Reduced Order Generalized Integrator based Current controller for Distributed Power Systems

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ABSTRACT
This paper presents about a fuzzy logic controller for three phase distributed generation system. An integrator to be implemented in a stationary reference frame called as the Reduced Order Generalized Integrator. The proposed ROGI based Fuzzy Controller is compared with the traditional ROGI based PI Controller. The currents injected to the grid are properly synchronized with the grid voltage. The proposed Controller minimizes the overshoot and under shoot response than the PI Controller. It ensures the stable output. The Controller has three injection strategies such as the balanced current injection, constant instantaneous active power injection and Maximum Instantaneous active power injection. This controller can perform successfully even during faulty grid conditions

Keywords
Reduced Order Generalized Integrator (ROGI), Distributed Phase Generation System (DPGS), Current Controller, Fuzzy logic Controller (FLC).

1. INTRODUCTION
The Voltage source converter is connected to the distribution system [1]-[4]. The Current injection technique by the controller has three major characteristics of

1) Ensuring high quality injected currents
2) Proper Synchronization with the network
3) Satisfactory Performance even there is a fault in the network.

There are various types of Controllers used in DPGS and they are of hysteresis Controller, Predictive controller and Proportional Integral (PI) type controller. The PI type Controller is mostly recommended [5] [6] since it nullifies the error between the controlled variable and the reference variable. Also, the Proposed Controller can be implemented in stationary reference frame directly.

The two reference frames are of stationary reference frame and rotating reference frame. The rotating reference has the disadvantage of transforming and anti transforming the signal (ie) the signals have to be transformed from the stationary reference frame to the rotating reference frame and again to anti transform [7]-[9].

Most of the existing Controllers have the Current Controller called second Order generalized Integrator. The SOGI have more number of states, because it cannot directly be implemented in stationary reference frame. During the Current injection for synchronization, it needs synchronization algorithms like Phase locked loop technique, kalman filter or discrete Fourier transform[10].The Synchronization algorithms need to be developed because the injected quality of sinusoidal signals are poor.

The controller cannot ensure the DPGS to withstand successfully during faulty conditions. It has severe voltage unbalance conditions. It cannot withstand successfully during the faulty conditions of short circuit between two phases or one phase with neutral.

So, these disadvantages are being fulfilled by the Proposed Controller that it does not require any synchronization algorithm, it can properly be synchronized with the network and it has less Computational burden[11]-[13].

Again by comparing the PI Controller and the intelligent fuzzy logic controller it respond quickly without any overshoot and undershoot and it has no steady state error.[14]

Now a day, much attention has been given to fuzzy logic controller (FLC) to overcome the problems. The fuzzy logic controller is being used for the three-phase grid connected inverter control purpose. As compared to the traditionally PI, PID, and the adaptive controller, the special merit of FLC is that it does not require the knowledge of mathematical model of the plant, and it is can be easily implemented.[15]

In the novel FLC, the fuzzy pre-compensator modifies the reference voltage to compensate undershoot and overshoot output response. After selecting the scaling factors, the next step is to choose the membership function. The membership functions used for the input and output fuzzy sets are shown.

In order to reduce the computation for on line implantation, the triangular functions are used as membership functions for all. The decision-making process is associated with a set of fuzzy logic rules. In accordance with the linguistic rules and the linguistic values of the inputs for the fuzzifier, the linguistic value of the output is computed. [16]

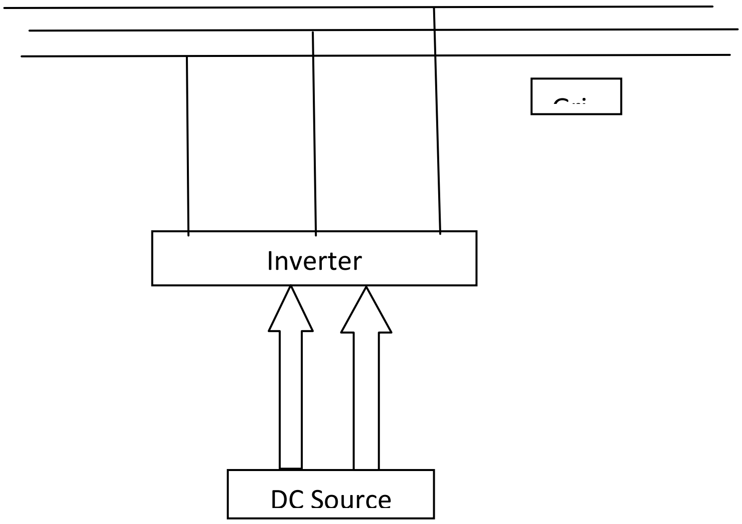

Fig 1:Basic block Diagram

2. ROGI

The ROGI is a complex space vector notation. The complex coefficients are cross coupled by imaginary gains between the αβ axis. An integrator in dq reference frame is rotated to an angle ' θ' to obtain the Stationary αβ reference frame.

$$u^{dq} = u_d + ju_q \quad (1)$$

$$y^{dq} = y_d + jy_q \quad (2)$$

$$py^{dq} = u^{dq} \quad (3)$$

Where 'p' is the derivative operator.

The relation between 'dq' reference frame and 'αβ' reference frame is given by,

$$u^{dq} = e^{-j\theta} u^{\alpha\beta} \quad (4)$$

$$y^{dq} = e^{-j\theta} y^{\alpha\beta} \quad (5)$$

$$y^{\alpha\beta} = \frac{u^{\alpha\beta}}{p - j\omega_0} \quad (6)$$

Where $\omega_0 = p\theta$

With two ROGI,s a SOGI can be constructed.

$$y_{\alpha\beta} = \hat{z}\ \frac{1}{p-j\omega_0} + \frac{1}{p+j\omega_0}\ u^{\alpha\beta} \quad (7)$$

$$= \frac{2p}{p^2+\omega_0^2}\ u^{\alpha\beta} \quad (8)$$

So, the ROGI is computationally more efficient than SOGI. But the ROGI is naturally for three phase systems .ROGI has less computational nature and avoids coordinate transformations. The three types of injection strategies here are based on the constant k_n

2.1 Balanced Current Injection

When k_n = 0, it produces a balanced current. It ensures that the currents are in phase with the grid voltage. The Current stress is reduced in the Converter switches. The frequency component of the current is balanced.

2.2 Constant Power Injection

In this case $k_n = -1$ must be chosen. It ensures ripple free active power injection. The ripples are controlled and are eliminated. It ensures the life time of the capacitors of the dc bus. It also reduces the risks of voltage falling below the acceptable level

2.3 Maximum Power Injection

In this case $k_n = 1$ is chosen. It maximizes the instantaneous active power injection. As like the constant power injection strategy, it reduces the stress on the dc bus capacitor and it ensure the dc bus voltage not below the allowable operating voltage. The MPI strategy reduces the resistive losses. It can increase the efficiency of the grid.

3. PROPOSED FUZZY CONTROLLER

In a DPGS the Current flows from source to the grid. Whenever the current flows from source to the grid, there will be a voltage drop in the grid. So, to rectify this drop a Current Controller is used. The Current Controller used here is ROGI .The ROGI gives the satisfactory performance.

The inverter pulses are being controlled. This Current Controller which comprises of fuzzy Controller and a Harmonic Controller. From fig 2 the fuzzy Controller a error value is generated and is given to the Current Controller for Controlling.

The harmonics are being controlled by harmonic Controller. The Controlled current is given to the ac side circuit which is the grid side.

Fuzzy control provides a formal methodology for representing, manipulating, and implementing a human's heuristic knowledge about how to control a system and for constructing nonlinear controllers via the use of heuristic information. Linguistic variables of FLC for three-phase VSI include "error", "error rate" and "output" which are represented by E, DE and U respectively

These linguistic variables take on the following values: positive big (PB), positive small (PS), zero (Z), negative small (NS), negativebig (NB).

Table 1. : Membership function

$\Delta e_n \backslash e_n$	NB	NS	ZE	PS	PB
NB	NB	NS	NS	ZE	ZE
NS	NB	NS	NS	ZE	PS
ZE	NS	NS	ZE	PS	PS
PS	NS	ZE	PS	PS	PB
PB	ZE	ZE	PS	PS	PB

The membership function used here is of triangular type. Defuzzification method is of centroid method.IF THEN Rules are used with AND function.

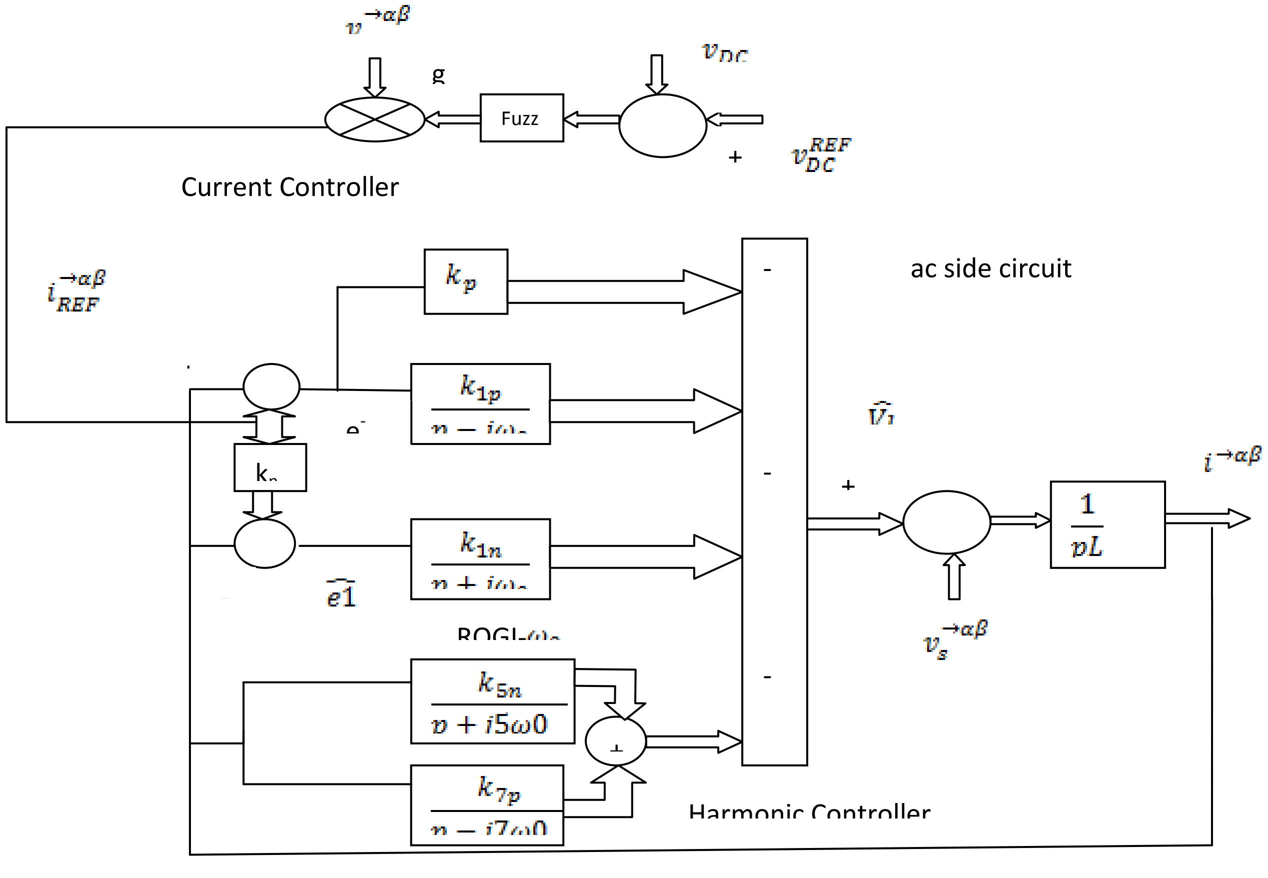

Fig 2: Functional Diagram of ROGI

4. SIMULATION RESULTS

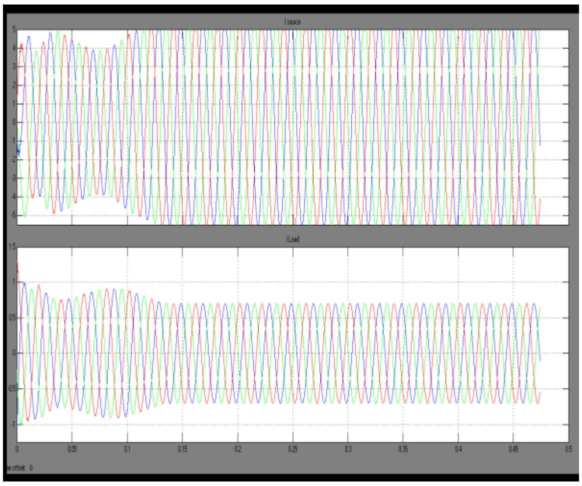

Fig3: PI Controller Output

From the Simulation result it is well understood that the load current has a sag. This is the main disadvantage of using PI Controller. So, this sag should be rectified. To rectify this, PI Controller is being replaced by Fuzzy Controller. The output is being expected without the sag.

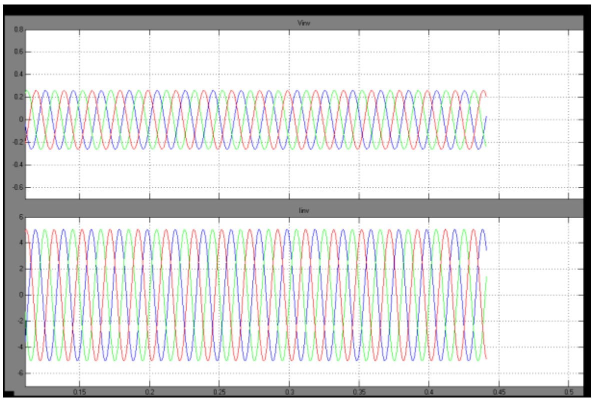

Fig 4: Fuzzy Output

The fuzzy Controller which gives the output without the sag. The fuzzy Controller performs well than the PI Controller. It maintains a steady output

5. CONCLUSION

Thus the Controller injects the current to the grid and it satisfies various criteria's. It is implemented directly in a stationary frame and the system is not much complex. It ensured the high quality current, controlled current, and current with reduced harmonics. A steady output response is obtained. A sag appears in the existing paper is being rectified in this paper using ROGI based Fuzzy logic Controller.

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