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ANALYSIS OF A DISTRIBUTED GENERATION SYSTEM WITH ADAPTIVE VOLTAGE CONTROL

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ABSTRACT

This thesis present a robust adaptive voltage control of three-phase voltage source inverter for a distributed generation system using harmonic filter. Proposed adaptive voltage control technique combines an adaption control term, harmonic filter and a state feedback control term. In addition, the proposed algorithm is depend upon the existing work, so we are incorporating the harmonic filter, by using of these filter we can analyze and measure the voltage changes accordingly existing research. In this paper, also we can see the graph for the active ad reactive power for the three phase inverter source. The simulation and experimental results are presented under the parameter uncertainties and are compared to the performances of the corresponding adaptive voltage controller to proposed control schematic filter using harm.

1. MODELING OF PROPOSED THEORY SYSTEM MODEL AND CONTROL STRATEGY STATE-SPACE MODEL OF A LOAD-SIDE INVERTER

Fig.1 describes a block diagram of a standalone DGS using renewable energy sources which are wind turbines, solar cells, fuel cells, etc. As depicted in Fig.1, the DGS is divided into six parts: an energy source, an ac–dc power converter (wind turbines) or a dc–dc boost converter (solar cells or fuel cells), a three-phase dc– ac inverter, an LC output filter, an isolation transformer, and a local load.

In this paper, a renewable energy source and an ac–dc power converter or a dc–dc boost converter can be replaced by a stiff dc voltage source (Vdc) because this paper focuses on designing a robust adaptive voltage controller under various types of loads such as balanced load, unbalanced load, and nonlinear load.

Also, this representation can be acceptable because the front converter (i.e., an ac–dc power converter or a dc–dc boost converter) can rapidly recover the reduced\ dc-link voltage when a heavyload is suddenly applied. The DG energy sources usually work together with energy storage devices (e.g., batteries, flywheels, etc.) in order to back up the DS systems during the transient, and increase the power quality and reliability Furthermore, the isolation transformer is not

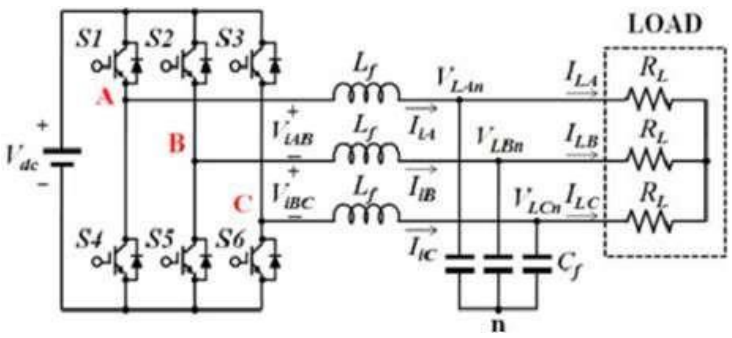


Fig.1 Schetamatic diagrame of three phase dc to ac inverter with an LC filterused toreduce cost and volume assuming that the customers need a low voltage ac source (below 600 V) which the DGSs using renewable energy sources can generate without the help of the transformer.

Fig.1 shows a schematic diagram of a three-phase dc–ac inverter with an LC filter in a standalone application. In this figure, it consists of a dc voltage source (Vdc), a three-phase inverter (S1toS6), an output filter (Lf and Cf), and a three- phase resistive load (RL). The LC output filter is an indispensable part in thiscircuit because it plays a role in eliminating harmonic components of the inverter output voltage caused by high- frequency switching actions. The LC output filter shown in Fig.1 yields the following state equations by using Kirchhoff's voltage law and Kirchhoff's current law:-

$$\frac{dV_L}{dt} = \frac{1}{C_f} I_i - \frac{1}{C_f} I_L \qquad (1)$$
$$\frac{dI_i}{dt} = -\frac{1}{L_f} V_L + \frac{1}{L_f} V_i$$

The state equations (1) in the stationary abc reference frame can be transformed to the following equations in the synchronously rotating d–q reference frame:

$$\dot{V}_{Ld} = \omega V_{Lq} + k_1 I_{id} - k_1 I_{Ld}$$
$$\dot{V}_{Lq} = -\omega V_{Ld} + k_1 I_{iq} - k_1 I_{Lq}$$
$$\dot{I}_{id} = \omega I_{iq} - k_2 V_{Ld} + k_3 V_{id} + k_4 V_{iq} \qquad (2)$$
$$\dot{I}_{iq} = -\omega I_{id} - k_2 V_{Lq} - k_4 V_{id} + k_3 V_{iq}$$

Where ω is the angular frequency (ω=2π·f), f is the fundamental frequency of output voltage or current,

$$k_1 = \frac{1}{C_f}, k_2 = \frac{1}{L_f}, k_3 = \frac{1}{2L_f}, k_4 = \frac{1}{2\sqrt{3}L_f}.$$

and in this work, the following assumptions are used to design an adaptive voltage controller:-

1) The desired loadd–qaxis voltages (VLqr and VLdr) are considered as constant during a small sampling period.

2) The loadd–qaxis currents (ILdandILq) vary slowly during a small sampling period as indicated in [28].

Denote the reference values (I∗idr and I∗iqr) of the inverter currents (IidandIiq) in the d– qaxis as

$$I^*_{idr} = I_{Ld} - \frac{1}{k_1}\omega V_{Lqr}, \quad I^*_{iqr} = I_{Lq} + \frac{1}{k_1}\omega V_{Ldr}. \qquad (3)$$

These inverterd–qaxis current references can be confined within the maximum allowable values as shown in [29]:-

$$I_{id(q)r} = \begin{cases} I^*_{d(q)r}, & If\ |I^*_{d(q)r}| \le I_{max} \\ \frac{I^*_{d(q)r}}{|I^*_{d(q)r}|} I_{max}, & If\ |I^*_{d(q)r}| > I_{max} \end{cases} \qquad (4)$$

Where Imax represents the maximum allowable magnitude of the inverter currents. It should be noted that the output filter capacitance Cf usually satisfies 0<Cf 1, i.e., 1k1 < ∞. Thus we may use the assumption 1k1±|Δk1|<∞ leading to the following equations:-

$$I_{idr} = I_{Ld} - \frac{1}{k_1}\omega V_{Lqr} \approx I_{Ld} - \frac{1}{k_1+\Delta k_1}\omega V_{Lqr} \qquad (5)$$
$$I_{iqr} = I_{Lq} + \frac{1}{k_1}\omega V_{Ldr} \approx I_{Lq} + \frac{1}{k_1+\Delta k_1}\omega V_{Ldr}$$

Where Δk1 denotes the imprecision of the parameterk1. From (2) and (3), four state variables are defined as follows:-

$$x_1 = V_{Ld} - V_{Ldr} , x_2 = V_{Lq} - V_{Lqr}$$
$$x_3 = I_{id} - I_{idr} , x_4 = I_{iq} - I_{iqr} .$$

With this definition, the system model (2) can be rewritten as:-

$$\begin{cases} \dot{x}_1 = \omega x_2 + k_1 x_3 \\ \dot{x}_2 = -\omega x_1 + k_1 x_4 \\ \dot{x}_3 = \omega I_{iq} - k_2 V_{Ld} + k_3 V_{id} + k_4 V_{iq} \\ \dot{x}_4 = -\omega I_{id} - k_2 V_{Lq} - k_4 V_{id} + k_3 V_{iq} \end{cases} \quad (6)$$

In considering the equation (5) and the uncertainties of system parameters, the model (6)becomes:-

$$\begin{cases} \dot{x}_1 = \omega x_2 + k_1 x_3 + \Delta k_1 x_3 \\ \dot{x}_2 = -\omega x_1 + k_1 x_4 + \Delta k_1 x_4 \\ \dot{x}_3 = k_3 V_{id} + k_4 V_{iq} + \Delta k_3 V_{id} + \Delta k_4 V_{iq} - (k_2 + \Delta k_2) V_{Ld} + \omega I_{iq} \\ \dot{x}_4 = -k_4 V_{id} + k_3 V_{iq} - \Delta k_4 V_{id} + \Delta k_3 V_{iq} - (k_2 + \Delta k_2) V_{Lq} - \omega I_{id} \end{cases} \quad (7)$$

Where Δk1 to Δk4 represent the uncertain components of four parameters (k1tok4), respectively.

2. CONTROL STRATEGY VERIFICATIO

In this paper, a prototype 450VA DG unit is considered to implement the proposed control algorithm. Table I gives the nominal parameters for simulations and experiments.

Table 1

Item	Values
DGS Rated power	450VA
dc link Vol	280V
Load out Vol	110V
Out putFeq	60Hz
Sampling Freq	5Khz
LC output filtert	Lf 10mH, Cf 6mic F
Resistive load	Rl 80ohm
Nonlinear load	Cdc 3300mic F,Rdc 500ohm
Harmonic filter	60hz,450VA

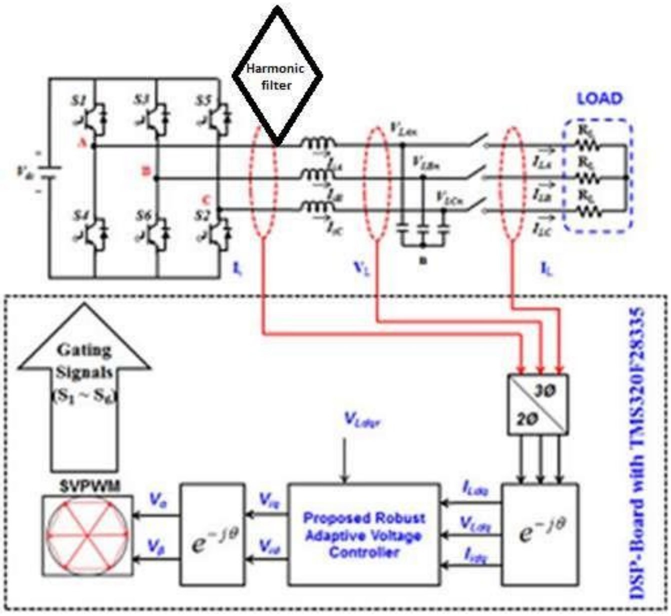


Fig. 2 Proposed Adaptive voltage control with Harmonic filter

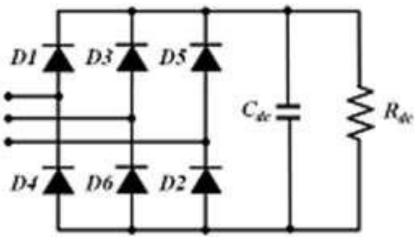


Fig. 3 Circuir Diagrame of non linear load Based on the nominal parameters given in Table I, the system model (2) can be rewritten as

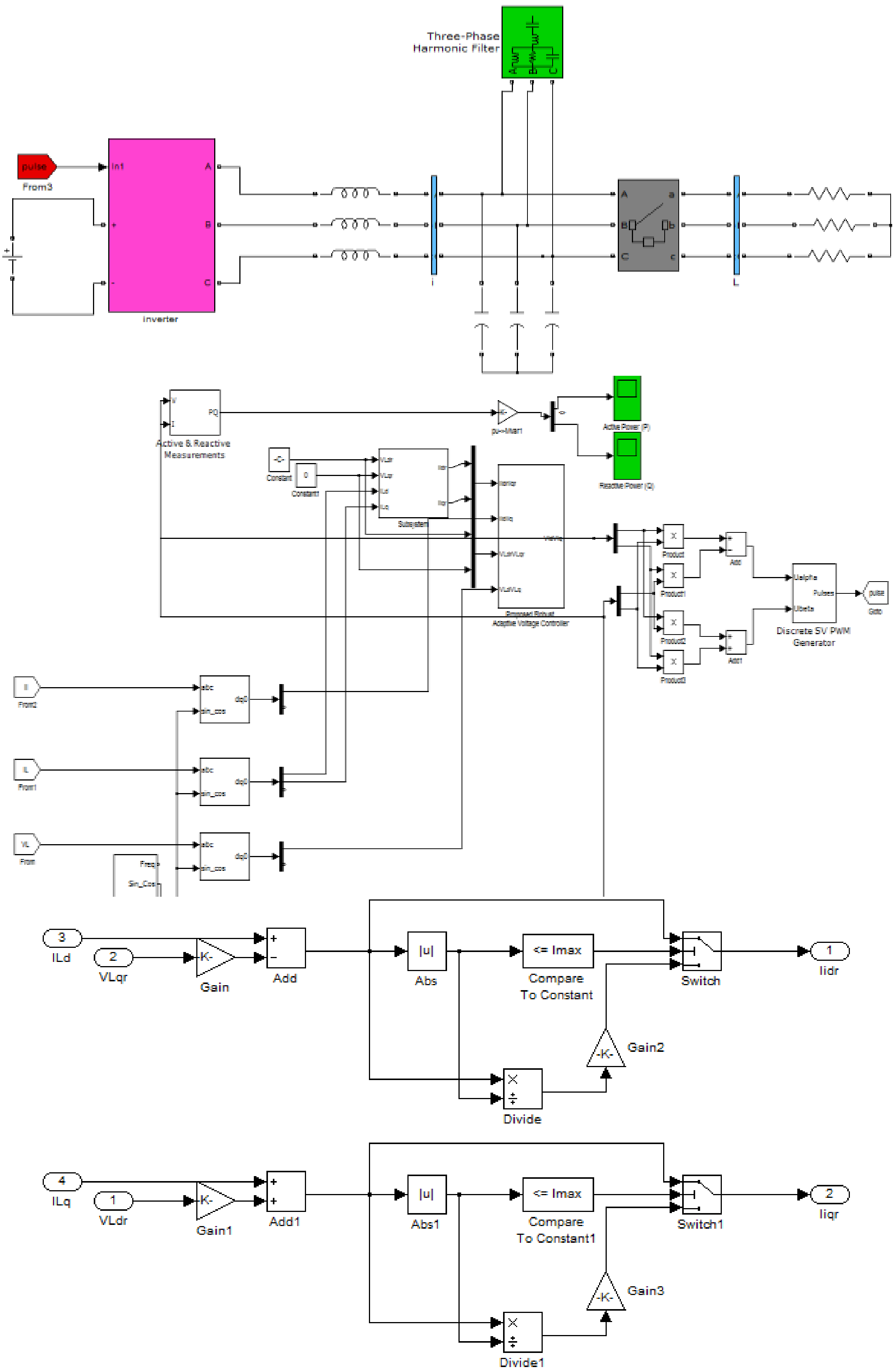
$$V_L^{\cdot}\ d = 377V_{Lq} + 166666.7?I_{id} - 166666.7I_{Ld}$$

$$V_L^{\cdot}\ q = -377V_{Ld} + 166666.7I_{iq} - 166666.7I_{Lq}$$

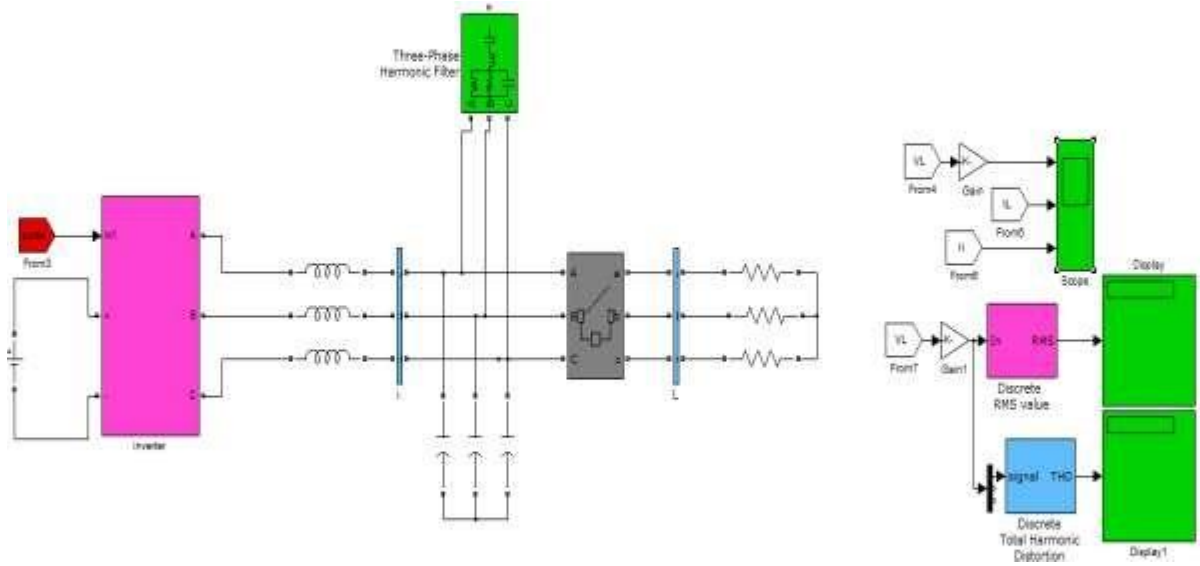
$$I_i^{\cdot} d = 377I_{iq} - 166.7V_{Ld} + 83.4V_{id} + 48.1V_{iq}$$

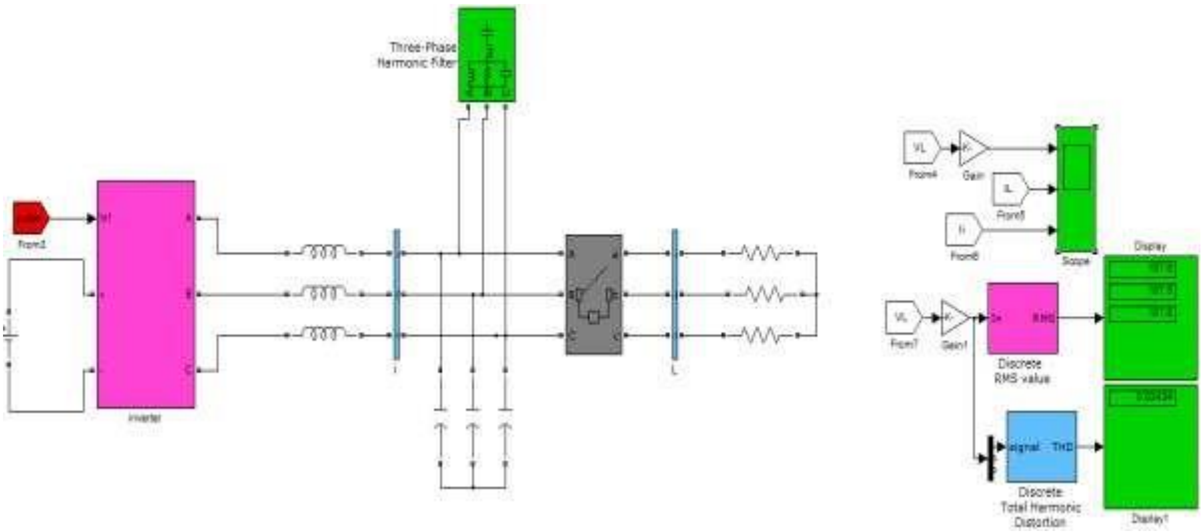
$$I_i^{\cdot} q = -377I_{id} - 166.7V_{Lq} - 48.1V_{id} + 83.4V_{iq}.$$

3. PROPOSED SIMULINK MODEL

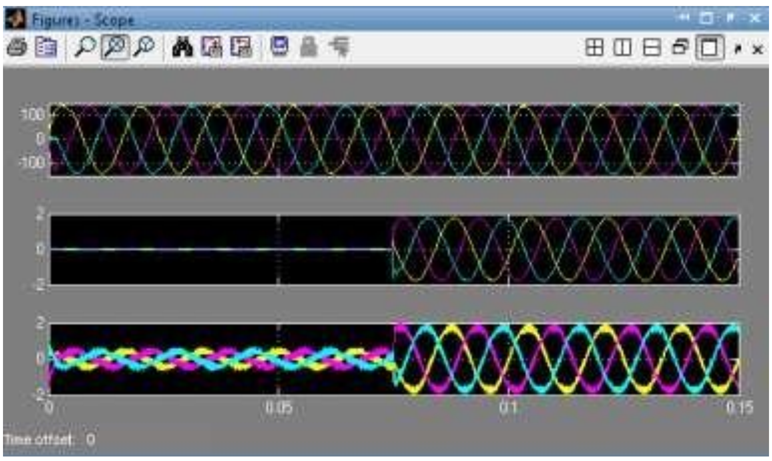


Simulink Model

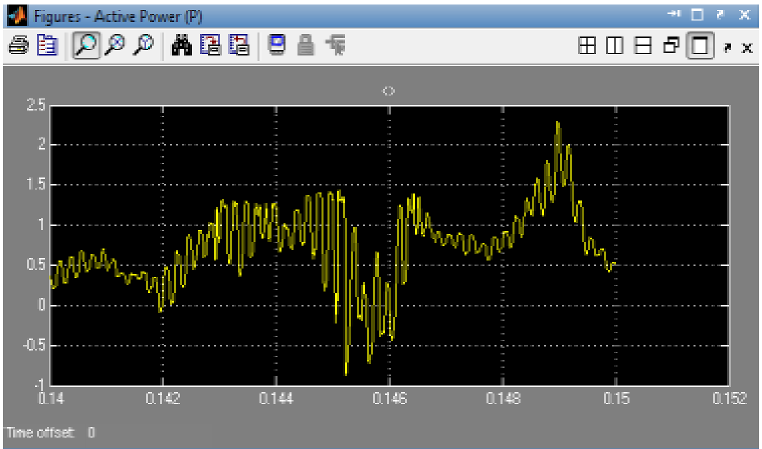


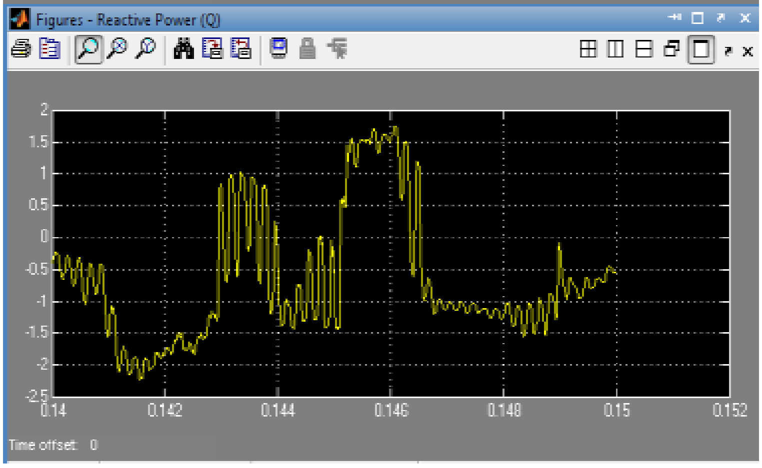


Running Model

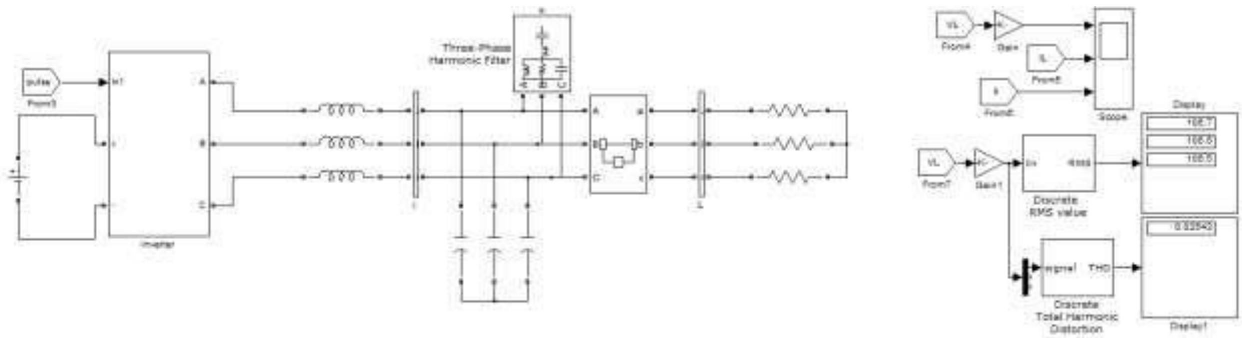


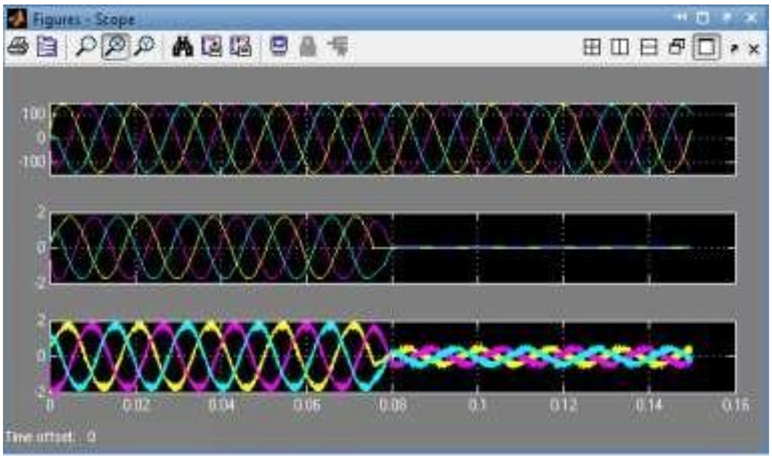
A Fig of load voltage 1, load current 2, and internal current3 respectively at Adaptive Control balanced resistive load (0% to 100%). With harmonic filter



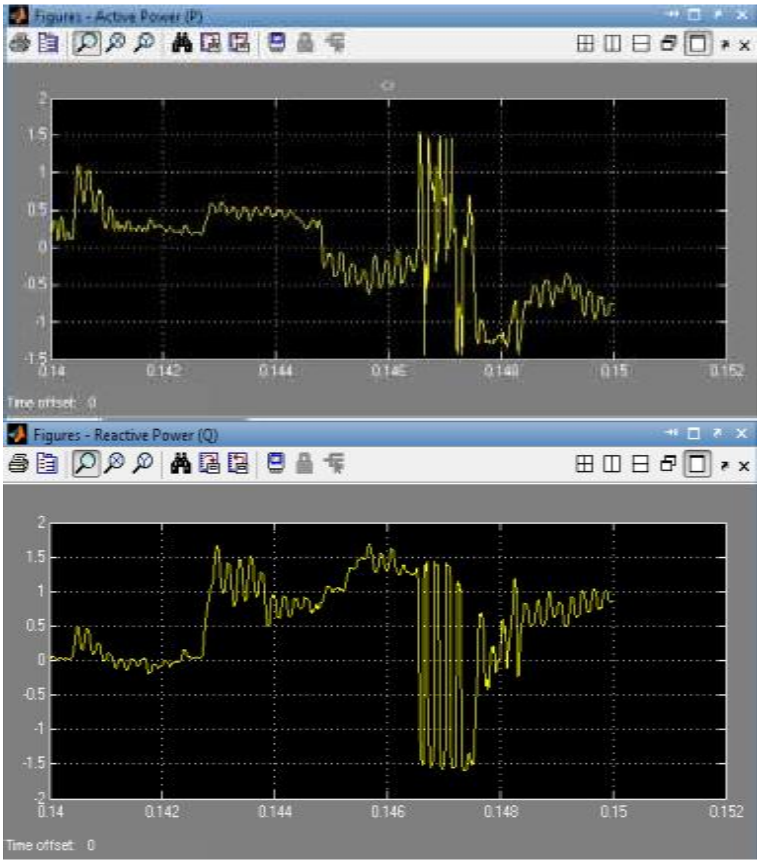


Proposed Adaptive control scheme with harmonic filer along with Active and Reactive Power

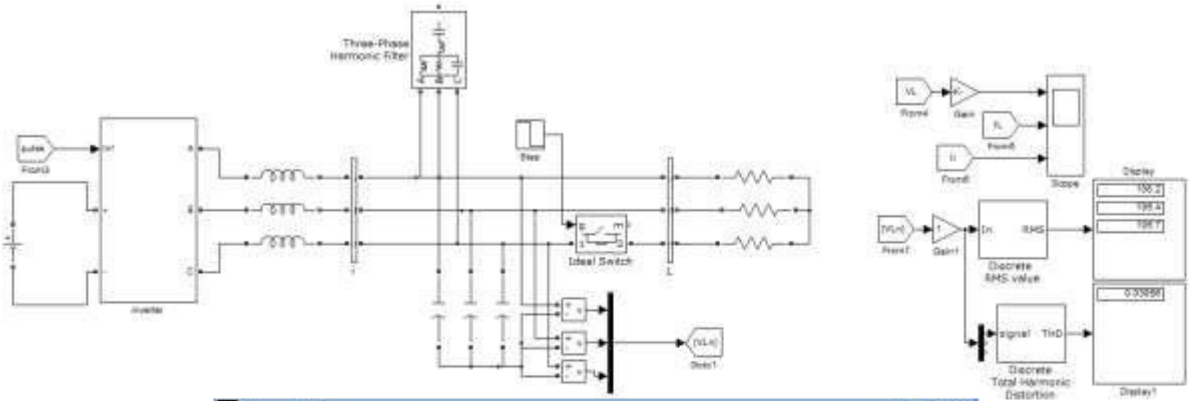


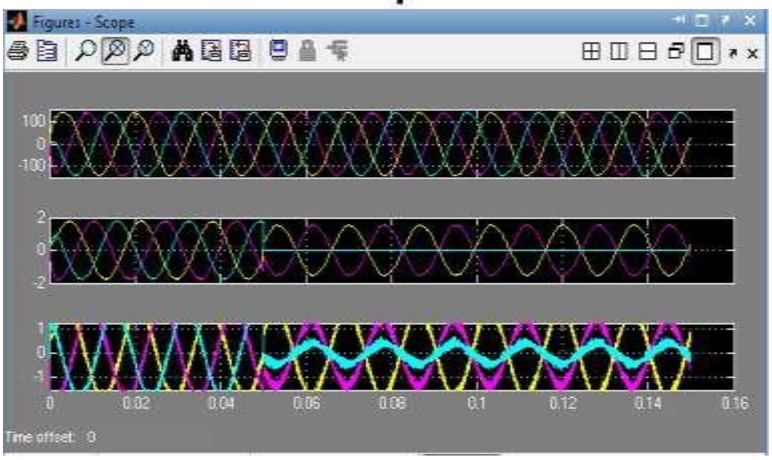


B Fig of load voltage 1, load current 2, and internal current3 respectively at Non Adaptive Control

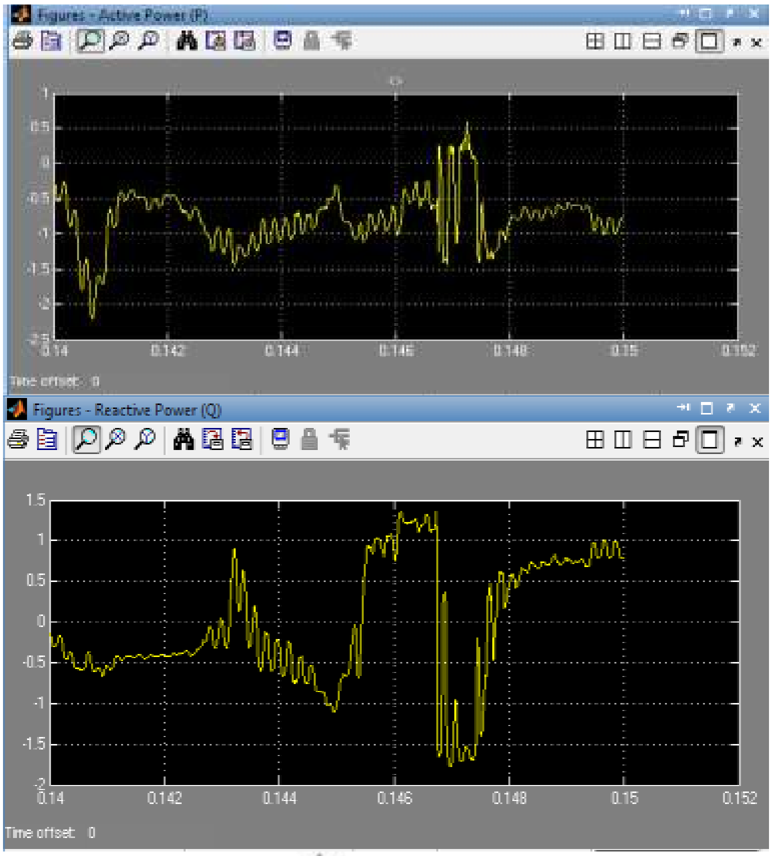


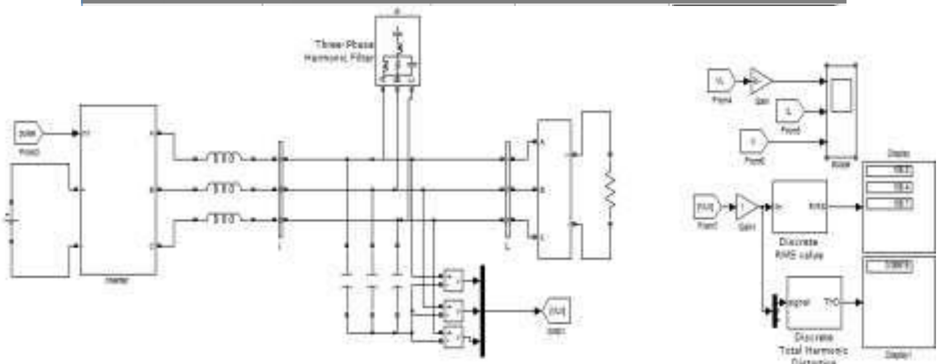
Balanced resistive load (100% to 0%). Active and reactive power

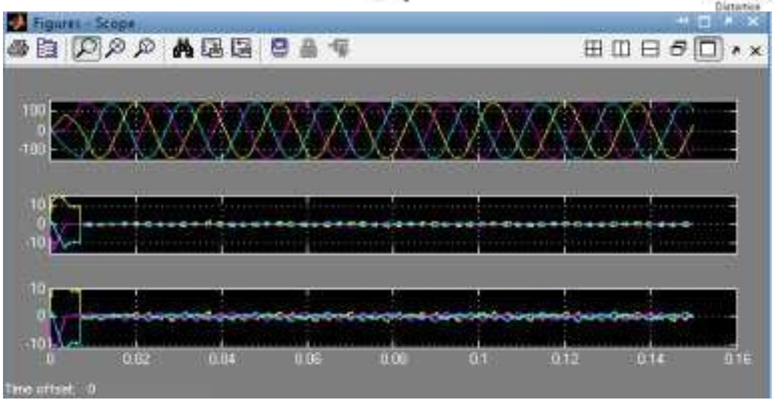




C Unbalanced resistive load







D Nonlinear load (i.e., a capacitive output load with a high crest factor of 2.25:1)

Fig. 4 Simulation results of the proposed adaptive voltage controller with150% uncertainties of system parameters (k1 to k4) under four different conditions. (a) Balanced resistive load (0% to 100%). (b) Balanced resistive load (100% to 0%). (c) Unbalanced resistive load. (d) Nonlinear load (i.e., a capacitive output load with a high crest factor of 2.25:1).

Table 2 Summary of simulation result in Steady state Analysis with harmonic filter

The Existing adaptive Voltage Controller				
Load Type	Load out Voltage Vrms			THD %
	Vla	Vlb	Vlc	
No load	109.9	109.7	109.8	0.04
Balance load	109.3	109.5	109.4	0.04
Unbalanced load a, b	109.7	109.9	109.3	0.04
Nonlinear load	109.5	108.6	108.4	0.38
The Proposed adaptive Voltage Controller with harmonic filter				
Load Type	Load out Voltage Vrms			
No load	107.6	107.5	107.8	0.02434
Balance load	106.7	106.5	106.5	0.02543
Unbalanced load a, b	108.2	106.4	106.7	0.03066
Nonlinear load	106.5	106.4	106.7	0.06919

As illustrated in Fig. 4, the inverter phase currents (Ii), load output voltages (VL), and load phase currents (IL) are measured and then are transformed to the quantities (Iidq , VLdq, ILdq) in the synchronously rotatingd–q reference frame, respectively. In this paper, a space- vector PWM technique is chosen to implement the control inputs (Vid and Viq)that the proposed voltage controller generates in real time. In the paper, simulations and experiments are carried out to verify the effectiveness of the proposed adaptive control algorithm under the following four conditions:-

1) **Balanced load (0%→100%):** Thebalanced resistive load is instantaneously applied to theinverter output terminals.
2) **Balanced load (100%→0%):** Thebalanced resistive load is instantaneously removed from theinverter output terminals.
3) **Unbalanced load:** The unbalancedresistive load is connected to the inverter output terminals, i.e., onlyphaseC is opened.
4) **Nonlinear load:** A three-phase full-bridge diode rectifier is connected to the inverter output terminals. As shown in Fig. 5, it is also connected in parallel with a capacitor (Cdc)and a resistor(Rdc), and the nonlinear load has a crest factor of 2.25:1.

4. CONCLUSION

We represent a robust adaptive voltage control strategy with harmonic filter of a three-phase inverter for a standalone distributed generation unit with changes in active and reactive power generation. This methos is not only simple, but is also robust to system uncertainties with the used of harmonic filter.

Finally, the simulation and experimental results have demonstrated that the proposed control scheme gives satisfactory voltage regulation performance such as fast dynamic behavior, small steady-state error, and low THD under various loads (i.e., no load, balanced load, unbalanced load, and nonlinear load) in the presence of the uncertainties of system parameters.

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