

Studies on Wave and Tidal Power Extraction Devices

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Abstract

Electric power from wave and tidal power is a form of pollution free and eco-friendly renewable energy which has a huge potential. This potential has not been realized high capital costs and environmental concerns. This paper discussed how the two problems could be resolved utilizing small scale technologies, innovative financing, and involving local communities of the coastal areas to ensure that all key impacts are manageable. Bangladesh has 710 km long coast line and long coastal area with 2~8 m tidal head/height rise and fall, most of which is protected against flooding by embankment and sluice gates. Therefore, the potential for wave and tidal power in the country is significant because the barrages necessary for creating controlled flow through turbines (to tap tidal power) are also needed for flood control. The wave climate has been studied for a long time at the coastal belt of Bangladesh. It has been shown that it is feasible to generate electricity using the Bay of Bengal. Our research study showed that all twelve months of the whole year are not feasible for wave and tidal power production but 8 months of the year (from the late March to October) are most suitable, feasible and viable for power production

Keywords: Harness, Converter, Tidal power, wave power.

I. Introduction

Wave energy devices can be fixed or floating and capture energy from the oscillation of waves at the surface or movement of the water column. Fig.1 below shows the areas with greatest wave power potential in the Celtic Seas and beyond, with potential at its greatest to the north and west of Scotland and the west of Ireland. Table 1 lists current activities related to wave energy generation within the SIMCelt project area.

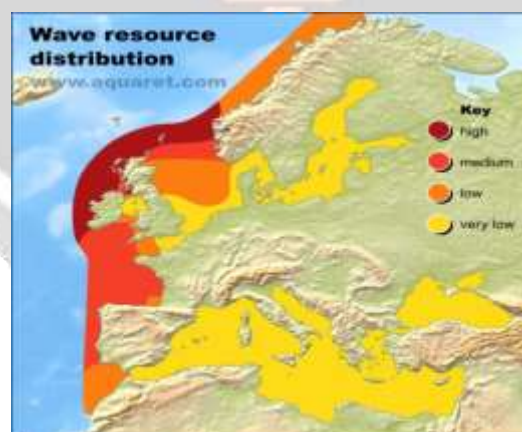


Fig. 1: Wave Resource Distribution in Europe
(Source: Aquaret.com)

Tidal current devices (turbines) are installed where there are strong ocean currents that can be used to generate energy from the fast moving waters. Tidal turbine rotors can be much smaller than wind turbine rotors, thus they can be deployed much closer together (Marine Current Turbines, 2017), however at low tidal depths close to shore generation capacity may be limited. Figure 2 shows the areas with greatest tidal stream potential in the Celtic Seas and beyond, with potential at its greatest to the west of Brittany, Gulf of St Malo, Cornwall, the Severn Estuary, Pembrokeshire coast, Anglesey, between Northern Ireland and south west Scotland and the Inner Hebrides. Table 2 lists current activities related to tidal stream energy generation within the SIMCelt project area.

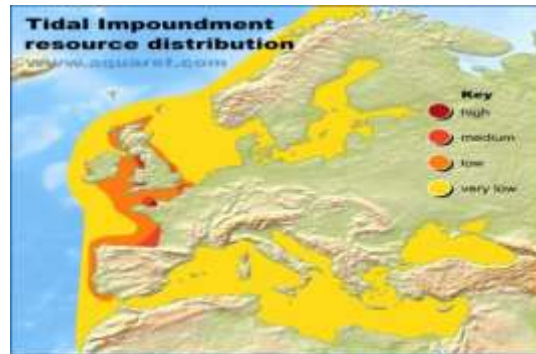


Fig. 2: Tidal Resource Distribution in Europe
(Source: Aquaret.com)

II. Methods and Materials

II.A. Tidal and Wave Power Turbine Alternatives

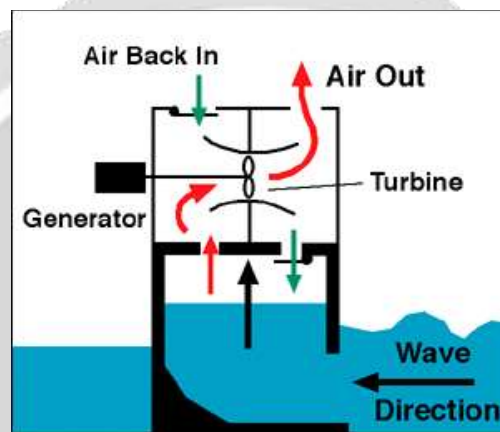


Fig.3 Wave and Tidal power turbine

The process in which Electricity is produced by using the force/movement of the waves is called Wave Power. Harnessing wave power the movement of waves on the surface of the sea is used to make large floats move up and down. These act as pumps which supply a continuous flow of water to turn a Turbine. Fig.3 is a schematic of a tidal power turbine which uses changes in air pressure caused by the tides to turn the turbine and generate electricity. This is very similar to the technique used in wave power generation

II A. Nonrenewable Energy and its impact

Energy is the driving force of the human civilization. The use of energy is indispensable in the day-to-day work, agriculture, transportation and communication, medical purposes, education, industries, entertainment etc. The conventional sources of energies are fossil fuels (like coal, petroleum and natural gases) and combustibles. But the stocks of conventional energy sources are limited and are depleting fast due to indiscriminate uses. Besides, the processes of gaining energies from conventional sources have immense harmful impact on the environment, e.g., firing of fossil-fuels emit tones of SO₂, NO₂, CO, CO₂ etc. which are liable for air pollution.



Fig. 4 Nonrenewable Energy and its impact

II.B. The World Energy Council Renewable Intensive Scenario

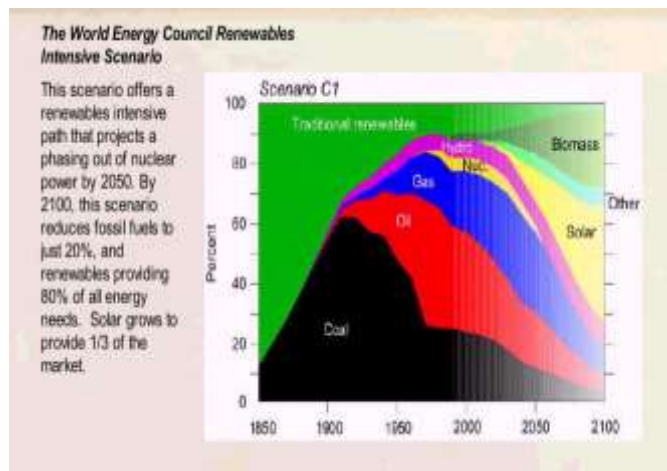


Fig.5. The World Energy Council Renewable Intensive Scenario

II.C. Ocean Wave Energy



Fig.6 Ocean Wave Energy

Ocean wave energy is captured directly from surface waves or from pressure fluctuations below the surface. Waves are caused by the wind blowing over the surface of the ocean. In many areas of the world, the wind blows with enough consistency and force to provide continuous waves. There is tremendous energy in the ocean waves. Wave power devices extract energy directly from the surface motion of ocean waves or from pressure fluctuations below the surface. Wave power varies considerably in different parts of the world, and wave energy can't be harnessed effectively everywhere. Wave-power rich areas of the world include the western coasts of Scotland, northern Canada, southern Africa, Australia, and the northwestern coasts of the United States.

II D. Classification of Ocean Wave Energy

1. Wave Energy
2. Tidal Energy
3. OTEC

II.E. Wave Energy Conversion:

Ocean energy conversion has been of interest for many years. Recent developments such as concern over global warming have renewed interest in the topic. This report focuses on wave energy converters (WEC) as opposed to ocean current energy converters. The point absorber and oscillating water column WEC devices are addressed with regards to commercial prospects, environmental concerns, and current state-of-the art. This report also provides an overview of the energy found in ocean waves and how each type of device utilizes the available ocean wave energy.

II.J: An overview of the energy found in ocean waves:

The ocean holds a tremendous amount of untapped energy. Although the oil crisis of the 1970s increased interest in ocean energy, relatively few people have heard of it as a viable energy alternative. In fact, hydroelectric dams are the only well known, mass producing water-based energy, but the ocean is also a highly exploitable water-based energy source. This presentation provides an overview of the energy found in ocean waves, the current state-of-the art in

methods used to extract this energy, commercial prospects, and environmental concerns associated with ocean wave energy extraction.

II.G: OCEAN ENERGY RESOURCES

Ocean energy comes in a variety of forms such as:

- (1) Marine currents,
- (2) Tidal currents,
- (3) Geothermal
- (4) Vents, and
- (5) Waves.

All are concentrated forms of solar or gravitational energy to some extent. Moreover, wave energy provides “15-20 times more available energy per square metre than either wind or solar” [16]. The most commercially viable resources studied so far are ocean currents and waves.

II.H: OCEAN CURRENTS

Two main types of ocean currents exist:

1. Marine currents and
2. Tidal currents.

Both types are influenced by the rotation of the Earth and are highly predictable. Marine currents such as the Gulf Stream in the Atlantic originate from differences in water temperature within the ocean. When water at the Equator warms up, it moves towards the poles then cools, sinks, and flows back towards the Equator. The speed with which this water conveyor belt moves is cyclic in that it speeds up and slows down over about a ten year period [21].

II.I: OCEAN WAVES

Ocean waves arise from the transfer of energy from the sun to wind then water. Solar energy creates wind which then blows over the ocean, converting wind energy to wave energy. Once converted, this wave energy can travel thousands of miles with little energy loss. Most importantly, waves are a regular source of power with an intensity that can be accurately predicted several days before their arrival [20]. Furthermore, wave energy is more predictable than wind or solar energy. Fig. 1 depicts wave power levels in kW/m of wave crest, the typical units for measuring wave energy.

II.K: Distribution of wave power levels (kW/m of wave front) T. W. Thorpe, ETSU, and November 1999 [11]

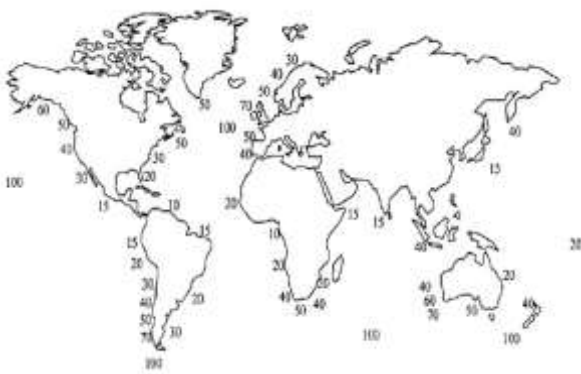


Fig.7 Approximate global distribution of wave power levels (kW/m of wave front) T. W. Thorpe, ETSU, and November 1999 [11]

II.L OCEAN WAVES

There is approximately 8,000 – 80,000 TWh/yr or 1 – 10 TW of wave energy in the entire ocean [9], and on average, each wave crest transmits 10 – 50 kW per meter. The energy levels depicted in Fig. 7 are important to keep in mind when designing any sort of wave power take-off device, but it should also be noted that wave power decreases closer to the shore because of frictional losses with the coastline.

III. Conclusion

There are a lot of advantages of wave energy. In spite of that there are there are disadvantages of wave energy:

- Sometimes you will get a lot of energy sometimes almost zero.
- Once you've built it, tidal power is free.
- It produces no greenhouse gases or other waste.
- It needs no fuel.
- It produces electricity reliably.
- Not expensive to maintain.
- Tides are totally predictable.
- Offshore turbines and vertical-axis turbines are not ruinously expensive to build and do not have a large environmental impact.

-A barrage across an estuary is very expensive to build, and affects a very wide area - the environment is changed for many miles upstream and downstream. Many birds rely on the tide uncovering the mud flats so that they can feed. Fish can't migrate, unless "fish ladders" are installed.

-Only provides power for around 10 hours each day, when the tide is actually moving in or out.

-There are few suitable sites for tidal barrages

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References

- [1] 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.
- [2] 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, November 10, 2014 (<http://www.sciencepublishinggroup.com/j/ajpc>) doi:10.11648/j.ajpc.20140305.15, ISSN:2327-2430 (Print); ISSN: 2327-2449(Online), 2014.
- [3] K. A. Khan, "Electricity Generation form Pathor Kuchi Leaf (Bryophyllum pinnatum) ", *Int. J. Sustain. Agril. Tech.* 5(4): 146-152, July 2009.
- [4] 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.
- [5] 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
- [6] 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
- [7] 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 ", *IPCBE* vol. 44 (2012) @ (2012) IACSIT Press, Singapore DOI: 10.7763/IPCBE. 2012. V44. 3
- [8] 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
- [9] 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
- [10] Tania Akter, M H Bhuiyan, Kamrul Alam 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
- [11] K. A. Khan, Inventors, Electricity Generation form Pathor Kuchi Leaf (PKL), Publication date 2008/12/31, Patent number BD 1004907, 2008
- [12] 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
- [13] 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
- [14] 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.
- [15] K. A. Khan, M S Alam, M A Mamun, M A Saime & M M Kamal, Studies on electrochemistry for Pathor Kuchi Leaf Power System, Published in the *Journal of Bangladesh J. Agric. And Environ.* 12(1): 37-42, June 2016
- [16] Mehedi Hasan, Lovelu Hassan, Sunjida Haque, Mizanur Rahman, Kamrul Alam 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
- [17] J. Sultana, K.A. Khan, and M.U. Ahmed. "Electricity Generation From Pathor Kuchi Leaf (PKL) (Bryophyllum Pinnatum)." *J. Asiat Soc. Bangladesh Sci.*, 2011, Vol. 37(4): P 167-179
- [18] M. Hasan, S. Haque and K.A. Khan, "An Experimental Study on the Coulombic Efficiency of Bryophyllum pinnatum Leaf Generated BPL Cell", *IJARIE*, ISSN(O)-2395-4396, Vol-2, Issue-1, 2016
- [19] Khan, Kamrul Alam, Akhlaqur Rahman, Md Siddikur Rahman, Aniqah 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.
- [20] Khan, Md Kamrul Alam, 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.
- [21] 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.
- [22] M Hasan and KA 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
- [23] 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.
- [24] 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.
- [25] 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.
- [26] Md. Afzol Hossain, Md. Kamrul Alam 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
- [27] K.A. Khan, M. A. Wadud, A K M Obaydullah and M.A. Mamun, PKL (Bryophyllum Pinnatum) electricity for practical utilization, IJARIE-ISSN(O)-2395-4396, Vol-4, Issue-1, Page: 957-966
- [28] 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.
- [29] 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.
- [30] 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.
- [31] 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.
- [32] Lovelu Hasan, Mehedi Hasan, Kamrul Alam 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.
- [33] Mehedi Hasan and Kamrul Alam 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.
- [34] 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 (ICCAAIT) 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
- [35] M.K.A.Khan, A K M Obaydullah, M.A. Wadud and M Afzol Hossain, "Bi-Product from Bioelectricity", IJARIE-ISSN(O)-2395-4396, Volume-4, Issue-2, Page-3136-3142, 2018
- [36] M.K.A.Khan and A K M Obaydullah, "Construction and Commercial Use of PKL Cell", IJARIE-ISSN(O)-2395-4396, Volume-4, Issue-2, Page-3563-3570, 2018
- [37] Md. Kamrul Alam Khan, "Studies on Electricity Generation from Stone Chips Plant (Bryophyllum pinnatum)", International J. Eng. Tech 5(4): 393-397, December 2008

- [38] Mr. 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
- [39] 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 IJARIE-ISSN(O)-2395-4396,Page: 4219 – 4227
- [40] 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 IJARIE-ISSN(O)-2395-4396,Volume-4, Issue-2, Page-3470-3478 ,2018.
- [41] K.A.Khan, M Hazrat Ali, M. A. Mamun, M. Mahbulul 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
- [42] 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
- References-2
- [43] Kamrul Alam Khan, "Copper Oxide Coating for use in Linear Solar Fresnel Reflecting Concentrating Collector ", Renewable Energy, An International Journal,Elsevier, WREN(World Renewable Energy Network), UK, RE: 12.97/859,1998
- [44] S. J. Hassan & K. A. Khan, "Determination of Optimum Tilt angles of Photovoltaic panels in Dhaka, Bangladesh."International J. Eng. Trach 4 (3): 139-142, December 2007. Webiste : www. Gscience. Net , 2007
- [45] S.J.Hassan & K. A. Khan, "Design, Fabrication and performance study of Bucket type solar candle machine", International J. Eng. Trach 4 (3), December 2007. Webiste : www. Gscience. Net, 2007
- [46] M. A. Hamid Khan & Dr. Md. Kamrul Alam Khan, "Nuclear science and Applications. Vol. 14, No. 11 June 2005", Nuclear science and Applications. Vol. 14, No. 11 June 2005
- [47] Kamrul Alam Khan, "Prospect of Solar Energy for Food Supply in Bangladesh", Bangladesh Journal of Scientific and Industrial Research BJSIR, 37 (1-4), January-December, 2002
- [48] B.K.Sen, K.A. Khan, M.A. Hamid Khan, M.A. Awal, "Studies on Optical & thermal properties of black copper solar selective coating on copper substance", Jahang. Phys. Studs. Vol. 9, 2001, Department of Physics, Jahangirnagar University, Savar, Dhaka, Bangladesh, 2001
- [49] M.N. Ahsan, B.K. Sen, K.A. Khan & M.A. Hamid Khan, "Performance of a Low Cost Built-in-storage Solar Water Heater", Nuclear Science and Applications vol. 8 No. 1-2, Dec 1999
- [50] A.J. Khan, Kamrul Alam Khan, Z.H. Mahmood &M.Hossain, "Performance of an Intermittently Tracked Linear Solar Fresnel Reflecting Concentrator", The Dhaka University studies, part B (science) vol. 39 No. 2 July, 1991
- [51] K.A. Khan, A.J. Khan & K.S. Rabbani, "Design & performance studies of a Linear Fresnel Reflecting Solar Concentrator-Receiver System", Bangladesh J.Sci. Res. 16 (2): 143-146, 1998
- [52] Md. Kamrul Alam Khan, "Studies on Electricity Generation from Stone Chips Plant (Bryophyllum pinnatum)", International J.Eng. Tech 5(4): 393-397, December 2008
- [53] Saiful Islam, K.A. Khan, A.K. Sadrul Islam & M. Junab Ali, "Design, Fabrication & performance study of a Paraboloidal Solar Medical Sterilizer" , Bangladesh J.Sci. Res. 18(2): 211-216, 2000 (December)
- [54] Md. Kamrul Alam Khan, Solar Selective Coating for use in Solar Concentrating Collector, Bangladesh J. Sci. Res. 16(2): 249-252, 1998 (December)
- [55] Md. Kamrul Alam Khan, The performance of a Fresnel Reflecting Concentrating Collector with Auxiliary Heating, Bangladesh J. Sci. Ind. Res. 34(2), 1999
- [56] Md. Kamrul Alam Khan, Production of Candles by Solar System in Bangladesh, Nuclear Science & Applications: vol. 7 No. 1,2: December 1998
- [57] Md. Kamrul Alam Khan, Field Testing of a Fresnel Reflecting Solar Concentrator, Nuclear Science & Applications: vol. 6 No. 1,2: December 1997
- [58] Md. Kamrul Alam Khan,A.J. Khan & K.S. Rabbani, Solar Thermal Steam Production & Distillation Device by Fresnel Reflecting Concentrator – Receiver System, Bangladesh J. Sci. Res. 16(2): 221-228, 1998 (December)
- [59] Md Shahidul Islam and Md. Kamrul Alam Khan, Performance Studies on Single Crystal Solar PV Modules for Practical Utilisation in Bangladesh, International J.Eng. Tech 5(3): 348-352, September 2008
- [60] Md. Kamrul Alam Khan, Studies on Fill Factor(FF) of Single Crystal Solar PV Modules For Use In Bangladesh, International J.Eng. Tech 5(3): 328-334, September 2008
- [61] Md. Kamrul Alam Khan, Performance Studies of Monocrystalline PV module considering the shadow effect, International J.Eng. Tech 5(3): 342-347, June 2008
- [62] Md. Shahidul Islam and Md. Kamrul Alam Khan, Study the Deterioration of a Monocrystal Solar silicon PV module Under Bangladesh Climate, International J.Eng. Tech 5(2):263-268, June 2008
- [63] Sheikh Jafrul Hassan and Md. Kamrul Alam Khan, Design, Fabrication And Performance Study of a Single phase Inverter for use in Solar PV system, International J.Eng. Tech 5(1):212-216, March, 2008
- Md. Kamrul Alam Khan, Soap Production Using Solar Power, International J. Eng. Tech 6(1):414-419, March 2009
Website :www.gscience.net

- [64] Md. Kamrul Alam Khan, Wave and Tidal Power Generation: An Overview, International J. Eng. Tech 6(1):420-423, March 2009 Website :www.gscience.net
- [43] Md. Kamrul Alam Khan, Materials Used in Electricity Generation by Solar Thermal System, International J. Eng. Tech 6(1):515-520, June 2009 Website :www.gscience.net
- [65]Md. Kamrul Alam Khan, Comparative Study on Single Crystal and Polycrystalline solar pv modules for use in Bangladesh climate, International J. Eng. Tech 6(1):527-529, June 2009 Website :www.gscience.net
- [43] Md. Kamrul Alam Khan, Solar Thermal Studies Of Open Sun Drying (OSD) of various Crops Under Bangladesh Climatic Condition, Int. J. Sustain. Agril. Tech. 5(7): 85-94, October 2009
- [66] Md. Kamrul Alam Khan, An Investigation on Various Solar Cells Under the Climatic Condition of Bangladesh, International J. Eng. Tech. 6(3): 547-551, September 2009
- [67] Md. Kamrul Alam Khan and M. Saiful Islam, Studies on Performance of Solar Photovoltaic System Under the Climate Condition of Bangladesh, Int. J. SOC. Dev. Inf. Syst. 1(1): 37-43, January 2010
- [68] Md. Kamrul Alam Khan, Application of Solar Thermal Technology for Various Developing Countries, International J. Eng. Tech. Vol 6, Issue 6, July 2009
- [69] S. M. Saifuddin & Md. Kamrul Alam Khan, Performance Study of Hybrid SPV, ST and BPL/PKL electricity Generation and storage for Practical Utilization in Bangladesh, International J. Eng. Tech : ISSN 1812 – 7711, V – 7, Issue 2, 2010
- [70] S. M. Saifuddin & Md. Kamrul Alam Khan, Survey of Hybrid Solar Photovoltaic (SPV) and Solar Thermal (ST) Collectors in Bangladesh, International J. Eng. Tech : ISSN 1812 – 7711, V – 7, Issue 3, 2010
- [71] S. M. Saifuddin & Md. Kamrul Alam Khan, Performance Study of Solar Photovoltaic and Solar Thermal Hybrid System Utilized in India, International J. Soc. Dev. Inf. Syst. 1 (4) : 10 – 16, July, 2010
- [72] Jesmin Sultana, K.A. Khan and Mesbah Uddin Ahmed, Present situation of Solar Photovoltaic System in different countries, ASA University Review, Vol-4, Issue-2, December-2010, ISSN:1997-6925
- [73] Ashique Al Rahman and Prof. Dr. Md. Kamrul Alam Khan, The Present situation of the Wave energy in some different countries of the world, IJCIT, ISSN 2078 5828(print),ISSN 2218-5224(online),Volume 02. Issue 01, Manuscript code:110754
- [74] Hasnat A,Ahmed P,Rahman M and Khan K A, Numerical Analysis for Thermal Design of a Paraboloidal Solar Concentrating Collector, International Journal of Natural Sciences(2011),1(3) 68-74
- [75] Prof. Dr. Md. Kamrul Alam Khan & Abul Hasnat Rubel, Simulated Energy Scenarios of the Power Sector in Bangladesh, ASA University Review, Vol-5, No.2, Page: 101-110, July-December, 2011,ISSN:1997-6925
- [76] Jesmin Sultana,Md.Kamrul Alam Khan and Mesbah Uddin Ahmed, Electricity Generation from Pathor Kuchi Leaf(BryophyllumPinnatum),J.Asiat.Soc.Bangladesh.Sci.,37(2):167-179, December 2011.
- [77]Mamun-Ar Rashid, Rashed-Al-Mamun,Jesmin Sultana,Hasnat A,Rahman M and Khan K A, Evaluating the Solar Radiation System under the Climatic Condition of Bangladesh and Computing the Angstrom Coefficients, International Journal of Natural Sciences (2012),2(1):38- 42. Received: November 2011, Accepted: March 28, 2012.
- [78] Jesmin Sultana, K.A. Khan and Mesbah Uddin Ahmed, The Present Situation of Solar Thermal Energy in the World, ASA University Review, Vol-4, Issue-2, December-2012,ISSN:1997-6925
- [79] Md. Kamrul Alam Khan, Md.Abdus Shatter,Shuva Paul,Shaniat Rahman Zishan,Md.Rashed Yousufe, A Study on Tidal Power Conversion for Use in Bangladesh, International Journal of Scientific Engineering Research, Volume 3, Issue 12,December-12, ISSN 2229-5518
- [80] M.S.A. Bhuiyan, K.A. Khan And M.A. Javed, A Computerized study on the metrological parameter conversions for rural agribusiness development, Journal of Innovation & Development Strategy (JIDS)(J. Innov. Dev. Strategy)J. Innov. Dev. Strategy 6(2):94-98(December 2012)
- [81]Md. Kamrul Alam 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 (IMPACT FACTOR: 1.4)
- [82] Md. Kamrul Alam Khan,Shuva Paul,Asif Zobayer,Shiekh Saif Hossain, A Study on Solar Thermal Conversion, International journal of Scientific and Engineering Research ,Volume-4,Issue-3,March-2013,ISSN2229-5518 (IMPACT FACTOR: 1.4)
- [83] M.S.A. Bhuiyan and K. A. Khan, Software Development Studies on the Metrological Conversions for Local Agri-Business Units of Area and Volume Weight Measures, Journal of Innovation & Development Strategy (JIDS), Canada, Volume:7 ,Issue: 1, April 2013. ISSN 1997-2571
- [84] M.N. Ahsan, S. Kumar, M. K. A.Khan, M. N. Khanam, R. Khatun, S. Akter., M.A.R.Aheikh, M.M. Islam, M. S.Islam, S.Saha and M. M. Alam, Study of Spatial Resolution of a Positron Emission Tomography(PET) System, Jagannath University Journal of Science, Volume: 2, Issue: 1, September 2013, ISSN 2224 – 1698.
- [85] Shuva Paul, Kamrul Khan and Ripon Kumar Kundu, Design, Fabrication and Performance Analysis of Solar Inverter, Published in the Proceedings of IEEE, ENERGYTECH 2013, USA, [Participated and Presented in the “EnergyTech2013Conference sponsored by the Institute of Electrical and Electronic Engineers(IEEE) at Case Western Reserve University in Cleveland, Ohio, USA, 21 may-23 May ,2013, USA.]
- [86] Shuva Paul, Kamrul Alam Khan and Ripon Kumar Kundu, Performance Studies of Mono-Crystal Silicon Solar Photovoltaic module with booster reflector under Bangladeshi Climatic condition, Published in the Proceedings of IEEE, ENERGYTECH 2013, USA.[Participated and Presented in the “EnergyTech2013Conference sponsored by the

Institute of Electrical and Electronic Engineers(IEEE) at Case Western Reserve University in Cleveland, Ohio, USA, 21 May-23 May, 2013, USA.]

- [87] Ashique-Al-Rahman and Kamrul Alam Khan, Feasibility Studies on WEC (Wave Energy Converter) for use in Coastal Belt at Cox's Bazar of Bangladesh under the Climate Condition of the Bay of Bengal, International Journal of Engineering and Innovative Technology, 3660 East Bay Drive, Apartment no.116 Largo, Florida US, 33771 (IMPACT FACTOR:1.895) (ISO 9001:2008 Certified)
- [88] K.A.Khan, A.Latif, S.Alam, Jesmin Sultana and Hazrat Ali, A Study on Internal Resistance of the Pathor Kuchi Leaf (PKL) Cell, Published in the journal of Agriculture and Environment. Vol.10, No. 1, June 2014, Page: 24-28.
- [89] M. N. Ahasan, D.A. Qadir, K.A.Khan and M. S. Haque, Simulation of a thunderstorm event over Bangladesh using wrf-arw model, Journal of Mechanical Engineering, Vol. ME 44, No. 2, December 2014 Transaction of the Mechanical Engineering Division, The Institute of Engineers, Bangladesh.
- [90] M. Kabir Uddin, M. Kamrul Alam Khan, M Abdus Sobhan, Farruk Ahmed, and M. Noor Nabi, On the Implications of Dynamic Wireless Spectrum Management Canons Issues in Uncertainty Use of Cognitive Radio, Published in the journal of the Bangladesh Electronics Society Journal (BESJ), Vol. 15,(1-2), 17-24, 2015
- [91] M. Kabir Uddin, M. Kamrul Alam Khan, Farruk Ahmed, and M. Noor Nabi, A Concept of Potential Radio Spectrum Administration Seeking Easy Access Spectrum (EAS) Paradigm Figured on Signal to Interference Noise Ratio (SINR) and Interference Thresholds, Published in the journal of the Bangladesh Journal of Scientific and Industrial Research, 2015 (in Review)
- [92] M. Kabir Uddin, M. Kamrul Alam Khan, M Abdus Sobhan, Farruk Ahmed, and M. Noor Nabi, Dispensation of Commons Radio Spectrum Management Framework Issues in Implementation: Challenges and Opportunities, Published in the Journal of Electronic Engineering, 2015 (in Review)
- [93] M. Kabir Uddin, M. Kamrul Alam Khan, M Abdus Sobhan, Farruk Ahmed, and M. Noor Nabi, Dispensation of Commons Radio Spectrum Management Using Conceptual Benefit and Cost Analysis Framework Issues in Bangladesh, Published in the journal of the Chittagong University Journal of Science, 2015 (in Press)
- [94] M. Shamsuzzama, S.Sikder, T. Siddiqua, M.S. Rahman, M.M.H. Bhuiyan, K.A. Khan, and D.Paul, Standardization of Gamma Radiation Field for Characterizing Radiation Detecting Instrument at SSDL facilities in Bangladesh, Published in the journal of the Bangladesh Journal of Physics (BJP), Vol. 18, 65-72, December 2015, ISSN No.: 1816-1081, BPS
- [95] MU Kabir, MA Sobhan, M KA Khan, MA Rouf Khan, Broad Network Wide Statistics of TCP Indicator Measurements to Reassume the Status of the Wireless 3G Network Monitoring, Published in the journal of the University of Information Technology and Sciences (UITS) Journal. Volume:4, Issue: 2, ISSN: 2226-3128
- [96] R.N. Sruti, M. M. Islam, M.M.Rana, M.M.H. Bhuiyan, K.A.Khan, M.K.Newaz and M.S. Ahmed, Measurement of Percentage Depth of a Linear Accelerator for 6 MV and 10 MV Photon Energies, Published in the journal of Nuclear Science and Applications, AEC, Dhaka, Bangladesh, Vol. 24, No. 1 & 2, Page No. 29-32, 2105
- [97] M. Kabir Uddin, M., M Abdus Sobhan, Farruk Ahmed, M Kamrul Alam Khan and M. Noor Nabi, A potential Electrical and Electronic Debris Management Model and Ecological Impact and Awareness Issues in Bangladesh, Journal of the National University Journal of Science. Vol. 2, No. 1, January-June 2015, ISSN: 1994-7763
- [98] Md. Mehedi Hasan, Md. Kamrul Alam Khan, Md.Nasfiqur Rahman and Md.Ziaul Islam, Sustainable Electricity Generation at the coastal areas and the Islands of Bangladesh Using Biomass Resource Published in the City University Journal, Vol-2, No.-1, March-2016, PP 09-13, 2016
- [99] M. U. Kabir, Prof. Dr. Farruk Ahmed, Dr. M A Sobhan And Kamrul Alam Khan, Dispensation of Commons Radio Spectrum Management Framework Issues in Implementation: Challenges and Opportunities, Published in the journal of the Bangladesh Electronic Society (BES), (ISSN: 1816-1510) Vol. 16 Number 1-2, June-December 2016 issue
- [100] K.A. Khan, M S Alam, M A Mamun, M A Saime & M M Kamal, Studies on electrochemistry for Pathor Kuchi Leaf Power System, Published in the Journal of Bangladesh J. Agric. And Envirin. 12(1): 37-42, June 2016
- [101] Tania Akter, M H Bhuiyan, Kamrul Alam Khan and M H Khan, "Impact of photoelectrode thickness and annealing temperature on natural dye sensitized solar cell", Published in the journal. of Elsevier. Ms. Ref. No.: SETA-D-16-00324R2
- [102] Md. Kamrul Alam Khan, Performance of electricity generation from Bryophyllum Leaf for Practical Utilization, Abstract published and Presented in the APS April meeting, January 28-31, 2017, Session T1 (Page No.: 201), Washington DC, USA. Bulletin of the American Physical Society, VOL 62, No. 1
- [103] 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, Available online 6 September 2017, In Press, Accepted Manuscript — Note to users
- [104] 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 IJARIE-ISSN(O)-2395-4396, Volume-4, Issue-2, Page-3470-3478, 2018
- [105] K.A.Khan, M Afzol Hossain, A K M Obaydullah and M.A. Wadud, PKL Electrochemical Cell and the Peukert's Law, Published in the IJARIE-ISSN(O)-2395-4396, Volume-4, Issue-2, Page:4219-4227, 2018
- [106] K.A.Khan, M Hazrat Ali, M. A. Mamun, M. Mahbulul Haque, A.K.M. Atique Ullah, Dr. Mohammed Nazrul Islam Khan, Lovelu Hassan, A K M Obaydullah, M A Wadud, 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
- [107] 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, International Journal Of Advance Research And Innovative Ideas In Education Volume 4 Issue 4 2018 Page 229-244
- [108] K.A.Khan, Mahmudul Hasan, Mohammad Ashraf Islam, Mohammad Abdul Alim, Ummay Asma, Lovelu Hassan, and M Hazrat Ali, A Study on Conventional Energy Sources for Power Production, International Journal Of Advance Research And Innovative Ideas In Education Volume 4 Issue 4 2018 Page 229-244
- [109] Md. Kamrul Alam 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 Accession Number: 17542905, DOI: 10.1109/EICT.2017.8275150, Publisher: IEEE, Conference Location: Khulna, Bangladesh
- [110] Bapy Guha, Fakhru Islam and K. A. Khan, Studies on Redox Equilibrium and Electrode Potentials, IJARIE-ISSN(O)-2395-4396, Volume-4, Issue-4, Page-1092-1102, 2018
- [111] Fakhru 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, IJARIE-ISSN(O)-2395-4396, Volume-4, Issue-4, Page-1103 -1113, 2018
- [112] Somiron Mistry, Prospect Of Solar Energy Use In Bangladesh, A Project Submitted to the Department of Mechanical Engineering in Partial Fulfillment of the Requirements for the Degree of Master Of Engineering In Mechanical Engineering, Department OF Mechanical Engineering Bangladesh University of Engineering & Technology Dhaka, Bangladesh, 2009.
- [113] 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
- [114] 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, Accepted in the Springer Nature, Series Title: Advs in Intelligent Syst., Computing, Volume Number: 812, Book Title: Contemporary Advances in Innovative and Applicable Information Technology, Book Subtitle: Proceedings of ICCAIAIT 2018, ISBN: 978-981-13-1539-8, 2018
- [115] 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.
- [116] 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.
- [117] K.A.Khan, Md.Shahadat Hossain, Md.Mostafa Kamal, Md.Anisur Rahman and Isahak Miah, Pathor Kuchi Leaf : Importance in Power Production, IJARIE-ISSN(O)-2395-4396, Vol-4 Issue-5, 2018
- [118] 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.
- [119] 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.
- [120] 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.