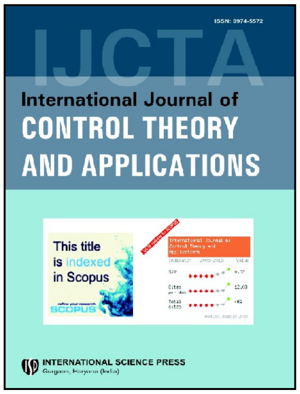

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Virtual Impedance Control for Hybrid Energy System Connected to Islanding Micro Grid

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Abstract: Low voltage level micro grid is behaved as a low inductance and high resistance line which introduce instability in the system connected to micro grid. Conventional P/W and Q/E droop control is not provides satisfactory performance under low voltage micro grid. Virtual impedance control is proposed for hybrid energy system (HES) connected to micro grid. Proposed control improves the stability of the system as well as dynamic response of the HES. Proposed control method is design and analyses for HES in MATLAB simulink. Results show the improved performance of the system under different operating conditions. Lastly comparison between conventional and proposed control design is also discussed and analysed in paper to justify the satisfactory result of proposed control design.

Index term: Distributed generation (DG), islanding operation, renewable energy, voltage and current control design and virtual negative resistance.

1. INTRODUCTION

Now days, new technologies are coming to provide better power quality and continuous power supply. It is clearly seen that alternate/Renewable energy would play a very vital role in the coming years for meeting the increasing energy consumption demand with clean environment. Among the different configurations of renewable energy system, distributed generation (DG) technologies are the best suitable choice. So many DG technologies are present including the photovoltaic system, wind turbine system, gas turbine, diesel engine, fuel cell, supercapacitor and battery systems [1]. At present scenario, wind energy and photovoltaic have become the most competitive alternatives. The fast advancement in power electronics area is also introduces the new era for the maintenance of power quality as they efficiently interface distributed energy systems to the grid. The integration of distributed energy system can result in several benefits including increased overall energy efficiency, reduced environmental impacts, cost reduction etc. [2]. But DG sources have their own limitations, wind DG source have voltage sag and harmonics because of continuously changing nature of wind. Gas turbine and diesel engine also have lesser power quality because of the frequently varying supply. Photovoltaic system also have limitations such as, having high starting cost and less efficient but it gives better performance and has pollute free as compare to other DGs. So, the photovoltaic system is used as DG source in this paper.

To improve power quality, many control schemes has been proposed like, Proper power flow regulation using vector control principle has been proposed in [3]. Dual Vector Current control uses two VCC's for positive and negative sequence components along with DC link voltage control in [4]. Synchronous PI current control has also been proposed which convert the three phase grid voltages to synchronously rotating (*dq*) frame for proper decoupling in [5]. The grid currents become DC variables and thus no steady state-state error adjustment is required. A method for active and reactive power control has been mentioned in [6]. It control scheme to maintain the DC link voltage constant by a Voltage Control Loop. However, the transient conditions has not been taken into account. Harmonics suppression techniques have also been proposed with the help of filters in [3] which are not considered the effects of filters on the control loop. Above discussed control schemes have so many problems. To improve the power quality and mitigate the aforesaid problems, this paper proposes frequency and voltage virtual impedance control method. In this control scheme, voltage or frequency are controlled by the control of active and reactive power using virtual impedance. This method improves the system stability and dynamic responses in transient as well as steady state conditions. DG system is connected to grid by taking grid impedance into account. In microgrid transmission line always behave as a high resistance low inductance line. So to suppress the adverse effect of high resistance on control loop and dynamic response, virtual negative impedance control scheme is proposed. Virtual negative impedance is improves the dynamic performance of system under different operating conditions [7].

This paper is divided in 4 sections, proposed control method is discussed in section 2, section 2 is divided into 2 parts (1-virtual negative control method, 2- voltage and current control design), and results are discussed and shown in section 3 to validate the proposed control scheme in different conditions. Lastly, Section 4 is concluded the outcome of the work and improvement in power quality using the proposed control scheme in DG system

2. PROPOSED CONTROL METHOD

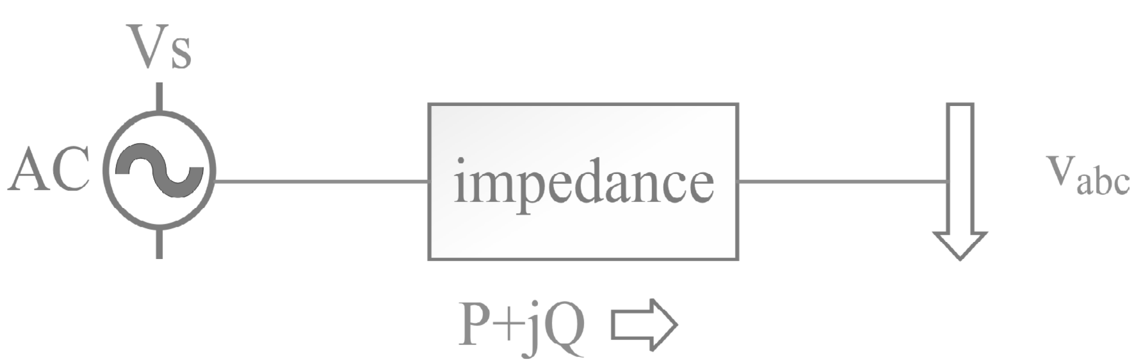

Figure 1: Equivalent circuit of the grid connected microgrid

V_S and V_{abc} are the reference voltage and the ac common bus voltage respectively and Z is the system impedance. The active and reactive power output of system is given below [8]

$$P = 3[V_s^2 \cos\theta - V_s V_{abc} \cos(\theta + \varphi)] / Z$$

$$Q = 3[V_s^2 \sin\theta - V_s V_{abc} \sin(\theta + \varphi)] / Z$$

Figure 2 shows the overall control strategy of the grid connected inverter in DG system connected to microgrid.

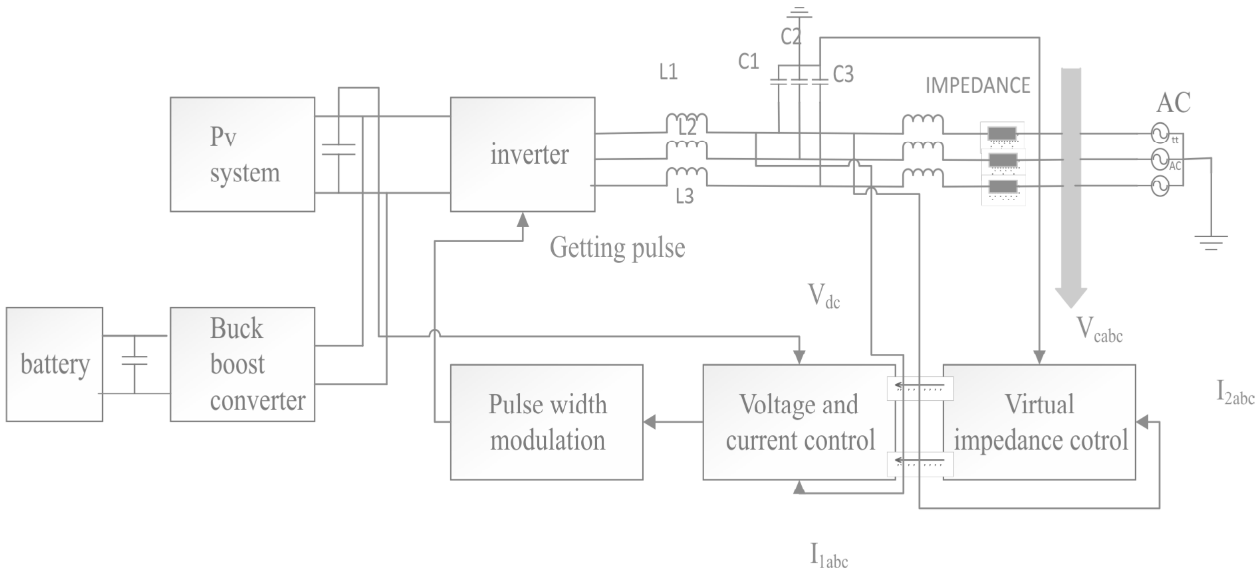

Figure 2: Block diagram of grid connected inverter in microgrid

The inverter is control and analyze in the Orthogonal (abc to αβ0) stationary frame. The three phase system can be convert in two independent signal phase system by this abc/αβ0 transformation principle. In the control diagram we discuss about virtual negative resistance and voltage-current design method.

Power decoupling strategy based on VNR

In fig. 3 virtual negative resistance design of grid connected inverter in a microgrid is shown. The stability issue for parallel inverters in a microgrid may fall in two category. The first one is the stability of the power control, it is related to output current and voltage of the inverter at the fundamental frequency. The second one deals with voltage and current of inverter at non fundamental frequency [9].

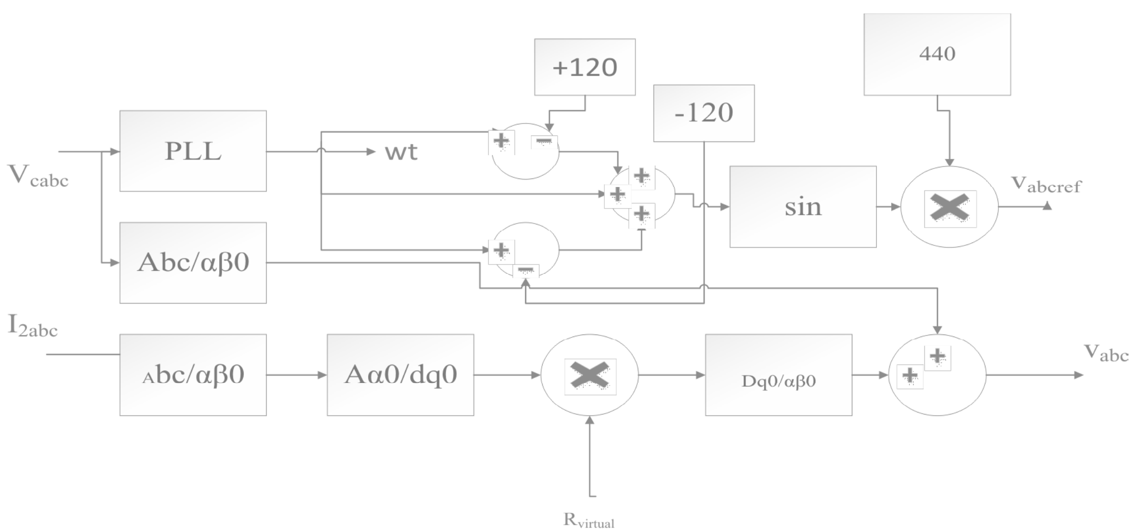

Figure 3: is the block diagram of virtual negative resistance

The output voltage and current equation are given below

$$V_{abc}(s) = V_{abcref}(s)G_{inv}(s) - Z_{inv}(s) + [R_v(s)G_{inv}(s) + (L_{line}s + R_{line}) * i_{1abc}(s)$$
$$= V_{abc\ ref}(s)G_{inv}(s) - Z_{sys}(s) * i_{1abc}(s)$$

$$i_{2abc}(s) = V_{abc\ ref}(s)G_{inv}(s) - V_{abc}(s)/Z_{sys}(s)$$

Where V_{abc} (s) and $V_{dc}(s)$ are the grid voltage and the output voltage of inverter, $V_{abc\ ref}(s)$ is the reference voltage, $G_{inv}(s)$ and $Z_{inv}(s)$ are the closed loop transfer function and the output impedance of the inverter[10].

Voltage and current control design

The reference voltage, frequency and amplitude will be controlled by the droop functions, generated in abc and transformed to αβ coordinates. The αβ coordinates are obtained by using the well-known Clarke transformation. Current and voltage are also transform from abc to αβ [11].

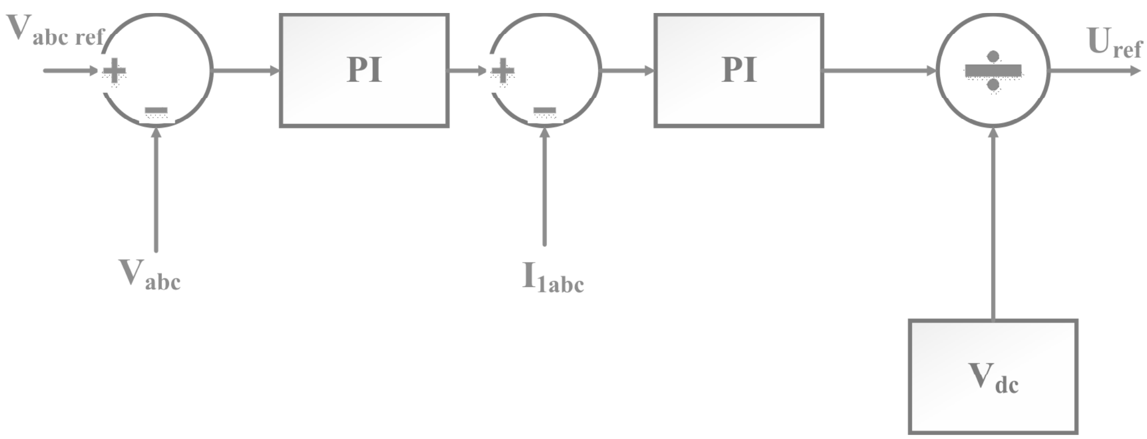

Figure 4: Block diagram of voltage and current control design

Fig. 4 shows the power stage of VSI consisting of a tree phase pulse width modulation (pwm) inverter and LCL filter. This LCL filter may exhibit a critically unstable response when trying to control output current with inverter voltage. The term proportional + resonant (PR) are used to tuned at fundamental frequency,5th, 7th and 11th harmonics. Not only current control loop but also voltage control loop includes current harmonic tracking in order to supply nonlinear currents to nonlinear loads.

The voltage and current controller are based on PR structure used to archive zero steady state error. Based on the abs to αβ coordinate transformation principal, a three phase system can be modeled in two independent single phase system.

$$i_{2abc}(s) = V_{abc\ ref}(s)G_{inv}(s) - V_{abc}(s)/Z_{sys}(s)$$

$$G_v(s) = k_{pv} + 2k_r w_c s/(s^2 + 2w_c s + w_n^2)$$

$$G_c(s) = k_{pi}$$

Where k_{pv} and k_{pi} are the proportional coefficients. G_v and G_c are the voltage and current controller. w_n is the frequency of the system[12].

3. RESULT

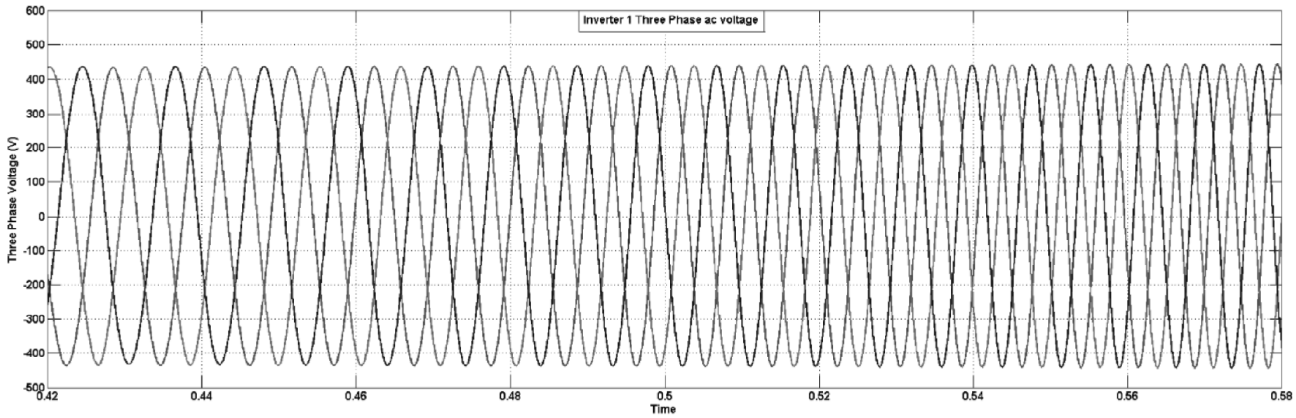

Figure 5: Output voltage of grid connected inverter in microgrid

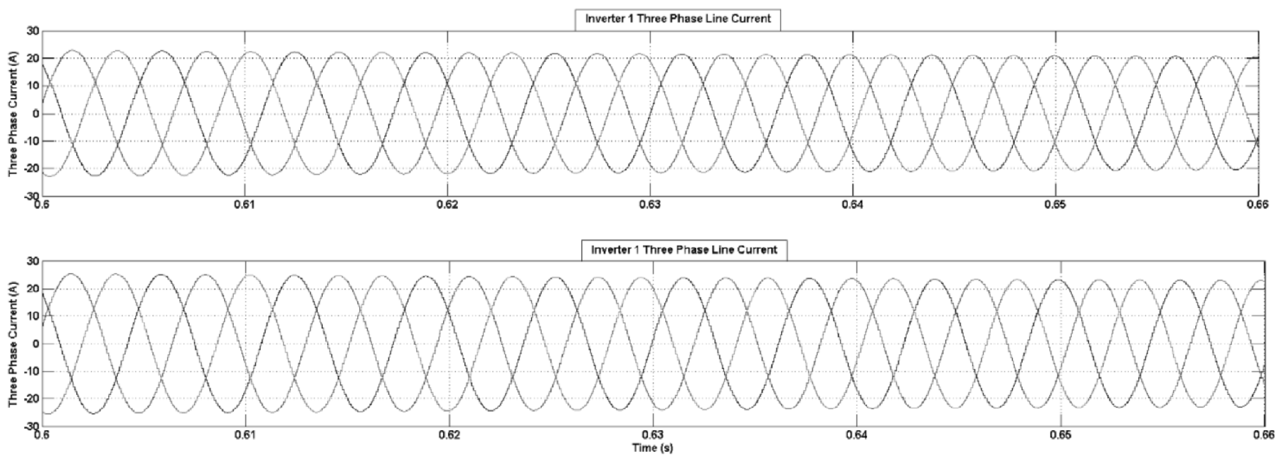

Figure 6: Output current of grid connected inverter in microgrid

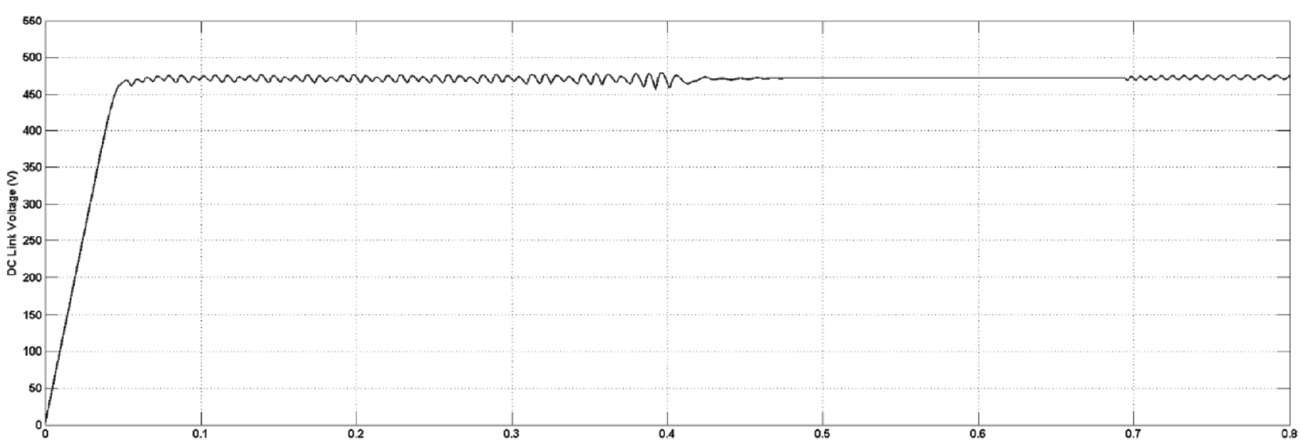

Figure 7: Input of inverter, which is the output of photovoltaic system

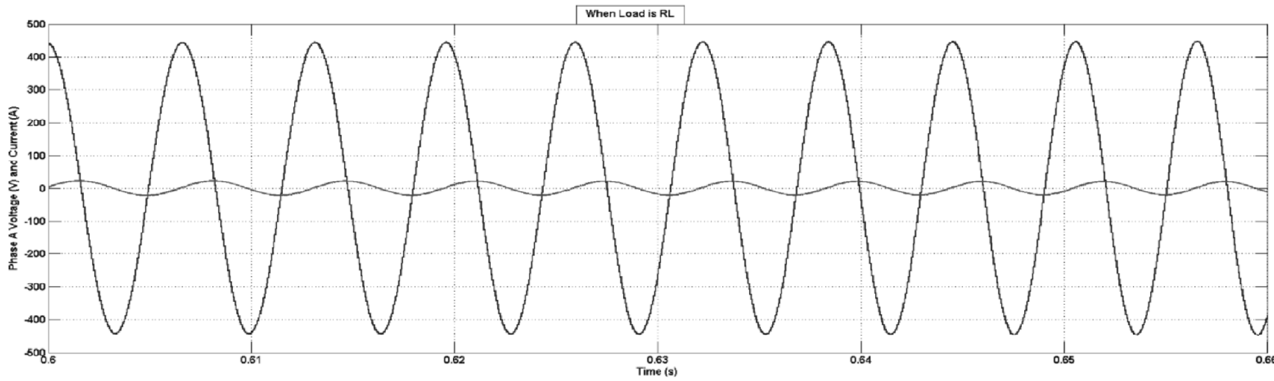

Figure 8: Output of voltage and current for single phase

4. CONCLUSION

The power quality in a low voltage microgrid can be decreased by designing the virtual resistance of the inverters to be negative called virtual negative resistance. The voltage and frequency are control by active and reactive power. So that voltage value fixed by using voltage and current control method, frequency fixed by virtual negative resistance. Experimental results of a low voltage microgrid consisting of two two 6-Kw inverters validate the control design.

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