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Interfacing DC islands with AC distribution system using Power Electronic Converter

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Abstract— **The informatics and telecommunication evolution leads the conversion of traditional grid into AC smart grid where various devices are connected to the network to improve efficiency and quality of the system. The DC distribution system involves easier reconfiguration and high quality of supply. In this paper battery, super capacitor, PV emulator, fuel cell are connected to the AC network through power electronic devices. The plug and play functionality are used in power electronic converter to connect the DC sources to the grid. MAT LAB is used for realizing the network and various test are carried out to improve voltage regulation, peak shaving and matching of requested and generated power profile goals are achieved.**

Keywords— ***Battery, Super Capacitor, Grid, Local Load, Dc Distribution System.***

INTRODUCTION

Nowadays, Centralized power generation grid are facing two problems such as shortage of fuel and emission of carbon dioxide. It can be overcome by using renewable energy resources such as wind, solar etc. such renewable energy resources are connected to the grid as power generation resources [1],[2].The power generation from the renewable energy are much smaller when compared to centralized power generation grid. In this type the storage devices can be implemented to increase the power profile. The voltage regulation is a difficult task when power is injected on low and medium voltage grid. For this reason mutual co-operation with demand side control is required by different distribution system operator because it is difficult to maintain power quality using only supply side control.

Nowadays smart grid plays an important role for the interconnection of various power electronic device to the grid. It can be used to improve the efficiency, balance the current in bipolar network of dc, improve stability and power quality of the system [3], [4]. When compared to ac network dc network also have some advantages such that the power electronic converters, PV, storage system are operated in dc which is used to avoid voltage disturbance, no increase of fault current etc. The main target in project is to connect dc islands with on ac grid.

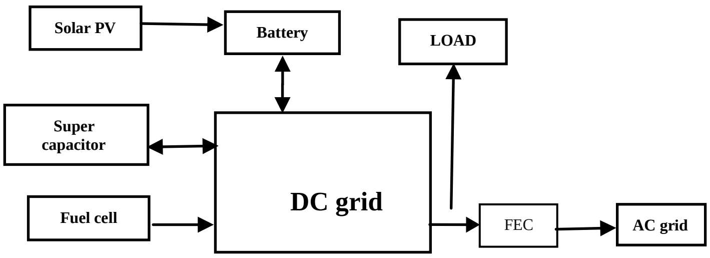

Fig 1

The power electronic converter interface battery, PV system, fuel cell, renewable energy resources with dc grid in order to avoid uncontrolled power flows between different elements. Each power controller are provided with control loops of PID and fuzzy so that information cannot overlapped [5]-[7].The plug and play functionality are interfaced with power electronic converter without a centralized management control unit. This decides the connection and disconnection of single device to a dc network. The main goal are:

1) Design a DC network to fulfill the dynamic performance of various storage devices.
2) Each controller are provided with control loop to avoid overlapping.
3) The behavior of the controlled device are controlled by the control loop.
4) Battery undergo self-charging and discharging function.

In this paper the description of test facility is given in section 1.1, section 1.1.1, and section 1.1.2 the numerical and experimental test are reported and discussed. Section 1.1.3 proposes control schemes of different controllers connected to the dc network.

I. TEST FACILITY FOR BLOCK DIAGRAM

The configuration of the test facility is realized in MAT LAB. The test facility was realized by studying the potentialities of LVDC distribution networks, operated with suitable control strategies for the different devices connected to the network. The network has been equipped with storage element in order to

1. To provide security for the system for a definite intervals of time when not enough power is available in this system to satisfy the demand.

2. To regulate constant voltage on DC grid if sudden unbalance occurs on power.

3. To increase the efficiency of the system using Fuzzy logic control schemes in power electronic controller.

The DC micro grid has the voltage level of 550V, and it is connected with PV, battery, fuel cell, super capacitor, dc\ac converter (FEC), controllable loads and dc\dc converter. The FEC has a voltage level of 30V and power varied up to 200kW.The power flow in this system depends on generation in case of no generation power flow occurs when generation surplus opposite flow is also possible. The ac/dc FEC are used to detect islanding condition and regulating DC voltage compared to AC voltage and frequency. The energy storage is composed of lithium ion battery with a rated power of 50kW, voltage level of 200V and capacity of 100Ah.The super capacitor also provided along with battery. The super capacitor is composed of 2 module and voltage rating of 200v. The dc/dc bidirectional converter of 200kW is used for connecting battery and super capacitor to the dc grid. The converter with control schemes can allow both the charging and discharging process. The interfacing of lithium ion battery with dc\dc converter is called battery converter (BC) and also the interfacing of converter with super capacitor is called super capacitor converter (SCC). PV emulator of 100KW power is used to control the generated power. The two resistive loads are connected to the dc grid. The fuel cell of kW are connected to the DC grid to provide reliable supply to the system.

II. MODELLING OF ELECTRICAL STORAGE SYSTEM

The modeling of electrical storage system is required for setting correct control strategy for different converter. The two working condition of storage devices in grid application are:

1. To guarantee the average power requested by the load.

2. Peak shaving function.

A. Lithium ion battery model

The lithium ion battery cause changes due to pulse event in multiple voltage and current limit. The lithium ion battery model related to state of charge response to voltage and current [8].The dynamic battery models for cell and system is compared and parameterized. Three commonly used equivalent circuit battery models are parameterized using a numeric optimization method and basic electrical tests with a lithium-ion polymer battery cell [9].

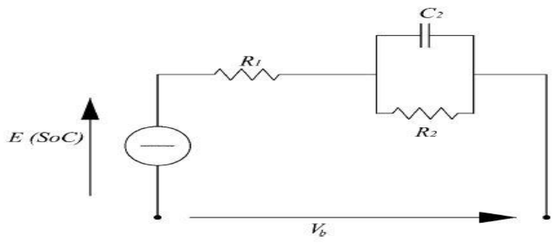

Fig 2 (battery model)

The modelling of energy storage system for power electronic devices to provide peak shaving, integration of renewable energy resources [12]. The lithium ion battery is modeled as electromotive force, *E (SoC)*, representing the open-circuit voltage as a function of the SoC, in series with the internal resistance R1, high frequency resistance of the device, and branch, R2C2, which dynamic behavior of battery. The temperature is kept constant then the equation of battery is:

$$E(S_0C) = E_0 - K_e.(1 - S_0C) \quad .... \quad (1)$$

$$S_0C = 1 - \frac{1}{C_n}\int i_b.dt \quad .... \quad (2)$$

Where
E_0= open-circuit voltage
S_0C =the state of charge of the battery
C_n=the nominal battery capacity
i_b = The current supplied by the battery.
k_e= voltage constant.

B super capacitor model

The modelling of dynamic behavior of the super capacitor and simulation is carried out using voltage and energy efficiency using impedance spectroscopy [10].The charge balancing circuits were employed to increase reliability, performance and life time of capacitor [11].

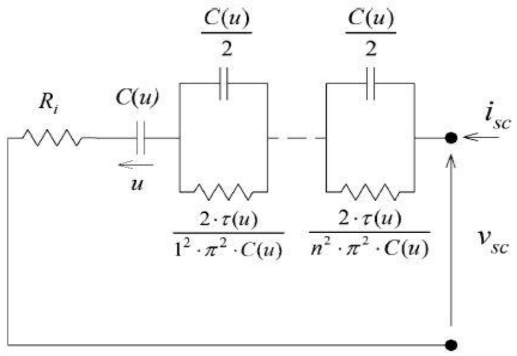

Fig 3(super capacitor model)

III. CONTROL STRATEGY

Control strategy for different converters are discussed in this section. The control strategy should ensure:

1) Dc voltage stabilization.
2) Control schemes are reconfigure automatically.
3) Self-recharge of the storage system.

The dc voltage are regulated by four controllers such as FEC, BC, SCC, FC and PVC. A controller or coordinated controller are required for voltage regulation. To realize robust control each controller are provided with separate control schemes so that each controller works independently without the intersection of information. Four control laws are given to four controllers. The control laws on converter is used to interconnect different devices into the dc bus. It ensure high power quality on dc bus. The traditional control loops are tuned to obtain the control laws. The converter dynamic response are tuned to provide voltage regulation at the dc bus. The control schemes on each converter is different because it is based on the measurement of voltage and current at the connection node. The voltage regulation on FEC is stiffly maintained because the voltage on ac grid is higher when compared to storage system. In PVC system maximum power tracking algorithm is used to track maximum power from the PV cell. The droop control is implemented in BC and SCC to ensure stability. The voltage reference of BC and SCC depends on SOC value of their systems and the function of goal of the network is called optimal SOC.The FEC feeding only mean power request from the ac grid. Thus the super capacitor supply power at transient of few seconds, battery operates from few seconds to several minutes. The dynamic performance of each device can split power based on bandwidths of converter while bandwidth implies response time of devices.

The converter is controlled by feedback chain and PI regulator or fuzzy controller. To obtain closed control transfer function for three units. The bandwidth of power unit depends on the value of regulator.

A. Front end controller

The FEC is controlled by using phase lock loop algorithm. When grid phase is locked, The FEC controls both direct and quadrature axis of current [13].Two feedback chains internal and external chains are used. The current as input and switching component control signal as output to internal feedback losses of oxygen reduction reaction are almost entirely responsible for the potential drop of the cell. However, at high current densities, the concentration losses become more significant. The output voltage of the single cell is given by Loop .The dc voltage, reactive power as input and the direct and quadrature axis current as output to external feedback loop. The control schemes of FEC is drawn. The closed loop transfer function is

$$\frac{3v_d(k_p s + k_i)R}{2RCs^2 + (3k_p v_d + 2)s + 3k_i v_d} \qquad \text{………… (9)}$$

Where *Vd* is the direct component of the grid voltage, *kp* and *ki* are the constants of the PI regulator, *C* is the total equivalent capacitance of the dc bus, and *R* is a resistive parameter representing the power absorbed by the dc bus. The feedback chain is realized on the square of dc voltage. In frequency domain, the dc voltage square is directly depends on the direct component of the grid current

$$\frac{V_{DC}^2}{I_d} = \frac{3v_d}{2}\frac{R}{sRC+1} \qquad \text{…………(10)}$$

From the above equation FEC time response are limited by bandwidth of low pass filter.

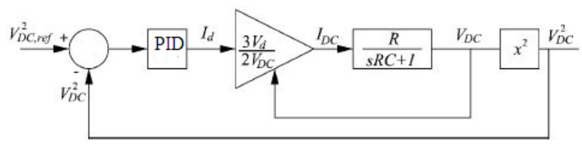

Fig .4 (control scheme Of FEC using PID).

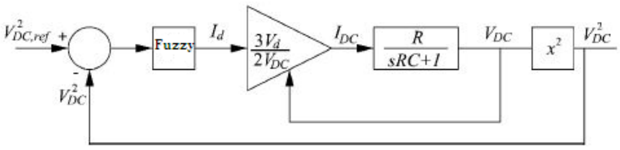

Fig.5 (control schemes of FEC using Fuzzy)

B. Battery converter

The BC is realized by connecting one end of inverter to bidirectional step up (or) step-down transformer. The high voltage side of transformer is connected to the capacitor and low voltage side of battery is connected by inductor. The battery converter has two feedback loops. The external loop regulate the dc voltage generating the reference current as output. The current in the inductance acting on duty cycle of switching component is controlled by the internal loop.
The dc voltage reference in function of SOC is changed to obtain self-recharge function. The droop action is necessary for battery to keep SOC to a desired value. Thus formulating closed loop transfer function droop action is neglected when its action is slow compared to dynamic action.

$$\frac{V_b(k_p s + k_i)R}{RCs^2 + (k_p V_b + 1)s + k_i V_b} \quad \ldots\ldots\ldots\ldots (11)$$

Where Vb is the battery voltage

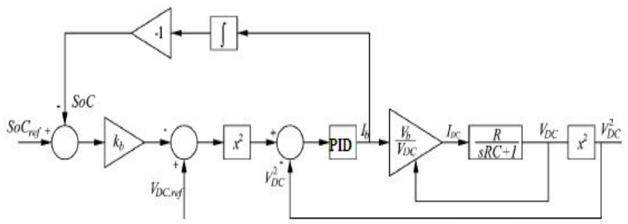

Fig 6 (control schemes of battery using PID)

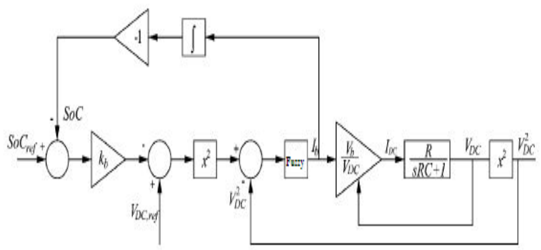

Fig 7 (control schemes of battery using Fuzzy)

C. SUPER CAPACITOR CONVERTER

The SCC has the same configuration of BC. The high voltage side of transformer is connected to the capacitor and low voltage side to battery by inductor. The battery converter has two feedback loops. The external loop regulate the dc voltage generating the reference current as output. The current in the inductance acting on duty cycle of switching component is controlled by the internal loop. The only difference is the control scheme of BC in relation to feedback on super capacitors' voltage.

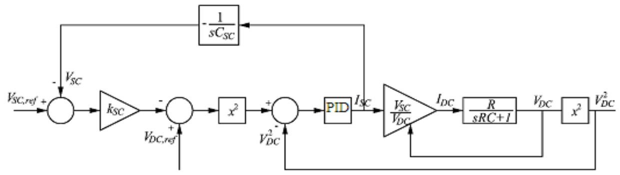

Fig 8 (control schemes of super capacitor using PID)

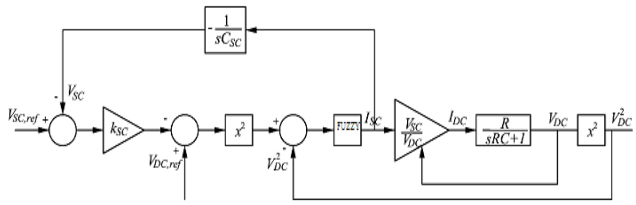

Fig 9 (control schemes of super capacitor using Fuzzy)

The dc voltage reference in function of super capacitor SOC is changed to obtain self-recharge function. The droop action is necessary for battery to keep SOC to a desired value. Thus formulating closed loop transfer function droop action is neglected when its action is slow compared to dynamic action.

$$\frac{V_{sc}(k_p s + k_i)R}{RCs^2 + (k_p V_{sc} + 1)s + k_i V_{sc}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (12)$$

Where *V*SC is the supercapacitors' voltage.

IV. NUMERICAL AND EXPERIMENTAL RESULTS

Many numerical and experimental test are performed to test the control strategy. To achieve the required bandwidth, the PID controller are tuned to parameter given in table 1.The bandwidth of three converters change as a function of the power supplied to the dc bus. The constants *k*b and *k*SC are chosen taking the maximum variation of the dc voltage and SoC of two storage devices. Considering the maximum allowable dc voltage is 450V. The desired SoC value is 95%.The desired voltage value of super capacitor has been set to 200 V.The variation of voltage on super capacitor must be lower than the battery converter, so capacitor acts faster than the battery.

Table 1
Parameters of converter regulators

FEC		ZC				SC			
k_p	k_i	k_p	k_i	k_b	SOC_{ref} [%]	k_p	k_i	k_{SC}	$V_{SC,ref}$ [V]
0.1	0.2	0.9	1	0	95%	100%	25	0	220

1. Grid

Increasing demand and greenhouse gas emission causes the increased use of renewable energy resources. The connection of dc sources to the AC grid is a difficult task. The DC power is produced by solar PV system and fuel cell then it is given to the DC grid using unidirectional power electronic converter with control schemes of PID and Fuzzy. The power is stored using battery and super capacitor in the grid. DC sources such as battery, super capacitor, solar PV are connected to the AC grid through FEC are simulated by using MATLAB. During DC grid connected with AC grid the Power produced from various sources such as battery, super capacitor, solar PV and load are shown. The Power produces from solar is nonlinear Power so it gets oscillates. The Power produced from battery and capacitor power depends on charging and discharging condition. The Power produced on the load remains constant.

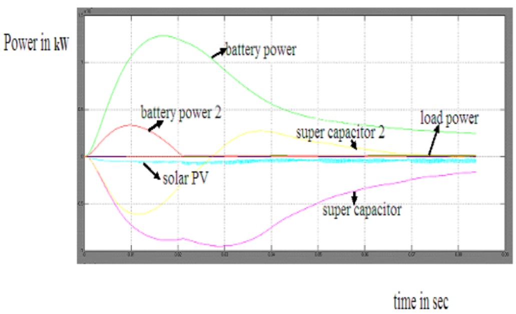

Fig 10(Power on various DC sources connected to AC grid using PID controller)

The various DC sources on DC grid are efficiently connected with AC grid by stabilizing the voltage, frequency etc. The Fuzzy logic controller is used to stabilize the Power under different voltage condition. The power produced on various DC sources connected to an AC grid is stimulated. The battery and capacitor undergoes charging and discharging continuously are indicated in the graph as rising and lowering of power.

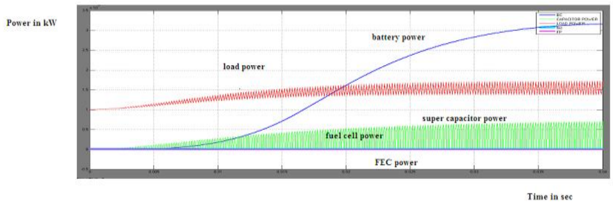

Fig 11 (Power on various DC sources connected to DC grid using Fuzzy controller)

2. Solar PV system

The solar PV system power generation depends on intensity and irradiance of sun. The solar power can be maximize by using MPPT controller which supplies required power to the grid. The solar PV is connected to the grid through power electronic controller. The output of power produced from the PV system is 600V, but it produces more losses and oscillation in the system because solar power depends on intensity of sun radiation.It may not be constant through out the day. The efficiency of solar using PID controller is 88%.

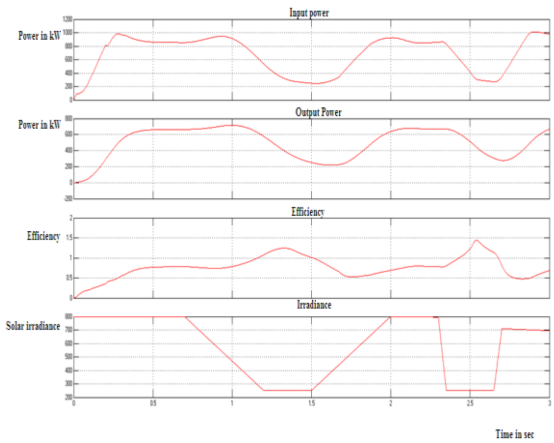

Fig 12 (Output Power of PV using PID controller)

The photo voltaic technology is in DC power can then be grid-connected through the use of power electronic converters. Therefore for these technologies voltage source inverters play a vital role to facilitate their integration to the network. Before introducing a photovoltaic generation system in large quantities there are a number of issues related to their connection to the distribution network that need to be resolved. These issues include stability, voltage and frequency control, maintaining power quality, protection, reliability and safety. The fuzzy logic controller is used to eliminate this issues. Fuzzy cannot require any calculation it depends on input and output power. It is used to stabilize the voltage and reduces the losses on power. During day time power is produced without any oscillation but during night time no power is produced because of the absence of radiation from sun so the power oscillates in the graph. The input power and output power varies depending on the radiation. The efficiency of the solar PV system using Fuzzy is 97%.

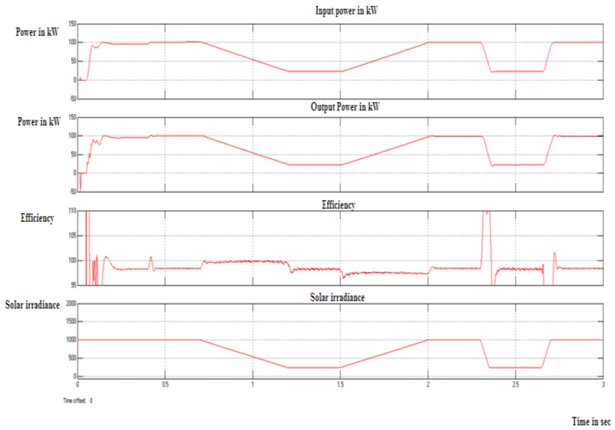

Fig 13 (Output Power of PV with fuzzy controller)

3. Battery

The battery is connected to the grid through power electronic converter. The battery charging and discharging occurs automatically by the control schemes in corporate in the Power converter. The battery efficiency can be improved by providing PID and Fuzzy control schemes on power electronic converter. The output of battery converter using PID is shown.The output power produced from the battery depends on charging and discharging condition.The output power produced by the PID controller is less than 700kW but the input poweris more than 800kW.Low power output is injected in to the grid. The efficiency Power produced in Battery is 90%.

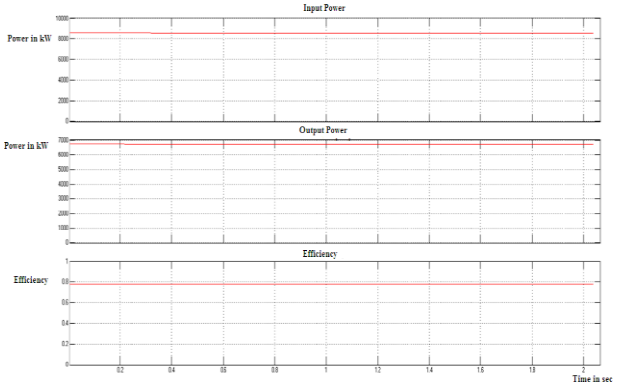

Fig 14 (Battery Power using PID controller)

The fuzzy logic controller used in battery system is to increase the charging and discharging Power .The Power produced in this system also stabilized no distortion is produced. The output of battery converter using Fuzzy controller is shown.The output power of the system is 8500 kW and input Power is 8700kW.It produce more power when compared to PID control schemes.The efficiency of the system is 94%.

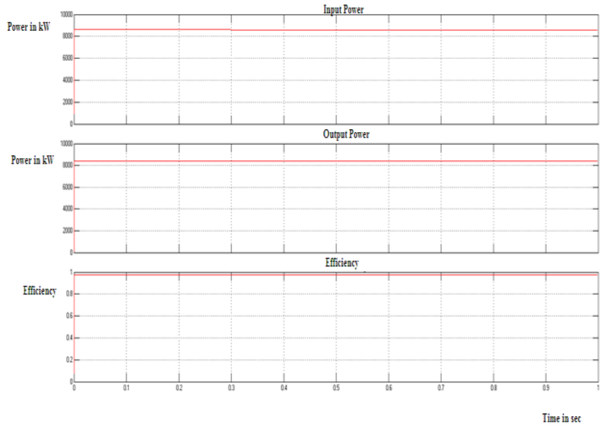

Fig 15 (Battery power using fuzzy controller)

4. Super capacitor

The capacitor is connected to the grid through power electronic converter. The battery charging and discharging occurs automatically by the control schemes in corporate in the Power converter. The capacitor efficiency can be improved by providing PID and Fuzzy control schemes on power electronic converter. The output Power of Super capacitor converter using PID is shown.The output power produced from the system is 3500 kWand the input power is 4900kW,so low power is produced in the output.The efficiency of the super capacitor using PID controller is 76% .

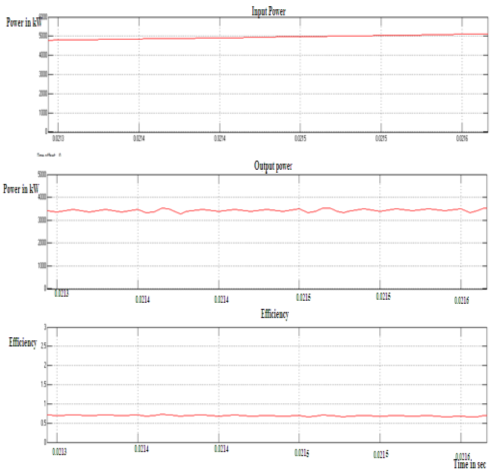

Fig 16 (Output power of Super capacitor using PID controller)

The fuzzy logic controller used in super capacitor is to stabilize the power. The stabilization of power is very difficult in super capacitor during charging and discharging condition. The output of super capacitor converter using Fuzzy controller is shown.The output power of capacitor is 3500kWand the input power is 4900kW.The efficiency of the system is 85%.

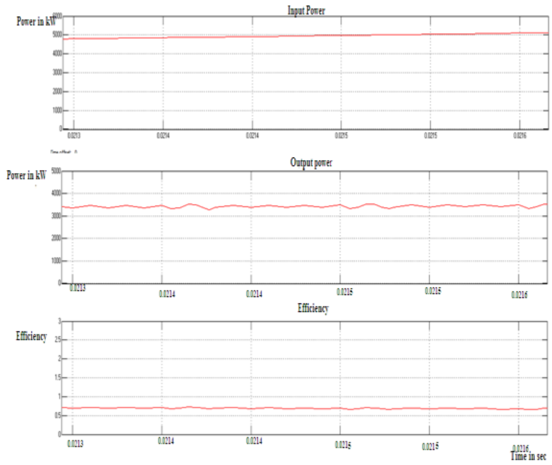

Fig17 (Output power of super capacitor with fuzzy controller)

5. Fuel cell

The fuell cell converet chemical energy into electrical energy using oxygen.The can produce electricity by using continuous supply of hydrogen and air.Fuel cell are different from batteries because fuel cell requires continuous supply of input.The output power from fuel cell is shown. The Fuel cell input Power is oscillated in uncontrolled stage but using fuzzy logic controller input Power is stabilize to 600 kW.The output power is also stabilize to 600kW using fuzzy logic controller.The efficiency of the system 96%.

Uncontrolled section controlled section

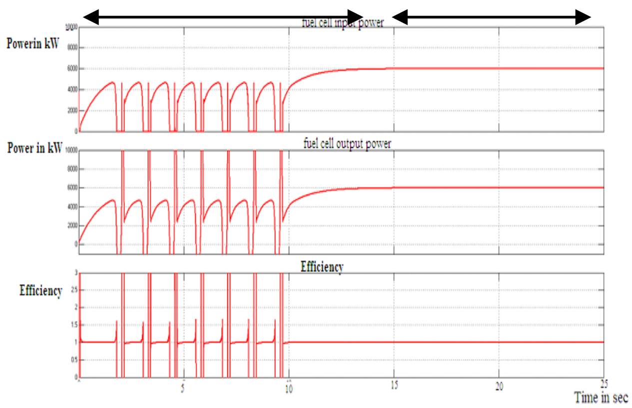

Fig 18 (Fuel cell output power)

V CONCLUSION

The renewable energy resources are used to improve efficiency, reduces cost of fuel and reduce emission of unwanted gases. The new technology used in storage system to achieve goals of voltage stabilization and regulation, peak shaving and continuity of services. The high quality distribution network is obtain by connecting dc network to ac network. The connection of dc grid to an ac grid various experiments are carried out in MATLAB.In this method each controller are provided with control strategy for connecting dc sources to dc grid.

In this paper all the components of the system are modelled and analyzed the system response due to variation in load. The necessary control strategy is proposed to a converter because the converter is controlled by dc bus voltage and it also used to show the capability of dc grid. The experimental simulation are carried out to set the control strategy for converter and also to verify the goals are achieved. The experimental result shows the continuity of service when a fault occurred on the ac grid, and voltage stabilization and regenerative actions were effectively performed by the dc microgrid. The dynamic response of different devices are decoupled by control of converter which makes the device work at its best potential. The experimental result also shows self-recharge are effectively achieved by providing control logic to storage system. The fuzzy controller are used increase the efficiency of PV, battery, fuel cell and super capacitor. The comparison of both PI and fuzzy controller are stimulated and their experimental results are also shown.

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computing techniques to power system studies. She is a life member of ISTE.

REFERENCES

[1] S. B. Kjaer, J. K. Pedersen, and F. Blaabjerg, "A review of single-phase grid-connected inverters for photovoltaic modules," IEEE Trans. Ind. Appl., vol. 41, no. 5, pp. 1292–1306, Sep./Oct. 2005.

[2] Frede Blaabjerg, Remus Teodorescu and Marco Liserre," Overview of Control and Grid Synchronization for Distributed Power Generation Systems," vol. 53, no. 5, October 2006.

[3] J. Lago and M. L. Heldwein," Operation and control-oriented modeling of a power converter for current balancing and stability improvement of DC active distribution networks," vol. 26, no. 3, pp. 877–885, Mar. 2011.

[4] Y. Sozer and D. A. Torrey, "Modeling and control of utility interactive inverters," IEEE Trans. Power Electron., vol. 24, no. 11, pp. 2475–2483, Nov. 2009.

[5] M. Rahimi and A. Emadi, "Discontinuous-conduction mode of dc–dc converters feeding constant-power loads," IEEE Trans. Ind. Electron.,vol. 57, no. 4, pp. 1318–1329, Jul. 2007

[6] Y. Chung,W. Liu, D. A. Cartes, E. G. Collins, and S. I. Moon, "Control methods of inverter-interfaced distributed generators in a microgrid system," IEEE Trans. Ind. Appl., vol. 26, no. 3, pp. 1078–1088, May/Jun.2010.

[7] S. V. Iyer, M. N. Belur, and M. C. Chandorkar, "A generalized computational method to determine stability of a multi-inverter microgrid," IEEE Trans. Power Electron., vol. 25, no. 9, pp. 2420 –2432, Sep. 2010.

[8] Kandler A. Smith, Christopher D. Rahn, and Chao-Yang Wang," Model-Based Electrochemical Estimation and Constraint Management for Pulse Operation of Lithium Ion Batteries," IEEE transactions on control systems technology, vol. 18, no. 3, may 2010.

[9] Markus Einhorn, Member, IEEE, Fiorentino Valerio Conte, Christian Kral, Senior Member, IEEE, and J¨urgen Fleig," Comparison, Selection, and Parameterization of

[10] Electrical Battery Models for Automotive Applications," IEEE transactions on power electronics, vol. 28, no. 3, march 2013.

[11] S. Buller, E. Karden, D. Kok, and R. W. De Doncker, "Modeling the dynamic behavior of supercapacitors using impedance spectroscopy," Ind.Appl. Conf., vol. 4, pp. 2500–2504, 2001.

[12] Dirk linzen, student member, IEEE, Stephan Buller, member,IEEE, Eckhard karden, member,IEEE, and Rik w. De doncker, fellow,IEEE,"Analysis and evaluation of charge-balancing circuits on performance, reliability, and lifetime of super capacitor systems," IEEE transactions on industry applications, vol. 41, no. 5, September/October 2005.