International Journal For Technological Research In Engineering
Volume 4, Issue 8, April-2017 *ISSN (Online): 2347 - 4718*

SOLAR PV AND FUEL CELL HYBRID POWER SYSTEM CONNECTED WITH BOOST CONVERETER

Khushal J Bhadra[1], Prof. R.D.Bhagiya[2], Prof. A.L.Vaghamshi[3]
[1]M.E Scholar, Power System, [2,3]Assistant Professor, Department of Electrical Engineering,
GOV. Engg College, Bhuj Gujarat Technological University, Gujarat, India

Abstract: A hybrid system of Solar Photovoltaic, Battery, Super capacitor , Hydrogen Fuel Cell to meet isolated DC load demand. The Solar Energy is the primary energy source, whereas battery and SC both are considered for their different power density to supply transient and steady load respectively. To increase the reliability of the system the fourth source Hydrogen Fuel Cell has been chosen to keep the battery fully charged. Sources are connected to DC bus by different DC-DC converters. A power flow control strategy adapts their variable DC voltage to Bus voltage by means of these converters. Work In this paper, Hydrogen Fuel Cell is chosen to work for a limited period. This will avoid the over sizing of the Hydrogen Fuel Cell and limit the operational cost of the system.
Key Words: Solar Photovoltaic, Hydrogen Fuel Cell, Hybrid System

I. INTRODUCTION

Due to the fast depletion of fossil fuel and increasing pollution rate renewable energy sources have become most effective source of energy. But the major challenge in integration of these renewable sources is its intermittent nature and cost. Solar Photovoltaic is one of the most effective renewable energy sources. But it is not available at night time. However, Hydrogen Fuel Cell can be available for the whole day, but it increases the system cost. This ensures the requirement of two or more renewable energy sources. Therefore, to make this kind of hybrid system more reliable and cost effective, there must be some energy storage devices to store the available energy as much as possible. Battery and Supercapacitor are used for storage purposes. The important advantage of battery is its high energy density, battery can store at least 3-30 times more charge than Super capacitor. Whereas, SuperCapacitors are able to deliver hundred to thousand time more power than a similar sized Battery. So Battery is able to supply long term energy demand and SC is essential to meet transient load demand. The energy management, lower running cost and system reliability are of particular interest. In this paper hybrid Solar PV- Fuel Cell system has been chosen for the application of standalone DC load isolated from the utility grid. It can be a critical load located in remote areas, telecom load, ATM, Hospital, military establishment etc. Battery and Supercapacitor both as the storage device make the system able to supply all type of loading condition. Whereas Solar PV and FuelCell, being the main sources try to keep the storage devices charged to desired level. In this study, a new control strategy has been proposed for Fuel Cell system. FC is only used to charge Battery when Battery SoC reaches below its specified minimum SoC limit, which will reduce fuel usage by reducing FC running period, thus reducing system operational cost. Section 2. describes the modelling of hybrid system description followed by control objectives of system in Section 3. the proposed energy management strategy has been described with individual controller model. In system description is presented. Section 4. comprise of validation of the objectives with result. It is followed by the conclusion in Section 6.

II. MODELLING OF SYSTEM

The proposed hybrid Energy system considering PV-FC is shown in Fig.1. The whole system is used to supply a variable DC load. PV and FC are used as the primary and auxiliary sources respectively while Battery and super capacitor are the energy storing elements. PV arrays are interfaced with the load by means of buck converter including maximum power point tracking to always extract maximum available solar power. Battery is the main energy storing device which is used to always charge the SC to its maximum voltage. It also supplies long term energy when PV is not available. SC is controlled by a cascaded voltage and current control loop to supply the sudden load change and DC bus voltage stabilization. Both Battery and SC are using bidirectional DC/DC converter for their controlling. The main advantage of hybrid system lies in control of FC, which is connected to the DC bus by means of Boost converter. Here FC only uses to charge the battery up to its maximum SoC limit when Battery reaches its minimum State of charge level.

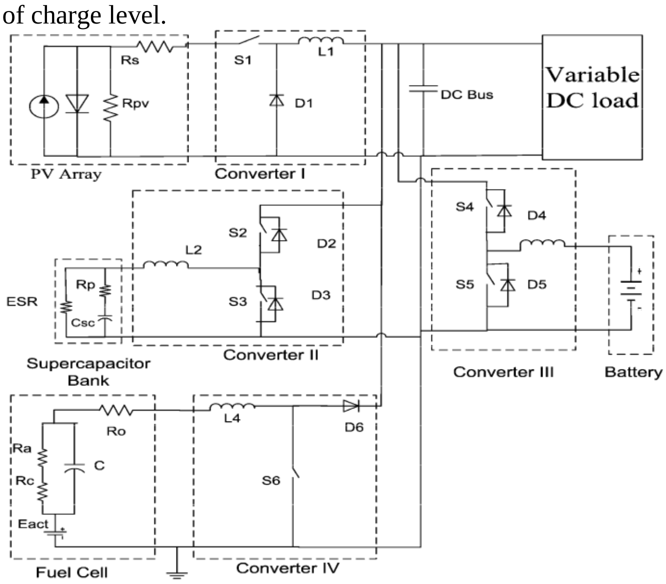


Fig 1. Hybrid System of Solar PV and Fuel Cell

III. CONTROLLING

A. Solar Photovoltaic : Solar PV is the most intermittent type of source. Its output varies with varying irradiance and temperature. Solar PV has been modelled by its circuit based model [10]. Fig.2 describes the model of Solar PV controller. It has two operational modes: Maximum Power point tracking and DC bus voltage control. The PV controller always works in MPPT mode if any one of the energy storage element is not at their fully charged state. If Super capacitor measured voltage (Vsc) is less than maximum SC voltage (Vscmax) or Battery measured SoC (BatSoc) in less that Battery maximum SoC limit (BatSoCmax), PV will operate in MPPT mode, In this paper, incremental conductance method is applied to extract maximum power from PV which operates by sensing the PV voltage (Vpv) and PV current (Ipv) [11,12]. The MPPT controller always regulates PV power to its maximum power (Pmpp). If more power is available it will always go to charge SC or battery. If both of the storage elements are at their maximum limit then PV converter will only control DC bus voltage. As more number of PV panel is connected in series DC/DC buck converter is used to control PV current. In this configuration 9 modules in 3 strings (each string with 3 modules in series) are connected to the DC bus.

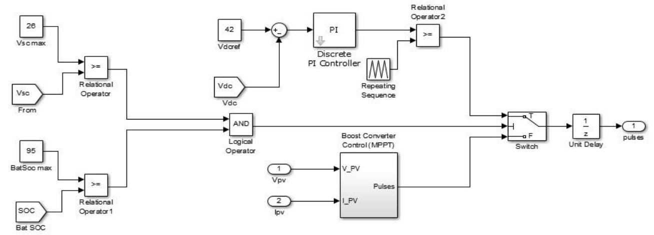


Fig 2. PV controller Modelling

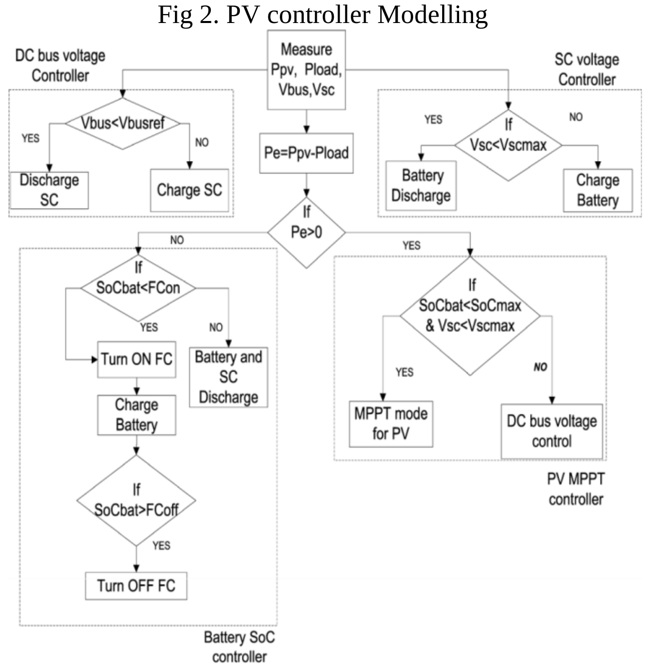


Fig 3 : Algorithm for Energy Management

B. Super Capacitor : SC has been chosen to deliver or absorb transient power during sudden load changes due to fast charging/discharging cycle, good efficiency and long lifetime. In literature, many different models for SC have been proposed. It is composed of three ideal circuit elements: equivalent series resistance (ESR), a parallel resistor (Rp) which is modeled for the leakage current found in all capacitors and an ideal Capacitor (Csc) [13]. SCs are connected to DC link by means of a two quadrant DC-DC Converter. This converter is driven by the complementary pulses applied to two switches S2 and S3. This converter is operating in three modes: off, charging mode and discharging mode. The SC current can be positive or negative depending on its charging or discharging state. In this paper, at the time of discharging, SC current is considered to be positive and at the time of charging, it is negative. Fig.4 depicts the control scheme of the SC converter. Here, SC converter is controlled by two cascaded PI controllers consists of outer voltage control by means of inner current control. DC bus voltage (Vbus) is sensed and compared with the DC bus voltage reference (Vbusref) to produce the error. This error is minimized by the PI controller and SC current reference (Iscref) is produced. This Iscref must be limited to maximum allowable charging discharging currents [Iscmax, Iscmin] by means of SC current regulation function [14]. In this study, current limits have been calculated by means of Equ. (1) and (2). It is compared with the actual SC current (Isc) and again the error is tuned and producing the complimentary pulses to drive the switches S2and S3.

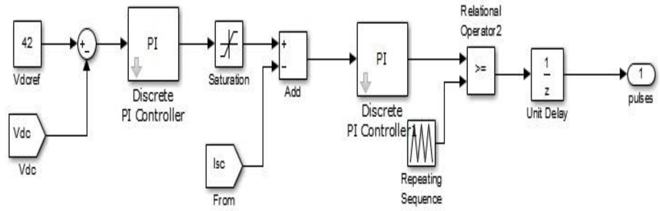


Fig 4 : Super Capacitor Controller Modelling

C. Controller Of Battery : The Battery bank serves as the primary and long term energy storage option in this hybrid system. It helps to smoothen out the fluctuating PV power by storing the excess PV power and by discharging when PV is not available. In this paper, the main objective of the battery is to keep the SC always charged to its maximum voltage (Vscmax). Since battery is having slower dynamics compared to SC due to its lower energy density, it is supplying the steady state load and SC supplies the transient load. Battery is also driven by bidirectional DC/DC converter like SC converter. As shown in Fig.5, it senses SC voltage (Vsc) and it is compared with the SC voltage reference (Vscref). This error is tuned by the PI controller and produce Battery current reference (Ibatref). This reference value can be positive or negative depending on the charging or discharging state of the SC. For the safety reason, Battery charging and discharging current rating [Ibatch,Ibatdis] is limited by battery current regulation function. The battery current (Ibat) will track this reference value and generate complementary pulses S4 and S5 for battery converter. These current ratings have been decided by battery charging rate.

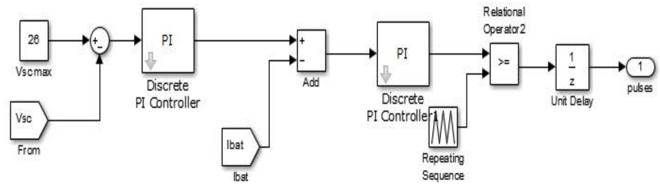


Fig 5 : Battery Controller Modelling

D. Hydrogen fuel Cell Controller : FC gives direct current at low voltage. Therefore DC/DC boost converter is connected to FC. Due to higher running cost of FC, a new control strategy has been proposed with FC to save fuel. Simultaneous operation of all energy sources will cause high system running cost. So a new control strategy has been employed by controlling the FC running period. Fig.6 shows that a relay decides the ON and OFF state of FC and if Battery SoC (BatSoC) is lower than minimum allowable SoC limit of Battery (BatSoCmin), FC current (Ifc) will be regulated to its reference value (Ifcref) and if it is more than maximum SoC limit of Battery (BatSoCmax), FC current will be zero. These control parameters can be chosen depending on system requirement and load demand. A current based MPPT technique is applied here to maintain the Fuel Cell current to its maximum value (Ifcmax).

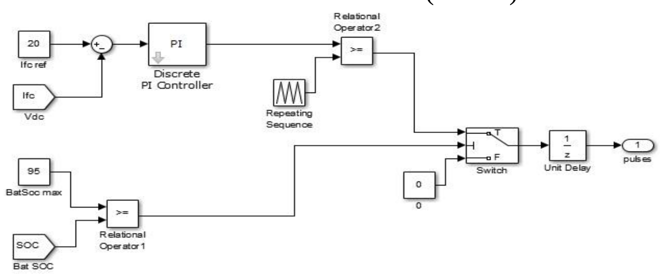


Fig 6 : FC Controller Modelling

IV. SYSTEM DETAILS

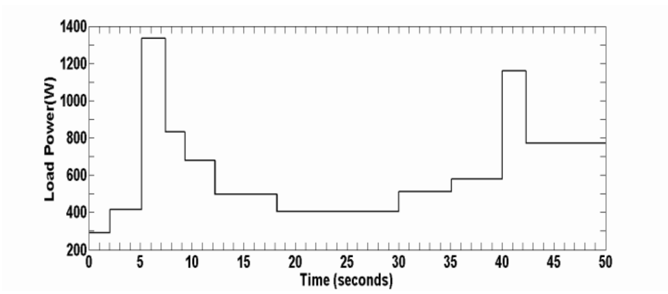


Fig 7 : Load Power Demand

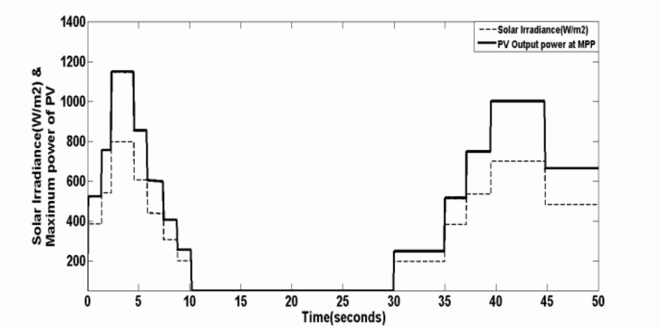
System Component	Ratings
PV Module	VoltageatMPP=35V, CurrentatMPP=4.7A, Power atMPP=0.165kWp
PV Array(3×3)	VoltageatMPP=(35×3)=105V, CurrentatMPP =(4.7×3)=14.1,Power
Battery	LeadAcid24V,400Ah,BatSoCmin =65%, BatSoCmax=95%
SC	Csc=300F,ESR=0.04Ω, Rp=0.015Ω, Vscmax=26V,Iscmax=+50A,
FC	24V,1.26kW,Ifcmax=45A
DC-DCConverter-I (BuckConverter)	L1=0.005F
DC-DCConverter-I (BidirectionalConverter)	L2=0.015F
DC-DCConverter-I (Bidirectional Converter)	L3=0.015mF
DC-DCConverter-I (BoostConverter)	L4=0.005F
Load	42V,0.520 kW

Table : 1 Components Data

V. RESULTS

Fig.8 illustrates that PV power output always tracks its maximum value with changing irradiance (G) that satisfies the first control objective. It is mentioned in Table. I that maximum PV array output power is 1480.6W at STC condition. It can be verified from Fig. 8 that at t=4sec, when G=0.8kW/m2, PV output power is matching with its maximum value of 1184.5W (=1480.6×0.8). Similarly, it can be verified for other instants also, Second objective is fulfilled by current sharing mechanism between various sources in variable solar irradiance as shown with various plots in Fig.9. Here an arbitrary load pattern has been considered with sudden load change as shown in Fig.9.a. At t=0sec Battery is fully charged and SC voltage is 24V, which is lower than its fully charged voltage 26V. It can be observed from Fig.9.a, 9.b, 9.c and 9.d that, as load is only 6A, and PV current is 12A, after supplying the load, PV charges the battery and SC. In this control strategy, battery is allotted to keep SC fully charged. Battery is discharging (shown with positive current), while SC is charging with the same current (shown with negative value) as illustrated in Fig.9.c and 9.d. At t=5sec, load current suddenly changes from 10 A to 30A. At that instant, SC suddenly changes from charging mode to discharging mode (-7A to +4A) to meet the sudden load change. But again when battery dynamics is allowing battery to discharge, SC starts charging with negative current. From t=10 sec to t=30sec, PV current is zero due to absence of solar insolation. In this period, first the load power has been shared by battery and SC. After that FC gets ON at t=12sec as Battery reaches 65% SoC limit. From t=12sec to t=27 sec, load has been shared by FC, Battery and SC. In the FC running time, it supplies the load and also charges the battery as shown in Fig.9.e. At t=27sec, FC gets OFF as Battery reaches its maximum SoC limit (95%). After that, from t=27sec to t=30sec again Battery and SC shared the load. At t=30sec, with PV restoration the same cycle continues. This shows that the load demand is shared by various sources according to the control objectives. The third control objective has been validated with the help of Battery SoC and FC Current waveform of Fig.9.f and 9.e respectively. The control logic is designed in such a way that when battery SoC reaches below 65%, FC gets ON and charges the battery. After that again when Battery reaches

95% SoC, FC gets OFF. It can be seen from Fig.9.f that around t=12sec, battery reaches its minimum SoC limit (65%) and FC gets ON. FC runs upto t=27sec and in this period FC was supplying the load and charges the battery. However, battery was only regulating the SC voltage. At t=27 sec, FC gets OFF, as battery has reached its 95% SoC and Battery and SC starts supplying the load till PV restores and Battery SoC again start to decrease. SC voltage is always regulated to its maximum voltage (26V) according to fourth control objective as shown in Fig.10. The last control objective has been satisfied by the result shown in Fig.11. DC bus voltage is fixed at 42V throughout the simulation period. This is achieved by SC controller. This keeps the load side end voltage constant



a.

Fig. 8.MaximumPV power outputwithvariable SolarIrradiance

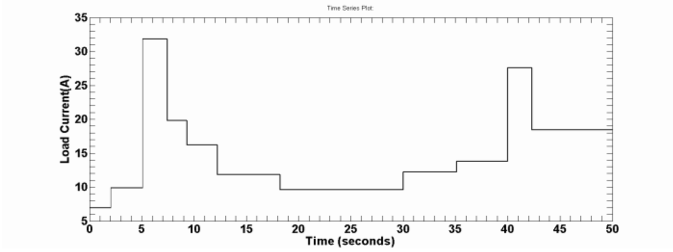


Fig 9.a Load Current

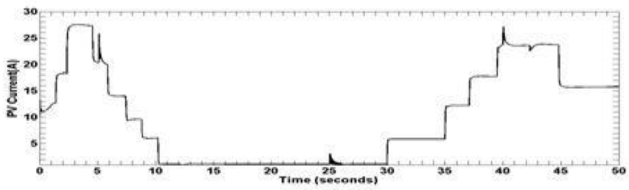


Fig 9.b PV Current

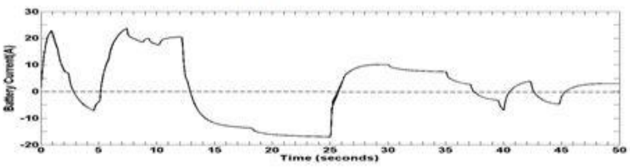


Fig 9.c Battery Current

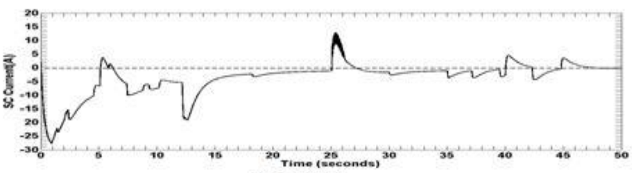


Fig 9.d SC Current

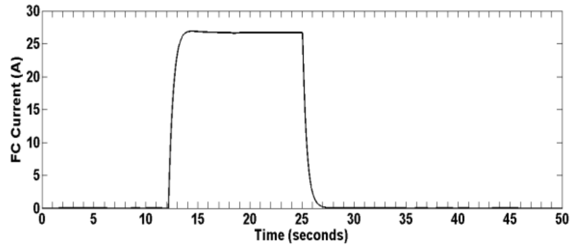


Fig 9.e FC Current

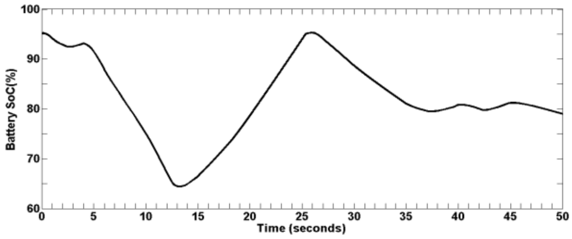


Fig 9.f Battery Soc

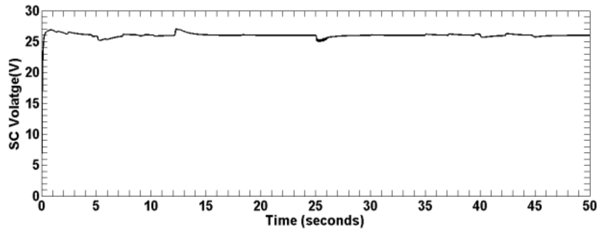


Fig 10 SC Voltage

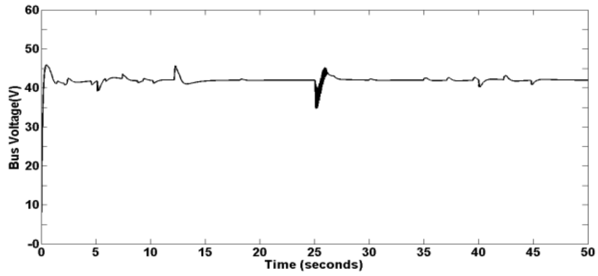


Fig 11 Bus Voltage

VI. CONCLUSION

This work presents an optimal energy management control strategy of PV-FC-Battery-SC hybrid system using PEM FC as auxiliary power source which will operate only for a small period. In FC, fuel cost is much higher compare to other sources running cost, it contributes a large amount in system cost value. Only by reducing the use, the size and the annualized cost of FC system can be reduced. This criterion has been considered in the proposed energy management strategy. The simulation results show the reliability of power supply and reduced fuel usage. This control strategy can be extended to any type of DC load pattern. The simulation results shows that classical PI controller based control strategy for hybrid system not only supplies the load, but also keep battery and SC almost fully charged and reduces FC usage by reducing FC running period.

REFERENCES

[1] J. Torreglosa, P. Garcia, L. Fernandez, and F. Jurado, "Predictive control forthe energy management of a FC–battery–SC tramway," IEEE

Trans. Ind. Inform., vol. 10, no. 1, pp. 276–285, Feb. 2014.

[2] P. Thounthong, S. Rael, and B. Davat, “Energy management of FC/Battery/SC hybrid power source for vehicle application,” J. Power Sources, vol. 190, no. 1, pp. 173–183, May 2009.

[3] A. S. Weddell, G. V. Merrett, T. J. Kazmierski, and B. M. Al-Hashimi, “Accurate supercapacitor modeling for energy harvesting wireless sensor nodes,” IEEE Trans. Circuits Syst. II, Exp. Brief, vol. 58, no.12, pp. 911–915, Dec. 2011.

[4] B. Prabodh, D. Vaishalee, “Hybrid renewable energy systems for power generation in stand-alone applications: A review,” Renewable Sustainable Energy Reviews, vo. 16, no. 5, pp. 2926ď2939, 2012.

[5] P. García, J. P. Torreglosa, L. M. Fernández, and F. Jurado, “Control strategies for high-power electric vehicles powered by hydrogen FC, battery and SC,” Expert Syst. Appl., vol. 40, no. 12, pp. 4791-4804, Sep. 2013.

[6] M. E. Glavin, P. K. W. Chan, S. Armstrong, and W. G. Hurley, ‘‘A standalone photovoltaic supercapacitor battery hybrid energy storage system,’’in Proc. 13th Power Electron. Motion Control Conf., pp. 1688--1695, Sep. 1--3, 2008.

[7] P. García, J. P. Torreglosa, L. M. Fernández, and F. Jurado, “Control strategies for high-power electric vehicles powered by hydrogen FC, battery and SC,” Expert Syst. Appl., vol. 40, no. 12, pp. 4791-4804, Sep.2013.

[8] P. Thounthong, A. Luksanasakul, P. Koseeyaporn, B. Davat, “Intelligent Model-Based Control of a Standalone Photovoltaic/Fuel Cell Power Plant With Supercapacitor Energy Storage,” Sustainable Energy, IEEE Transactions, vol. 4, no. 1, pp. 240-249, Jan. 2013.

[9] X.Guiting, Z. Yan and Z. Dakang, “ Synthetically Control of a Hybrid PV/FC/SC Power System for Standalone Applications,” J. Applied Sciences., vol.5, no. 5, pp.1796-1803, 2013.

[10] Gilberts M. Masters, ‘‘Renewable and Efficient electric power systems,’’wiley interscience, 2004.

[11] A.Safari, and S. Mekhilef, “Incremental conductance MPPT method of PV systems”, 24th Canadian conference on electrical and computer Engineering, May 2011, Canada.

[12] E. Koutroulis, K. Kalaitzakis, N.C.Voulgaris, "Development of a microcontroller-based, photovoltaic maximum power point tracking control system," Power Electronics, IEEE Transactions on , vol.16, no.1, pp.46,54, Jan 2001.

[13] P. Thounthong, S. Rael, and B. Davat, “Control strategy of FC and SCs association for a distributed generation system,” IEEE Trans. Ind. Electron., vol. 54, no. 6, pp. 3225–3233, Dec. 2007.

[14] P. Thounthong, S. Ra¨el, B. Davat, Utilizing fuel cell and supercapacitors for automotive hybrid electrical system, in: Proceedings of IEEE-APEC 2005, Texas, USA, 6--10 March, 2005, pp. 90--96.

[15] P. Thounthong, S. Rael, and B. Davat, “Control strategy of FC and SCs association for a distributed generation system,” IEEE Trans. Ind. Electron., vol. 54, no. 6, pp. 3225–3233, Dec. 2007.

[16] A. Emadi, Y.J. Lee, K. RajashekaraPower electronics and motor drives in electric, hybrid electric, and plug-in hybrid electric vehicles IEEE Trans Ind Electron, vol.55,no. 6 ,, pp. 2237ď2245, 2008.

