use in Linear Solar Fresnel Reflecting Concentrating Collector",Published in the journal. of Elsevier, Renewable Energy, An International Journal, WREN(World Renewable Energy Network), UK, RE: 12.97/859,1998

[10] Muhammad Riazul Hamid, Characterization of a Battery cell fueled by Bryophyllum Pinnatum sap, International Journal of Scientific & Engineering Research, Volume 4, Issue 3, ISSN 2229-5518, March-2013.

[11] Muhammad Riazul Hamid, Akib Yusuf, Abu Md. Abdul Wadud, and Md. Mosfiqur Rahaman, Design and Performance Test of a Prototype of a 12 Volt DC Battery Fueled by Bryophyllum Pinnatum Sap and Improvement of Its Characteristics, Department of Electrical and Electronic Engineering, Ahsanullah University of Science and Technology, Dhaka, Bangladesh, Email: {drhamidbd, shohan933}@gmail.com, {akib147, sshaon95}@yahoo.com, International Journal of Electronics and Electrical Engineering Vol. 4, No. 5, October 2016.

[12] K A Khan, " Electricity Generation form Pathor Kuchi Leaf (Bryophyllum pinnatum) " , Int. J. Sustain. Agril. Tech. 5(4): 146-152, July 2009.

[13] K A Khan and Md. Eyashir Arafat, "Development of Portable PKL (Pathor Kuchi Leaf) Lantern", Int. J. SOC. Dev. Inf. Syst. 1(1): 15-20 January 2010.

[14] K. A. Khan and Ranen Bosu, "Performance study on PKL Electricity for Using DC Fan", Int. J. SOC. Dev. Inf. Syst. 1(1): 27-30, January 2010

[15] K A Khan and Md. Imran Hossain," PKL Electricity for Switching on the Television and Radio",Int. J. SOC. Dev. Inf. Syst. 1(1): 31-36, January 2010

[16] Shuva Paul, K A Khan, Kazi Ahad Islam, Baishakhi Islam and Musa Ali Reza, "Modeling of a Biomass Energy based (BPL) Generating Power Plant and its features in comparison with other generating Plants ",IPCBEE vol. 44 (2012) @ (2012) IACSIT Press, Singapore DOI: 10.7763/ IPCBEE. 2012. V44. 3

[17] K. A. Khan, Shuva Paul, Md. Adibullah, Md.Farhat Alam, Syed Muhammad Sifat, Md. Rashed Yousufe, " Performance Analysis of BPL/PKL Electricity module ", International Journal of Scientific & Engineering Research Volume 4, Issue3, March-2013 1 ISSN 2229-5518

[18] K A Khan, Shuva Paul,Asif Zobayer,Shiekh Saif Hossain, A Study on Solar Photovoltaic Conversion, International journal of Scientific and Engineering Research ,Volume-4,Issue-3,March-2013,ISSN2229-5518, 2013

[19] Tania Akter, M H Bhuiyan, K A Khan and M H Khan, "Impact of photo electrode thickness and annealing temperature on natural dye sensitized solar cell", Published in the journal. of Elsevier. Ms. Ref. No.: SETA-D-16-00324R2, 2017

[20] K A Khan, Inventors, Electricity Generation form Pathor Kuchi Leaf (PKL), Publication date 2008/12/31, Patent number BD 1004907,2008

[21] K A Khan, Technical note "Copper oxide coatings for use in a linear solar Fresnel reflecting concentrating collector", Publication date 1999/8/1, Journal Renewable energy, Volume 17, Issue 4, Pages 603-608, Publisher – Pergamon, 1999

[22] K A Khan, Shuva Paul, A analytical study on Electrochemistry for PKL (Pathor Kuchi Leaf) electricity generation system, Publication date 2013/5/21, Conference- Energytech, 2013 IEEE, Pages 1-6, Publisher, IEEE,2013

[23]T.A.Ruhane, M.Tauhidul Islam, Md. Saifur Rahaman, M.M.H. Bhuiyan, Jahid M.M. Islam, M.K.Newaz, K A Khan, Mubarak A. Khan, "Photo current enhancement of natural dye sensitized solar cell by optimizing dye extraction and its loading period" , Published in the journal of Elsevier : Optik - International Journal for Light and Electron Optics, 2017.

[24] K A Khan, M S Alam, M A Mamun, M A Saime & M M Kamal, Studies on electrochemistry for Pathor Kuchi Leaf Power System, Ppublished in the Journal of Bangladesh J. Agric. And Envirin. 12(1): 37-42, June 2016

[25] Mehedi Hasan, Lovelu Hassan, Sunjida Haque, Mizanur Rahman, K A Khan, A Study to Analyze the Self-Discharge Characteristics of Bryophyllum Pinnatum Leaf Fueled BPL Test Cell, Published in the Journal of IJRET, Vol-6 Iss-12, Dec-2017

[26] J. Sultana, K A Khan, and M.U. Ahmed. "Electricity Generation From Pathor Kuchi Leaf (PKL) (Bryophillum Pinnatum)." J.Asiat Soc. Bangladesh Sci., 2011, Vol. 37(4): P 167-179

[27] M. Hasan, S. Haque and K A Khan, "An Experimental Study on the Coulombic Efficiency of Bryophyllum pinnatum Leaf Generated BPL Cell",IJARIIE, ISSN(O)-2395-4396, Vol-2, Issue-1, 2016

[28] MM Hasan, MKA Khan, MNR Khan and MZ Islam, "Sustainable Electricity Generation at the Coastal Areas and the Islands of Bangladesh Using Biomass Resources", City University Journal, Vol. 02, Issue. 01, P. 09-13, 2016.

[29] M Hasan and K A Khan, "Bryophyllum pinnatum Leaf Fueled Cell: An Alternate Way of Supplying Electricity at the Off-grid Areas in Bangladesh" in Proceedings of 4th International Conference on the Developments in Renewable Energy Technology [ICDRET 2016], P. 01, 2016. DOI: 10.1109/ICDRET.2016.7421522

[30] M Hasan, KA Khan, MA Mamun, "An Estimation of the Extractable Electrical Energy from Bryophyllum pinnatum Leaf", American International Journal of Research in Science, Technology, Engineering &Mathematics (AIJRSTEM), Vol. 01, Issue. 19, P. 100-106, 2017.

[31] M K A Khan, M. S. Rahman, T. Das, M. N. Ahmed, K. N. Saha, and S. Paul, "Investigation on Parameters performance of Zn/Cu Electrodes of PKL, AVL, Tomato and Lemon juice based Electrochemical Cells: A Comparative Study,"In Electrical Information and Communication Technology (EICT), 2017 3rd International Conference on, pp. 1-6. IEEE, 2017. DOI: 10.1109/EICT.2017.8275150,IEEE, Khulna, Bangladesh, Bangladesh, 7-9 Dec. 2017.

[32] Md. Afzol Hossain, M K A Khan, Md. Emran Quayum,''Performance development of bio-voltaic cell from arum leaf extract electrolytes using zn/cu electrodes and investigation of their electrochemical performance'', International Journal of Advances in Science Engineering and Technology, ISSN: 2321-9009, Vol-5, Iss-4, Spl. Issue-1, Nov-2017

[33] K A Khan , M. A. Wadud , A K M Obaydullah and M.A. Mamun, PKL (Bryophyllum Pinnatum) electricity for practical utilization, IJARIIE-ISSN(O)-2395-4396, Vol-4, Issue-1, Page: 957-966

[34] M. M. Haque, A.K.M.A. Ullah, M.N.L Khan, A.K.M.F. F. Kibria and K A Khan,"Phyto-synthesis of MnO2 Nanoparticles for generating electricity," In the International conference on Physics-2018, Venue-Department of

Physics, University of Dhaka, Dhaka-1000,Bangladesh, Organizer-Bangladesh Physical Society(BPS, 08-10 March, 2018.

[35] Lovelu Hasan,Mehedi Hasan, K A Khan and S.M. Azharul Islam, "SEM Analysis of Electrodes and measurement of ionic pressure by AAS data to identify and compare the characteristics between different bio-fuel based electrochemical cell, " In the International conference on Physics-2018, Venue-Department of Physics, University of Dhaka, Dhaka-1000,Bangladesh, Organizer-Bangladesh Physical Society(BPS, 08-10 March, 2018.

[36] Mehedi Hasan and K A Khan, "Identification of BPL Cell Parameters to Optimize the Output Performance for the Off-grid Electricity Production, " In the International conference on Physics-2018, Venue-Department of Physics, University of Dhaka, Dhaka-1000,Bangladesh, Organizer-Bangladesh Physical Society(BPS, 08-10 March, 2018.

[37] K A Khan, M.S.Bhuyan,M. A. Mamun,M.Ibrahim,Lovelu Hassan and M A Wadud, "Organic electricity from Zn/Cu-PKL electrochemical cell ", Published in the Souvenir of First International Conference of Contemporary Advances in Innovative & Information Technology(ICCAIAIT) 2018,organized by KEI, In collaboration with Computer Society of India(CSI), Division-IV(Communication). The proceedings consented to be published in AISC Series of Springer,2018

[38] M K A Khan , A K M Obaydullah, M.A. Wadud and M Afzol Hossain, "Bi-Product from Bioelectricity", IJARIIE-ISSN(O)-2395-4396, Volume-4, Issue-2, Page-3136-3142 , 2018

[39] M K A Khan and A K M Obaydullah , "Construction and Commercial Use of PKL Cell", IJARIIE-ISSN(O)-2395-4396, Volume-4, Issue-2, Page-3563-3570, 2018

[40] M K A Khan, "Studies on Electricity Generation from Stone Chips Plant (Bryophyllum pinnatum)", International J.Eng. Tech 5(4): 393-397, December 2008

[41] K A Khan, M Afzol Hossain, A K M Obaydullah and M.A. Wadud, "PKL Electrochemical Cell and the Peukert's Law ", Vol-4 Issue-2, 2018 IJARIIE-ISSN(O)-2395-4396,Page: 4219 – 4227

[42] K A Khan, M.A.Wadud, M Afzol Hossain and A.K.M. Obaydullah, "Electrical Performance of PKL (Pathor Kuchi Leaf)Power", Published in the IJARIIE-ISSN(O)-2395-4396,Volume-4, Issue-2, Page-3470-3478 ,2018.

[43] K A Khan, M Hazrat Ali, M. A. Mamun, M. Mahbubul Haque, A.K.M. Atique Ullah, Dr. Mohammed Nazrul Islam Khan, Lovelu Hassan, A K M Obaydullah, M A Wadud, "Bioelectrical Characteristics of Zn/Cu- PKL Cell and Production of Nanoparticles (NPs) for Practical Utilization'' , 5th International conference on 'Microelectronics, Circuits and Systems', Micro2018, 19th and 20th May,2018,Venue: Bhubaneswar, Odisha, India, Organizer: Applied Computer Technology, Kolkata, West Bengal, India, Page: 59-66, www.actsoft.org , ISBN: 81-85824-46-1, In Association with: International Association of Science, Technology and Management, 2018

[44] M.M. Hassan, M. Arif and K A Khan, "Modification of Germination and growth patterns of Basella alba seed by low pressure plasma", Accepted in the " Journal of Modern Physics", Paper ID: 7503531,2018

[45] K.A.Khan, S.M.Maniruzzaman Manir, Md. Shafiqul Islam, Sifat Jahan, Lovelu Hassan, and M Hazrat Ali. "Studies on Nonconventional Energy Sources for Electricity Generation" Internation Journal of Advance Research And Innovative Ideas In Education , Volume 4 Issue 4 2018 Page 229-244

[46] K A Khan, Mahmudul Hasan, Mohammad Ashraful Islam, Mohammad Abdul Alim, Ummay Asma, Lovelu Hassan, and M Hazrat Ali. "A Study on Conventional Energy Sources for Power Production" Internation Journal Of Advance Research And Innovative Ideas In Education, Volume 4 Issue 4 2018 Page 214-228

[47] M K A Khan ; Md. Siddikur Rahman ; Tanmoy Das ;Muhammad Najebul Ahmed ; Kaushik Nandan Saha ; Shuva Paul, Investigation on parameters performance of Zn/Cu electrodes of PKL, AVL, Tomato and Lemon juice based electrochemical cells: A comparative study, Publication Year: 2017, Page(s):1-6, Published in: 2017 3rd International Conference on Electrical Information and Communication Technology (EICT), Date of Conference: 7-9 Dec. 2017, Date Added to IEEE Xplore: 01 February 2018, ISBN Information: INSPEC AccessionNumber: 17542905,DOI: 10.1109/EICT.2017.8275150,Publisher: IEEE,Conference Location: Khulna, Bangladesh

[48] K A Khan and M. M. Alam, " Performance of PKL (Pathor Kuchi Leaf) Electricity and its Uses in Bangladesh", Int. J. SOC. Dev. Inf. Syst. 1(1): 15-20, January 2010.

[49] K A Khan, M. H. Bakshi and A. A. Mahmud, "Bryophyllum Pinnatum leaf (BPL) is an eternal source of renewable electrical energy for future world", American Journal of Physical Chemistry 2014;3(5):77-83,published,online,November10,2014(http://www.sciencepublishinggroup.com/j/ajpc)doi:10.11648/j.ajpc.20140305.15,ISSN:2327-2430 (Print); ISSN: 2327-2449(Online),2014.

[50] M K A Khan, An Experimental Observation of a PKL Electrochemical Cell from the Power Production View Point, Presented as an Invited speaker and Abstract Published in the Conference on Weather Forecasting & Advances in Physics, 11-12 May 2018, Department of Physics, Khulna University of Engineering and Technology (KUET), Khulna, Bangladesh.

[51] Bapy Guha, Fakhrul Islam and K A Khan ,Studies on Redox Equilibrium and Electrode Potentials, IJARIIE-ISSN(O)-2395-4396, Volume-4, Issue-4, Page-1092-1102 , 2018

[52] Fakhrul Islam, Bapy Guha and K A Khan , Studies on pH of the PKL Extract during Electricity Generation for day and night time collected Pathor Kuchi Leaf , IJARIIE-ISSN(O)-2395-4396, Volume-4, Issue-4, Page-1102-1113 , 2018

[53] K A Khan, Mohammad Lutfor Rahman, Md. Safiqul Islam, Md. Abdul Latif, Md. Afzal Hossain Khan, Mohammad Abu Saime and M Hazrat Ali, Renewable Energy Scenario in Bangladesh, Published in the journal of IJARII, Volume-4,2018, Issue-5, page : 270-279, ISSN(O)-2395-4396.

[54] K A Khan and Salman Rahman Rasel, Prospects of Renewable Energy with Respect to Energy Reserve in Bangladesh, Published in the journal of IJARII, Volume-4,2018, Issue-5, page : 280-289, ISSN(O)-2395-4396.

[55] K A Khan, Md.Shahadat Hossain, Md.Mostafa Kamal,Md.Anisur Rahman and Isahak Miah ,Pathor Kuchi Leaf : Importance in Power Production, IJARIIE-ISSN(O)-2395-4396 , Vol-4 Issue-5, 2018

[56] K A Khan, M.Hazrat Ali, M. A. Mamun, M. Ibrahim,A K M Obaidullah, M. Afzol Hossain and M Shahjahan, PKL Electricity in Mobile Technology at the off-grid region, Published in the proceedings of CCSN-2018, 27-28 October, 2018 at Kolkata, India.2018

[57] K A Khan and Afzol Hossain, Off-grid 1 KW PKL Power Technology: Design, Fabrication, Installation and Operation, Published in the proceedings of CCSN-2018, 27-28 October, 2018 at Kolkata, India,2018

[58] K A Khan, M. A. Mamun, M. Ibrahim, Mehedi Hasan, Md. Ohiduzzaman A K M Obaidullah, M.A Wadud and M Shajahan, PKL electrochemical cell for off-grid Areas: Physics, Chemistry and Technology, Published in the proceedings of CCSN-2018, 27-28 October, 2018 at Kolkata, India.2018

[59] K A Khan, and Salman Rahman Rasel. "Studies on Wave and Tidal Power Extraction Devices" International Journal of Advance Research And Innovative Ideas In Education Volume 4 Issue 6 2018 Page 61-70

[60] K A Khan, Sultan Mahiuddin Ahmed , Mousumi Akhter , Md Rafiqul Alam , and Maruf Hossen . "Wave and Tidal Power Generation" Internation Journal Of Advance Research And Innovative Ideas In Education Volume 4 Issue 6 2018 Page 71-82

[61] K A Khan, Md. Atiqur Rahman, Md. Nazrul Islam, Mahmuda Akter, and Md. Shahidul Islam. "Wave Climate Study for Ocean Power Extraction" Internation Journal Of Advance Research And Innovative Ideas In Education Volume 4 Issue 6 2018 Page 83-93

[62] K A Khan, Md.Sujan Miah, Md. Iman Ali, Sujan Kumar Sharma, and Abdul Quader. "Studies on Wave and Tidal Power Converters for Power Production" Internation Journal of Advance Research And Innovative Ideas In Education Volume 4 Issue 6 2018 Page 94-105

[63] K.A.Khan , and Farhana Yesmin. "PKL Electricity- A Step forward in Clean Energy" Internation Journal Of Advance Research And Innovative Ideas In Education Volume 5 Issue 1 2019 Page 316-325

[64] K.A.Khan, M Hazrat Ali, A K M Obaydullah, M A Wadud, "Candle Production Using Solar Thermal Systems ",1st International Conference on 'Energy Systems, Drives and Automations', ESDA2018, Page: 55-66.

[65] K.A.Khan and Farhana Yesmin, "Cultivation of Electricity from Living PKL Tree's Leaf" International Journal Of Advance Research And Innovative Ideas In Education Volume 5 Issue 1 2019 Page 462-472

[66] K.A.Khan , and Farhana Yesmin. "Solar Water Pump for Vegetable field under the Climatic Condition in Bangladesh" Internation Journal Of Advance Research And Innovative Ideas In Education Volume 5 Issue 1 2019 Page 631-641

[67] K.A.Khan, Salman Rahman Rasel and Md. Ohiduzzaman, "Homemade PKL Electricity Generation for Use in DC Fan at Remote Areas",1st International Conference on 'Energy Systems, Drives and Automations', ESDA2018, Page: 90-99.