BAUET JOURNAL
Published by
Bangladesh Army University of Engineering & Technology
Journal Homepage: http://journal.bauet.ac.bd/

Observation of Fuel Cell Technology and Upgraded Photovoltaic System for Rural Telecom System in Bangladesh

Md. Mahmudul Hasan[1] *, Nafiul Hasan[2], Md. Momtazur Rahman[3]

12,3 Department of Electrical and Electronic Engineering, Faculty of Electrical and Electronic Engineering, Bangladesh Army University of Engineering & Technology, 6431, Natore, Bangladesh

Abstract: The objective of this paper is to explore feasibility of green power generation for telecommunication system in Bangladesh. The possibility of solar, fuel cell as primary and backup power source for base transceiver station (BTS) at telecom sites, local data transmission system etc. situated in remote area as well as in islands off the national grid or having poor electricity supply is deeply analyzed here. Power assurance to BTS even in massive black out is the real headache of today's global world. Among various types of fuel cell proton exchange membrane fuel cell (PEMFC) and an upgraded photovoltaic system (solar) have introduced here. Enhancing the PEMFC efficiency to 57.26% and lifetime of PEMFC is also conceptualized in this paper. Not only power assurance but also environmentally friendly technology has also given deep concern.

Keywords: *Fuel cell; Proton exchange membrane fuel cell; Photovoltaic system; Base transceiver station; Renewable energy*

Introduction: Mobile telecommunication system or basically cellular network is a combination of base transceiver station, mobile switching center etc. These stations and switching centers need continuous power supply even in black outs. As traditional backup power supply lead acid battery and diesel generator (DG) are familiar. But they have major disadvantage of sulfation and pollution, noise, high cost, low efficiency of 33% respectively. At present only 10% of rural households have electricity [1]. In a prediction, national grid of Bangladesh might be capable of giving electricity to some parts of Bangladesh within next 30 years. In addition, On November 01, 2014 Bangladesh faced massive blackout [2]. The whole country was without electricity for 10 hours. Such blackouts can be happened anytime for any reason such as natural disaster or power grid failure. BTS situated in remote areas having no national grid supply. Addition to that in islands, primary and secondary both power supplies has to be ensured. At the rest of the places, BTS have to be equipped with backup power supply.

Operation of Fuel Cell: The operation of fuel cell is alike a battery. Chemical energy of a fuel cell and oxidant is converted into electricity. Usually Hydrogen, the fuel is derived from natural gas, electrolysis of water or biogas. Fuel cell doesn't need any recharging. There are various types of fuel cells. Table 1 shows them with features. Ramos et al. argued that with specific reactant flow pressure & between ranges of operating temperature, PEMFC is far better option [3-5].

Proton Exchange Membrane Fuel Cell (PEMFC): Krishna et al. concluded that the low operating temperature is not capable of taking so much time to warm up and to start generating electricity.

PEMFC has the lowest operating temperature between 600-1000°C with an efficiency of 35%-45% which means it needs seconds to start up [6]. Alkaline fuel cell (AFC) is also very fast starting and have

Article history:
Received 20 November 2017,
Received in revised form 20 December 2017
Accepted 27 December2017,
Available online 30 March 2018

Corresponding author details:
E-mail address: mubin.eee.kuet@gmail.com
Tel: +8801722095042

a good efficiency (40%-50%) but PEMFC have very much greater power density (about 3.8-6.5 KW/m^3) than all others [7-9]. Besides it comes in various configuration allowing plug and play installation [10]. MCFC, SOFC have high operating temperature and works better than the conventional power plants. Fig 1 represents PEMFC. Generally, hydrogen is used as fuel which can be easily produced by biogas as Bangladesh is an agricultural country [11]. A report says Bangladesh had waste disposal of 22.4 million tons/year and it is predicted to have 47064 tons/day in 2025 [12-13]. So it is not a big deal to arrange sufficient amount of hydrogen for the fuel cells to be installed

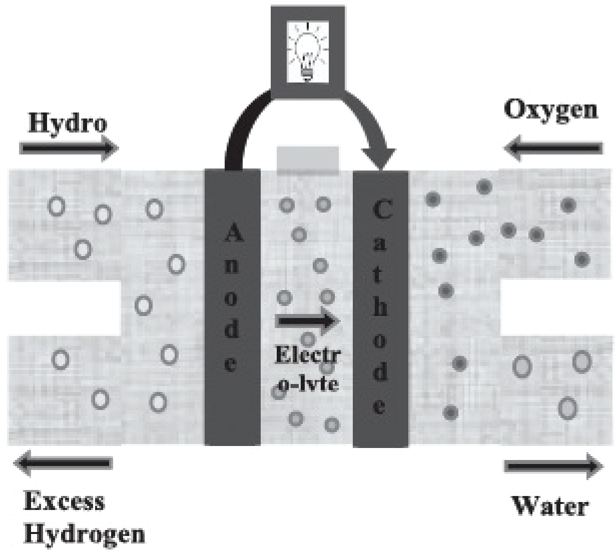

Fig.1: Structure of PEMFC. [19]

Table 1. Various Types of Fuel Cell [14-16]

Fuel cell	Prime cell components	Fuel	Power density KW/m^3	Efficiency	Operating temperature (^0C)
PEMFC	Carbon	H_2, CH^3OH	3.8-6.5	30-45%	60-100
AFC	Carbon	H_2	1.0	40-50%	100-250
PAFC	Graphite	H_2	0.8-1.9	55%	150-250
MCFC	Stainless steel	CO	1.5-2.6	55-65%	500-700
SOFC	Ceramic	CO	0-1.5	55-65%	700-1000

Development of Fuel Cell Technology for Mobile Network: Many countries have been already introduced with fuel cell in the matter of mobile telecommunication system inluding neighboring country India [17]. Pereiara et al. expected in a case study that in 2020 sales of fuel cell is to be reached at 100000 units/year in Europe as 17000 units sold till 2012 [18]. The commPac which is shown in Fig. 2 indicates that 5 KW contains 60 KWh of energy. At the outside of the cabinet hydrogen cyclenders can be added. Case study shows that based on 6 cyclinders at 8.5 Nm^3 at 200 bars each, a 5 KW commPac operates for 15 hours [19-21]. At menville telecom site during 5 months of experiment AXANE got 2900 hours of operation, 2.6 MWh is produced, 1000 hours' average lifetime for membranes and 1 month of operation without any interruption.

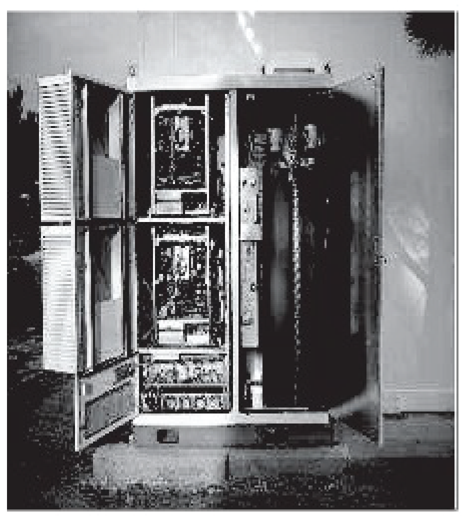

Fig. 2: Comm Pac Balises (60 kWh) [19]

Nokia Siemens Networks have developed a fuel cell system. The system is designed especially for base stations and available in either methanol fuelled or direct hydrogen configuration. Nokia Siemens Networks and Ballard Power System won E-Tech award at CTIA 2013 in "Green Telecom and Smart Energy Solutions" category [22]. Ballard's FCgen-1020ACS is expected to see expansive deployment across several large markets [23].

Enhancement of Efficiency and Lifetime of PEMFC: Luna et al. proposed a non linear model predictive control strategy to ensure maximum active area in the cathod catalyst layer (avoiding fuel) and oxidant starvation at both sides of the fuel cell; providing 57.26% efficiency [24-26]. According to the given simulation, development of a real PEMFC based system is in progress. A sysnthetic driven cycle based on new European driving cycle (NEDC) was used to experiment the control strategy [27].

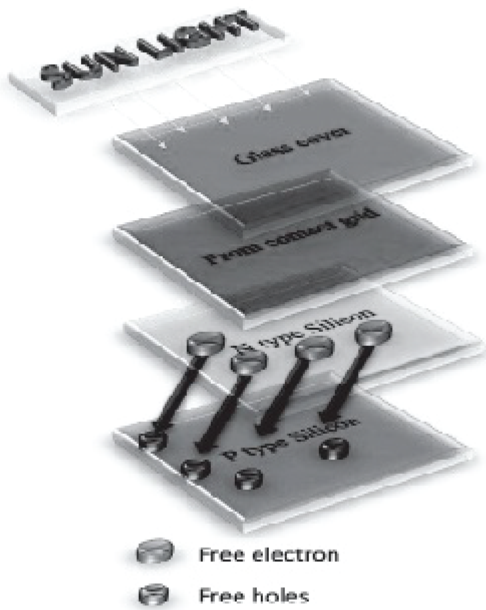

Fig. 3: Solar panel construction [28]

Solar Cell: N type and P type silicon has free electrons and holes respectively. Sun ray consists of photons, impact with negative charged electrons. So electrons loose from atoms and cause electric potential difference. Due to the structure current starts flowing [28-30]. Sohag et al. concluded that an accurate and efficient solar tracking system using image processing and LDR sensors increase 30% efficiency of solar panel [31]. They suggested PLC to control many solar panels and Raspberry Pi instead of using computer to minimize the cost [32-33]. Fig. 3 gives a perspective of operating principle of solar panel.

Cost Analysis: R.K pachauri et al conducted a case study in India of 3 outdoor BTS including a 10 KVA diesel generator and 48 V, 600 Ah battery [34-35]. Average electrical power demand of that site was 2.52 KW [36]. Solar and fuel cell have average life time of 25 years and 26000 hours respectively. It is seen that cost of PV and FC energy is 310.76 INR/day; for 6 hours/day and 14 hours'/day operation respectively. The battery bank of 600Ah supplied power for 4 hours/day. This scenario can be similarized for BTS at remote places or in islands having no national grid supply [37].

On the other hand, it was 794.16 INR/day while using diesel generator set for 8 hours/day and rest of the time grid supply and 600Ah battery bank power supplied. In this case total cost is 997.16 INR/day [38-39]. Instead of diesel generator, if fuel cell is used for 8 hours/day, cost would be 171.69 INR/day. So total cost will be now 374.69 INR/day [40-41]. This perspective can be similarized for BTS at urban and rural areas where load shedding is a common scenario. Ballard Power Systems received initial 100-unit order from Reliance Jio Infocom for backup power system at India in 2015 [42]. It is a matter of great regreat that this fuel cell technology is not introduced yet in Bangladesh.

To visualize the cost of fuel cell and compare with cost of diesel generator at Bangladesh, a case study is conducted. A 10 KVA Kirloskar SEKG10A55 diesel generator set of 10000 hours' lifetime costs 370000 BDT in Dhaka. According to Bangladesh petroleum corporation price of diesel is 65 BDT/liter [43-45]. The generator consumes 1.25 litre/hour. Table 2 shows estimated total cost 3222500 BDT for 26000 hours of operation. To compare we equalize both cases for the same time period (26000 hours).

In the case of 3 KW Horizon PEM fuel cell, Table 3 shows estimated total cost 1611977 BDT (including installation cost of 11570 $) for 26000 hours of operation [46]. The exchange rate between USD and BDT is 1:78, INR and BDT is 1:1.27, British pound and BDT is 1:107.40 according to Bangladesh bank [47].

Table 2. Cost Analysis of Diesel Generator

10 KVA diesel generator	**Estimated Level of cost for 26000 hours (BDT)**
Installation cost	370000 × 2.6 times = 962000
Fuel cost	65×1.2×26000= 2112500
Total cost	3074500

Table 3. Cost Analysis of Fuel Cell

Horizon 3 KW PEMFC	**Estimated Level of cost for 26000 hours (BDT)**
Installation cost	11570 $ × 78 = 902460
Fuel cost	{(171.9 INR × 1.27)/8}×26000 = 709517
Total cost	1611977

For IPS sytem, Rahimafrooz JUMBO 10 KVA, 7500 watts and 15 units of 150 Ah IPB150TT battery of tall tabular plate was selected. These cost 499000 BDT and 255300 BDT respectively, a total amount of 754300 BDT with a warranty of 30 months [48-50]. Table 4 gives a clear view of this. IPS system will act as backup power source.

Table 4. Cost Analysis of Is System

System	**Estimated Installation cost for 10000 hours (BDT).**
IPS 10 KVA , 7500 W	499000
Battery 150 Ah (1 life time)	17020 × 15 units = 255300
Total	754300

For solar system to generate 3 KW, 21 sq. meter solar is required; which costs about 644400 BDT. 15 units of 150 Ah battery is also required [51]. Table 5 makes a clear perspective.

Table 5. Cost Analysis of Solar System

Solar 3 KW	Estimated cost for 10000 hours (BDT)
Panel 21 sq m.	£6000×107.4 =644400 BDT
Battery 150 Ah	17020 × 15 units =255300
Total	899700

In this circumstances stated above it can be concluded that using of PEMFC instead of diesel generator saves about 1462523 BDT (saving of 47% with respect to diesel generator) over the period of 26000 hours.

If IPS, solar and diesel generator (DG) acts as secondary power source; the data of table 2 is needed to be equalized. Installation cost of DG will (37000BDT/10 years) =37 BDT/hour. For 8 hours it would be 37 × 8 = 296 BDT excluding fuel cost of 78 BDT/hour if load shedding of 8 hours/day is assumed [52]. Table 6 gives a better view of these data. Diesel generator as secondary power source costs 1150000 BDT for the same time period of IPS, solar system is said.

Table 6. Cost Analysis of Diesel Generator and Pemfc as a Backup Power

10 KVA diesel generator	Estimated cost for 10000 hours (BDT)
Installation cost (1 unit= 10000 hours)	370000
Diesel	78×10000=780000
Total	1150000
PEMFC	(1611977/260000) ×10000=619991

Analyzing all the data Fig. 4 shows, as secondary power source, saving of IPS, solar, PEM fuel cell are 35%, 22%, 46% respectively with respect to diesel generator. Fuel cell power plants are already in operation all over the world including the largest fuel cell power plant of 59 MW in Hwasung city at South Korea [53].

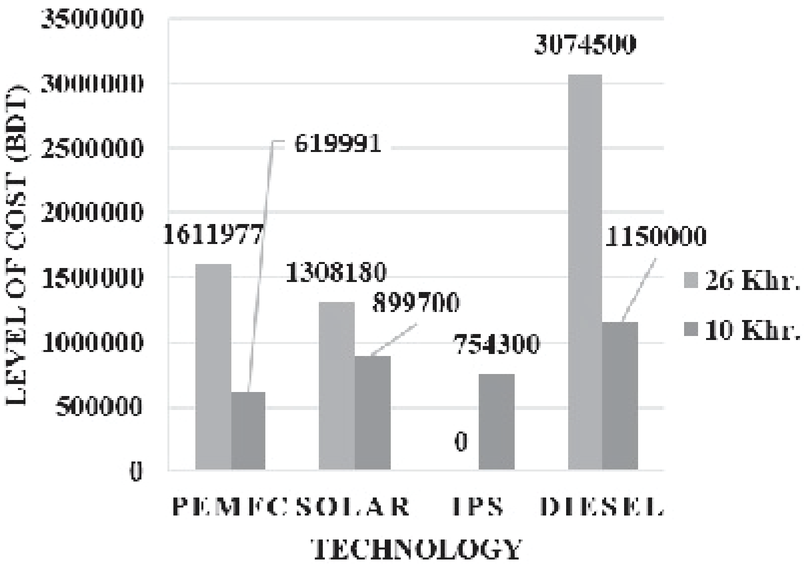

Fig. 4: Level of cost (BDT) v/s technology

Future Scope: Nernst is the ideal standard voltage [54]. Activation voltage drop, ohmic voltage drop, concentration voltage drop affects the efficiency of fuel cell. To manage the power flow fuzzy logic parameter tuning is to be used. It will keep balance between FC and battery. Lyapunov theory shows relativeness. MATLAB simulation shown in [55] gives rise to this possibility. The efficiency is tried to be increased more.

Discussion: For both primary and secondary power supply PEM fuel cell is better. Diesel generator causes environment pollution and costly; infact it costs near to double of PEMFC. Fuel cell, solar are renewable energy but IPS is just an instant solution for a rich class of buyers. The national grid doesn't get supported by using IPS. Renewable energy decreases the demand on national grid power supply and fossil fuels as most of our power plants are based on fossil fuels. According to BPDB 62.97% of our total electricity generation comes along from natural gas [56-57]. The analysis points out that PEMFC can be used in islands also, not only for BTS but also for whole locality. Fuel cell based power plant have already installed in developed countries and operating. The world is going after renewable energy and efficient technology; fuel cell is the best one.

Conclusion: Massive blackout isn't unfamiliar to Bangladesh. However, load shedding is a common scenario in Bangladesh and there are certain locality having no access to the national grid but mobile telecommunication has to be established there also. As secondary power source for telecommunication, fuel cell is remarkable since they have low cost than others, easy to maintain, available fuel management, efficient technology and eco-friendly. Bangladesh has large telecom market (since densely populated country) where fuel cell industries are willing to invest. This paper succesfully visualize the necessity of introduction to fuel cell as well as renewable energy in Bangladesh telecom sector. It also emphasizes on the use of renewable energy instead of traditional diesel generator for environmental safety and which will make the world a better place to live.

References:

[1] K. Anam, H. A. Bustam, "Power Crisis & Its Solution through Renewable Energy in Bangladesh", Cyber Journals: Multidisciplinary Journals in Science and Technology, Journal of Selected Areas in Renewable and Sustainable Energy (JRSE) (September Edition, 2011).

[2] J. Twidell, T. Weir, "Renewable Energy Resources". Routledge, 2015.

[3] C. A. Ramos Paja, et aI., "Minimum Fuel Consumption Strategy for PEM Fuel Cells", IEEE Transactions on Industrial Electronics, vol. 56, No. 3, pp. 685-696, Mar. 2009.

[4] W. Su, H. Eichi, W. Zeng, and M.-Y. Chow, "A survey on the electrification of transportation in a smart grid environment," IEEE Transactions on Industrial Informatics, vol. 8, no. 1, pp. 1–10, 2012.

[5] U. Eberle, B. M¨uller, and R. von Helmolt, "Fuel cell electric vehicles and hydrogen infrastructure: status 2012," Energy & Environmental Science, vol. 5, no. 10, pp. 8780–8798, 2012.

[6] D. Feroldi, M. Serra, and J. Riera, "Design and analysis of fuel-cell hybrid systems oriented to automotive applications," IEEE Transactions on Vehicular Technology, vol. 58, no. 9, pp. 4720–4729, 2009.

[7] R. Krishna, M.L. N. Kumar "Fuel Cell for Telecom Applications: A Low Cost Green Back-up Power System Alternative to Diesel Generators", IEEE transactions on industrial electronics.

[8] M. Jang, M. Ciobotaru, and V. G. Agelidis, "Design and implementation of digital control in a fuel cell system," IEEE Transactions on Industrial Informatics, vol. 9, no. 2, pp. 1158–1166, 2013.

[9] I. L. Sarıo˘glu, O. P. Klein, H. Schr¨oder, and F. K¨uc¸ ¨ukay, "Energy management for fuel-cell hybrid vehicles based on specific fuel consumption due to load shifting," IEEE Transactions on Intelligent Transportation Systems, vol. 13, no. 4, pp. 1772–1781, 2012.

[10] Waste Atlas. (2012). country Data: Bangladesh.

[11] J. Bauman and M. Kazerani, "A comparative study of fuel-cell–battery, fuel-cell–ultracapacitor, and fuel-cell–battery–ultracapacitor vehicles," IEEE Transactions on Vehicular Technology, vol. 57, no. 2, pp. 760–769, 2008.
[12] M. Chen and G. A. Rincon-Mora, "Accurate electrical battery model capable of predicting runtime and iv performance," IEEE Transactions on Energy Conversion, vol. 21, no. 2, pp. 504–511, 2006.
[13] Z. Jiang and R. A. Dougal, "A compact digitally controlled fuel cell/battery hybrid power source," IEEE Transactions on Industrial Electronics, vol. 53, no. 4, pp. 1094–1104, 2006.
[14] X. Hu, N. Murgovski, L. M. Johannesson, and B. Egardt, "Optimal dimensioning and power management of a fuel cell/battery hybrid bus via convex programming," IEEE/ASME Transactions on Mechatronics, vol. 20, no. 1, pp. 457–468, 2015.
[15] C. Carrejo, R. Giral, E. Arango, C. Ramos-Paja, C. Olalla, and C. Alonso, "Fuel cell hybrid topologies selection and control," in 2011 International Conference on Power Engineering, Energy and Electrical Drives (POWERENG). IEEE, 2011, pp. 1–6.
[16] Y. Ates, O. Erdinc, M. Uzunoglu, and B. Vural, "Energy management of a FC/UC hybrid vehicular power system using a combined neural network-wavelet transform based strategy," International Journal of Hydrogen Energy, vol. 35, no. 2, pp. 774–783, 2010.
[17] M. Karthik and K. Gomathi, "Design, modeling and simulation study of a cascaded optimal neural network based fuel cell powered electric vehicle," in 2014 IEEE 2nd International Conference on Electrical Energy Systems (ICEES). IEEE, 2014, pp. 71–76.
[18] C. P. Bahia, P. Paulmier "Operational Feed-Back on Fuel Cell Solutions for Telecom Needs", AXANE Fuel Cell Systems SA.
[19] P. Thounthong, S. Rael, and B. Davat, "Energy management of fuel cell/battery/supercapacitor hybrid power source for vehicle applications," Journal of Power Sources, vol. 193, no. 1, pp. 376–385, 2009.
[20] M. Pahlevaninezhad, P. Das, J. Drobnik, G. Moschopoulos, P. K. Jain, and A. Bakhshai, "A nonlinear optimal control approach based on the control-lyapunov function for an AC/DC converter used in electric vehicles," IEEE Transactions on Industrial Informatics, vol. 8, no. 3 pp. 596–614, 2012.
[21] The NOKIA Notebook (2014).
[22] D. Feroldi, M. Serra, and J. Riera, "Energy management strategies based on efficiency map for fuel cell hybrid vehicles," Journal of Power Sources, vol. 190, no. 2, pp. 387–401, 2009.
[23] J. Luna, E. Usai, A. Husar, and M. Serra, "Enhancing the Efficiency and Lifetime of a Proton Exchange Membrane Fuel Cell using Nonlinear Model Predictive Control with Nonlinear Observation", IEEE transactions on industrial electronics.
[24] F. R. Salmasi, "Control strategies for hybrid electric vehicles: Evolution, classification, comparison, and future trends," IEEE Transactions on Vehicular Technology, vol. 56, no. 5, pp. 2393–2404, 2007.
[25] J. P. Torreglosa, P. Garcia, L. M. Fernandez, and F. Jurado, "Predictive control for the energy management of a fuel-cell-battery-supercapacitor tramway," IEEE Transactions on Industrial Informatics, vol. 10, no. 1, pp. 276–285, 2014.
[26] M. Mayur, S. Strahl, A. Husar, and W. G. Bessler, "A multi-timescale modeling methodology for PEMFC performance and durability in a virtual fuel cell car", International Journal of Hydrogen Energy, vol. 40, no. 46, pp. 16 466–16 476, 2015.
[27] D.U. Ike, A. U. Adoghe, A. Abdulkareem, "Analysis of Telecom Base Stations Powered by Solar Energy".
[28] A. Taghavipour, M. Vajedi, N. L Azad, and J. McPhee, "Predictive power management strategy for a phev based on different levels of trip information," in Engine and Powertrain Control, Simulation and Modeling, vol. 3, no. 1, 2012, pp. 326–333.
[29] D. Gao, Z. Jin, and Q. Lu, "Energy management strategy based on fuzzy logic for a fuel cell hybrid bus," Journal of Power Sources, vol. 185, no. 1, pp. 311–317, 2008.
[30] M. H. A. Sohag, M.M. Hasan, M. M. Khatun, M. Ahmad, "An Accurate and Efficient Solar Tracking System Using Image Processing and LDR Sensor", Proceedings of International Conference on Electrical Information and Communication Technology (EICT 2015).
[31] H. Hemi, J. Ghouili, and A. Cheriti, "A real time fuzzy logic power management strategy for a fuel cell vehicle," Energy Conversion and Management, vol. 80, pp. 63–70, 2014.
[32] A. A. Ferreira, J. A. Pomilio, G. Spiazzi, and L. de Araujo Silva, "Energy management fuzzy logic supervisory for electric vehicle power supplies system," IEEE Transactions on Power Electronics, vol. 23, no. 1, pp. 107–115, 2008.

[33] R. K. Pachauri, Y. K. Chauhan, "Hybrid PV IFC Stand Alone Green Power Generation: A Perspective for Indian Rural Telecommunication Systems", International Conference on Issues and Challenges in Intelligent Computing Techniques (ICICT), 2014.
[34] O. Tremblay, L.-A. Dessaint, et al., "A generic fuel cell model for the simulation of fuel cell vehicles," in 2009 IEEE Vehicle Power and Propulsion Conference. IEEE, 2009, pp. 1722–1729.
[35] B. Azzopardim, N. Espinosa, and V. R. Garcia, "Economical Assessment of Solar Electricity from Organic Pbotovoltaic Systems," in Proceedings of lET conference on Renewable Power Generation at Edinburgh, 6-8 Sept.2011, pp. 1-2.
[36] M. Hilairet, M. Ghanes, O. B´ethoux, V. Tanasa, J. Barbot, and D. Normand-Cyrot, "A passivity-based controller for coordination of converters in a fuel cell system," Control Engineering Practice, vol. 21, no. 8, pp. 1097–1109, 2013.
[37] K. Jin, et aI., "A Hybrid Fuel Cell Power System," IEEE Transactions on [ndustrial Electronics, vol. 56, no. 4, pp. 212-222, Nov. 2008.
[38] L. Gao, S. Liu, and R. A. Dougal, "Dynamic lithium-ion battery model for system simulation," IEEE Transactions on Components and Packaging Technologies, vol. 25, no. 3, pp. 495–505, 2002.
[39] T. Das and S. Snyder, "Adaptive control of a solid oxide fuel cell ultra-capacitor hybrid system," IEEE Transactions on Control Systems Technology, vol. 21, no. 2, pp. 372–383, 2013.
[40] W. J. Rugh, Linear System Theory. Prentice Hall Upper Saddle River, NJ, 1996, vol. 2.
[41] Brochure of The Bangladesh Petroleum Corporation (2017).
[42] B. Wahdame, D. Candusso, X. Franois, F. Harel, M. C. Pra, D. Hissel, and J. M. Kauffmann, "Analysis of a fuel cell durability test based on design of experiment approach," IEEE Transactions on Energy Conversion, vol. 23, no. 4, pp. 1093–1104, 2008.
[43] CHen, Yi Baolian. "Fuel cell: Theory and technology and application." Beijing: Chemical Industry Press, 2003:181-308.
[44] Larminie J, Dicks A. Fuel cell systems explained. New York: Wiley ,2000:11-18
[45] WANG Cai-sheng, Nehrir M H, Shaw S R. "Dynamic models and model validation for PEM fuel cells using electrical circuits." IEEE Transaction on Energy Conversion, 2005, 20(2): 442-449.
[46] Brochure of The Rahimafrooz Company, Bangladesh (2018).
[47] Shan Y Y, Choe S Y. "A high dynamic PWM fuel cell model with temperature effects. Journal of Power Sources, 2005, 145:30-39."
[48] Jeferson M C, Felix A F, et al. "An electrochemical -based fuel cell model suitable for electrical engineering automation approach". IEEE transactions on Industrial Electronics, 2004, 51(5):1103-1110.
[49] Berning T, Lu D M, Djilali N D. "Three-dimensional computational analysis of transport phenomena in a PEM fuel cell". J Power Sources, 2002,106(1/2):284-294.
[50] Baschuk J J, LI Xiao-guo. "Model of polymer electrolyte membrane fuel cells with variable degrees of water flooding." Journal of Power Sources, 2000, 86(1/2): 181-196.
[51] (2017), Brochure of The Rahimafrooz Company, Bangladesh
[52] Shan Y Y, Choe S Y. "A high dynamic PWM fuel cell model with temperature effects". Journal of Power Sources, 2005, 145:30-39.
[53] Jeferson M C, Felix A F, et al. "An electrochemical -based fuel cell model suitable for electrical engineering automation approach". IEEE transactions on Industrial Electronics, 2004, 51(5):1103-1110.
[54] Joshua G, Daniel R L. "Model-based control of fuel cells." Journal of Power Sources, 2004, 135:135-151.
[55] X. Qian, z. Shi et al "Measurement and control platform of the Proton Exchange Membrane of Fuel Cell based on the MATLAB/Simulink", Chinese Automation Congress (CAC), 2017
[56] M. M. Hasan, M. M. Rahman, N. Hasan, M.A. Alim M.M. Islam, "Geothermal Power Generation possibility and Geothermal sites in Bangladesh: A Review", Bangladesh Army University of Engineering & Technology journal, Volume 01, Issue 01, 2017.
[57] J. chen, C. Xu, C. Wu, W. Xu, "Hybrid Systems for Electric Vehicles, Adaptive Fuzzy Logic Control of Fuel-Cell-Battery Hybrid Systems for Electric Vehicles", IEEE Transactions on Industrial Informatics, volume 14, issue 1, Jan, 2018