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Fuzzy Logic Controller Based Energy Management for a Grid-Connected Wind/Fuel Cell/Battery Hybrid Renewable Energy System

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Abstract**-** ***Renewable energy, such as wind, solar energy and fuel cells are desirable for power generation due to their unlimited existence and environmental friendly nature. This paper deals with system integration and fuzzy logic based controller design for power management of a grid connected Hybrid renewable energy source (HRES). The hybrid system is the combination of fuel cell, wind turbine, and battery storage via a common current source interface multiple-input dc-dc converter. This converter is used to integrate the renewable energy sources to the utility grid. A two- level control system is implemented, comprising a Fuzzy logic controller, which ensures the power management between intermittent RE generation, energy storage, and grid, as well as local controllers for the photovoltaic, wind unit. Simulations are performed in MATLAB/Simulink.***

Keywords: Energy Management, Wind System, Fuel Cell, Hybrid Storage System, Stability and Power Quality Analysis, Fuzzy Logic Controller.

I. INTRODUCTION

The use of renewable energy increased greatly just after the first big oil crisis in the late seventies. At that time, economic issues were the most important factors, hence interest in such processes decreased when oil prices fell. The current resurgence of interest in the use of renewable energy is driven by the need to reduce the high environmental impact of fossil-based energy systems. Harvesting energy on a large scale is undoubtedly one of the main challenges of our time [1]. Future energy sustainability depends heavily on how the renewable energy problem is addressed in the next few decades. Although in most power-generating systems, the main source of energy (the fuel) can be manipulated, this is not true for solar and wind energies. The main problems with these energy sources are cost and availability: wind and solar power are not always available where and when needed. Unlike conventional sources of electric power, these renewable sources are not dispatch able‖ the power output cannot be controlled. Daily and seasonal effects and limited predictability result in intermittent generation. Smart grids promise to facilitate the integration of renewable energy and will provide other benefits as well [2]. Industry must overcome a number of technical issues to deliver renewable energy in significant quantities. Control is one of the key enabling technologies for the deployment of renewable energy systems. Solar and wind power require effective use of advanced control techniques.

In addition, smart grids cannot be achieved without extensive use of control technologies at all levels [3]. The penetration level of green and renewable energy sources/distributed generation units are expected to grow in the near future as there is a probability of rundown conventional fuels for power generation. The distributed generation is classified as renewable and non-renewable. The distributed generation sources such as Fuel cells, Wind and Solar energy are increasing daily due to increase in demand for electrical power [4-7]. These energy sources are environmental friendly, reduces transmission and distribution losses, peak load shaving, can be used as backup sources and etc.

Therefore a Hybrid power system seems to an alternative for supplying isolated sites. The renewable energy sources combination with energy storage can complement each other to provide a continuous and reliable supply to isolated sites. Highlights some important issues and challenges in the design and management of hybrid sources. System configuration, generator unit sizing, storage needs and energy management are addressed. Also the latest status of fuel cell technology development and its application in the transportation, stationary and portable micro power generation are discussed in these papers.

The hybrid energy system requires an efficient energy management system, so that the sources are utilized efficiently at low cost. In ref [6], the authors have discussed two power management strategies and compared their performance experimentally. The control system discussed is to co-ordinate the various sources, particularly their power exchange in order to meet the load demand reliably. Hybrid system consisting of wind turbine and micro turbine are addressed in ref [7]. In this reference the energy management is optimized using particle swarm optimization. Actual wind and end-use load profile were used for simulation studies. Various techniques of modeling control and simulation of hybrid power system is discussed in Ref [7]-[10]. In this paper a fuzzy logic controller is designed to provide an optimized energy management to manage the sources depending on the real time load profile. The fuzzy rules for both sources and load parameters are developed for an optimized energy management.

II. DESCRIPTION OF HYBRID RENEWABLE ENERGY SYSTEM

The proposed system is structured in two buses-DC bus and AC bus. WT, SOFC, ELZ and battery make the architecture of DC bus, and the power transferring among these components happens through a proper CEMCA. Domestic Load (DL) and National Grid Station (NGS) are connected to AC bus. The output voltages of WT and SOFC are regulated through two DC–DC boost converters while the bidirectional power flow of battery with the rest of the system happens through a buck boost converter. The output of DC bus is integrated to the NGS and/or grid connected load via three phase inverter. The CEMCA works in such way to track the load for 24 Hrs if only one source is available. The dynamic performance and stability of the proposed algorithm requires the simulation of the HRES over a long time. Therefore, steady-state simulation models have been performed for each distinct component. Figure 1 indicates a schematic layout of the proposed HRES.

III. CONTROL OF SYSTEM COMPONENTS

A. *Control of WT System*

The output power of WT system depends on the variation of wind speed. To effectively utilize the WT system, it is always operated at Maximum Power Point (MPP). To track the MPP of the WT system, a DC–DC boost converter controlled through torque reference-based Maximum PowerPoint Tracking (MPPT) is used. This MPPT control method keeps the operating point of the WT on its maximum power coefficient for any wind speeds, adjusting the duty cycle of the WT DC–DC converter, which produces a variation of its rotational speed. The control system for WT is depicted in figure 2. The relation between optimal torque and mechanical angular velocity of the PMSG rotor is given as

$$\tau_{m-opt} = \lambda_{opt}\omega_m^2 \qquad (1)$$

Where, α_{opt} is the optimal constant in-terms of optimal tip speed ratio.

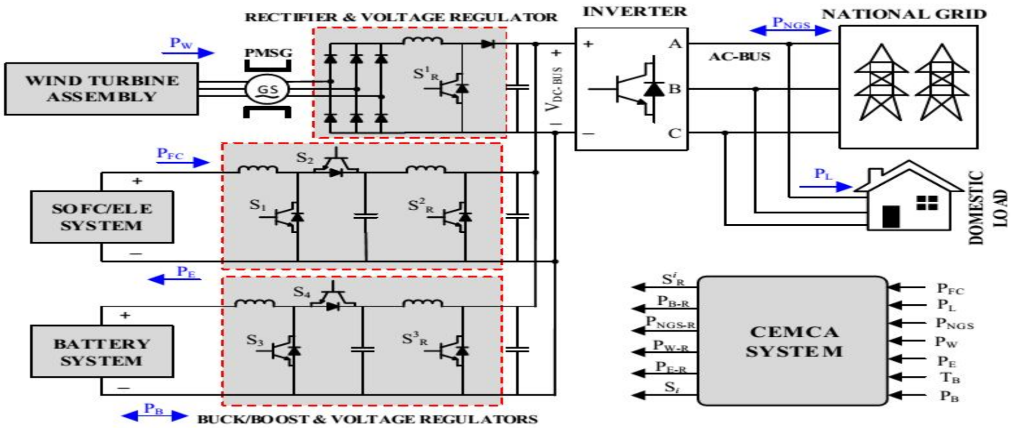


Fig.1 Complete structure of proposed HRES

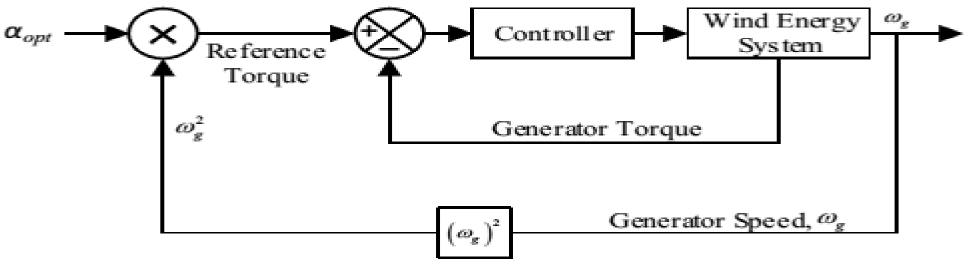


Fig.2 Control of WT system

B. Control of SOFC System

The assembly of SOFC is linked with DC bus through boost converter. Here, the boost converter is controlled via Proportional Integral Differentiator (PID) controller. The PID controller tries to reduce the error, which is the difference of reference voltage by CEMCA and actual voltage of SOFC. The output of PID controller denotes the variation in duty cycle. The output voltage generated by boost converter is based on duty cycle provided by PWM generator. The control system for SOFC is depicted in figure.3.

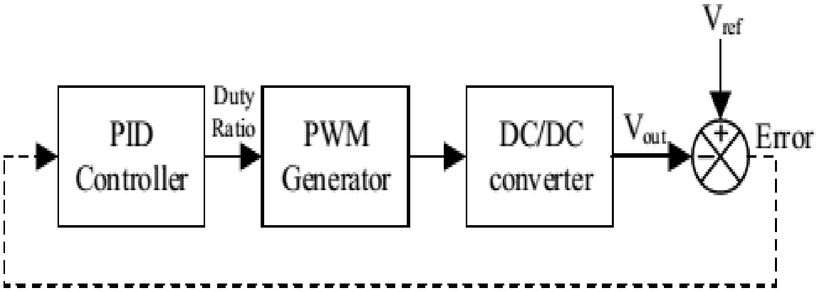


Fig.3 Control scheme of SOFC/ELZ system

C. Control of Battery System

The linking of the battery to the DC bus is established though DC-DC buck-boost converter. The power flow from the battery to the DC bus is made via boost mode while the buck mode is used to charge the battery from DC bus. The PID controllers are used to control the battery buck-boost converter. The control diagram of buck-boost converter is depicted in figure 4. IR is the reference current determined as IR =PB-R/VB.

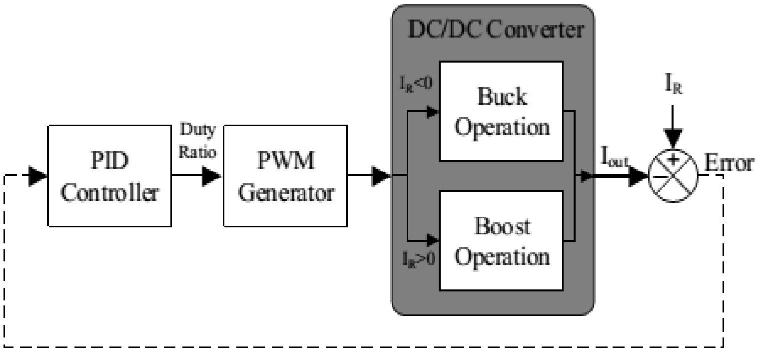


Fig.4 Control scheme of battery system

D. Control of Inverter

The DC bus of the HRES is connected to the grid through a three phase inverter. Here, the inverter is controlled using Proportional Integral (PI) controllers followed by hysteresis current control scheme as depicted in figure.5. The proposed control scheme generates suitable pulses for driving the controllable switches of the inverter. The PI controllers try to reduce the error which is the difference between the reference and actual values of the active and the reactive powers. The PI controllers adjust the error and thus control the corresponding powers. It is essential for the grid current to be in phase with the grid voltage and has unity power factor. Therefore, a phase locked loop is used which estimates and adjusts the phase angle of grid voltage. The estimated phase voltage angle is then used to synchronize the inverter to the grid.

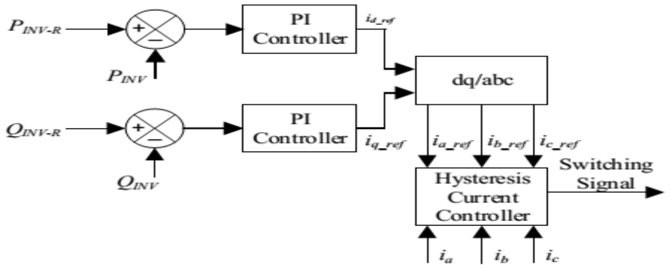


Fig.5 Control scheme of inverter system

IV. CEMCA OF PROPOSED SYSTEM

The proposed CEMCA is capable to satisfy the load demands for the 24 Hrs using the WT/SOFC/ELZ/Battery HRES. The CEMCA performs the entire energy measurement. Based upon the requirement, the CEMCA provides the control signals for the energy sources and/or power converters attached in the HRES. The operating schemes employed in the CEMC Aare as follows:

1) The power provided by WT system has the priority in satisfying the demand over that supplied by the SOFC and/or the battery system.
2) If WT system generates more power than the demand, the surplus power will be utilized to charge the battery bank.
3) If still there is surplus power in the system, then it will be supplied to NGS followed by ELZ to produce hydrogen for SOFC
4) Likewise, if the total power produced by the WT system is less than the demand, then the required powers will be provided from the SOFC.
5) If the net power supplied by the WT/SOFC combination is less than the demand, then battery system will be transferred the required power.
6) If still the power demand exceeds, then the difference will be covered from the NGS.

Based on the above stated points, the proposed algorithm work flow is shown in figure 5.

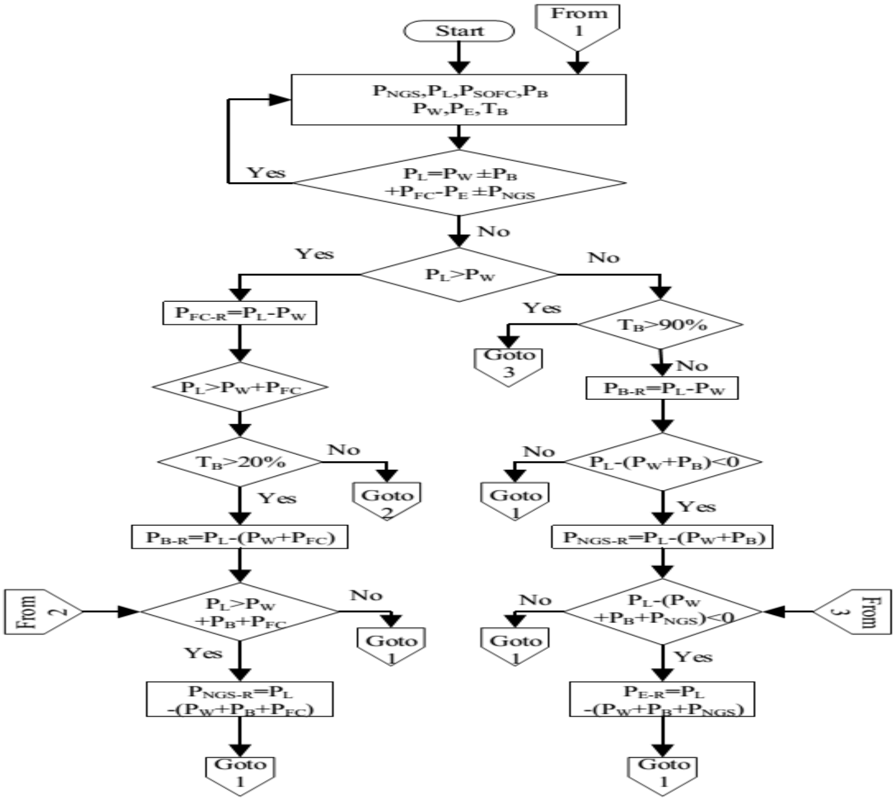


Fig.6 Work flow of proposed algorithm

The proposed algorithm is divided in the following operating modes: Mode A: Excess Power Battery Charging SOFCD is connected NGS Extracts ELZ Connected (EPBCSDNEEC),Mode B: Deficient Power Battery Charging SOFC Connected NGS Delivers ELZ Off (DPBCSCNDEO), Mode C: Deficient Power Battery Discharging SOFC Connected NGS Delivers ELZ Connected (DPBDSCNDEC), Mode D: Deficient Power Battery Discharging SOFC Connected NGS Delivers ELZ Off(DPBDSCNDEO), Mode E: Deficient Power Battery Discharging SOFC Connected NGS Extracts ELZ Connected(DPBDSCNEEC), Mode F: Deficient Power Battery Discharging SOFC Connected NGS Extracts ELZ Off(DPBDSCNEEO)

A. Mode A: EPBCSDNEEC

In this mode, the WT generates power more than the load demand. Therefore, there is no need of SOFC in this mode. Since, SOFC is disconnected, while the excess power generated by WT is used for battery charging purposes. There is still excess power presented in the system, because, battery charges only with its predefined rate of charge. This excess power is supplied to NGS while the residual is used for electrolysis.

B. Mode B: DPBCSCNDEO

This operating mode lies for a very short period of time, but this is a very important mode. Here, the system encountered the shortage of power from WT side and needs a backup system. So, SOFC is turned on and start supplying its maximum available power. On the other side, the battery plays an unpredictable role, because, battery is still charging in this mode regardless of deficient power. This behavior of the battery is due to its slow charging/discharging rate. In this state, the CEMCA moves out from mode A (i.e., from excess power to deficient power), but due to predefined charging rate of battery, still it does not restore it to its discharging state. Hence, in this case, NGS facilitates SOFC on overcoming load demand with no residual excess power inside the system which keeps the ELZ in off state.

C. Mode C: DPBDSCNDEC

This is the most common operating mode generated by CEMCA, which lies for the majority of time period. In this case, the system faced a shortage of power from WT side and SOFC is immediately turned on to overcome the shortage. But it falls due to its maximum power limitations. The shortage of power exceeds the maximum power given by SOFC. Therefore, the last options are the battery and NGS. They not only fulfills the load demand, but also produces some excess power which is utilized by ELZ.

D. Mode D: DPBDSCNDEO

This mode is like to mode C. In this mode, the system met the shortage of power which is caused by WT system. The active players of this mode are SOFC, NGS and ELZ. The SOFC providing its maximum power along with battery which provides energy with a predefined rate of discharge and NGS satisfies residual shortage with no excess power remains in the system. Therefore, ELZ has no role in this mode.

E. Mode E: DPBDSCNEEC

Here, the WT is unable to satisfy the load demand. The SOFC provides its maximum available power. The battery also provides its maximum power with pre-defined discharging rate. The NGS extracts power from the system. This abnormal behavior of NGS is due to battery discharging rate. Actually, upon rapid decrease in load demand, the battery output power also starts decreasing, but it only decreases with its defined rate of discharge. Therefore, this power gap leads in injection of excess power inside the system which is consumed by NGS followed by ELZ.

F. Mode F: DPBDSCNEEO

In this mode, the WT is unable to meet the demand and the shortage of power is managed from the combination of SOFC and battery. The NGS absorbs all the excess power generated by SOFC/battery with no residual excess power. Hence, ELZ has no role in this mode.

V. FUZZY LOGIC CONTROLLER

The Fuzzy control is a methodology to represent and implement a (smart) human's knowledge about how to control a system. A fuzzy controller is shown in Figure.6. The fuzzy controller has several components:

1) A rule base that determines on how to perform control
2) Fuzzification that transforms the numeric inputs so that the inference mechanisms can understand.
3) The inference mechanism uses information about the current inputs and decides the rules that are suitable in the current situation and can form conclusion about system input.
4) Defuzzification is opposite of Fuzzification which converts the conclusions reached by inference mechanism into numeric input for the plant.

The fuzzy logic controller provides an algorithm, which converts the expert knowledge into an automatic control strategy. Fuzzy logic is capable of handling approximate information in a systematic way and therefore it is suited for controlling nonlinear systems and is used for modeling complex systems, where an inexact model exists or systems where ambiguity or vagueness is common. The fuzzy control systems are rule-based systems in which a set of fuzzy rules represent a control decision mechanism for adjusting the effects of certain system stimuli. With an effective rule base, the fuzzy control systems can replace a skilled human operator.

The rule base reflects the human expert knowledge, expressed as linguistic variables, while the membership functions represent expert interpretation of those variables.

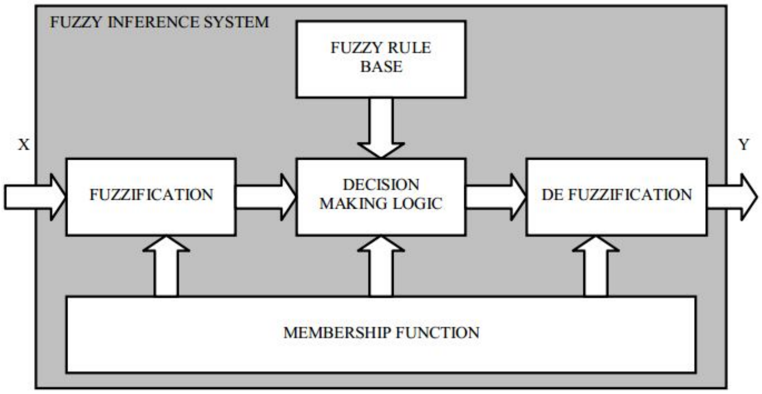


Fig.7 Block diagram of fuzzy control system

Fig.7. shows the block diagram of fuzzy control system. The crisp inputs are supplied to the input side Fuzzification unit. The Fuzzification unit converts the crisp input in to fuzzy variable. The fuzzy variables are then passed through the fuzzy rule base. The fuzzy rule base computes the input according to the rules and gives the output. The output is then passed through de-fuzzification unit where the fuzzy output is converted to crisp output.

Scaling factor in a fuzzy logic controller is very important. Selection of suitable values for scaling factors are made based on the knowledge about the process to be controlled and sometimes through trial and error to achieve the best possible control performance. This is so because, unlike conventional non-fuzzy controllers to date, there is no well-defined method for good setting of scaling factors for fuzzy logic controllers. But the scaling factors are the main parameters used for tuning the fuzzy logic controller because changing the scaling factors changes the normalized universe of discourse, the domains, and the membership functions of input /output variables of fuzzy logic controller.

Fuzzy logic is a form of logic that is the extension of boolean logic, which incorporates partial values of truth. Instead of sentences being "completely true" or "completely false," they are assigned a value that represents their degree of truth. In fuzzy systems, values are indicated by a number (called a truth value) in the range from 0 to 1, where 0.0 represents absolute false and 1.0 represents absolute truth. Fuzzification is the generalization of any theory from discrete to continuous. Fuzzy logic is important to artificial intelligence because they allow computers to answer ‘to a certain degree’ as opposed to in one extreme or the other. In this sense, computers are allowed to think more 'human-like' since almost nothing in our perception is extreme, but is true only to a certain degree. The below Fig.8 specifies the membership functions for proposed fuzzy logic controller, the error & change in error is same with respect to output function. The membership function is divided into seven sets: NL: Negative Large, NM: Negative Medium, NS: Negative Small, Z: Zero, PS: Positive Small, PM: Positive Medium, PL: Positive Large. The rules for proposed fuzzy logic controller are illustrated in Table. I.

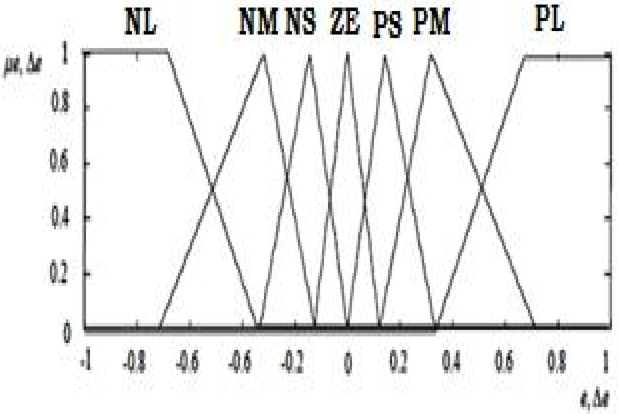


Fig.8. Normalized Membership Function

Table I: Fuzzy Rules

e Δe	NL	NM	NS	EZ	PS	PM	PL
NL	NL	NL	NL	NL	NM	NS	EZ
NM	NL	NL	NL	NM	NS	EZ	PS
NS	NL	NL	NM	NS	EZ	PS	PM
EZ	NL	NM	NS	EZ	PS	PM	PL
PS	NM	NS	EZ	PS	PM	PL	PL
PM	NS	EZ	PS	PM	PL	PL	PL
PL	NL	NM	NS	EZ	PS	PM	PL

VI. MATLAB/SIMULINK RESULTS

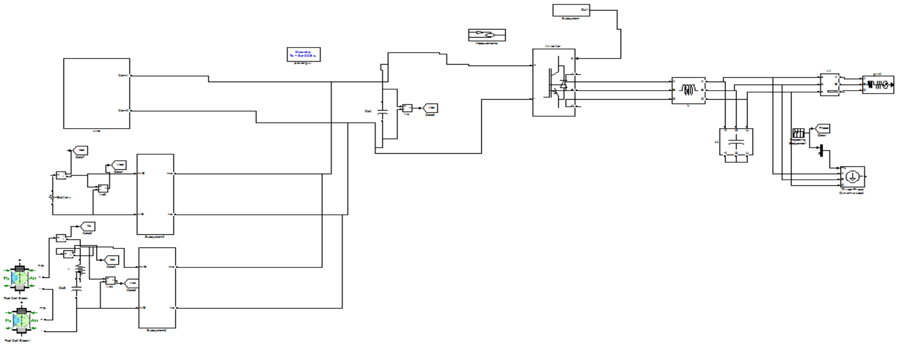
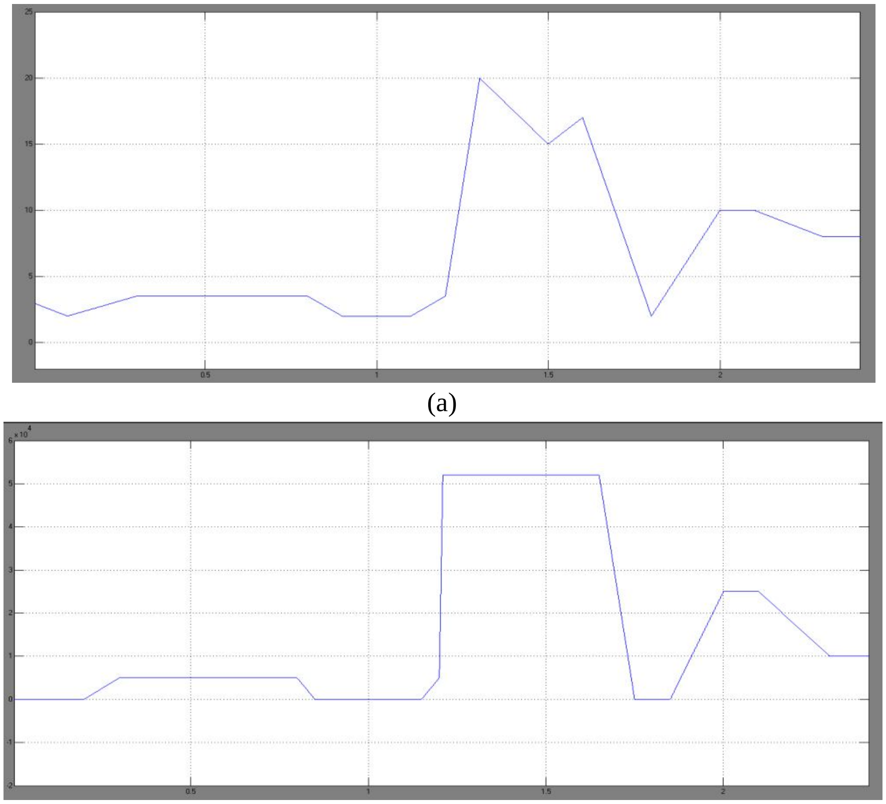


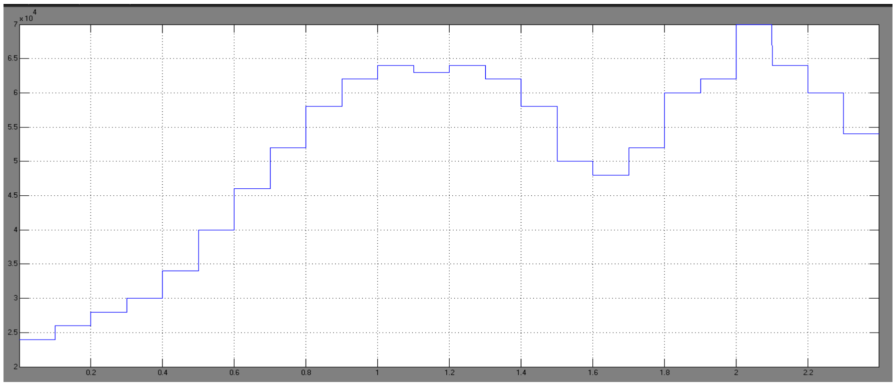
Fig.9 Simulink model of Grid Connected Hybrid Power system



(a)

(b)

Fig.10 (a) Wind speed and (b) output power vs time


× 10^4
7
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6
5.5
5
4.5
4
3.5
3
2.5
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1.2
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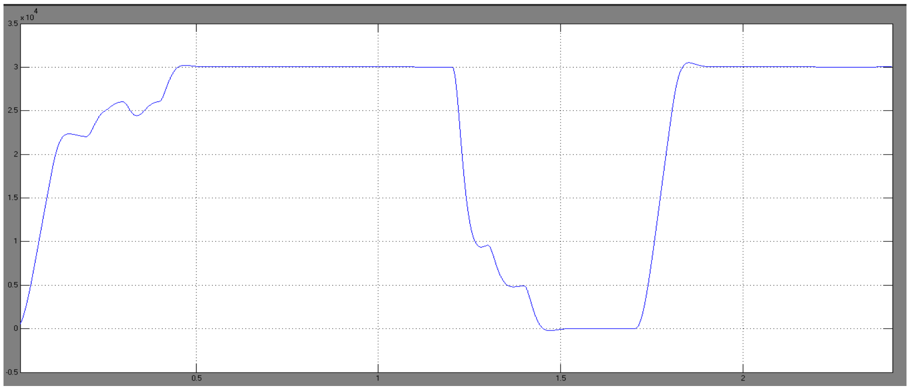
2.2

(a)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0.5
1
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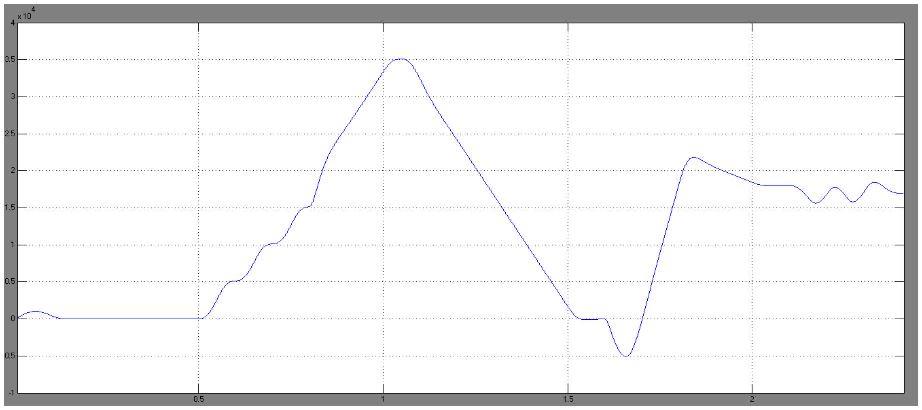
(b)


× 10^4
4
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2.5
2
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1
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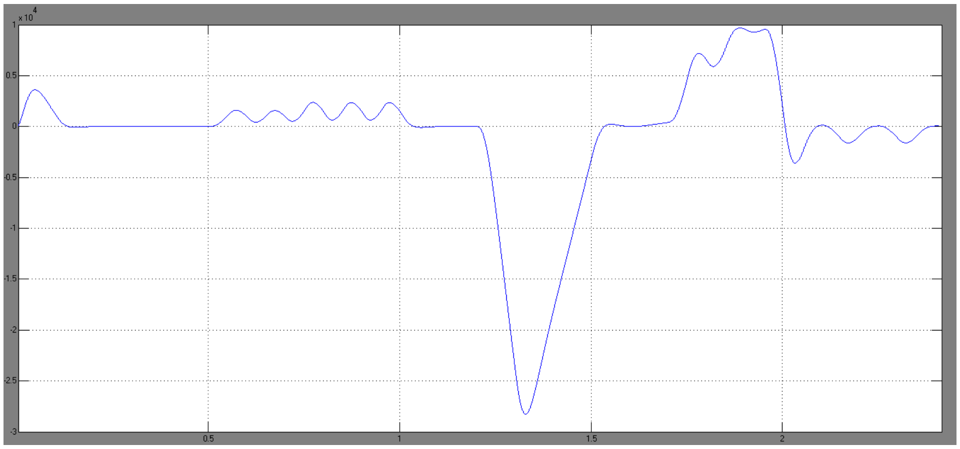
0
0.5
-1
0.5
1
1.5
2

(c)


× 10^4
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-2
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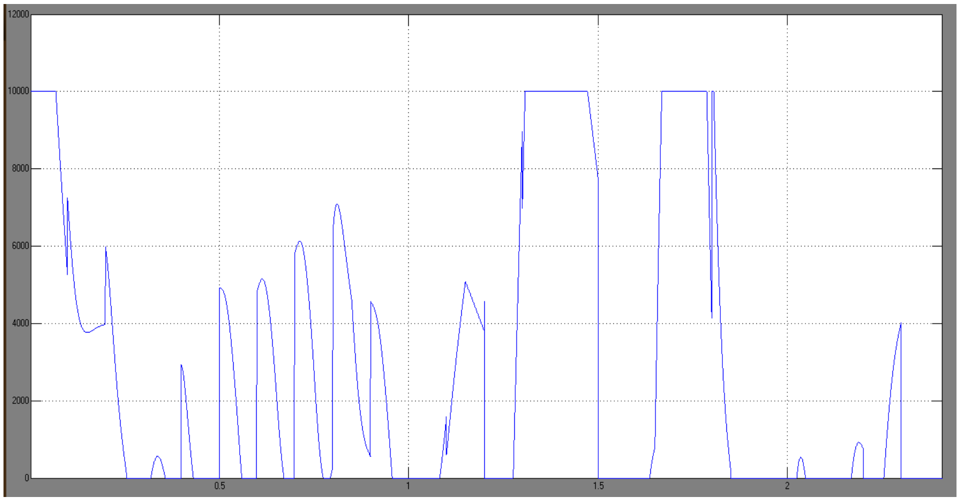
0.5
1
1.5
2

(d)



(e)

Fig.11 Output powers (a) PL (b) PFC (c) PB (d) PNGS (e) PE

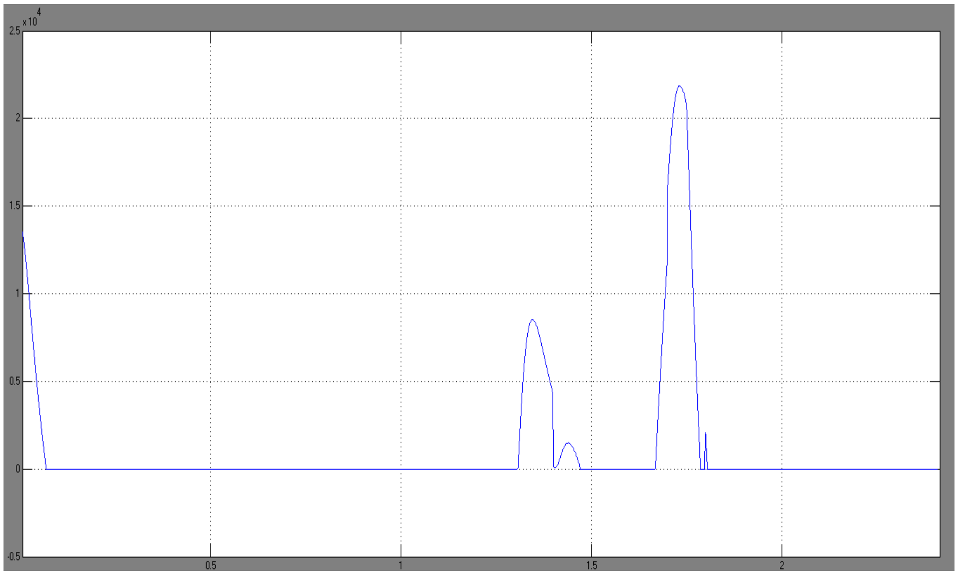


Fig.12 Net power inside the system

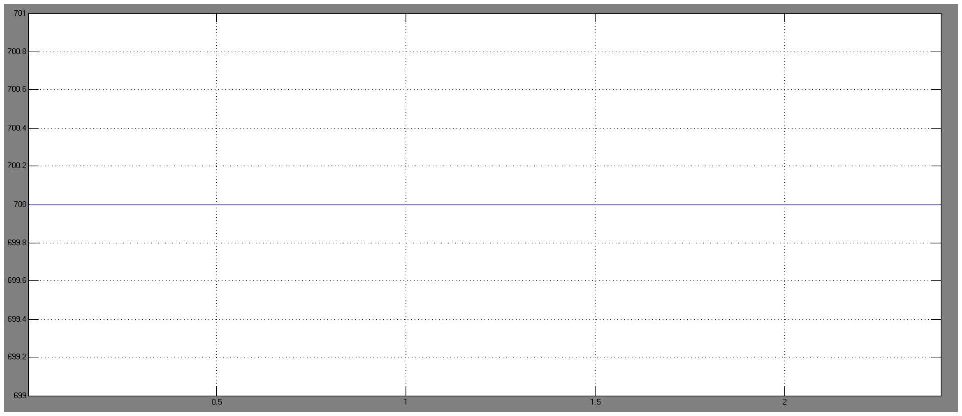


Fig.13 DC-Bus Voltage

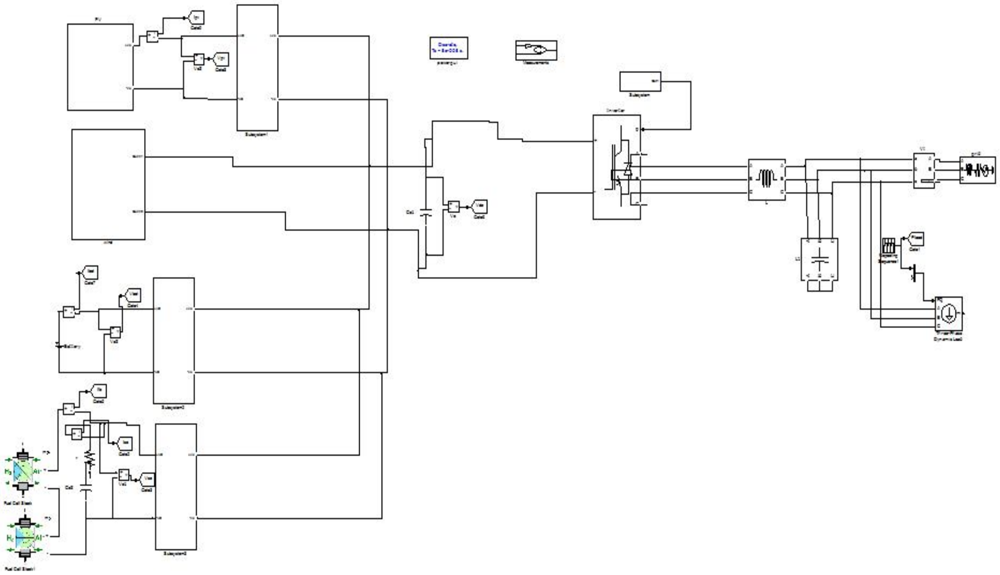
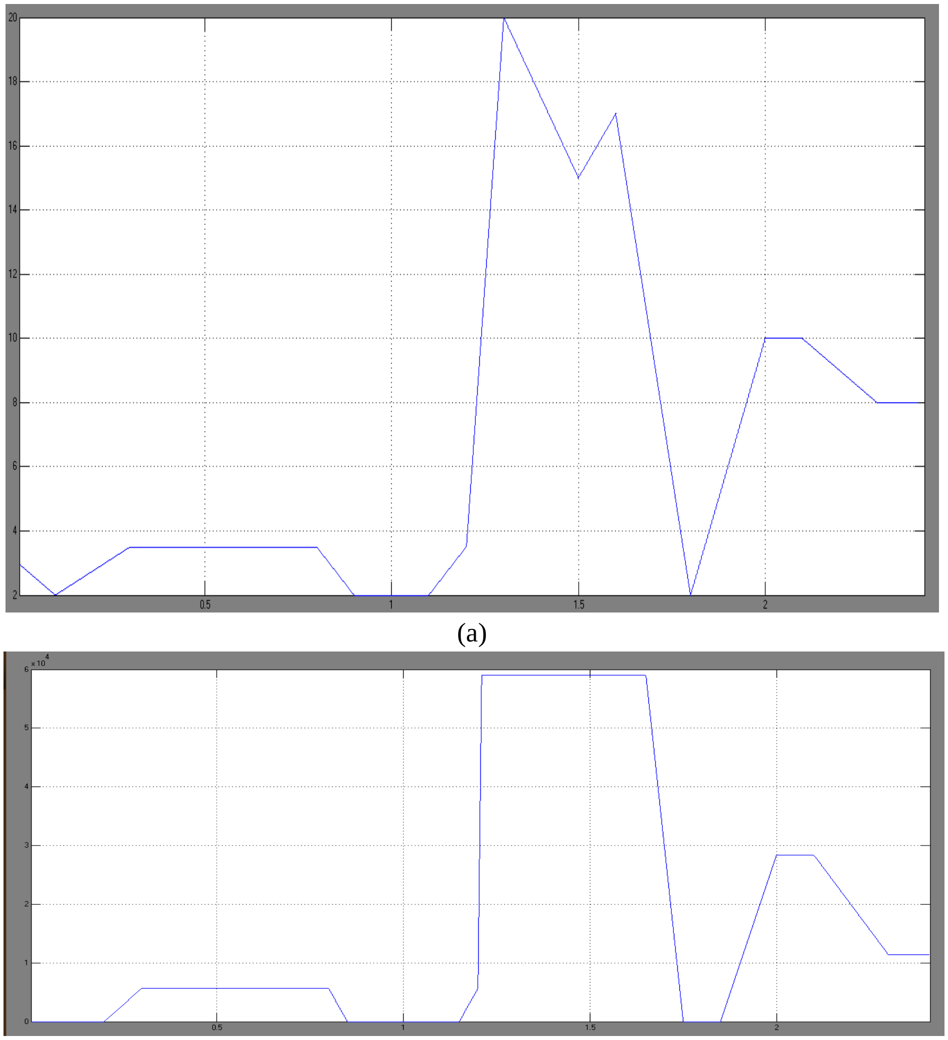


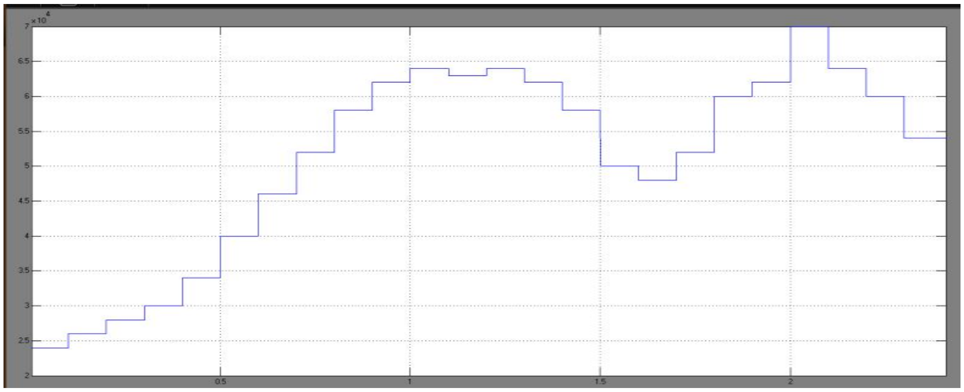
Fig.14 Simulink model of Grid Connected Hybrid Power system with Fuzzy logic controller



(a)

(b)

Fig.15 (a) Wind speed and (b) output power vs time


×10^4
7
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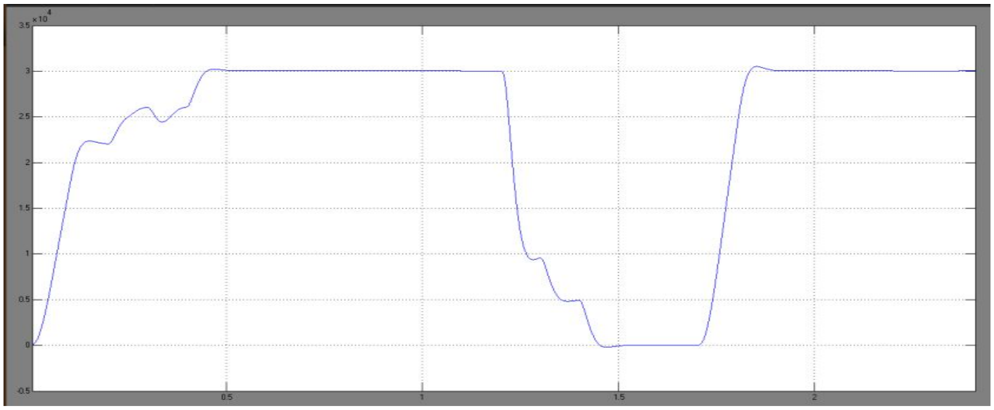
(a)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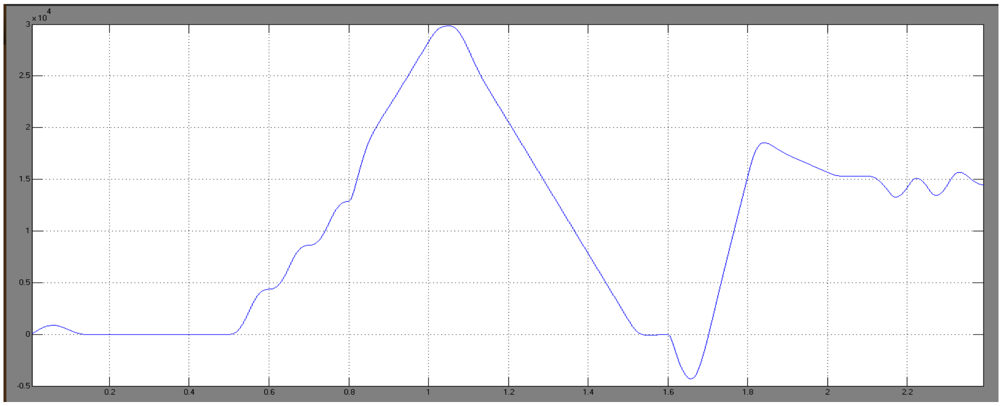
(b)


×10^4
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1.5
1
0.5
0
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0.2
0.4
0.6
0.8
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1.2
1.4
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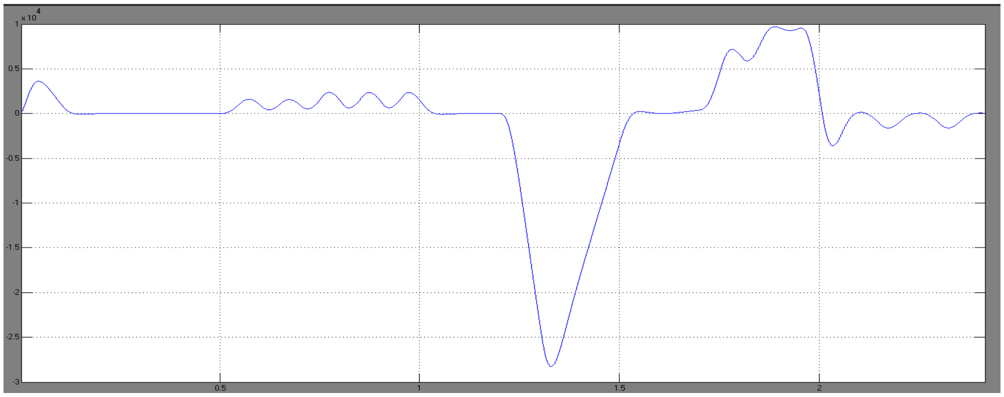
(c)


×10^4
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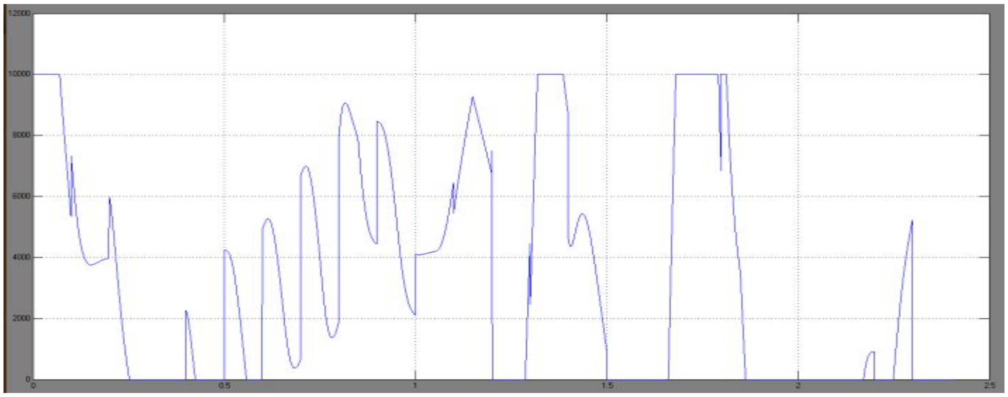
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
0.5
1
1.5
2

(d)



(e)

Fig.16 Output powers (a) PL (b) PFC (c) PB (d) PNGS (e) PE

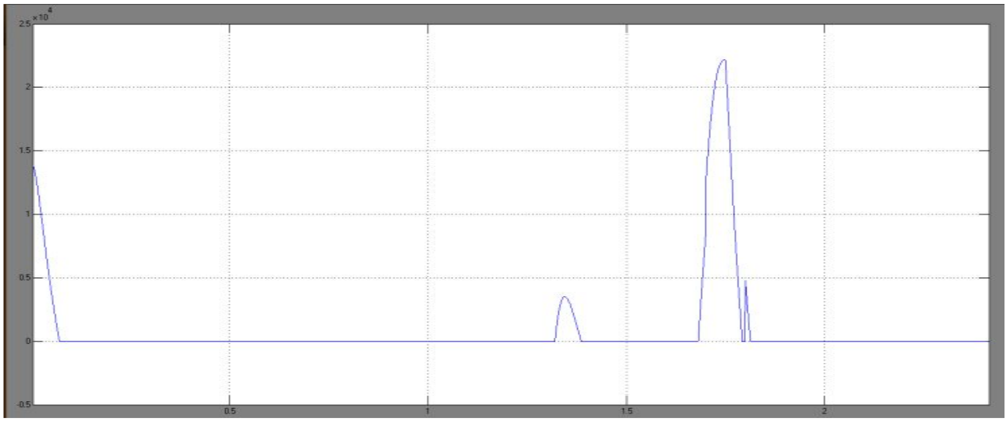


Fig.17 Net power inside the system

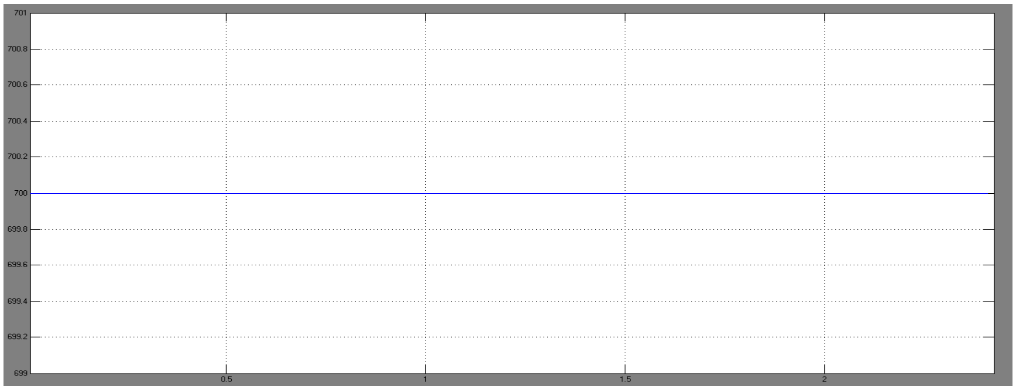


Fig.18 DC-Bus Voltage

VII. CONCLUSION

This paper presents a fuzzy based optimized EMS for a standalone hybrid power system, consisting of Fuel cell and a wind turbine as primary renewable energy sources and battery as back up energy storage systems. The optimized controller monitors the battery SOC, hydrogen level and the net power and accordingly allocates the sources to meet the load. The ultimate aim of the control strategy is to provide continuous supply to meet the load. The controller performance under transient condition (like sudden load removal) is to be validated. Otherwise, the simulation results prove that the performance of the proposed system is satisfactory under different source and load conditions. Thus the ultimate aim to provide a continuous power supply to the load is achieved.

REFERENCES

[1] N. Gyawali and Y. Ohsawa, “Effective voltage and frequency control strategy for a stand-alone system with induction generator/fuel cell/ultracapacitor,” in Integration of Wide-Scale Renewable Resources Into the Power Delivery System, 2009 CIGRE/IEEE PES Joint Symposium, pp. 1–11, 2009.

[2] G. O. Suvire and P. E. Mercado, "Dstatcom with flywheel energy storage system for wind energy applications: control design and simulation," Electr. Power Syst. Res., vol. 80, no. 3, pp. 345–353, 2010.

[3] R. Fernandez, P. Battaiotto, and R. Mantz, "Impact of wind farms voltage regulation on the stability of the network frequency," Int. J. Hydrogen Energy, vol. 33, no. 13, pp. 3543–3548, 2008.

[4] S. Obara, "Analysis of a fuel cell micro-grid with a small-scale wind turbine generator," Int. J. Hydrogen Energy, vol. 32, no. 3, pp. 323–336,2007.

[5] T. Zhou and B. Francois, "Modeling and control design of hydrogen production process for an active hydrogen/wind hybrid power system," Int. J. Hydrogen Energy, vol. 34, no. 1, pp. 21–30, 2009.

[6] O. C. Onar, M. Uzunoglu, and M. S. Alam, "Dynamic modeling, design and simulation of a wind/fuel cell/ultra-capacitor-based hybrid power generation system," J. Power Sources, vol. 161, no. 1, pp. 707–722, 2006.

[7] P. Costamagna, L. Magistri, and A. F. Massardo, "Design and part-load performance of a hybrid system based on a solid oxide fuel cell reactor and a micro gas turbine," J. Power Sources, vol. 96, no. 2, pp. 352–368, 2001.

[8] M. J. Khan and M. T. Iqbal, "Dynamic modeling and simulation of a small wind–fuel cell hybrid energy system," Renew. Energy, vol. 30, no. 3, pp. 421–439, 2005.

[9] F. I. Khan, K. Hawboldt, and M. T. Iqbal, "Life cycle analysis of wind–fuel cell integrated system," Renew. Energy, vol. 30, no. 2, pp. 157–177, 2005.

[10] B. Delfino and F. Fornari, "Modeling and control of an integrated fuel cell-wind turbine system," in 2003 IEEE Bologna Power Tech Conference Proceedings, vol. 2, pp. 583–588, 2003.

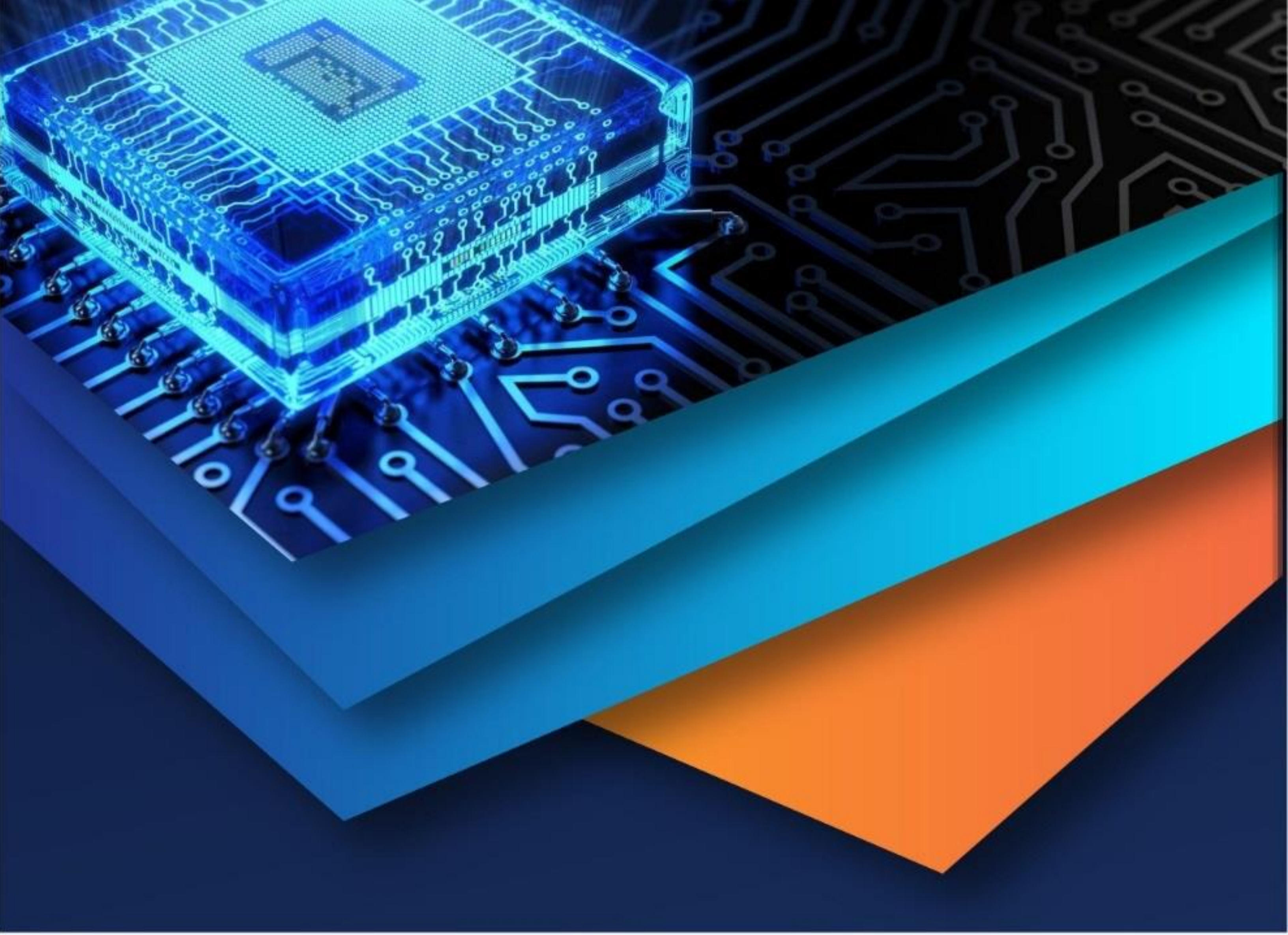
[11] S. Z. Hassan, T. Kamal, S. Mumtaz, and L. Khan, "Performance of grid integrated photovoltaic/fuel cell/electrolyzer/battery hybrid power system," in 2nd International Conference on Power Generation Systems and Renewable Energy Technologies, Islamabad Pakistan, 2015.

[12] H. De Battista, R. J. Mantz, and F. Garelli, "Power conditioning for a wind–hydrogen energy system," J. Power Sources, vol. 155, no. 2, pp. 478–486, 2006.

[13] P. Garcia, L. M. Fernandez, C. A. Garcia, and F. Jurado, "Energy management system of fuel-cell-battery hybrid tramway," IEEE Trans. Ind. Electron., vol. 57, no. 12, pp. 4013–4023, 2010.

[14] E. Muljadi and H. E. McKenna, "Power quality issues in a hybrid power system," IEEE Trans. Ind. Appl., vol. 38, no. 3, pp. 803–809, 2002.

[15] A. A. Chowdhury and D. O. Koval, "Probabilistic wind energy modeling in electric generation system reliability assessment," IEEE Trans. Ind. Appl., vol. 47, no. 3, pp. 1507–1514, 2011.



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