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CONTROL OF ISLANDED VOLTAGE IN VSC-BASED DISTRIBUTED GENERATION SYSTEM USING ANFIS TECHNIQUE

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ABSTRACT

In this paper islanding operation of a voltage source converter based DG system with fuzzy logic controller is presented. In the grid-connected mode, a microgrid including its loads and DG units is connected to the main grid at the point of common coupling (PCC), the voltage-sourced converter is operated in the active and reactive power (PQ) control mode, by using conventional control scheme to control the active and reactive power exchange with the grid. In the islanded mode, the proposed ANFIS is used to control the voltage of the islanded system despite the load variability and uncertainties. The salient features of the proposed ANFIS are: 1) efficient to deal with the nonlinear systems 2) design does not depend on the mathematical model of the system and 3) less sensitive to the parameters variation than the conventional controllers. The frequency of the islanded system is dictated through the use of an internal oscillator. The simulation results are presented by using Matlab/simulink platform. The dynamic response of the DG system using the ANFIS have good transient behaviors compairing to the FLC and PI controllers.

KEYWORDS:, Autonomous operation, distributed generation (DG), fuzzy logic controller (FLC), voltage source converter, ANFIS.

INTRODUCTION

Distribution generation systems are widely used in today's distribution networks. They provide strong environmental, economical, technical and social benefits which drives their high depth of penetration. Distribution of generation units within an electric power system offers technical advantages in terms of power quality and reliability as well as energy management and efficiency. It also offers economical advantages in terms of reducing capital investment for construction of power systems since distribution of generation units eliminates the need for having extensive transmission systems [2],[3]. In the distribution networks, the penetration of DG units about the concept of microgrid and it can be operated both grid connected and islanded modes [4],[5]. Due to safety concerns, present utility practices do not allowed in the islanded mode of operation. DG system with its local load is present in autonomous operation as they formed island, in this case any portion of the utility grid is not included. At the point of common coupling, a microgrid including its loads and DG units is connected to the microgrid in grid connected mode. It provides fixed voltage and frequency of the main grid for the microgrid. Each DG unit controls its real/reactive power exchanges based on well known dq-currents control techniques. In islanded mode of operation frequency and voltage have no longer.

In islanded mode for the reliable and robust operation of a microgrid, it requires better control strategies are secure operation and satisfactory performance in a wide range operating conditions. In autonomous mode to control the operation of the DG system several methods are used. By using droop characteristics the current of multiple DG units are controlled in autonomous mode. In this strategy load dynamics are not included. DG unit of a voltage and frequency are controlled in islanding system. The converter is represented by an ideal current source, the controller may fail, however the load dynamics is faster than the current source dynamics. With a power factor correction capacitor for a microgrid a robust control is introduced. The DG unit and its local load of a autonomous operation a simple control scheme is presented, in this scheme load disturbances are not taken. In the autonomous operation of a DG unit is introducing the servomechanism and multivariable controller, in this case load disturbances are taken, in the islanded system the controllers design depends on the state space model and complex.

In electric power system applications conventional proportional-integral (PI) controllers are widely used. They suffer from sensitivity to parameter variation and system non linearity in PI controllers. The PI controller requires precise linear mathematical models, which are difficult to obtain and may not give satisfactory performance under parameter variations, load disturbances, etc. Recently Fuzzy Logic Controllers (FLCs) have been introduced.

Advantages of FLCs:
1. The controller design does not depend on the mathematical model.
2. To deal with the nonlinear systems.
3. To get better performance

In electric power systems to solve many problems by applying FLCs. For autonomous operation of a DG unit and its load a simple FLC is used. To reduce the number of controllers by using four PI controllers are replaced two FLCs are fully controlled by VSC. By using MATLAB software the simulation results have been developed. Under different load conditions the proposed controller provides excellent performance and robust stability for the DG system.

STUDY SYSTEM

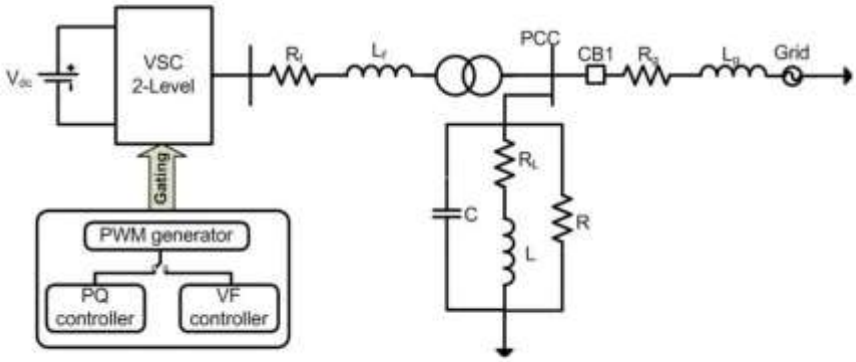


Fig.1.Single line diagram of the DG system.

Single line diagram of the DG system is as shown in above Fig.1. In DG unit has DC voltage source, series filter and a two level VSC. At the PCC, the DG unit is connected to the utility grid through a step up transformer. Three-phase parallel RLC circuit is connected at the PCC. The parameters of the DG system are given in table I.

Table 1. Parameter Of The DG System

Parameter	value
R_f	1.5 mΩ
L_f	300 µH
V_{dc}	1500 V
R	76 Ω
L	111.9 mH
R_L	0.3515Ω
C	62.86 µF
R_g	1 mΩ
L_g	10 mH
Vs	13.8 kV
F	60 Hz

Either the islanded mode or grid connected mode, the system operated based on the utility grid circuit breaker, CB1. In an active and reactive power (PQ) control mode of the DG unit is operated in grid connected mode. A cascaded control scheme is adopted in this mode. To receive the active and reactive power references of the outer controller and the inner controller to generate the d and q current references. The voltage and frequency are forced by the utility grid in grid connected mode. Where as in the islanded mode, the DG unit of a voltage and frequency are controlled and to reach suitable operation of the islanded system. The voltage source converter is entirely controlled by PI cascaded control scheme and to maintain constant frequency and load voltage in both inner and outer controllers. By using trial and error the PI controller are fine tuned. To control the voltage and frequency of the islanded system and to achieve improved responses when islanding is detected.

FLC

By using FLC, to achieve improved responses of the DG system. In the cascaded control scheme the four PI controllers are replaced by two FLCs. An internal oscillator, the system frequency is determined in islanded mode. The transformation angle $\theta(t)$ is obtained by integrating the rated angular frequency from abc to dq frame the transformation is used. As shown in Fig.2, actual load voltage signals (v_d and v_q) are compared with load voltage signals of a d and q references, to give up the error signals $e_d(t)$ and $e_q(t)$, to represent the change of error signals are $\Delta e_d(t)$ and $\Delta e_q(t)$. $e_d(t)$,$\Delta e_d(t)$ and $e_q(t)$, $\Delta e_q(t)$ are the inputs of the first and second FLC(FLC1 & FLC2). The d and q axis voltage signals ($v_{dn}(t)$ and $v_{qn}(t)$) are updated by the outputs of the FLCs ($m_d(t)$ and $m_q(t)$). To exchange

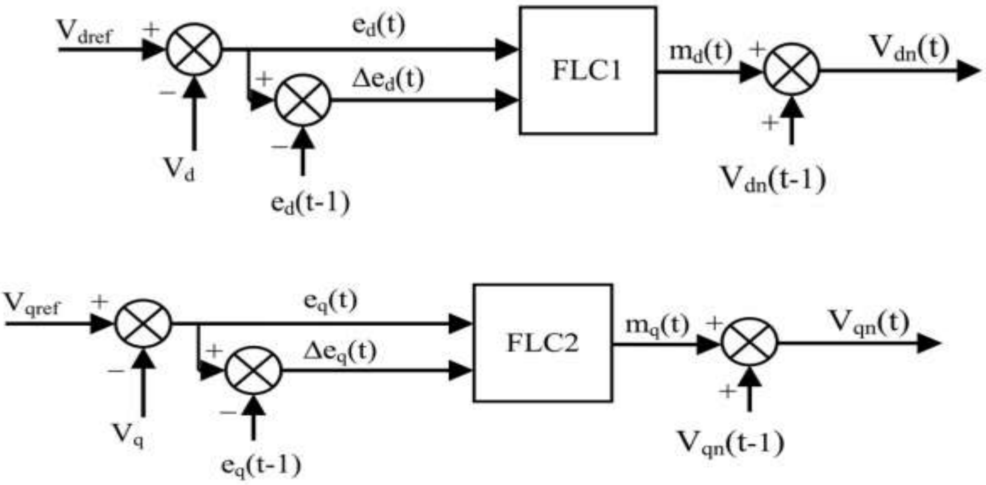
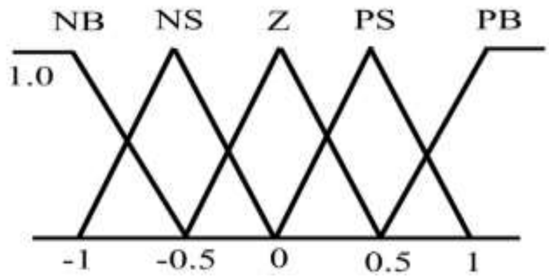


Fig.2. Block Diagram of the FLCs

the signals from dq to abc reference frame and then are compared to a triangular carrier waveform to generate the firing pulses of insulated gate bipolar transistors (IGBTs) of the VSC.

An important step in the design of FLC is to select optimimum scaling factors of the input and output membership functions. To get this optimization techniques are used where the deviation between dq terminal voltages and references voltages is going to be minimized. The main problem here is not having a closed form mathematical model which associates the dq terminal voltages to the parameters of membership functions of the FLC. This problem can be defeated by using time domain



[1] Inputs

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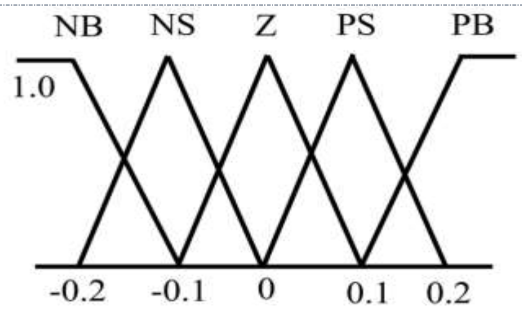

[2] Outputs

Fig.3. Membership function of the FLCs

Table 2.Fuzzy Rule Table

m_d / m_q		$\Delta e_d / \Delta e_q$				
		NB	NS	ZO	PS	PB
e_d / e_q	NB	PB	PB	PS	PS	ZO
	NS	PB	PS	PS	ZO	NS
	ZO	PS	PS	ZO	NS	NS
	PS	PS	ZO	NS	NS	NB
	PB	ZO	NS	NS	NB	NB

simulation tools in addition with black-box optimization techniques. Where, the successive valuation of the objective function for different set of parameters can be done. During this process the time domain simulation program, i.e., MATLAB is used to estimate the value of objective function. Firstly the time domain simulation was initialized by using an initial set of parameters and then the value of objective function is calculated. Then depending upon the optimization algorithm and the objective function value, a new set of parameter is determined. The procedure is repeated till an optimum set of parameters is obtained. The two controllers of inputs and output membership functions are equal. The following fuzzy sets are negative big (NB), negative small(NS), Zero(Z),positive big(PB),positive small(PS). IF-THEN rules are used to develop fuzzy rules. 25 rules is here to reach the desired output signals, as shown in table II.

PROPOSED ANFIS

ANFIS are a class of adaptive networks that are functionally equivalent to fuzzy inference systems. Its inference system corresponds to a set of fuzzy IF–THEN rules that have learning capability to approximate nonlinear functions. Hence, ANFIS is considered to be a universal estimator. For using the ANFIS in a more efficient and optimal way.By using the ANFIS the responses for the load voltage, real and reactive powers to the load, and the converter currents are improved and shown in Fig.4-5.ANFIS is better response compare to PI and FLC are shown in below Table III-IV.

SIMULATION RESULTS

In this section the main objective is to evaluate the developed FLC and display its capability to maintain the voltage at the desired level irrespective of the load variations. These are explained to compare between the results obtained from the proposed FLCs and conventional PI controllers.

Change of the LC Load parameters:

At the same time as the system is operated in the islanded mode with the load parameters set to those of Table 1, several load changes are applied.

1. The change of the load inductance L from 111.9 to 222mH
2. The change of the load capacitance from 62.86 to 100µF

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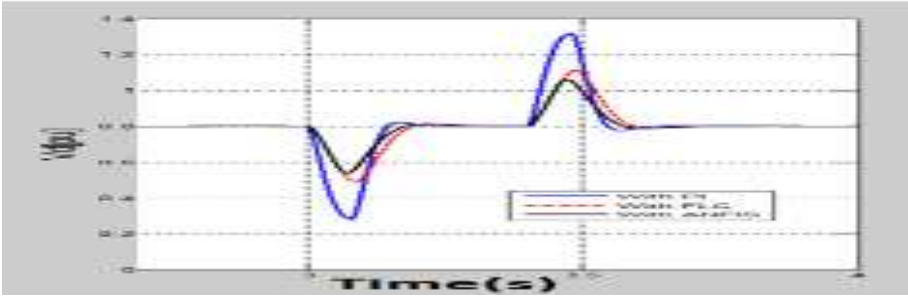
At t=3s and at t=3.4s the changes is applied then the load is switched back to the original value. As the controller response to both increasing and decreasing the load parameters is captured.



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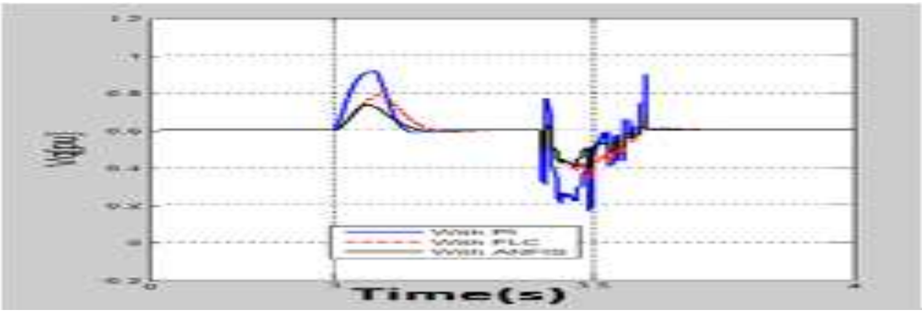

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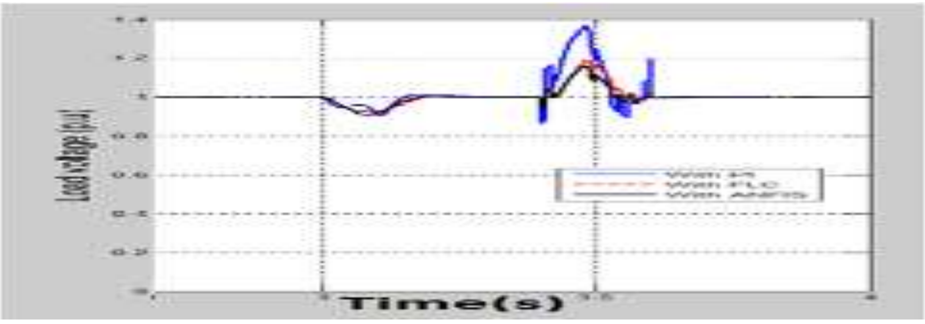

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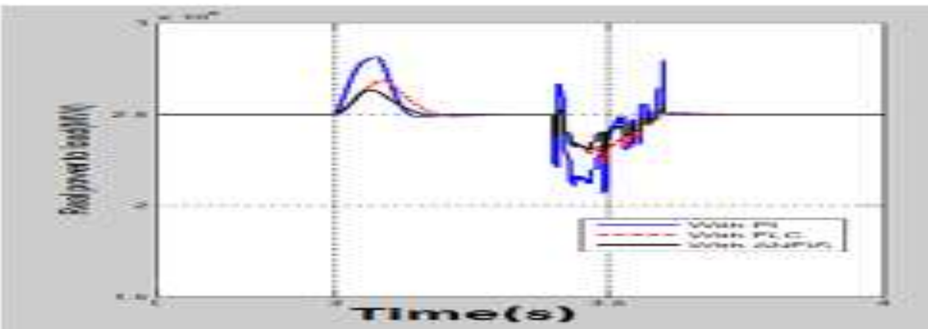

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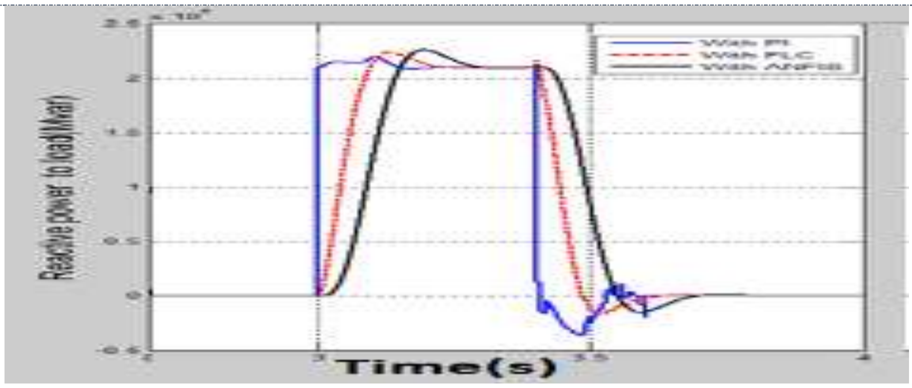

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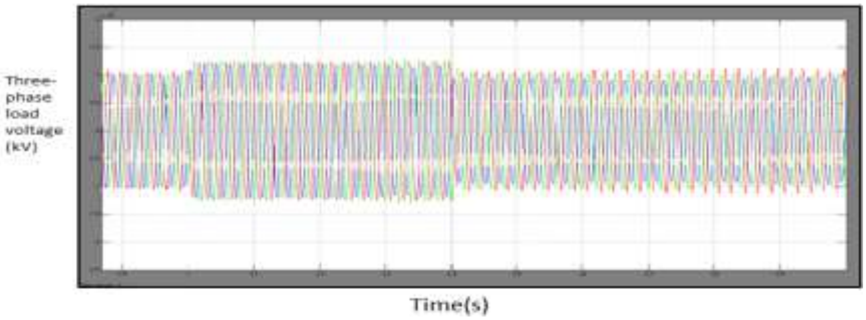

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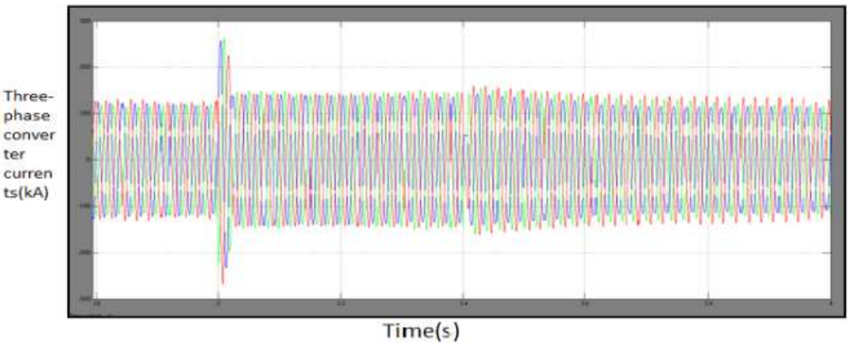
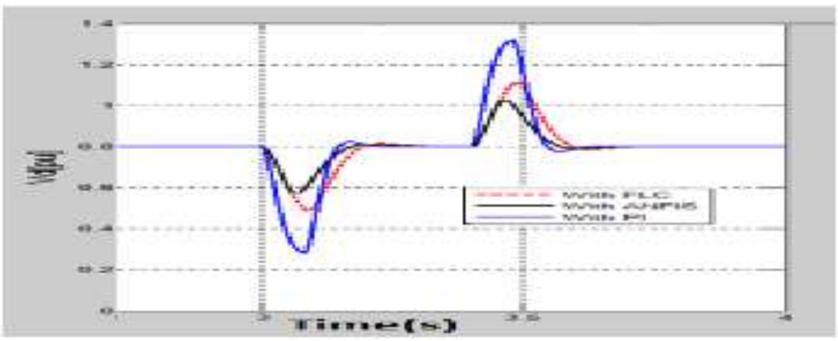


(g)

Fig.4. Responses for the change of the load Inductance L from 111.9 to 222mH (a) V_d (b) V_q(c) Load voltage(rms) (d) Load real power (e) Load reactive power (f)Three-phase load voltage (g) Three-phase converter currents



(a)

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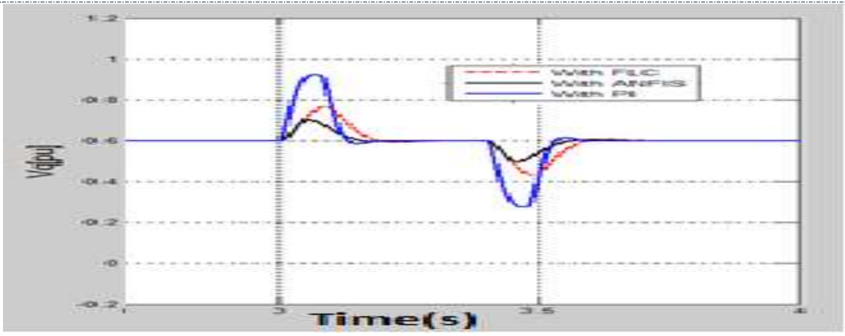

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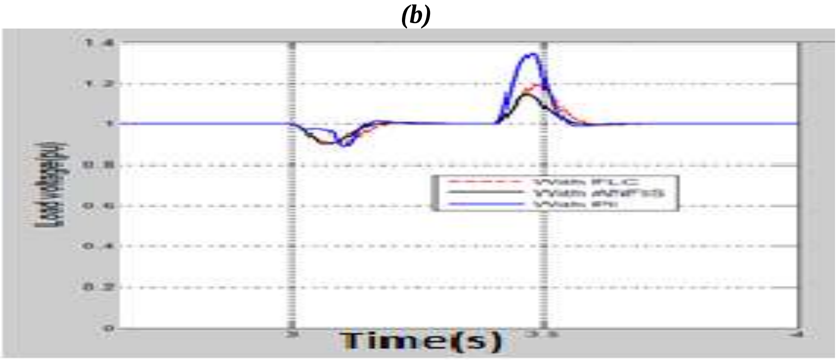

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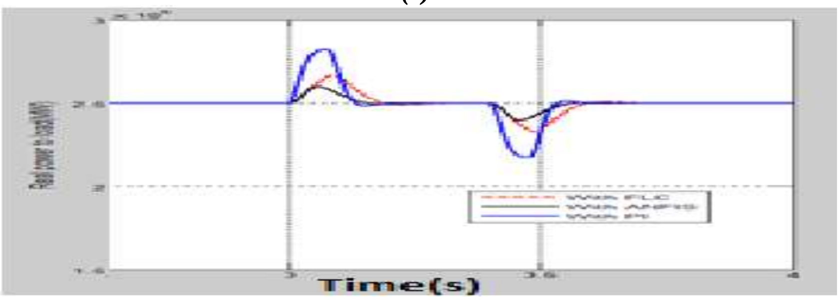

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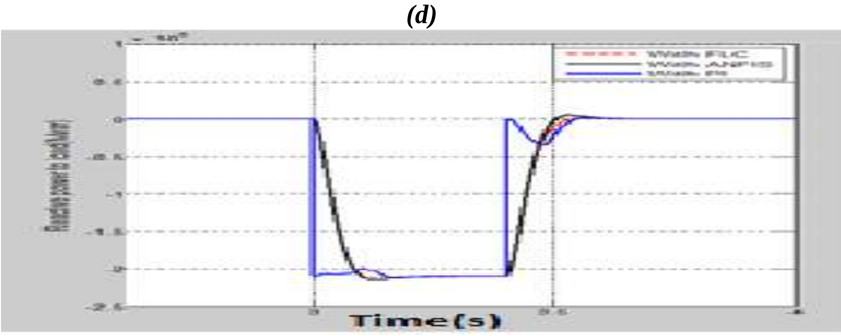

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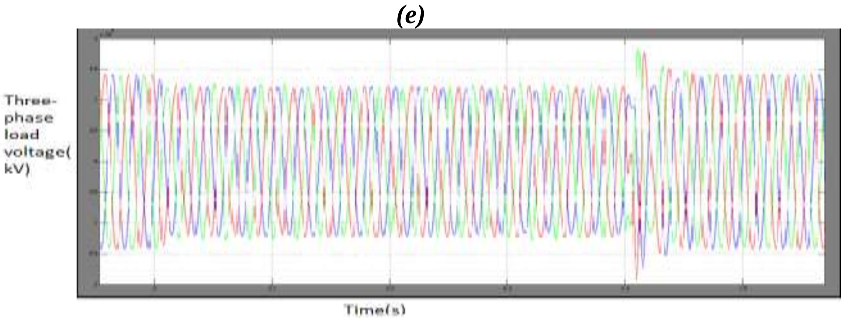

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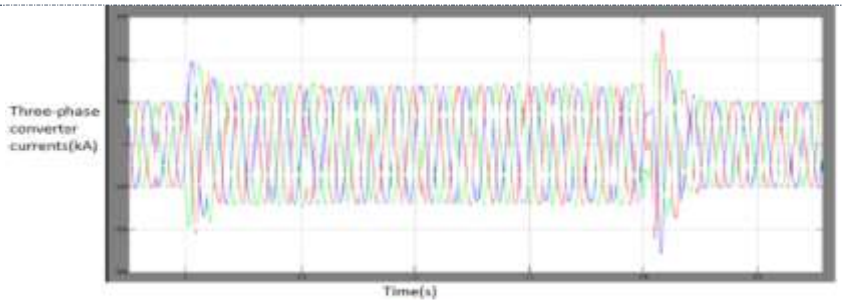

(g)

Fig.5. Responses for the change of the load capacitance from 62.86 to 100µF (a) V_d (b) V_q(c) Load voltage(rms) (d) Load real power (e) Load reactive power (f)Three-phase load voltage (g)Three-phase converter currents

Table 3.Condition for the change of load inductance L

	Maximumpeak over shoot			Peak time(t_p)			Rise time(t_r)		
	PI	FLC	ANFIS	PI	FLC	ANFIS	PI	FLC	ANFIS
V_d	62.5	37.5	31.2	3.44	3.43	3.42	3.4	3.41	3.42
Vq	50	33.3	16.6	3.3	3.2	3.1	3.1	3.2	3.3
Load voltage	39	19	17	3.44	3.43	3.42	3.4	3.41	3.42
Real power	12	4	3.2	3.2	3.15	3.1	3.11	3.12	3.13

Table 4.*Condition for the change of load capacitance C*

	Maximum peak over shoot			Peak time(t_p)			Rise Time(t_r)		
	PI	FLC	ANFIS	PI	FLC	ANFIS	PI	FLC	ANFIS
V_d	62.5	40	38.5	3.48	3.47	3.3	3.4	3.41	3.42
Vq	50	16.6	8.33	3.18	3.15	3.11	3.1	3.12	3.13
Load voltage	39	19	18	3.45	3.44	3.43	3.4	3.41	3.42
Real power	12	4	2	3.2	3.18	3.11	3.1	3.12	3.13

CONCLUSION

In this paper has presented a FLC for the autonomous operation of an electronically coupled DG unit and its local load with the purpose of achieving better transient responses under the different load conditions.

The simulation results using the ANFIS has a better damped response and a faster transient behavior in comparison with that obtained by using the FLC and PI controller?

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