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Fuzzy Logic Controller Based AC grids in DC Islanding Modes

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ABSTRACT- This project presents the operation of a distributed generation (DG) system driven by a dc-dc step-up converter and a dc-ac voltage source inverter (VSI) interfaced with the power grid by Fuzzy Controller. To create a stable mode when different kinds of loads are connected locally or when working under contingency, the step-up converter must regulate the dc link voltage, allowing the VSI to stabilize its terminal voltage. The power flow between the grid and the DG is controlled by applying a power/voltage method that regulates the amplitude and the displacement of the grid voltage synthesized by the DG, while a phase locked loop algorithm is used to synchronize the grid and DG by fuzzy. Additionally, a set of simulations are performed independent of the load type or its work regime (whether it is connected to the grid). The effectiveness of the proposed method is evaluated by experimental results by using Fuzzy Logic Controller.

Index Terms—DC distribution networks, smart grid, storage systems, fuzzy logic control.

I. INTRODUCTION

The interconnection of distributed generators (DGs) to the utility grid through power electronic converters has raised concern about proper load sharing between different DGs and the grid. Mircogrid can generally be viewed as a cluster of distributed generators connected to the main utility grid, usually through voltage-source-converter (VSC) based interfaces. Concerning the interfacing of a microgrid to the utility system, it is important to achieve a proper load sharing by the DGs [1-2]. In general, a microgrid is interfaced to the main power system by a fast semiconductor switch called the static switch (SS). It is essential to protect a micro grid in both the grid-connected and the islanded modes of operation against all faults. Inverter fault currents are limited by the ratings of the silicon devices to around 2 per unit rated current. Fault currents in islanded inverter based microgrids may not have adequate magnitudes to use traditional over current protection techniques [3-4]. To overcome this problem, a reliable and fast fault detection method is proposed. The aim of this paper is to set up power electronics interfaced microgrid containing distributed generators. A scheme for controlling parallel connected DGs for proper load sharing is proposed.

This fuzzy-PI controller consists of a fuzzy logic controller and a conventional PIconnected in series. The fuzzy logic controller has two inputsignals, and the output signal of the fuzzy logic controller isthe input signal to

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the conventional PI controller. The controlperformance of the fuzzy-PI controller is tested under loadconditions using the MATLAB/SIMULINK simulationplatform [8-9]. In this study, fuzzy-PI controller algorithm,strategies, and modeling are developed and simulated in MATLAB/SIMULINK to develop an intelligent controltechnique for a microgrid in grid-connected and islandingmodes. The main objective of the inverter control system isto generate and stabilize the 50 Hz sinusoidal-shape AC(alternating current) output voltage and frequency. With thegrid synchronization algorithm, we can interconnect theinverter to the utility grid. The proposed fuzzy-PI controlstrategy has better robustness and adaptability with respectto the different parameters than the conventional strategy [10-14].

The simulation results demonstrate that the model ispotentially useful in studying the microgrid system. It isespecially suitable for a micro grid operated in both gridconnectedand islanded modes. The microgrid systemsimulation model is built in the MATLAB/Simulinkenvironment and implemented using the SimPower System toolbox [15].

II. MODELING OF ELECTRICAL STORAGE

In order to correctly set up the control strategy for the different converters of the dc system, the modeling of the electrical storage devices is required. In particular, the ability of the model to represent the behavior of the electric storage over the full dynamic range of utilization is needed. The two operative working conditions of a storage device in grid applications are the following:
1) an energy function in which the device has to guarantee the average power requested by the application;
2) a peak shaving function in which the storage has to absorb/deliver the requested peak power above or below a certain reference average power.

In general, the first function is characterized by a significantly lower charge and discharge dynamic. Among the various models available in the literature, we gave attention to lumped models capable of interpolating the device behavior as seen from the terminals.

A. ZEBRA Battery Model

The ZEBRA battery model comes from the lead acid battery dynamic models available in the literature. In particular, lead acid battery models based onelectrochemical impedance spectroscopy are described, while third-order models that show a good compromise between complexity and precision are described.

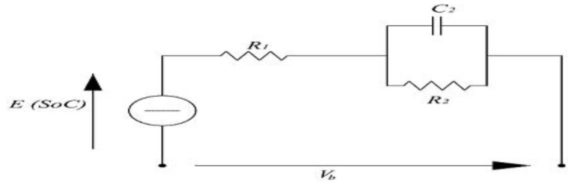

Fig.1 ZEBRA battery model.

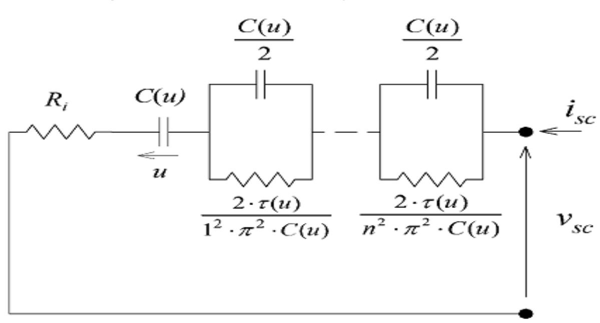

Fig.2 Super Capacitor Model.

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The model used for our purpose is represented in Fig. 1.The ZEBRA battery is modeled as an electromotive force, E(SoC), representing the open-circuit voltage as a function of the SoC, in series with the internal resistance, R1, which takes into account the high-frequencyresistance of the device, and the parallel branch, *R*2*C*2, which takes into account the dynamic behavior of the battery.

In addition, for our purpose, the battery temperature is considered to be constant during the work cycle, so that the equations

$$E(SoC) = E_0 - K_e \cdot (1 - SoC) \quad (1)$$

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

Where *E*0 is the open-circuit voltage when the battery is fully charged, *SoC* is the state of charge of the battery, *Cn* is the nominal battery capacity, *Ke* is a voltage constant, and *ib*is the current supplied by the battery.

B. Super capacitor Model

A super-capacitor model capable of representing the dynamics of the device in the typical frequency range of 10 mHz up to 100 Hz is represented in Fig. 2 This model, introduced, was integrated in a more general model, where a simplified procedure for the parameteridentification was presented.

In this model, we have the following:

1) *Ri* represents the high-frequency resistance, which was available from the manufacturer's datasheet;2) *C(u)* = *C*0 + *KV* × *u*, where *C*0 and *KV* are constants evaluated by a constant current charge test, as described.

3) *τ(u)* = 3 ×(*R*dc− *Ri*) × *C(u)*, where *R*dc represents the dc resistance reported in the manufacturer's datasheet.

The super-capacitor and battery models used are unable to represent the redistribution and self-discharge of the devices.

For our purposes, these phenomena, which take place at very low frequencies, almost close to dc, can be neglected without significant error

III.CONTROL STRATEGY

A control strategy for the network converters has been defined. In order to make the dc network capable of achieving all of the aims discussed in the previous sections, the control strategy should ensure:

1) the stabilization of the dc voltage during transients and at a steady state for different kind of loads;

2) the automatic configurability of the control scheme if one or more devices are unavailable;

3) The self-recharge of the storage systems;

4) The optimal utilization of all of the devices.

It is evident that to achieve the first goal, dc voltage control has to be implemented. However, there are four converters that can regulate the dc voltage: FEC, ZC, SCC, and PVC.

The possibility of splitting the voltage regulation requires the use of only one controller or of coordinated controllers. However, in order to realize a more robust control, it would be preferable to have separate controllers for the different units capable of working independently from the presence of the other units. The proposed control strategy is to design four control laws for the four converters. The control laws have to be adapted to the different devices they connect to the dc bus and have to be integrated in order to ensure both optimal workingconditions for the different systems and high power quality on the dc bus. As will be shown in the next sections, these laws can be obtained using traditional control loops suitably tuned and modified. One of the innovative modifications consists in the self-recharge function that each storage system has to implement in order to keep, autonomously, its own SoC around the desired value. The tuning of the dynamic responses of the converters has to be coordinated to make each device work at its best and, at the same time, to guarantee the stabilization of the dc bus voltage. Thus, the dynamic response of each converter is tuned to optimally exploit the controlled device but it is also coordinated with the dynamic performances of the other converters. On the contrary, from an operation viewpoint, the controls of the four converters are independent from each other because they are based only on the measurement of voltage and current at their connection node.

The duty of imposing a stationary dc bus voltage can be assigned only to one converter; otherwise, the difference between the voltages measured at the different converters would cause a continuous power flow from one converter to another, even in the absence of loads. The stiff voltage regulation has been committed to the FEC because the amount of energy in the ac network is consistently greater than the energy stored in the storage systems, and unlike the PV field, it is not dependent on weather conditions. The PVC implements a maximum power point tracking algorithm in order to draw the maximum possible energy from the PV field. It shuts down if a maximum voltage threshold is reached. Indeed, this happens only if the system is not able to absorb the energy produced by the PV field (i.e., if the ac network is not available and all of the storage systems are fully charged). The ZC and SCC contribute to voltage regulation but, in order to ensure stability, a droop control is implemented.

In particular, in order to also perform the self-charging action, the droop is realized by taking into account the SoC. Thus, the voltage references for the ZC and SCC are dependent on the SoC values for the two storage systems, respectively. An optimal SoC has to be defined as a function of the goal of the network. For example, the optimal SoC for the batteries could be higher during the nighttime and lower during the daytime because the failure of the ac network during the daytime could be covered by the PV field, while the PVC cannot give energy to the loads during the nighttime.

In order to amplify the action of the supercapacitors when they are close to the optimal SoC, the SCC voltage reference is tuned to the supercapacitors' voltage instead of the supercapacitors' energy (proportional to the square of the voltage). In this way, their energy contribution is low when they are far from the optimal SoC.

In order to achieve the optimal use of the devices, it is also advisable that the power supplied by the FEC be the smoothest possible, feeding only the mean power request from the ac grid. Moreover, the supercapacitors should supply power during transients of a few seconds, while the batteries should work at time periods ranging from a few seconds to some minutes. The split of the power according to the dynamic performances of each device can be obtained based on the bandwidths of the converters' controllers. Indeed, the choice of

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different bandwidths implies different response times for the different devices.

As shown below, each converter is controlled by means of a feedback chain and PI regulator. In order to obtain the desired bandwidth for a power unit, it is necessary to choose suitable values for the regulator constants. It is, therefore, advisable to find the closed-loop transfer functions for the three power units.

A Front-End Converter

The FEC is a traditional active front end. In order to control the FEC, a phase lock loop algorithm is implemented. After locking the grid phase, the control of the FEC operates on the rotating reference controlling the direct and quadrature components of the current. Two nested feedback chains are implemented. The internal one uses the currents as inputs and the switching component control signals as outputs; the external one has the dc voltage and reactive power as inputs and the direct and quadrature currents as outputs. In relation to the dcvoltage control, only the external chain is interesting. If the internal chain is much faster than the external one and is capable of setting the desired currents, the control scheme of the FEC can be drawn as reported in Fig. 3.

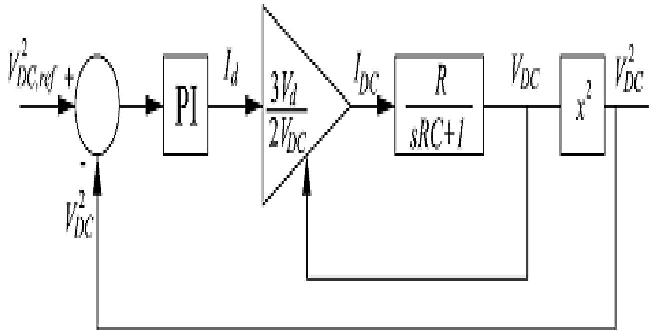

Fig.3. Control scheme of FEC.

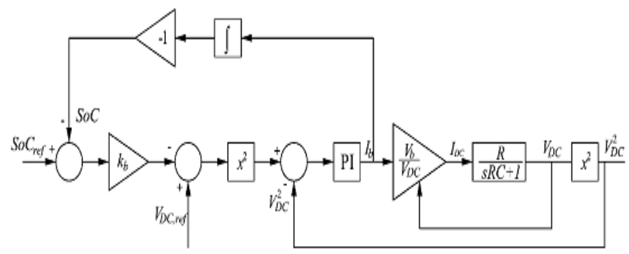

Fig.4.Control scheme of ZC.

The closed-loop transfer function is

$$\frac{3\,V_d\,(k_p\,s+k_i)\,R}{2RC\,s^2+(3\,k_p\,V_d+2)\,s+3\,k_i\,V_d} \quad (3)$$

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.

As shown in Fig. 3.The feedback chain is realized on the square of the dc voltage. In this way, indeed, the tuning of the regulator is easier. In fact, in the frequency domain, the square of the dc voltage directly depends on the direct component of the grid current

$$\frac{V_{\rm DC}^2}{I_d}=\frac{3\,V_d}{2}\,\frac{R}{s\,RC+1}. \quad (4)$$

From (3), it is clear that the control system operates, globally, as a low-pass filter whose bandwidth limits the time response of the FEC.

B. ZEBRA Converter

The ZC is realized with one inverter leg acting as a bidirectional step-down/step-up converter. The high-voltage side is connected to the dc bus with an output capacitance, while the LV side is connected to the ZEBRA by means of an inductor. In addition, the ZC is operated

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with two nested feedback chains. The internal one controls the current in the inductance acting on the duty cycle of the switching components, while the external one regulates the dc voltage generating the reference current as an output.

The self-recharge function is obtained changing the dc voltage reference in function of the SoC. This sort of droop action ensures that the battery tries to keep its SoC around the desired value. In any case, this action is slow if compared to the dynamic action of the control loop and can, therefore, be neglected in formulating the closed-loop transfer function

$$\frac{V_b\ (k_p\, s + k_i)\, R}{RC\, s^2 + (\,k_p\, V_b + 1)\ s +\ k_i\, V_b} \tag{5}$$

Where Vbis the battery voltage

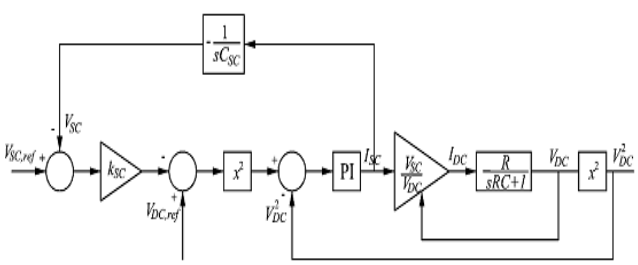

Fig.5.Control scheme of SCC.

C. Super capacitors Converter

The SCC is realized using the same configuration as the ZC. The high-voltage side is connected to the dc bus with an output capacitance, while the LV side is connected to the super capacitors by means of an inductor. In addition, the SCC is operated with two nested feedback chains. The internal chain controls the current in the inductance acting on the duty cycle of the switching components, while the external one regulates the dc voltage generating the reference current as an output.

The self-recharge function is obtained changing the dc voltage reference in function of super capacitors voltage. This sort of droop action is introduced in order to keep the super capacitors SoC around the desired value. Anyway, if *k*SCis small enough, the action of the droop chain is slow if compared to the dynamic action of the control loop, and the closed-loop transfer function is

$$\frac{V_{SC}\ (k_p\, s + k_i)\, R}{RC\, s^2 + (\,k_p\, V_{SC} + 1)\ s +\ k_i\, V_{SC}} \tag{6}$$

Where$V_{SC}$is the super capacitors' voltage.

IV.FUZZY LOGIC CONTROL

L. A. Zadeh presented the first paper on fuzzy set theory in 1965. Since then, a new language was developed to describe the fuzzy properties of reality, which are very difficult and sometime even impossible to be described using conventional methods. Fuzzy set theory has been widely used in the control area with some application to power system [5]. A simple fuzzy logic control is built up by a group of rules based on the human knowledge of system behavior. Matlab/Simulink simulation model is built to study the dynamic behavior of converter. Furthermore, design of fuzzy logic controller can provide desirable both small signal and large signal dynamic performance at same time, which is not possible with linear control technique. Thus, fuzzy logic controller has been potential ability to improve the robustness of compensator.

The basic scheme of a fuzzy logic controller is shown in Fig 6 and consists of four principal components such as: a fuzzy fication interface, which converts input data into suitable linguistic values; a knowledge base, which consists of a data base with the necessary linguistic definitions and the control rule set; a decision-making logic which, simulating a human decision process, infer the fuzzy control action from the knowledge of the control rules and linguistic variable definitions; a de-fuzzification interface which yields non fuzzy control action from an inferred fuzzy control action [10].

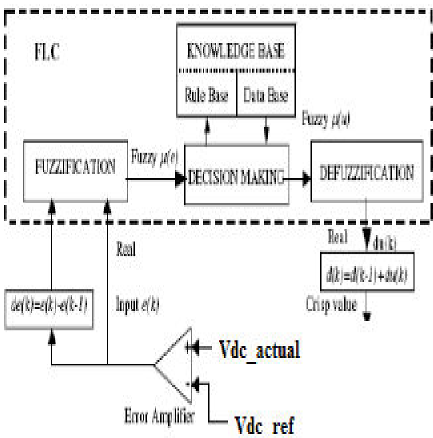

Fig.6.Block diagram of the Fuzzy Logic Controller (FLC) for proposed converter.

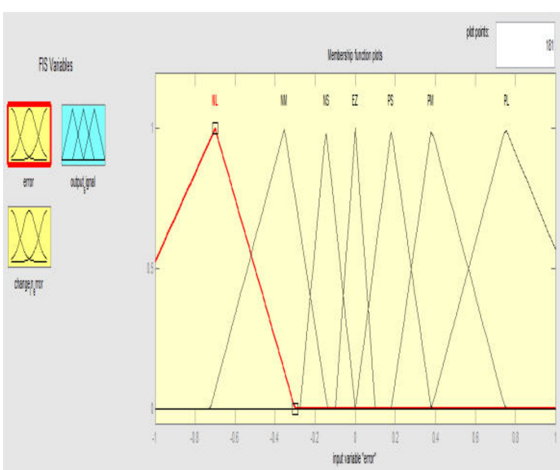

Fig.7. Membership functions for error.

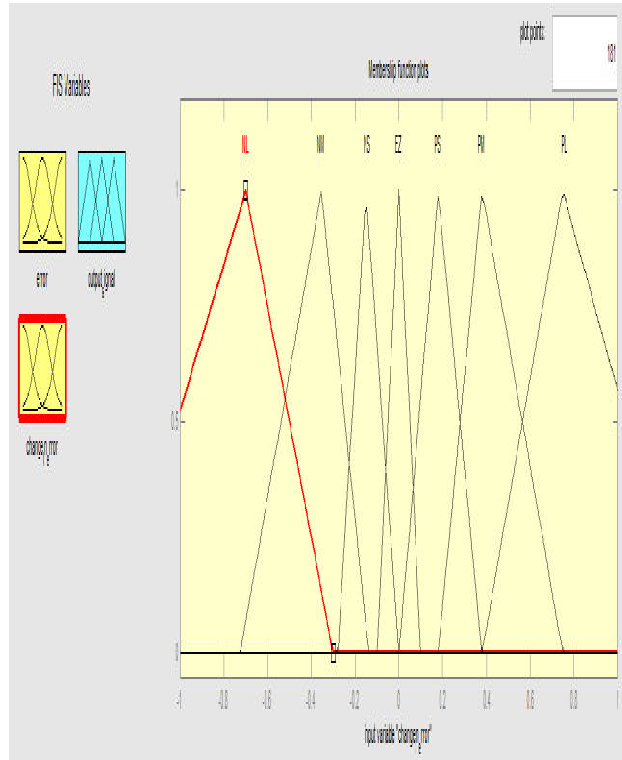

Fig.8. Membership functions for change in error.

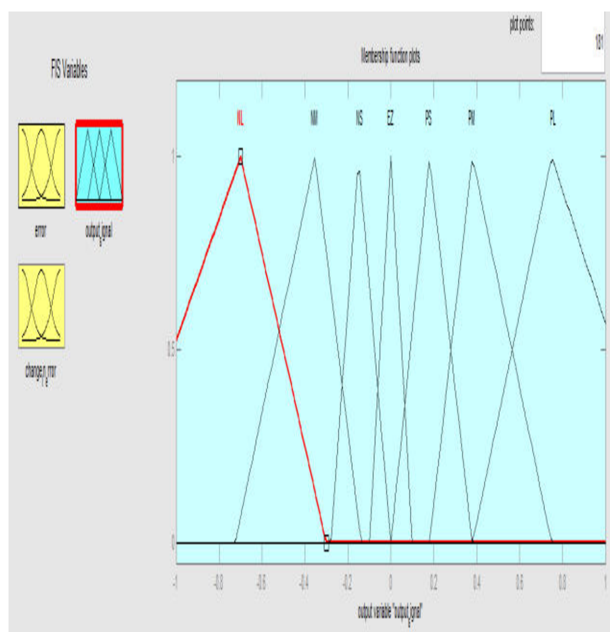

Fig.9. Membership functions for Output.

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Table I
Table rules for error and change of error.

Error / Change error	NL	NM	NS	EZ	PS	PM	PL
NL	NL	NL	NL	NL	NM	NS	NL
NM	NL	NL	NL	NM	NS	EZ	NM
NS	NL	NL	NM	NS	EZ	PS	NS
EZ	NL	NM	NS	EZ	PS	PM	EZ
PS	NM	NS	EZ	PS	PM	PL	PS
PM	NS	EZ	PS	PM	PL	PL	PM
PL	EZ	PS	PM	PL	PL	PL	PL

V.MATLAB/SIMULINK RESULTS

CASE I: PI CONTROLLER BASED SYSTEM

A. During load change condition

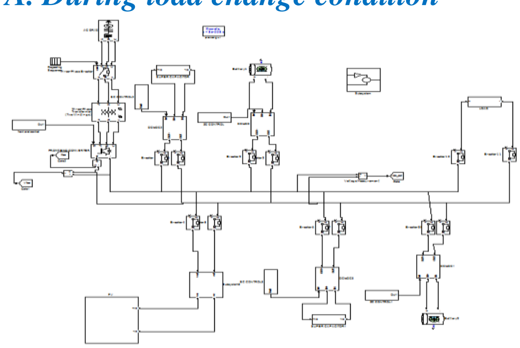
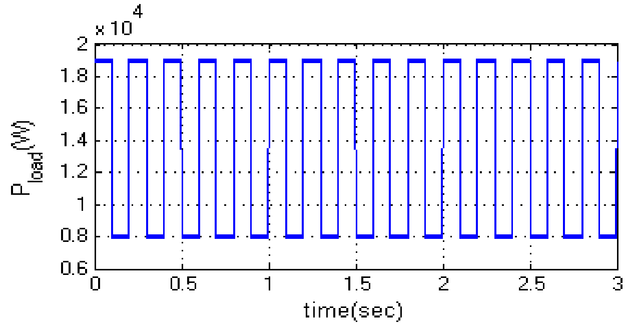
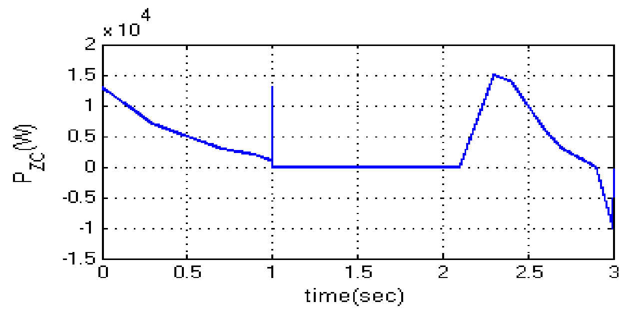


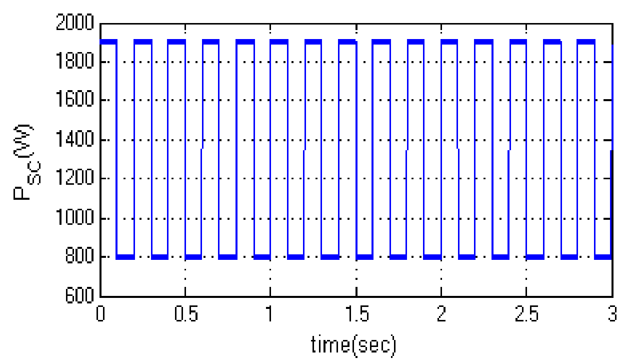
Fig.10. Simulink circuit for load changing condition



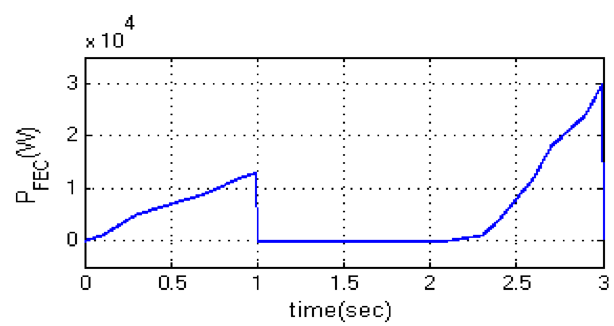
(a)



(b)



(c)



(d)

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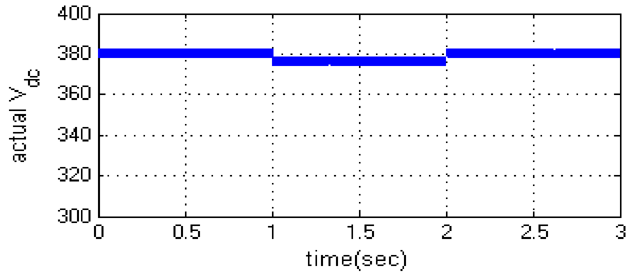
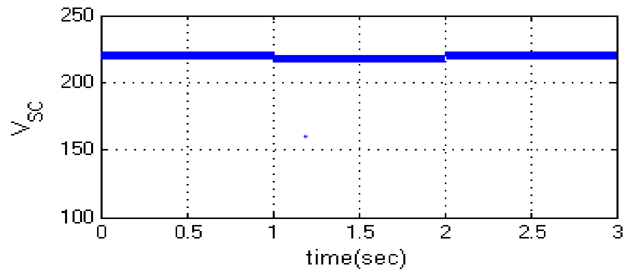


(e)



(f)

Fig.11. simulation results for (a) power at load (b) power at zebra converter (c) power at super capacitor (d) power at front end converter (e) actual dc link voltage (f) voltage super capacitor

B. During fault condition

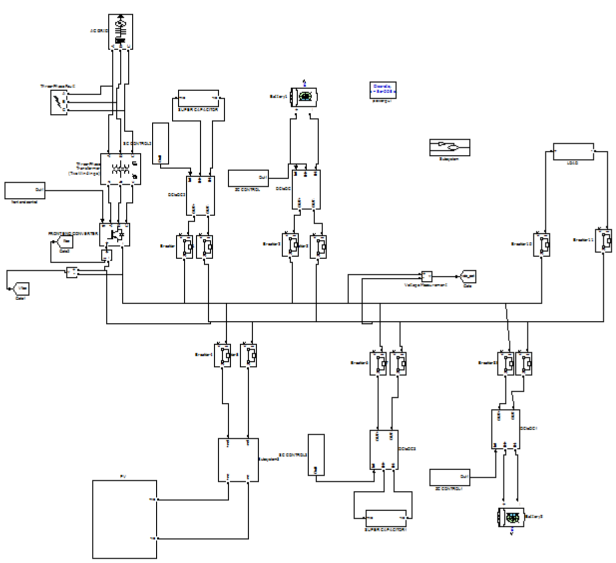
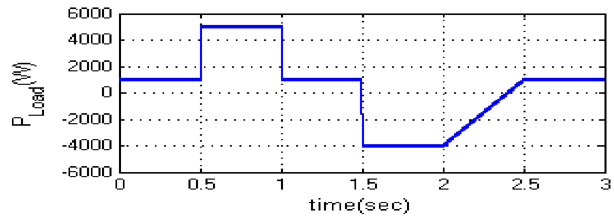
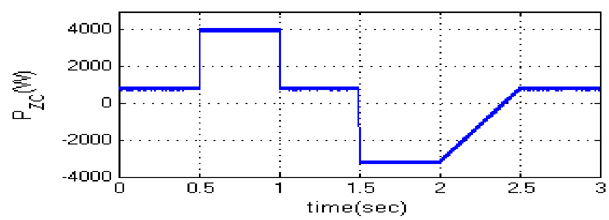


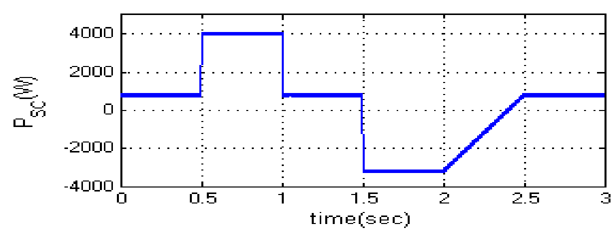
Fig.12. Simulink circuit for fault condition



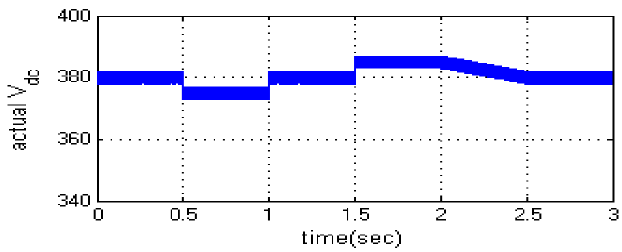
(a)



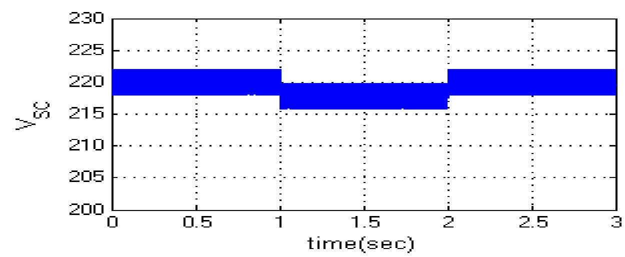
(b)



(c)



(d)



(e)

Fig.13. simulation results for (a) power at load (b) power at zebra converter (c) power at super capacitor (d) actual dc link voltage (e) voltage super capacitor.

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C. During regenerative braking condition

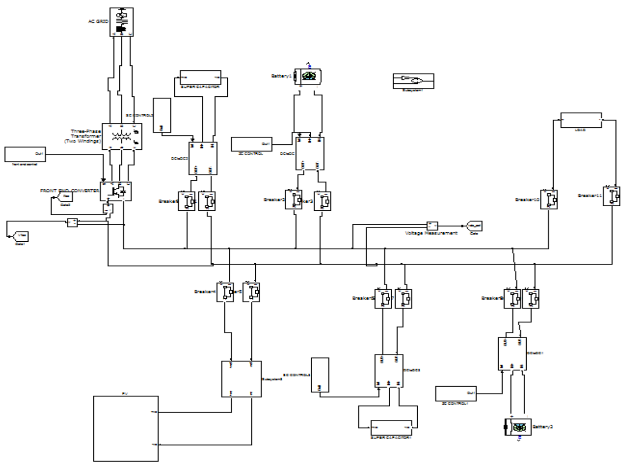
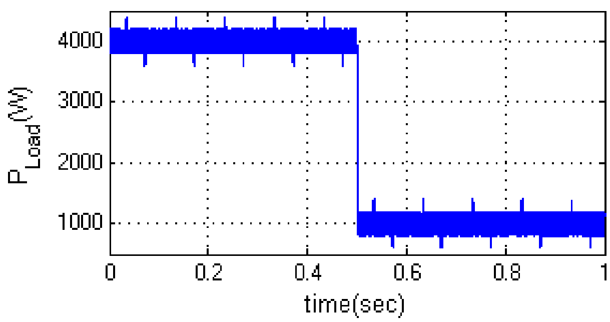
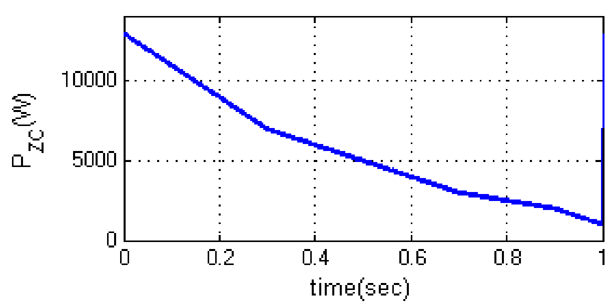


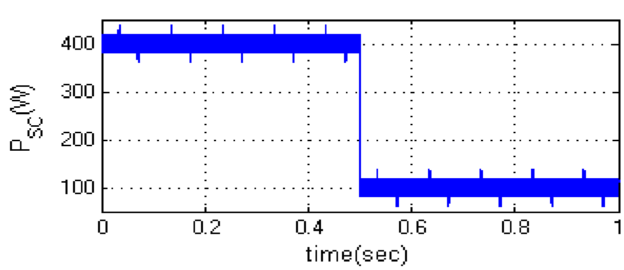
Fig.14. Simulink Circuit Fault Condition.



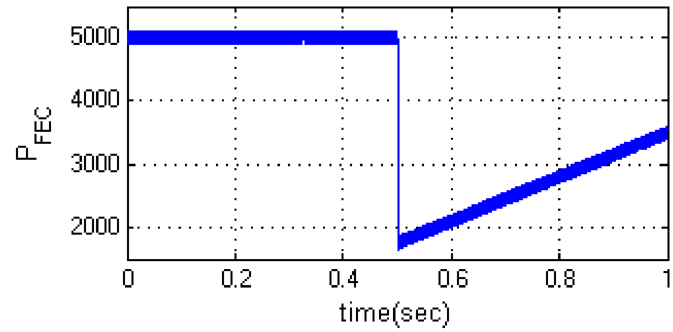
(a)



(b)



(c)



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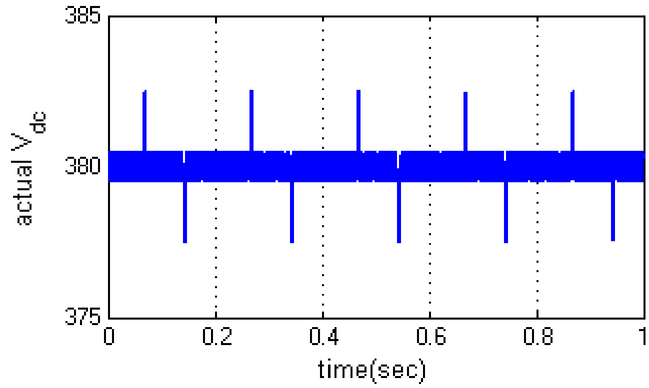
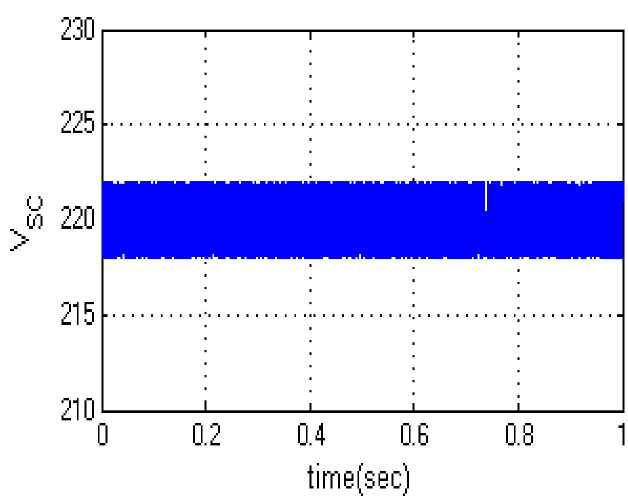


(e)



(f)

Fig.15. simulation results for (a) power at load (b) power at zebra converter (c) power at super capacitor (d) power at front end converter (e) actual dc link voltage (f) voltage super capacitor

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Case II: Fuzzy controller based system

A. During load change condition

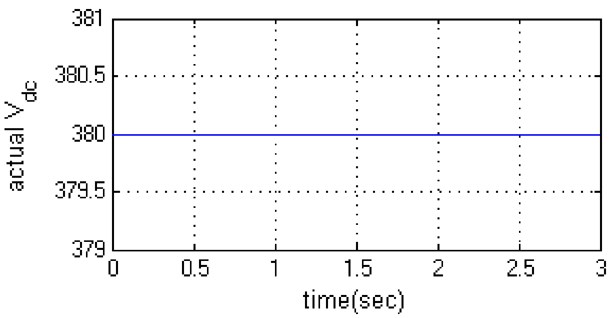

Fig.16. actual dc link voltage

B. During fault condition

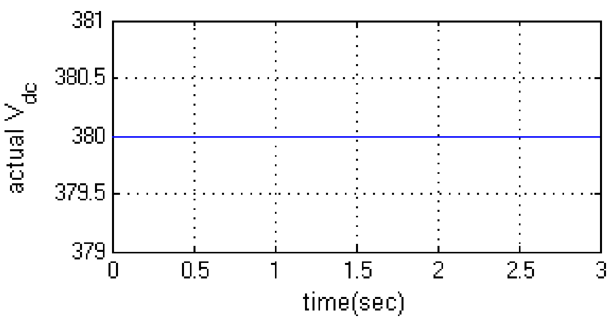

Fig.17. actual dc link voltage

C. During regenerative braking condition

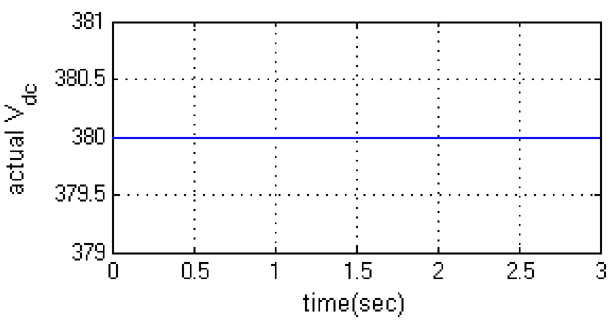

Fig.18. Actual Dc Link Voltage.

VI.CONCLUSION

This paper presents an alternative solution to connecting a DG system to the grid, whereby the amplitude and displacement of the voltage synthesized by the DG is regulated with respect to the grid voltage and the control variable before and after the contingency is always the same by using Fuzzy Logic Controller. Additionally, a dc-dc step-up converter and a dc-ac VSI are used in a DG system as an interface with the power grid.

The simulation and experimental results demonstrate that the connection of DG sources can have adverse effects, depending on the connection procedures by Fuzzy Controller.

To improve the DG operation, the dc link voltage must be controlled, in this case by a dc-dc step-up converter. Fuzzy controller is associated with resonant regulators were used as a solution to produce distortion-free DG voltage, even when the local load is nonlinear or when distortion occurs in the grid voltage.

REFERENCES

[1] N. Hadjsaid, R. Caire, and B. Raison, "Decentralized operating modes for electrical distribution systems with distributed energy resources," in Proc. IEEE Power Energy Soc. General Meeting, Jul. 26–30, 2009, pp. 1–4.

[2] A. Soni and C. S. Ozveren, "Renewable energy market potential in U.K," in Proc. 42nd Int. Univ. Power Eng. Conf., Sep. 4–6, 2007, pp. 717–720.

[3] Y.-w. Song, "American policy on renewable energy and its inspiration," in Proc. Int. Conf. Manag. Sci. Eng., Nov. 24–26, 2010, pp. 1513–1519.

[4] P. Sarikprueck, S. K. Korkua, W.-J. Lee, and P. Lumyong, "Developing important renewable energies in Thailand," in Proc. IEEE Power Energy Soc. General Meeting, Jul. 24–29, 2011, pp. 1–8.

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[5] J. M. Carrasco, L. G. Franquelo, J. T. Bialasiewicz, E. Galvan, R. C. P. Guisado, M. A. M. Prats, J. I. Leon, and N. Moreno-Alfonso, "Power-electronic systems for the grid integration of renewable energy sources: A survey," IEEE Trans. Ind. Electron., vol. 53, no. 4, pp. 1002– 1016, Jun. 2006.

[6] M. D. Hopkins, A. Pahwa, and T. Easton, "Intelligent dispatch for distributed renewable resources," IEEE Trans. Smart Grid, vol. 3, no. 2, pp. 1047–1054, Jun. 2012.

[7] X. Mamo, S. Mallet, T. Coste, and S. Grenard, "Distribution automation: The cornerstone for smart grid development strategy," in Proc. IEEE Power Energy Soc. General Meeting, Jul. 26–30, 2009, pp. 1–6.

[8] Standard for Interconnecting Distributed Resources with Electric Power Systems, IEEE Standard 1547, 2003.

[9] Reference technical rules for the connection of active and passive consumers to the HV and MV electrical networks of distribution Company, CEI 0-16 fasc. 9251, 2008.

[10] Reference technical rules for the connection of active and passive users to the LV electrical Utilities, CEI 0-21 fasc. 11666, 2011.

[11] M. E. Baran and N. R. Mahajan, "DC distribution for industrial systems: Opportunities and challenges," IEEE Trans. Ind. Appl., vol. 39, no. 6, pp. 1596–1601, Nov./Dec. 2003.

[12] A. Kwasinski and C. N. Onwuchekwa, "Dynamic behavior and stabilization of DC micro grids with instantaneous constant-power loads," IEEE Trans. Power Electron., vol. 26, no. 3, pp. 822–834, Mar. 2011.

[13] 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," IEEE Trans. Power Electron., vol. 26, no. 3, pp. 877–885, Mar. 2011.

[14] C. D. Xu and K. W. E. Cheng, "A survey of distributed power system— AC versus DC distributed power system," in Proc. 4th Int. Conf. Power Electron. Syst. Appl., Jun. 8–10, 2011, pp. 1–12.

[15] V. Musolino, L. Piegari, E. Tironi, L. Martini, A. Brambilla, and C. Tornelli, "Simulations and field test results for potential applications of LV DC distribution network to reduce flicker effect," in Proc. 14th Int. Conf. Harmonics Quality Power, Sep. 26–29, 2010, pp. 1–6.