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DESIGN OF COMPENSATOR FOR REDUCTION OF POWER OSCILATIONS IN GRID CONNECTED DG

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Abstract

Stability is the most important feature of power system networks. But the inclusion of power electronic devices has negative impedance instability. In addition to that local instabilities may arise due to converter when interacting with the other dynamic subsystems. This paper discusses a simple control technique for interconnection of distributed generation resources to the AC power grid tied converters. The concerned method introduces a required active signal at the control loop of the converter due to which the input impedance of the grid tied converter changes. Simulations are conducted in SIMULINK, used to examine the performance of the system after the application of control technique.

Key Words—Distributed generation, compensator, Interfacing converter, small signal modeling, stability

1 INTRODUCTION

Modern power system with distributed generation (DG) which includes photovoltaic (PV), wind turbine ,fuel cell and micro hydro turbines are introduced at the distribution level due to emission of various toxic pollutants by the conventional energy sources such as thermal and nuclear counterparts. Conventional power stations, such as hydro electric generating plant, Thermal, gas and nuclear powered plants, and many other large scale solar power stations work under centralized environment and from these sources energy need to be transmitted over long distances [1.2]. On the other hand, Distributed Energy Resources (DER) work under decentralized environment, Very effective and flexible Technologies are used very close to the load they serve, though the capacities of them only ten megawatts or less [3-4]. One can operate these DERs according to the flexibility of the system requirement. So the use of DERS increasing very rapidly in the distribution system.

So, these DERs are connected to the grid at distribution level with various interfacing devices depending on the type of DER. But, DERs should be handled within a smart grid carefully as the voltage levels and power levels depend on various factors. Distributed generation with storage improve the availability of energy from many sources and may mitigate environmental impacts and improves the reliability of supply [5-6].

When compared with Conventional centralized electric grids [7-8] Micro grids are localized, small in scale and modernized.. Micro grids can be isolated from the main grid and can operate independently, which strengthens the supply of power and reduce the affect of grid disturbances. Mostly low voltage AC grids use diesel generators for supplying power to a small community [9]. But, In Micro grids different distributed energy resources with different sources of energy, such as solar hybrid power systems are used which reduce the emission of various toxic pollutants.

This paper discusses a simple control technique for interconnection of distributed generation resources to the AC power grid tied converters. The concerned method introduces a required active signal at the control loop of the converter due to which the input impedance of the grid tied converter changes. The effectiveness of the control technique that has been proposed in the considered system is verified by the simulations in SIMULINK .This paper is mainly divided into four sections. The first part deals with the configuration and illustration of system. The second section deals with the design of compensator. The third section depicts the simulation results and final section gives the conclusion of the paper that compares the simulation results with and without the use of compensator designed.

2 CONFIGURATION AND ILLUSTRATION OF SYSTEM

Fig.1 depicts the considered system configuration. As shown, a DG source is considered with the use of an ideal solar source. DC to AC converter is used to between the dc link and AC power grid. In reality, The DG solar source is interfaced to AC power grid through converter.

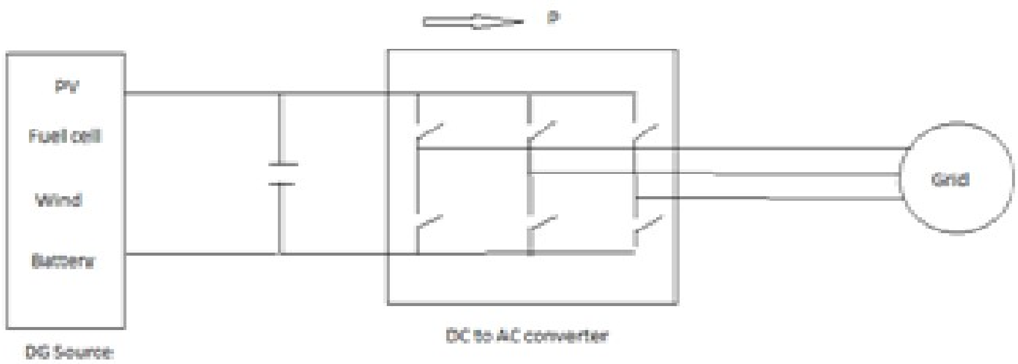

Fig 1 system under study

Design of the system

An ideal solar energy source is considered to generate required voltage. A converter using IGBTs as switching devices is designed to tie the DG source to the power grid. Here two simulations are considered, one without compensator and the other with compensator the difference occurs in the control loop in the two simulations and outputs of two simulations are compared to check the stability occurred in the outputs.

DG solar source

The distributed generation source considered in this paper is an equivalent circuit of ideal voltage source. In this paper an ideal solar source is taken as the DG source. The fig2 shows the ideal solar source circuit. In the circuit optical losses are represented in current source itself, recombination losses are represented by parallel diode and ohmic losses are represented by resistors. The equivalent circuit for DG solar source is shown in Fig2.

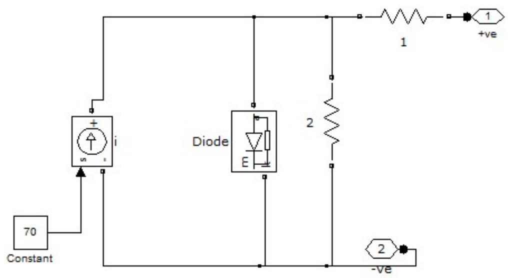

Fig 2 Ideal DG solar source

The relation between current and voltage are given by:

$$I = I_o\left(e^{qv/kt} - 1\right) - I_l \tag{1}$$

Where

I_o is reverse saturation current ; I_l is light generated current ; t is temperature : v is voltage

Converter

In the d–q reference frame DC to AC converter current equations are described as follows:

$$V_{ld} = (R + SL)I_{ld} - \omega L I_{lq} + V_{gd} \tag{2}$$

$$V_{lq} = (R + SL)I_{lq} - \omega L I_{ld} + V_{gq} \tag{3}$$

Where V_{ld} , V_{lq}, I_{ld} and I_{lq} are the d–q axis converter's output voltages and currents. V_{gd} and V_{gq} are the d and q axis grid voltages. Laplace operator S is used.

The equations of current controller are given as

$$V_{ld}^{inv} = \left(I_{ld}^{ref} - I_{ld}\right)\left(K_p + \frac{K_i}{s}\right) - \omega L I_{lq} + V_{gd} \quad (4)$$

$$V_{lq}^{inv} = \left(I_{lq}^{ref} - I_{lq}\right)\left(K_p + \frac{K_i}{s}\right) - \omega L I_{ld} + V_{gq} \quad (5)$$

$$I_{ld}^{ref} = P^{ref}/1.5V_{gd} \quad (6)$$

$$I_{lq}^{ref} = Q^{ref}/1.5V_{gd} \quad (7)$$

Where proportional gain and the integral gain of PI controller is represented with K_p and K_i. Since, As we need to concentrate on power, Q^{ref} is considered very low than P^{ref} in distributed generation systems .Presuming high efficient dc/ac converter, applying linearization on the power equation with $\overline{I_q} = 0$ and the term dI_{lq} is ignored, we get:

$$\bar{V}_{dc} dI_{inv} + \bar{I}_{inv} dV_{dc} = 1.5(\bar{V}_{ld} dI_{ld} + \bar{I}_{ld} dV_{ld}) \quad (8)$$

Applying small modifications for (2)

$$dV_{ld} = (R + sL) dI_{ld} \quad (9)$$

By substituting (9) in (8), we get:

$$\bar{V}_{dc} dI_{inv} + \bar{I}_{inv}\, dV_{dc} = 1.5\big(\bar{V}_{ld} + \bar{I}_{ld}(R + sL)\big) dI_{ld} \quad (10)$$

Applying small modifications on (4) with

$$V_{ld}^{inv} = \left(\frac{\bar{V}_{dc}}{V_{dc}}\right) V_{ld}$$

we get the following relation

$$dV_{ld} - (\bar{V}_{ld}/\bar{V}_{dc}) dV_{dc} = -(K_p + K_i/s)\, dI_{ld} \quad (11)$$

The impedance transfer function of the converter is derived by solving equations (9) and (11) and substituted in (10) as follows:

$$dZ_{inv}(s) = \frac{dV_{dc}(s)}{dI_{inv}(s)} = \frac{a_2 s^2 + a_1 s + a_0}{b_2 s^2 + b_1 + b_0} \quad (12)$$

Where

$a_2 = \overline{V_{dc}^2} L$

$a_1 = \overline{V_{dc}^2} R + \overline{V_{dc}^2} K_p$

$a_0 = \overline{V_{dc}^2} K_i$

$b_2 = 1.5\overline{V_{ld} I_{ld}} L - \overline{V_{dc} I_{inv}} L$

$b_1 = 1.5\overline{V_{ld} I_{ld}} + 1.5\overline{V_{ld} I_{ld}} R - \overline{V_{dc} I_{inv}} K_p - \overline{V_{dc} I_{inv}} R$

$b_o = -\overline{V_{dc} I_{inv}} K_i$

3 COMPENSATOR DESIGN

This paper discusses a simple control technique for interconnection of distributed generation resources to the AC power grid tied converters. The concerned method introduces a required active signal at the control loop of the converter due to which the input impedance of the grid tied converter changes. Fig 3 shows the proposed control technique circuit. Here the transfer function of DC link is taken which acts as a lag compensator to increase the DC gain. The idea behind lag compensators is to apply a Band-Aid to a system which is already designed. In this case, you would like to keep your previous design, but crank up the DC gain. To the control loop a reference of 400v is given along with DC link voltage. The error between the voltages is adjusted by the lag compensator giving a stable output voltage. Fig 4 is the bode plot of the compensator.

Lag Compensator: $K(s) = K\left({}^{s+a}/_{s+b}\right)$

Where a >b. The phase of K(s) < 0

The lag compensator used here is

$K(s) = \left({}^{1}/_{2e-3s+0.5}\right)$

Here the gain margin g_m is infinite

Phase margin p_m is 120.0007

Gain cross over frequency w_{gm} is NaN

Phase cross over frequency w_{pm} is 433.0001

The gain margin is infinite means, The phase plot of Bode never crosses -180 degrees. That mean the phase crossover frequency can't be determined as the phase plot is always above the -180 degree line. Hence the system is inherently stable because the corresponding gain margin is infinite.

Compensator Design In MATLAB

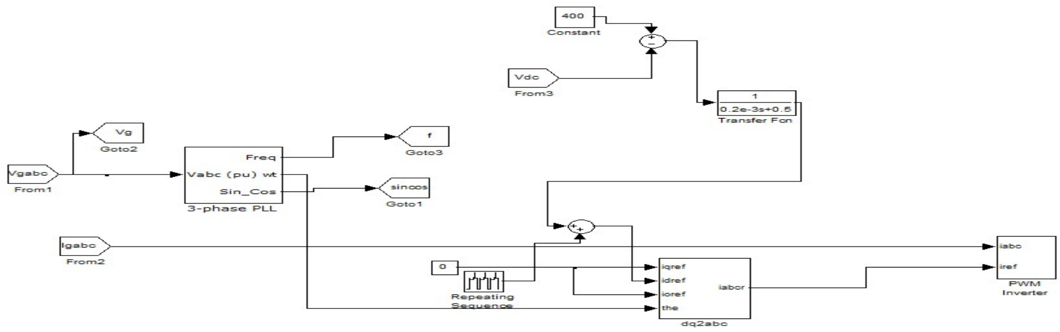

Fig.3. Proposed control technique circuit

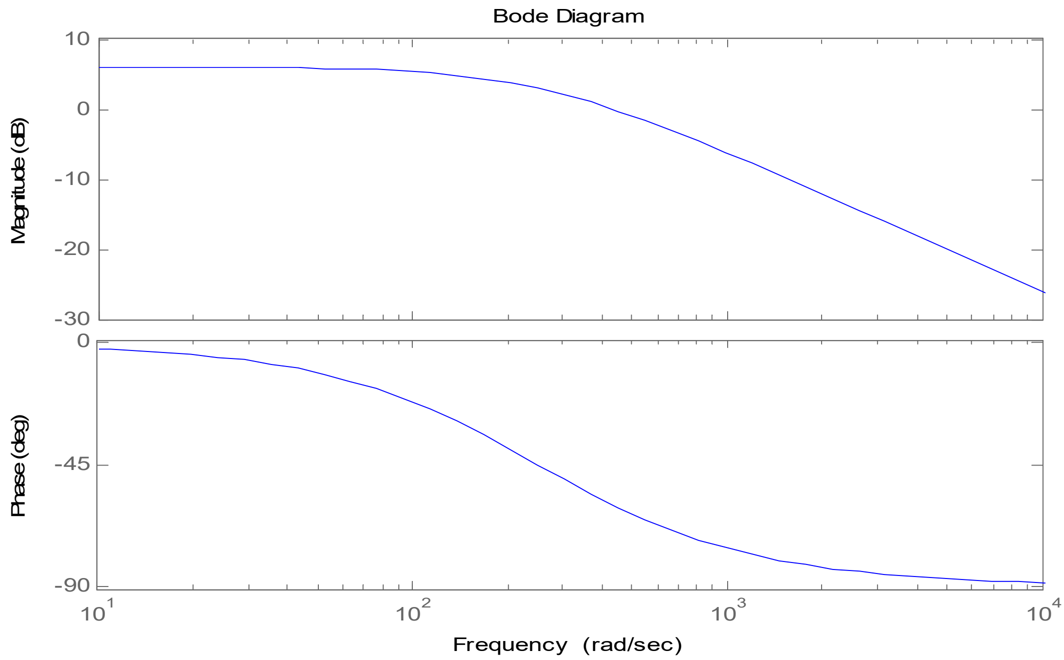

Fig 4. Bode plot of compensator

4 SIMULATION RESULTS

To analyze the performance a system with low voltage is simulated in SIMULINK environment. The simulated parameters are listed below

$R_{dc} = 0.01ohm \ \ L_{dc} = 0.25mH, C_{dc} = 4700\mu F$

R=0.05ohm, $L = 2mH \ \ , V_{dc,nom} = 400v$

Uncompensated system

In the case Uncompensated system without the use of the compensator the responses of the dc link voltage and grid power are observed and are shown in Fig 6 and Fig 7 respectively.

Compensated system

In Compensated system (MATLAB design) with the use of compensator, the responses of the dc link voltage and grid power are observed and are shown in fig 8 and fig 9 respectively

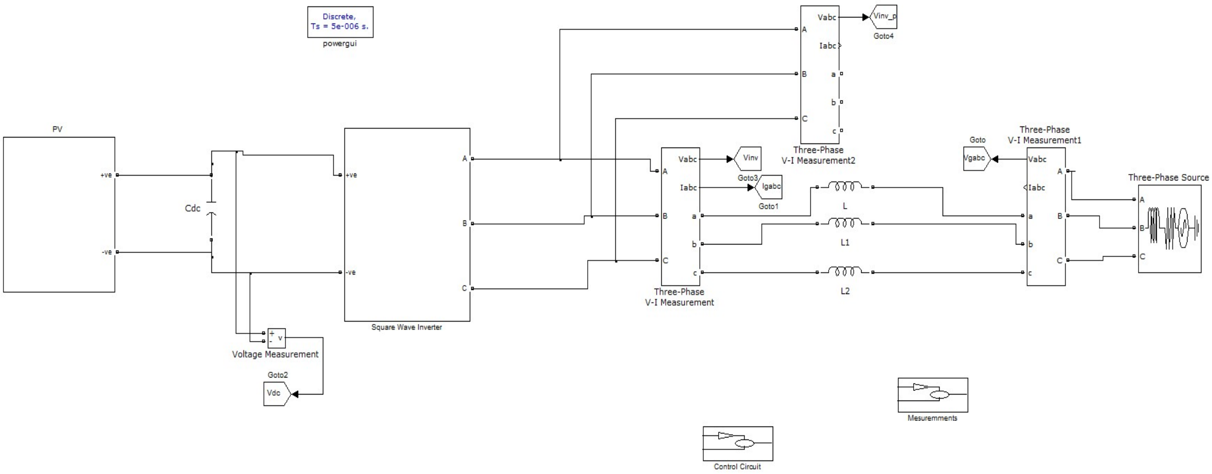

Fig 5.DG system

Results

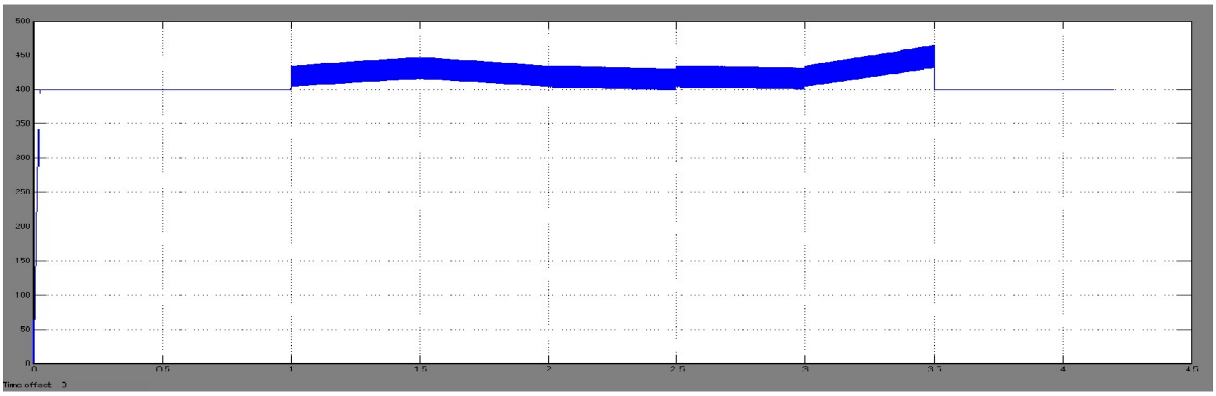

Fig 6 DC link voltage before the use of compensator

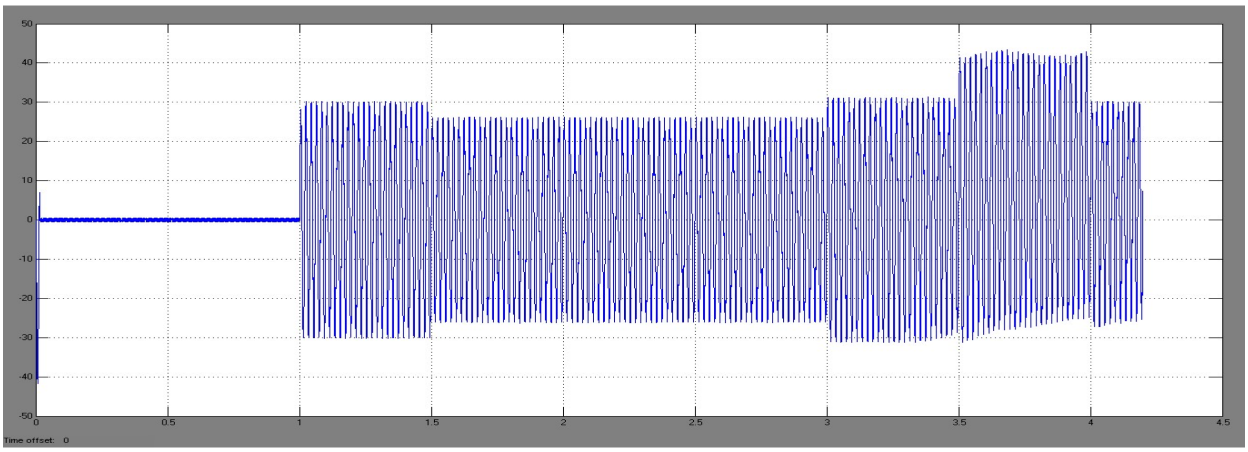

Fig 7 Grid power before the use of compensator

Fig 8 DC link voltage after the use of compensator

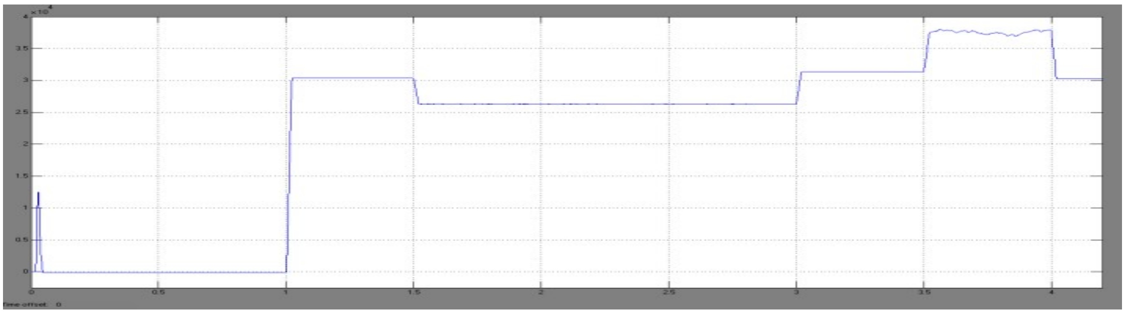

Fig 9 grid power after the use of compensator

5 Conclusion

The concerned method introduces a required active signal at the control loop of the converter due to which the input impedance of the grid tied converter changes. Simulations are conducted in SIMULINK used to examine the performance of the system after the application of control technique. From the results we conclude that the oscillations on the output power and the DC link voltage are reduced greatly.

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