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Modeling and Simulation of AC/DC Grid Side Voltage Source Converter Used in Wind Power Generation System using fuzzy logic control

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ABSTRACT:

The control characteristics of the ac/dc grid-side voltage source converter (VSC) used to connect wind power systems with the grid are of significant grandness for the overall grid execution. In this paper, voltage oriented control FL and phase locked loop (PLL) are used to regulate grid-side dc voltage and system power factor by decoupled control theory. The mathematical models of grid-side converter and the control strategy of grid-side converter based wind power generation system are analyzed. The control performance is assessed through simulation approach using MATLAB, SimPowersystem, which verifies that the developed control mechanism is feasible to apply for grid-side converter based wind power generation system and the grid-side converter is controlled well.

Keywords :

Grid side voltage source converter, wind power generation, voltage oriented control, phase locked loop, decoupled control theory.

I.INTRODUCTION:

Wind power generation has been renowned as the most rapidly growing technology due to the increasing incursion of renewable energy resources in modern power system networks. Governments of the whole world are constrained for alternative energy sources such as wind power, solar energy, biomass electricity and ocean energy. Among the above given alternatives, wind energy is a naturalistic way of tackling the natural energy. Wind energy has been intensively analyzed in late years in many different countries, which resulted in several different forms like fixed speed system with a squirrel cage induction generator (SCIG), the variable speed system with permanent magnet synchronous generator (PMSG) and the variable speed system with a doubly fed induction generator (DFIG) to improve the efficiency, power rating, cost benefit effectiveness etc.As the wind turbines continuously become larger and the variable speed technology is solely used, a major contribution to the overall grid power quality and control is modified by these systems. This characteristic is mainly implemented by appropriately controlling the power electronic devices that connect wind power systems with the grid. For example, the grid through a back to- back dc-link is connected to the rotor in DFIG wind applications. In this topology, the rotor-side converter is responsible for the control of the active and reactive power commuted between the stator and the grid, whereas the grid side converter (GSC) is responsible for the dc voltage regulation at a certain desired level and for the reactive power regulation at unity power factor operation. Also, in the cases of squirrel cage induction generators or permanent magnet synchronous generators wherein a similar dc-link is used, the main tasks of the GSC devices remain the same, i.e. dc-voltage and power factor regulation. It is well known that the wind power generation system with back to back voltage source converter control mechanism is very complex. Therefore the grid side voltage source converter based wind power generation system is only studied in this paper. In this paper, the complete model of the fundamental device of a grid-side VSC is obtained. The model is developed on the synchronously rotating, voltage oriented, dq reference frame since in this frame all the sinusoidal quantities are transformed into dc quantities in steady-state.

EXTENTION:

Fuzzy logic control used In wind power generation here we hide the pi control , because pi control is old systems and fixed parameters and difficute to control and problems can’t be solved easly in recent years, the number and variety of applications of fuzzy logic have increased significantly.

The applications range from consumer products such as cameras, camcorders, washing machines, and microwave ovens to industrial process control, medil instrumentation, decision-support systems, and portfolio selectionca, fuzzy Logic Toolbox software, fuzzy logic should be interpreted as FL, that is, fuzzy logic in its wide sense.

II.THREE PHASE GRID MODEL:

Suppose the grid is a symmetrical three-phase voltage source. So its voltage model can be defined as follows:

$$\begin{cases} V_a = V_m.\cos(wt) \\ V_b = V_m.\cos\left(wt - \frac{2\pi}{3}\right) \\ V_c = V_m.\cos\left(wt - \frac{4\pi}{3}\right) \end{cases} \quad (1)$$

$$\begin{cases} i_{ag} = I_m.\cos(wt) \\ i_{bg} = I_m.\cos\left(wt - \frac{2\pi}{3}\right) \\ i_{cg} = I_m.\cos\left(wt - \frac{4\pi}{3}\right) \end{cases} \quad (2)$$

III.MODELING of THREE PHASE VSC EXPRESSED in ABC REFERENCE FRAME:

The system under consideration, shown in Fig.1, represents a VSC connected to the grid through an R-L filter while the dc–side consists of a capacitor parallel with a resistance. The modeling and circuit analysis of VSC is given next. First, let us define Sk (k = a,b,c) as the switch function of phase, k.

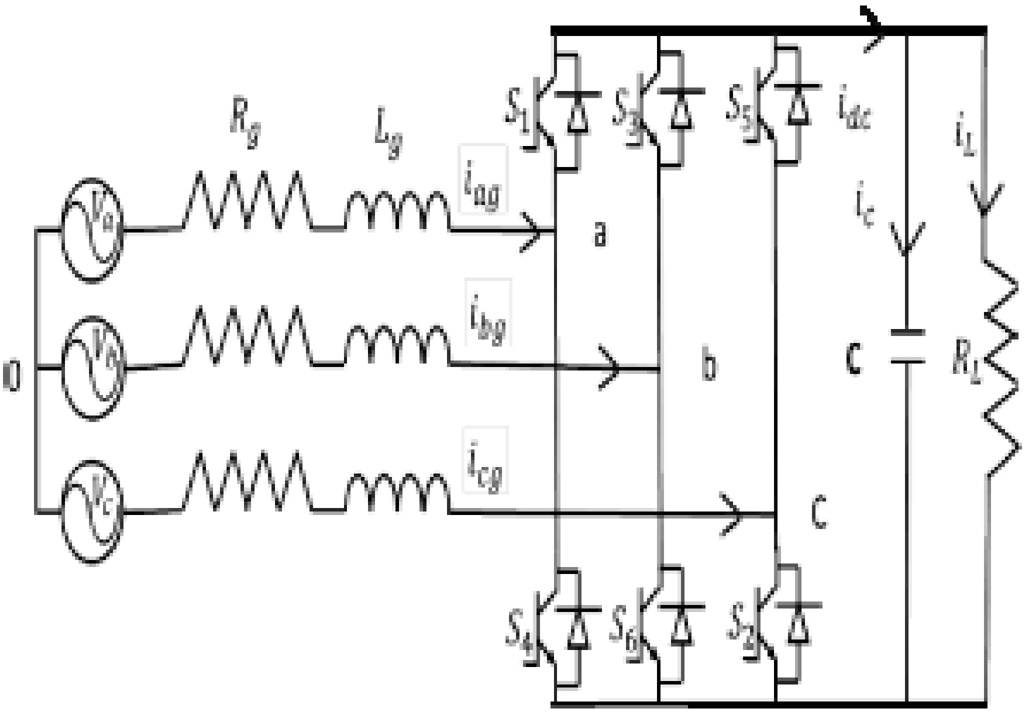

Fig.1 grid side VSC

Based on the principle that any two switches in the same leg cannot be on at the same time, one can write the following definition [10]:

$$S_k = \begin{cases} 1 & upper \quad IGBT \quad on \\ 0 & upper \quad IGBT \quad off \end{cases} \quad (3)$$

Applying Kirchhoff's laws to the circuit of Fig.1, the instantaneous values of the currents can be obtained, and written as following:

$$\begin{cases} L_g \dfrac{di_{ag}}{dt} = V_a - R_g i_{ag} - V_{(a,0)} \\ L_g \dfrac{di_{bg}}{dt} = V_b - R_g i_{bg} - V_{(b,0)} \\ L_g \dfrac{di_{cg}}{dt} = V_c - R_g i_{cg} - V_{(c,0)} \end{cases} \quad (4)$$

Here, V (a,0),V (b,0) and V (c,0)are the voltages from the ac side of the VSC to the power neutral point 0, and can be obtained by (5) .

$$\begin{cases} V_{(a,0)} = V_{(a,N)} + V_{(N,0)} \\ V_{(b,0)} = V_{(b,N)} + V_{(N,0)} \\ V_{(c,0)} = V_{(c,N)} + V_{(N,0)} \end{cases} \quad (5)$$

For a balanced three-phase system

$$V_{(a,0)} + V_{(b,0)} + V_{(c,0)} = 0 \quad (6)$$

Substituting from (5) into (6), the following (7) can be deduced as:

$$V_{(N,0)} = -\frac{V_{(a,N)} + V_{(b,N)} + V_{(c,N)}}{3} \quad (7)$$

Considering phase-a, when the upper IGBT is on and lower IGBT is off, $Sa=1$ and $V(a.n) = Vdc$. Similarity, when the upper IGBT is off and lower IGBT is on, $S_{a=0;}$ $and\ Van=0$. Therefore, based on the above characteristic, $V_{(aN)} = Vdc.Sa$

Considering phase-a, when the upper IGBT is on and lower IGBT is off, $S_a = 1$ and $V_{(a,N)} = V_{dc}$. Similarity, when the upper IGBT is off and lower IGBT is on, $S_a = 0$ and $V_{(a,N)} = 0$. Therefore, based on the above characteristic, $V_{(a,N)} = V_{dc}.S_a$.

$$\text{Therefore} \begin{cases} V_{(a,N)} = S_a V_{dc} \\ V_{(b,N)} = S_b V_{dc} \\ V_{(c,N)} = S_c V_{dc} \\ V_{(N,0)} = -\frac{1}{3}(S_a + S_b + S_c)V_{dc} \end{cases} \quad (8)$$

Substituting from (5) and (8) into (4), the set of (9) derived as:

$$\begin{cases} L_g \dfrac{di_{ag}}{dt} = V_a - R_g i_{ag} - V_{dc}\left(S_a - \dfrac{1}{3}\sum\limits_{k=a,b,c} S_k\right) \\ L_g \dfrac{di_{bg}}{dt} = V_b - R_g i_{bg} - V_{dc}\left(S_b - \dfrac{1}{3}\sum\limits_{k=a,b,c} S_k\right) \\ L_g \dfrac{di_{cg}}{dt} = V_c - R_g i_{cg} - V_{dc}\left(S_c - \dfrac{1}{3}\sum\limits_{k=a,b,c} S_k\right) \end{cases} \quad (9)$$

Under the assumption that the power switch resistances of a balanced three-phase system could be neglected, the power relationship between the ac side and dc side is given as follows:

$$\sum_{k=a,b,c} i_{kg}(t)V_{kN}(t) = i_{dc}(t)V_{dc} \quad (10)$$

By combining (8) with (10), the following (11) as:

$$i_{dc}(t) = i_{ag}(t)S_a + i_{bg}(t)S_b + i_{cg}(t)S_c \quad (11)$$

By applying Kirchhoff's laws to the positive node of the dc-link capacitor, as follows:

$$\begin{cases} i_c = C\dfrac{dV_{dc}}{dt} \\ i_{dc} = i_c + i_L \\ i_{dc} = S_a i_{ag} + S_b i_{bg} + S_c i_{cg} \\ i_L = \dfrac{V_{dc}}{R_L} \end{cases} \quad (12)$$

(12) can also be expressed by a single equation, and given as follows [11]:

$$C\frac{dV_{dc}}{dt} = S_a i_{ag} + S_b i_{bg} + S_c i_{cg} - \frac{V_{dc}}{R_L} \quad (13)$$

For a balanced three-phase system

$$V_a + V_b + V_c = 0 \quad (14)$$

$$i_{ag} + i_{bg} + i_{cg} = 0 \quad (15)$$

Therefore, (9) along with (13) through (15) constitute the three-phase voltage source converter model expressed in the abc reference frame, and are rewritten as follows [12]:

$$\begin{cases} C\dfrac{dV_{dc}}{dt} = \sum\limits_{k=a,b,c} S_k i_{kg} - i_L \\ L_g \dfrac{di_{kg}}{dt} + R_g i_{kg} = V_k - V_{dc}\left(S_k - \dfrac{1}{3}\sum\limits_{j=a,b,c} S_j\right), k=a,b,c \\ \sum\limits_{k=a,b,c} V_k = \sum\limits_{k=a,b,c} i_{kg} = 0 \end{cases} \qquad (16)$$

IV. GRID SYNCHRONIZATION METHOD

The output voltage phase angle of the three phase system has to follow their respective grid voltage phase angle and, as a consequence, the reference currents will be in phase to their corresponding voltages. The independent synchronization can be implemented with a PLL shown in Fig. 2

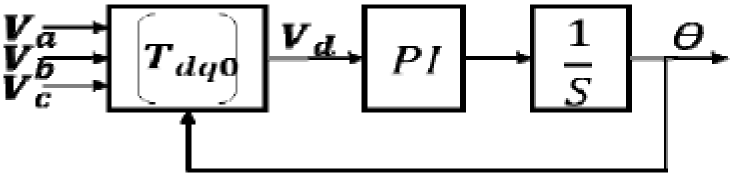

Fig.2 The configuration of three phase PLL

Where $$[T_{dq0}] = \frac{2}{3}\begin{bmatrix} \cos\theta & \cos\left(\theta - \frac{2\pi}{3}\right) & \cos\left(\theta - \frac{4\pi}{3}\right) \\ -\sin\theta & -\sin\left(\theta - \frac{2\pi}{3}\right) & -\sin\left(\theta - \frac{4\pi}{3}\right) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \qquad (17)$$

$\theta = \omega t$, in (1)

V. MODELING of THREE PHASE VSC EXPRESSED in DQ SYNCHRONOUS REFERENCE FRAME

Although the voltage source converter model expressed in the abc frame has straightforward meanings, all the components in the abc model are time variant, which will bring troubles and difficulties to controller designs. Hence, it is necessary to transform the abc model to a dq model which rotates at synchronous speed, so that the three-phase voltage inputs and the current components will be transformed to dc values.

Applying the transformation matrix (17) in (16) and eliminating the zero-sequence components due to a balanced three-phase system, the VSC model expressed in the dq synchronous reference frame can be deduced and given as in [13], [14]:

$$\begin{cases} C\dfrac{dV_{dc}}{dt} = \dfrac{3}{2}\left(i_{dg}S_d + i_{qg}S_q\right) - i_L \\ L_g\dfrac{di_{dg}}{dt} - wL_g i_{qg} + R_g i_{dg} = V_d - V_{d1} \\ L_g\dfrac{di_{qg}}{dt} + wL_g i_{dg} + R_g i_{qg} = V_q - V_{q1} \end{cases} \quad (18)$$

Where, $V_{d1} = V_{dc}S_d$ and $V_{q1} = V_{dc}S_q$.

The active and reactive power of a grid-side converter expressed in the dq synchronous reference frame are given as follows:

$$P_g = \frac{3}{2}\left(V_d i_{dg} + V_q i_{qg}\right) \quad (19)$$

$$Q_g = \frac{3}{2}\left(V_q i_{dg} - V_d i_{qg}\right) \quad (20)$$

FUZZY CONTROL DESIGN OF GRID SIDE VSC:

In recent years, the number and variety of applications of fuzzy logic have increased significantly. The applications range from consumer products such as cameras, camcorders, washing machines, and microwave ovens to industrial process control, medical instrumentation, decision-support systems, and portfolio selection. Here fuzzy logic control is used wind power generation and control of outputs (currents, constant dc - link voltages , active and reactive power , reactive power should be zero and maintain unity p.f) and eliminating harmonics ripples

What can fuzzy logic toolbox software do?

You can create and edit fuzzy inference systems with Fuzzy Logic Toolbox software. You can create these systems using graphical tools or command-line functions, or you can generate them automatically using either clustering or adaptive neuro-fuzzy techniques.

If you have access to Simulink software, you can easily test your fuzzy system in a block diagram simulation environment. The toolbox also lets you run your own stand-alone C programs directly. This is made possible by a stand-alone Fuzzy Inference Engine that reads the fuzzy systems saved from a matlab session.

You can customize the stand-alone engine to build fuzzy inference into your own code. All provided code is ansi compliant.Because of the integrated nature of the matlab environment, you can create your own tools to customize the toolbox or harness it with another toolbox, such as the Control System Toolbox, Neural Network Toolbox, or Optimization Toolbox software.

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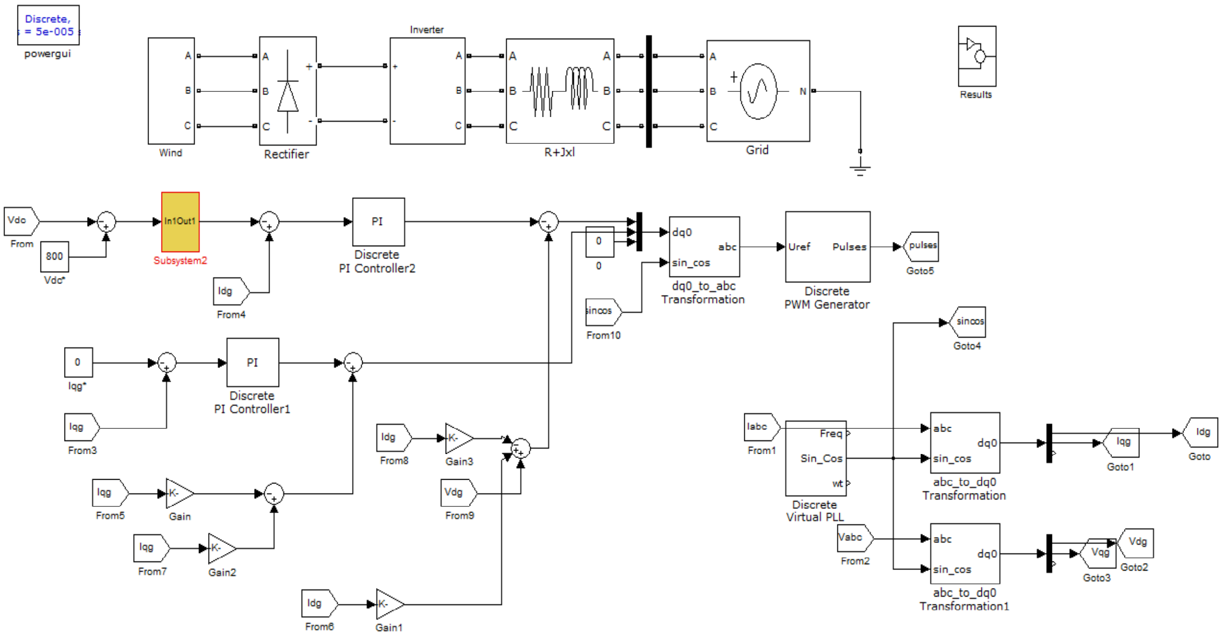
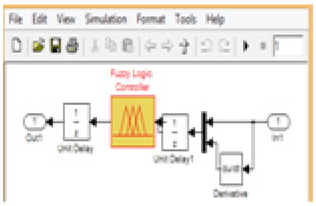




control mechanism of grid side converter Subsystem-2

- Specialized GUIs for building fuzzy inference systems and viewing and analyzing results.

- Membership functions for creating fuzzy inference systems.

- Support for AND, OR, and NOT logic in user-defined rules.

- Standard Mamdani and Sugeno-type fuzzy inference systems.

- Automated membership function shaping through neuroadaptive and fuzzy clustering learning techniques.

- Ability to embed a fuzzy inference system in a Simulink model.

- Ability to generate embeddable C code or stand-alone executable fuzzy inference engines

RESULTS AND DISCUSSION:

pi control is old systems , fixed parameters , control difficulte , problems con't solve here we use fuzzy logic in wind power generation In fuzzy Logic Toolbox software, fuzzy logic should be interpreted as FL, that is, fuzzy logic in its wide sense Another basic concept in FL, which plays a central role in most of its applications, is that of a fuzzy if-then rule or, simply, fuzzy rule. Although rule-based systems have a long history of use in Artificial Intelligence (AI), In order to validate the effectiveness of the presented control scheme, the closed loop control system for a grid side VSC in a wind power generation unit is simulated. Fig.4 shows grid current is synchronized and for better visibility the time offset is set to 0.7 sec. so the control strategy is feasible to apply for grid side converter based wind power generation system. Fig.5 shows the dc-link voltage is maintained constant at 800 V.

The dc-link voltage response of the grid side VSC what the input voltages are, the grid side converter control scheme will try to keep the dc-link voltage constant is shown in Fig.6. In Fig.7, the dc side active power is near 17 KW. To supply the dissipated energy of the resistor RL = 37.5 Ω, the VSC needs to provide power flow near 17 KW to the dc bus. In Fig.8 the reactive power approximately zero and it ensures the unity power factor operation of the system. In dq synchronous reference frame, d-axis align with grid phase-a voltage i.e. d-axis voltage equals to the peak amplitude of grid phase-a voltage and q-axis voltage equals to zero are shown in Fig.9 and Fig.10.

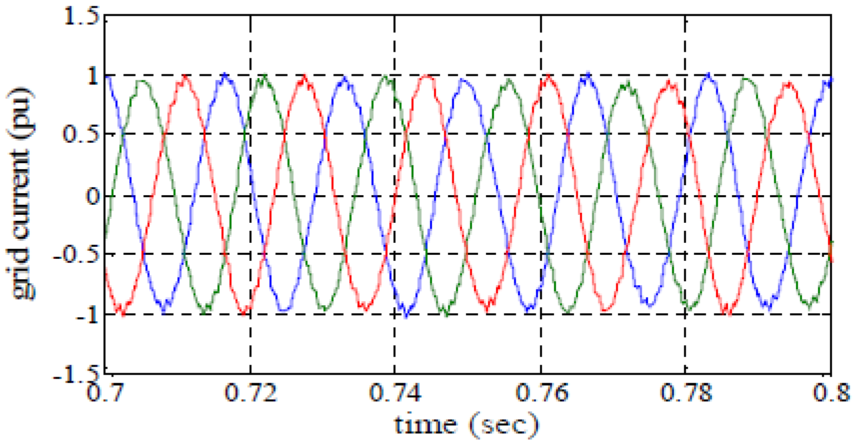


Fig.4 grid current

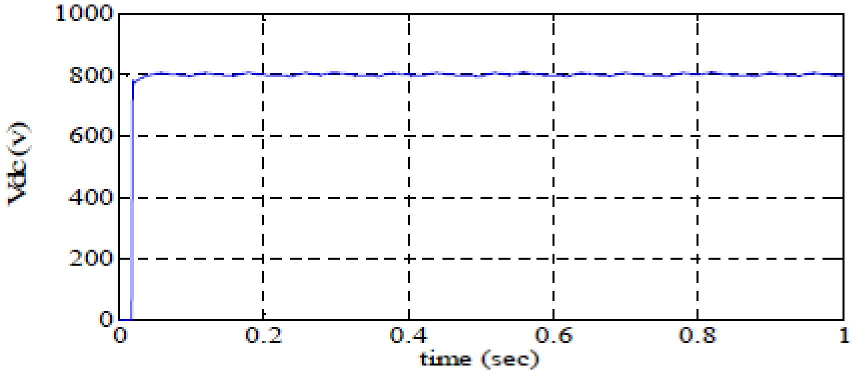


Fig.5 dc-link voltage

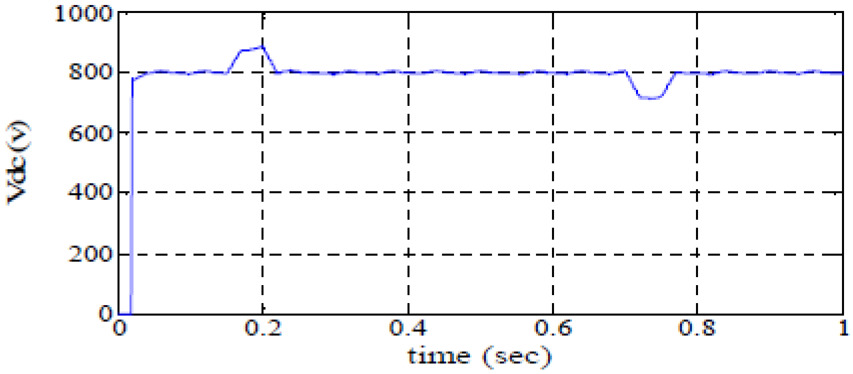


Fig.6 dc-link voltage with grid sag and swell

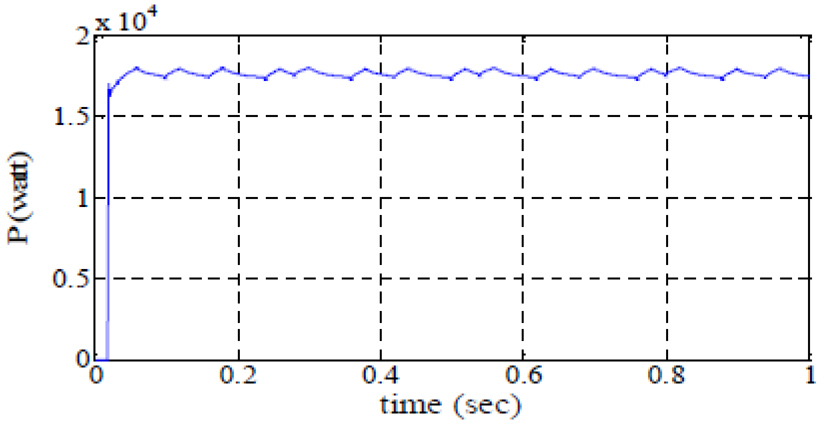


Fig.7 active power

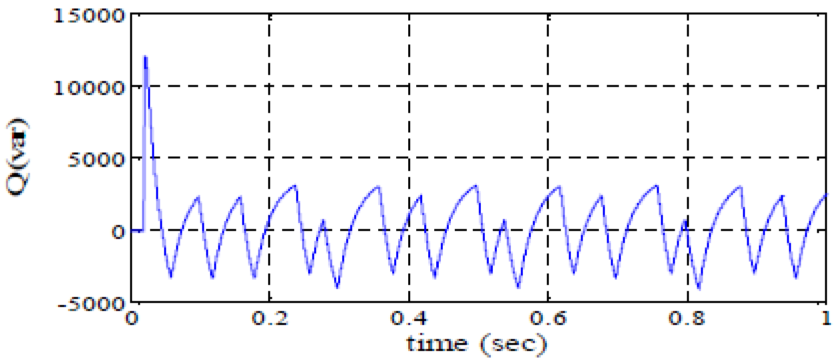


Fig.8 reactive power

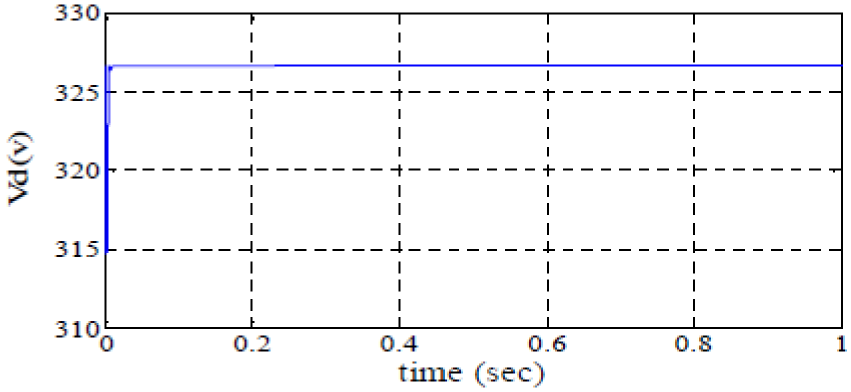


Fig.9 direct-axis voltage of grid

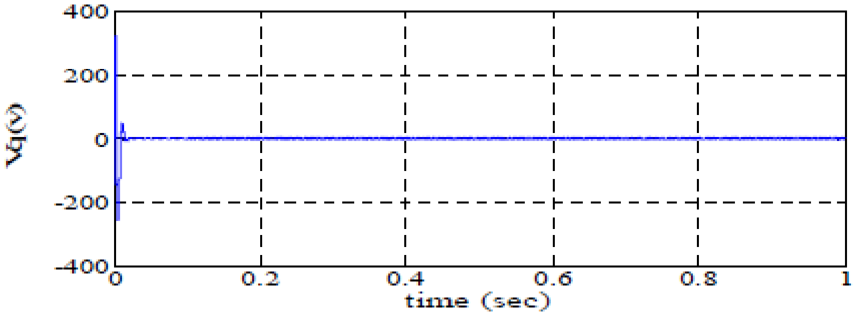
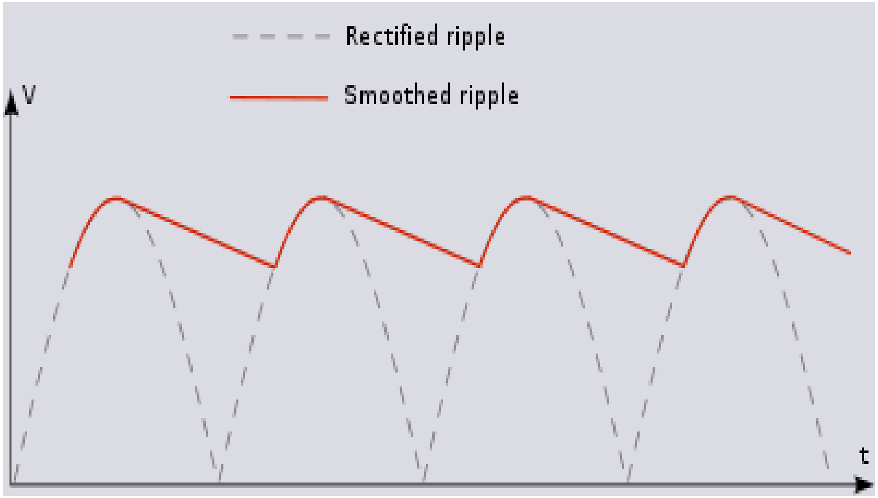


Fig.10 quadrature-axis voltage of grid



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APPENDIX

TABLE-A
DETAILED PARAMETERS OF GRID SIDE VSC

Grid Voltage (line to line)	400 V
Frequency (f)	50 Hz
Grid Resistance (R_g)	0.01 Ω
Load Resistance (R_L)	37.5 Ω
Grid Inductance (L_g)	1.2 mH
Capacitance (C)	23 μF
Modulation Index (m)	0.8
Reference DC-link Voltage	800 V

TABLE-B
GAINS OF PI CONTROLLERS

K_{p1} , K_{i1}	0.1, 10
K_{p2} , K_{i2}	0.01, 1
K_{p3} , K_{i3}	0.01, 5

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