

## A Novel Power Quality Control Strategy in DG Systems with Single-Phase Inverter

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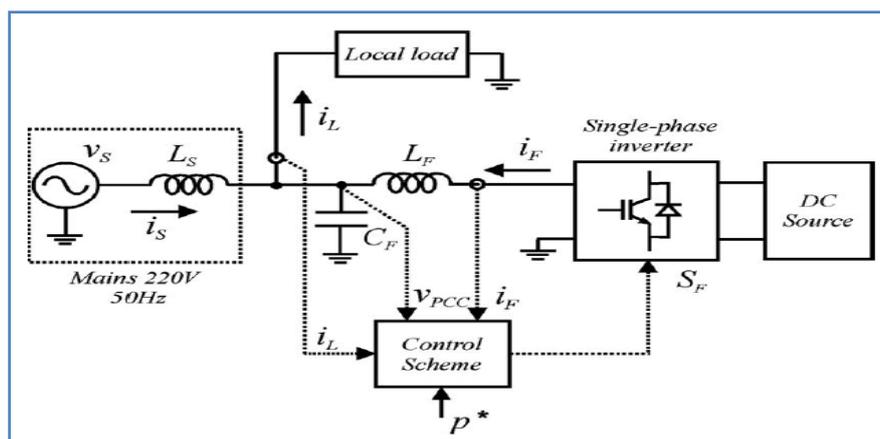
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**Abstract:-** Distributed generation (DG) systems came into existence due to the need for integration of various power generation plants. In order to interact with such systems power electronic converters are widely used. In this paper, we study single-phase inverter for interfacing with DG systems that need certain features pertaining to quality such as reactive power compensation. When the DG unit functions are integrated with devices like single - phase inverter, it gets equipped with power filter capabilities. Thus the power flow can be controlled from the energy sources that are renewable. The converter also helps in load current harmonic compensation. The proposed control scheme comprises a repetitive controller, instantaneous reactive power and sinusoidal signal generator that depend on current reference generator. We built a prototype application that simulates the proof of concept. The empirical results revealed that the proposed scheme is feasible and effective.

**Index Terms:-** DG, power quality, power quality control strategy, single – phase inverter

### I. INTRODUCTION

Of late, there have been constant hikes in oil prices. Due to this conventional power generation systems are becoming costly. To cope with this, people started using many alternative energy resources. In this context one can see different kinds of power generation plants. When such plants are able to work together renewable energy is possible. Thus the concept of distributed generation (DG) of electricity has become very important area in the research circles. There are plenty of power sources including photovoltaic panels and other means [1], [2], [13]. The DG has changed how the power systems work. It has empowered people to use plethora of types of power generation strategies and combine them to a common power grid. This concept is known as distributed generation of electricity. The DG has many advantages including providing reliable power supply, reliability in power distribution and reduction of emission of green house gases. In addition to this the DG bestows many power quality benefits [4]. With renewable energies, the cost of power generation and distribution goes down so as to enable systems to distribute power for affordable prices. As all industries depend on power supply, the research with respect to renewable energy sources has assumed much importance in modern times. Besides providing plenty of benefits, the DG also increases production that will have its positive impact on the industries and society in general.



**Fig. 1 – Overview of DG unit connected to electric grid**

As can be seen in figure 1, it is evident that the distributed generation of power has improved productivity besides enhancing reliability and reducing the cost of power supply to industries and households. The energy sources have various characteristics with respect to outputs. There are some inverters which are commercial that can operate when connected to grid. They work either normal mode or grid-connected mode [5], [6]. When they are connected to grid, the reference current is calculated from the reference active power [7]. Figure 1 uses local nonlinear loads in order to integrate power quality functions. Filtering features are equipped with single-phase inverter with the help of active power filters (APF). Thus the active power flow is controlled by the inverter and compensates with reactive power. The APF can also be integrated with single phase converters need certain techniques that are to be adapted to single-phase systems. The remainder of the paper is structured as follows. Section II provides review of literature. Section III provides the proposed system. Section IV presents experimental results while the section V concludes the paper.

## II. RELATED WORKS

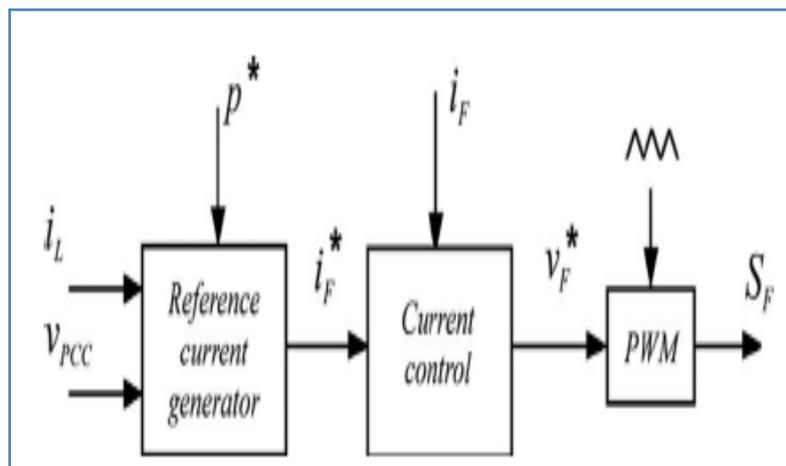
Power distribution systems have been around right from the inception of producing power. Recently we came to know many types of generation of power. These energy generation techniques paved the way to generate renewable power. Thus the Review of literature helps in p

In the literature various solutions are found to work with APFs. These solutions are capable of computing harmonic extraction task [8], [9], [10], [11], [12], [13], and [14]. The methods explored in the literature pertaining to APF based solutions, are of two types. They are direct and indirect methods. There is some theories association with these solutions. They are known as synchronous reference frame (SRF) [9], [10], [11], and [12] theory and instantaneous reactive power (IRP) theory [13], [14], [15]. For the purpose of finding reference current the controller known as proportional – integral (PI) is used [16], [17]. Out of the solutions the SRF and IRP are the most important techniques that were explored in the literature. Three-phase systems featured these strategies originally. However, they can be used with other systems as well.

In case of three – phase systems both SRF and IRP operate with two different orthogonal axes. In case of single phase systems, a fictitious variable is used where 90 degrees shift is used as part of solution. Thus from a single variable it is possible to generate two variables. This will allow the applications of the theories such as SRF and IRP. Hilbert transform [13] is used to compute such imaginary variables. This has resulted in a system which is non casual and thus it can't be implemented directly. However, it is useful to known approximation using finite-impulse response (FIR) which is a filter [8]. Alternatively IRP can be integrated with another technique known as sinusoidal as proposed in [18]. As inverter is used as an active filter as of now the current harmonics compensation features are operated. In this paper complete features have been experimented with respect to DG and integration with single-phase inverters with respect to the current harmonics compensation. A dedicated inverter scheme is also proposed in this paper using FIR filter approach. From the computational perspective the proposed scheme is very effective.

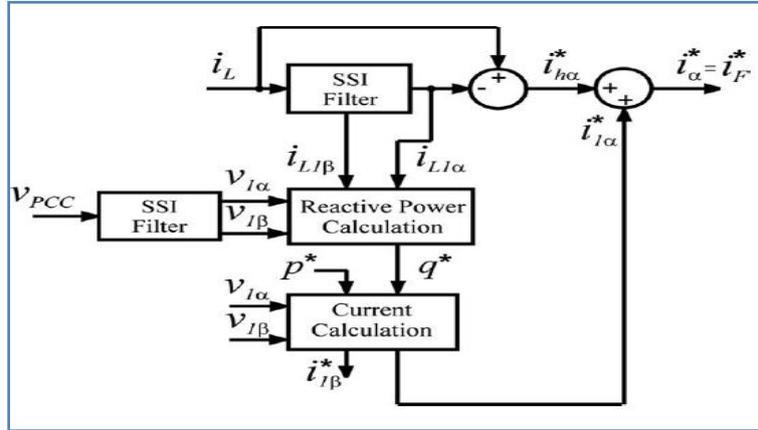
## III. THE PROPOSED INTERTER CONTROL SCHEME

The inverter control scheme proposed in this paper has enhanced features for power distribution quality. Moreover the inverter is designed in such a way that it works with DG systems. This will help in improving quality power distributions. The inverter control scheme is shown in **figure 2**.



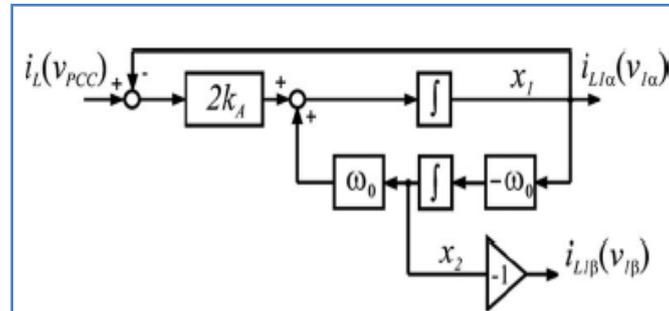
**Fig. 2 –Overview of inverter control scheme**

As seen in figure 2, it is evident that the reference current generator is responsible to generate inverter reference current. The controlling process is based on a repetitive controller. The reference current generate takes inputs such as  $i_L$ (non-linear load current),  $V_{PCC}$ (PCC voltage) and  $p^*$ in order to generate  $i^*_F$ (inverter reference current) that is further used by current control component. SSI filter is used by reference current generation scheme which is presented in **figure 3**.



**Fig. 3 –Reference current generation scheme**

As can be seen in figure 3, it is evident that the SSI filter, reactive power calculation, current calculation, are part of the reference current generation scheme. For the load current SSI filter has been applied. The SSI filter is used to generate reference currents as discussed in this paper earlier. The structure of SSI filter is as shown in **figure 4**.



**Fig. 4 –Overview of SSI filter**

Two SSI filters are used to generate fundamental reference current. The filters are mathematically deduced as follows.

$$H_1(s) = \frac{I_{L1\alpha}(s)}{I_L(s)} = \frac{2k_A \times s}{s^2 + 2k_A \times s + \omega_0^2} = \frac{V_{1\alpha}(s)}{V_{PCC}(s)}$$

$$H_2(s) = \frac{I_{L1\beta}(s)}{I_L(s)} = \frac{2k_A \times \omega_0}{s^2 + 2k_A \times s + \omega_0^2} = \frac{V_{1\beta}(s)}{V_{PCC}(s)}$$

Finally a current control scheme is used to control current based on repetitive controller. To be more flexible enough we used fuzzy controller for this. The fuzzy logic controller is more flexible for the purpose when compared with conventional PI controller. The following section provides experimental results.

#### IV. EXPERIMENTAL RESULTS

We made experimental with DG system with a single phase inverter. The overview of experimental setup is as shown in figure 5.

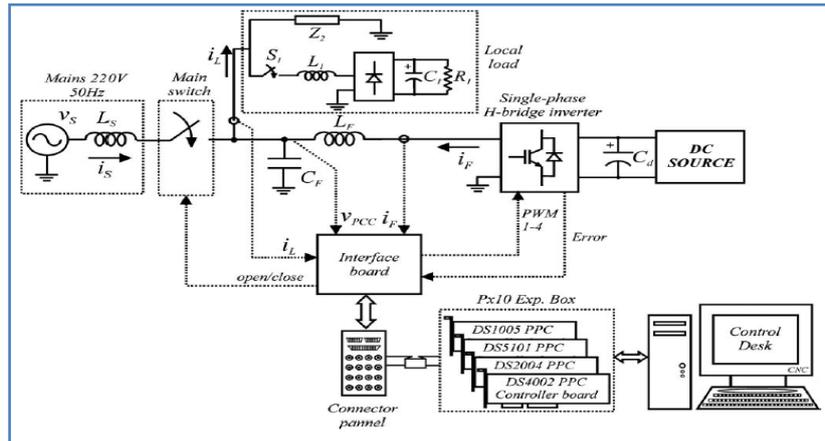


Fig. 5 – Overview of the experimental setup with single phase inverter

The experiments are made in terms of active power generation, current harmonics compensation, and reactive power compensation. The results of the experiments are presented below that visualize steady – state operation, inverter transient response and steady linear resistive – inductive load.

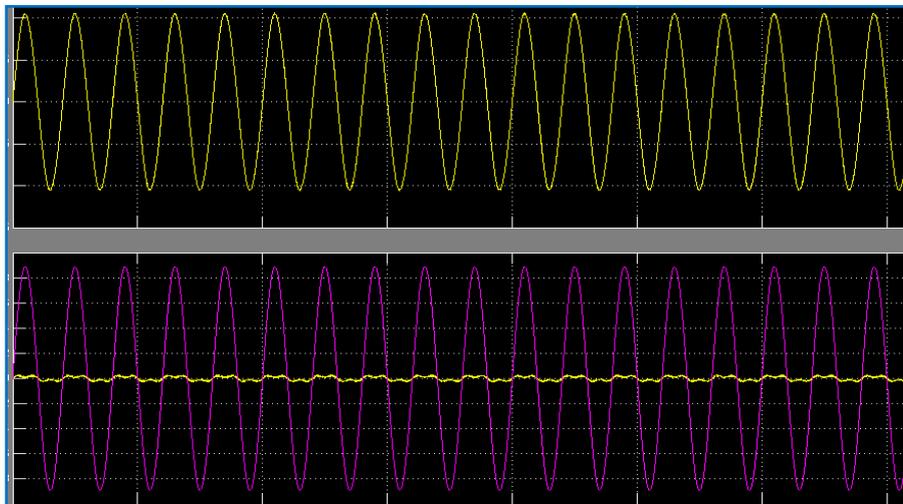


Fig. 6 –Steady state operation of the inverter

As can be viewed in figure 6, the result of steady state operation of the inverter that injects active power required by the resistive load is used. The injection is controlled by the fuzzy controller scheme.

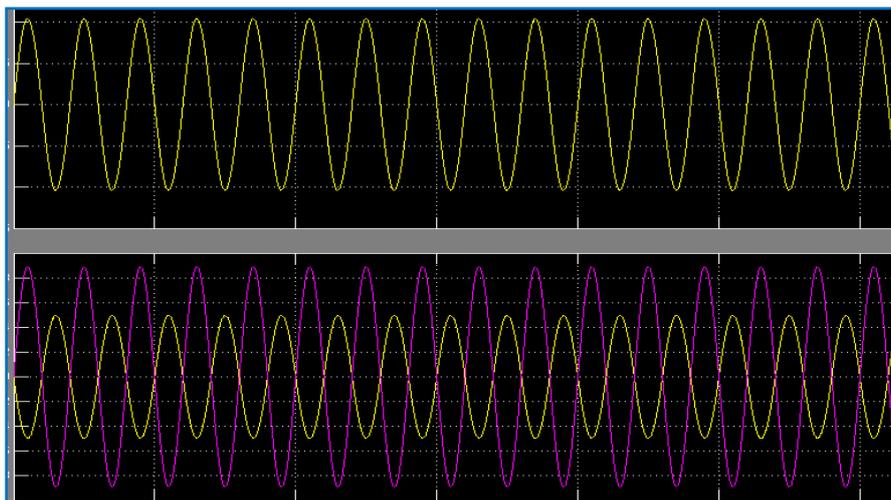
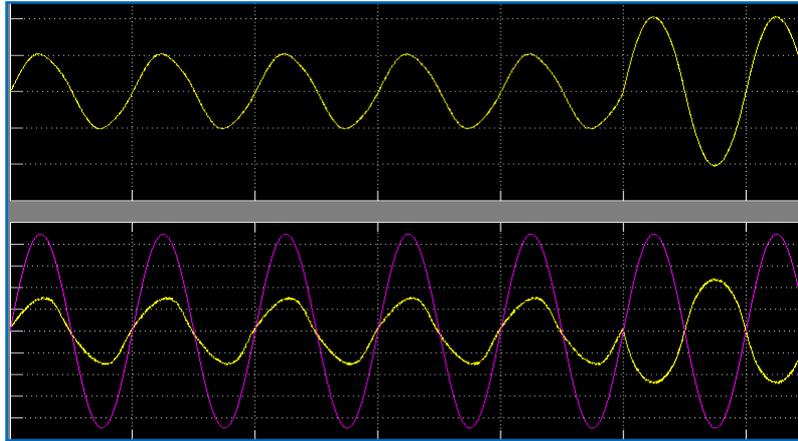


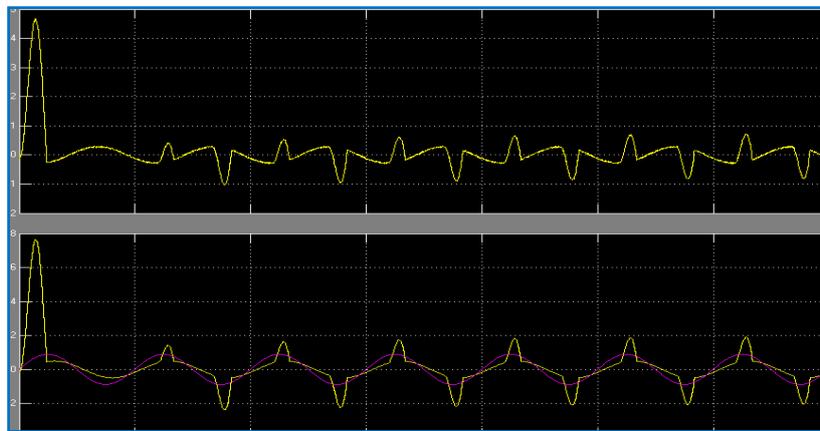
Fig. 7 – Steady-state operation for 3kw active power generation

As can be viewed in figure 7, the results of steady state operation for 3kw active power generation is shown. Fuzzy is used in the control scheme.



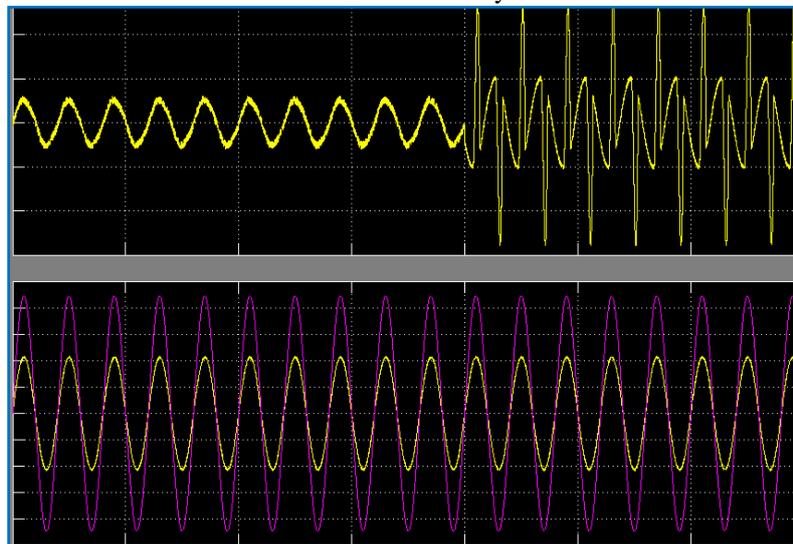
**Fig. 8 – Inverter transient response with reactive power compensation enabled**

As can be viewed in figure 8, inverter transient response is shown when reactive power compensation is enabled besides the load is resistive inductive. The fuzzy control scheme is used.



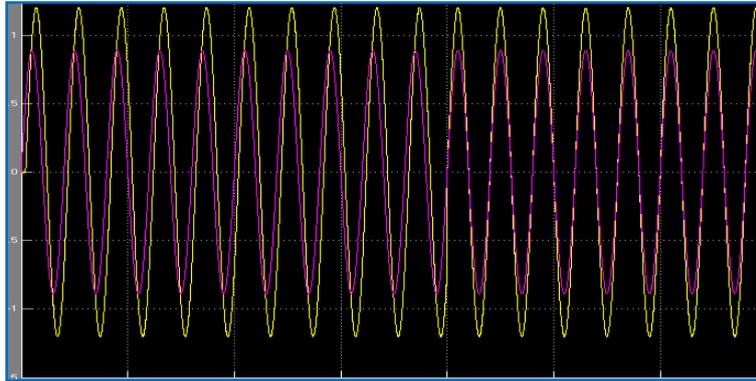
**Fig. 9 – Steady-state operation for 1kw active power generation**

As can be viewed in figure 9, the results of steady state operation for 1kw active power generation and the compensating the c/t harmonics of local load is shown. Fuzzy is used in the control scheme.



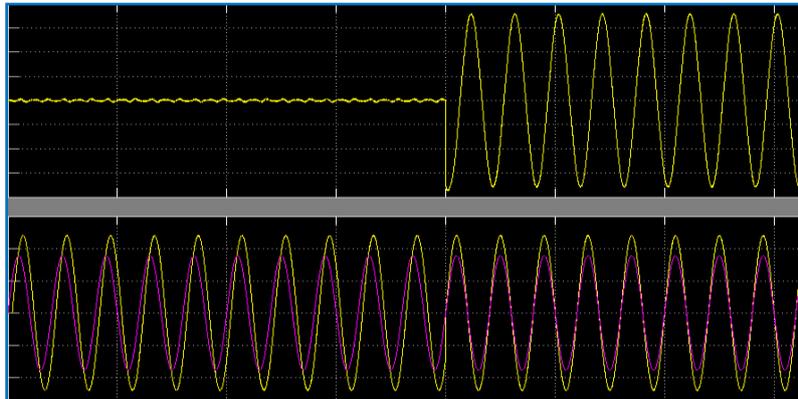
**Fig. 10 – Steady-state operation for 1kw active power generation**

As can be viewed in figure 9, the results of steady state operation of the inverter injecting 1kw active power generation and the compensating the c/t harmonics of local load is shown. Fuzzy is used in the control scheme.



**Fig. 11 – Steady-state linear resistive-inductive load operation**

As can be viewed in figure 11, the results of steady state linear resistive-inductive load operation are shown. Fuzzy is used in the control scheme.



**Fig. 12 – Inverter transient response with reactive power compensation enabled**

As can be viewed in figure 12, inverter transient response is shown when reactive power compensation is enabled besides the load is resistive inductive. The fuzzy control scheme is used.

## V. CONCLUSION

In this paper we study distributed generation (DG) systems that enable integration of multiple power generation sources or plants to a common grid. We use a single-phase inverter for DG systems for the experiments in order to improve power quality in such systems. The quality features studied include reactive power compensation and harmonic power compensation. The SSI filter is used by the current reference generator. Experimental are made with a grid-connected single-phase inverter that can inject power into the grid in order to compensate local load reactive power besides the local load current harmonics. The strategy followed for the experiments integrate the power quality features into the proposed scheme. We built a prototype application that demonstrates the proof of concept through simulations. The results are encouraging.

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