Sliding Mode Control System of Single Phase Buck-Boost Inverter with Buffer Inductor

Purwadi Agus Darwito[1], Arief Abdurrakhman[1], and Almas Fachrullah[1]

***Abstract - Inverter is one of the primary components of a distributed electric power plants that serve as modifiers DC voltage into AC. In this research is applied of the Sliding Mode Control on Inverter Buck Boost One phase with Buffer Inductor. In the Open Loop test with the source voltage of 60 Volts, generate graphics output voltage in the form of a sinusoidal wave with maximum amplitude of about 400 volts. In the Closed Loop test, the graph output voltage can be controlled to follow a set point with SMC control method of order 2, and the resulting value Error Steady State smallest at 300 Volt, which* amounted to 3.33%. The smallest sensitivity value of 0.29 when the input voltage changes by 32%.**

Index Terms - Inverter, SPBBI-BI, sliding mode control

INTRODUCTION

In the distributed generator system (DG-system) of electrical power needed to control the inverter output voltage despite energy sources and the existing load fluctuates. There are various types and inverter topologies that have been used, one of new inverter topology is a single phase Inverter Buck Boost with buffer inductor. The advantages of this type is the inverter can produce output voltage value is almost 2 times the given input voltage and suitable for use as an induction motor drives are typically used in electric cars [1]. For the purpose of controlling the output voltage of the inverter takes the appropriate control system. In this research, the type of control system applied Sliding Mode Control (SMC). Sliding Mode Control (SMC) is one commonly used control method for nonlinear systems and switching systems or non-continuous. This method is widely used in control systems Converter, Inverter, Motor and Robotics System. Sliding mode control also has a robust nature that is insensitive to changes in the parameters [2]. based on the characteristics of the SMC, the SMC method used in this research so that the system can be be controlled properly. Some parameters were achieved in this research is able to follow the setpoint output voltage, output voltage is generated having Error steady state (Ess) and Over shoot low and the output voltage has a low sensitivity level also if there change of the input voltage and load values given.

METHOD

The method used in this research are as follows :

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A. The Model Plant of Inverter Buck Boost One Phase with Buffer Inductor System Without a Controller

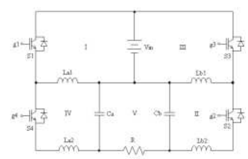

Figure 1. Plant circuit Inverter Buck Boost One phase with Buffer Inductor.

Case 1

This condition occurs if the S1, S2 ON and S3, S4 OFF. Then obtained the equivalent circuit of Figure 1, and from the circuit obtained in the form of state space models for case 1 are:

$$\begin{bmatrix} \frac{di_{Lb}}{dt} \\ \frac{dV_{Cb}}{dt} \end{bmatrix} = \begin{bmatrix} 0 & \frac{1}{L_1+L_2} \\ \frac{-1}{C_b} & \frac{1}{RC_b} \end{bmatrix} \begin{bmatrix} i_{Lb} \\ V_{Cb} \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{-1}{RC_b} \end{bmatrix} V_{Ca} \tag{1}$$

Case 2

This condition occurs if the S1, S2 OFF and S3,S4 ON. Then obtained the equivalent circuit of Figure 1, and from the circuit obtained in the form of state space models for case 2 is :

$$\begin{bmatrix} \frac{di_{La}}{dt} \\ \frac{dV_{Ca}}{dt} \end{bmatrix} = \begin{bmatrix} 0 & \frac{1}{L_1+L_2} \\ \frac{-1}{C_a} & \frac{1}{RC_a} \end{bmatrix} \begin{bmatrix} i_{La} \\ V_{Ca} \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{-1}{RC_a} \end{bmatrix} V_{Cb} \tag{2}$$

B. The Design of The Controller Inverter Buck Boost One Phase with Buffer Inductor Using SMC

1. Determination the state of the controlled variable

There are two variables are controlled, the output voltage error (e) and changes in voltage error (de/dt). The equation is:

$$\begin{bmatrix} \dot{x1} \\ \dot{x2} \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -\frac{1}{CL} & 0 \end{bmatrix} \begin{bmatrix} x1 \\ x2 \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{Vca+Vcb}{CL} \end{bmatrix} u + \begin{bmatrix} 0 \\ V\ddot{ref} + \frac{Vref}{CL} - \frac{Vcb}{CL} \end{bmatrix} \tag{3}$$

Where : $x1 = e = error; x2 = \frac{de}{dt} = error\ rate;$

$u = control\ signal\ from\ SMC; Vref = reference\ voltage$

2. Determination of sliding surface and control theorem SMC

Sliding mode control is a control method that is widely used for non-linear control system including the control of power electronics systems such as power converters, inverters, active filters, and so forth. The main advantages of sliding mode control is to have robust nature so that it can cope with the control system parameters tend to change [3].

Sliding Surface on the phase plane variable state also determined that the controller can achieve the desired response. The equation of the sliding surface [4] are:

$$S = kx1 + x2 \tag{4}$$

Where : S : Sliding Surface; k : Sliding Coefficient

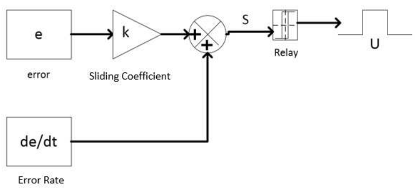

Figure 2. Block Diagram SMC.

3. Achievement and circumstances of SMC
Controller that has been designed considered successful when they fulfill two main properties of SMC methods, that is the achievement and circumstances. For achievement of SMC by the equation:

$$\dot{V}(t) = -x.V(o).\exp(-xt) \qquad (5)$$

for a state of SMC based on the equation:

$$S > 0 \rightarrow \dot{S} < 0 \rightarrow k\left(\dot{Vo} - \dot{Vref}\right) + \left(\ddot{Vo} - \ddot{Vref}\right) < 0 \quad (6)$$

or

$$S < 0 \rightarrow \dot{S} > 0 \rightarrow k\left(\dot{Vo} - \dot{Vref}\right) + \left(\ddot{Vo} - \ddot{Vref}\right) > 0 \quad (7)$$

C. *Implementation and Simulation Controller SMC on Buck Boost Single Phase Inverter with Buffer Inductor*

The difference of the system Inverter Buck Boost One phase with Buffer Inductor with the controller and the system without a controller is a system designed to be closed loop so that the required two additional elements that is the controller (SMC) and voltage sensors.

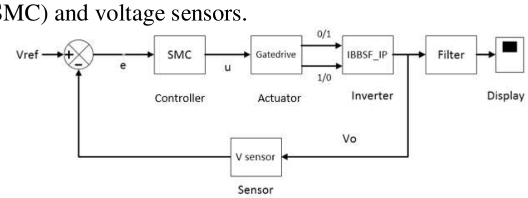

Figure 3. Block diagram of the control system.

RESULTS AND DISCUSSION

A control system is categorized robust if : (1) low sensitivity, (2) stable despite the change parameter variations, (3) the performance of the system remains in the criteria set although there are changes system parameters. Robustness of the system is also beginning to be used by many people [5].

1. *The open loop response of Inverter Buck Boost One Phase with Buffer Inductor*

Open Loop response testing performed in MatLab Simulink R 2009 A. Responses were obtained as shown in Figure 4.

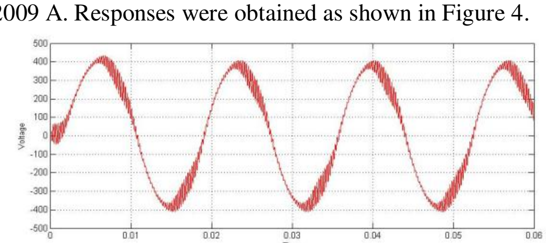

Figure 4. Response Voltage Open Loop using MatLab R2009A; Modulation Ratio = 0.8.

In the Open Loop Response testing, it was found that the value of the output voltage amplitude of 380 volts with an overshoot initial wave reaches 420 volts.

2. The Closed Loop Response of Inverter Buck Boost One Phase with Buffer Inductor Using SMC

Tests conducted with the software Matlab Simulink R2009A, by varying the amplitude set point value (SP) is 36 volts, 120 volts, 240 volts, 311 volts, 400 volts. Error Steady State (Ess) smallest setpoint is on 311 volts with a 1.02% and largest Ess there on setpoint 36 volts that is equal to 23.61%. The smallest overshoot values occurred at setpoint 36 volts at 47.5 volts and overshoot values occurred at 240 volts with a value setpoint 277.4 volts.

CONCLUSION

Overshoot occurs mainly due to the use of lowpass filter allows the frequency signal with a frequency lower than the cutoff frequency of the filter still escapes. Error steady state occurs because of possible impairment on the signal magnitude and because the filter cut off frequency that is used only a passive lowpass filter so it can not adjust the value of the gain of the output voltage to meet the setpoint. The main advantages from the use of SMC in this test method is that it can eliminate ripple that occurs during open-loop test.

In the test system sensitivity by varying the input voltage value and the resistance value resulting conclusion that the greater change in both parameters of the reference value, the sensitivity will be smaller, with the smallest 0,29 sensitivity value when the input voltage changes by 32%.

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