FUZZY LOGIC PI CONTROL APPLIED TO STATIC VAR COMPENSATOR USING N.P.C INVERTER TOPOLOGY

M. Benghanem, A.Draou, , and M.Ermis*

Applied Power Electronics Laboratory, Faculty of Electrical Engineering, Dept. of Electrotechnics, University of Sciences and Technology of Oran, BP 1505 El Mnaouar (31000 Oran),ALGERIA.
Tel: +213–41422377, Fax:+213–41421581, Email : adraou@yahoo.com , mbenghanem@hotmail.com
**B.I.L.T.E.N TÜBITAK Middle East Technical University inonu Blvd, Ankara*

Abstract : Recent advances in the power handling capabilities of static switches has made the use of the voltage source inverters (VSI) feasible at both the transmission and distribution levels. As a result, a variety of VSI based equipment such as the static Var compensators (STATCOM) are used to make flexible AC transmission systems (FACTS) possible. The ability of these FACTS equipments to control reactive power system as well as to improve system stability needs the use of VSI with high voltage and high power capabilities. Recently, a neutral point clamped inverter or three-level inverter hqs been used. It has the advantages that the blocking voltage of each switching device is one half of dc link voltage and the harmonics contents output voltage are far less than those of two-level inverter at the same switching frequency. This paper presents the control of STATCOM using three-level inverter to regulate load reactive power using Fuzzy PI. The simulation is carried out using the PLECS toolbox, for the fast simulation of power electronic circuits under Simulink.

I. INTRODUCTION

The fast growing development of ultra rapid power switching devices and fast and efficient controllers has lead to flexible control of electric power system, and the increase in use of converters for large scale reactive power compensation. Such an ASVC is made up of two level voltage source inverter and presents a fast response time, reduced harmonic pollution. However, for very high power application and voltages these ASVC's are unsuitable.

To minimize harmonics injection from a STATCOM into the system, various multilevel voltage source inverter configurations have been suggested in [1].

The multilevel inverters usually synthesize a staircase voltage wave from several levels of dc voltage sources, typically obtained from capacitors voltages.

Neutral point clamped inverter or three-level inverter was reported in the literature [2]. It has the advantages that the blocking voltage of each switching device is one half of dc link voltage and the harmonics contents output voltage are far less than those of two-level inverter at the same switching frequency.

This paper presents the modelling and analysis of this type of inverter used for static var compensation. The ASVC uses three-level voltage source inverter (VSI) transforming a DC component to AC through a set of capacitors, which are used, as a power storage device. Furthermore, a simplified mathematical model of the ASVC is derived, and various simulation results presented using PLECS Toolbox under simulink [3].

II. OPERATING PRINCIPLE

A. Main circuit configuration

The static VAR compensator (ASVC) which uses a three-level converter of the voltage source type is shown in Figure 1. The main circuit consists of a bridge inverter made up of twelve power GTO's with antiparallel diodes, which is

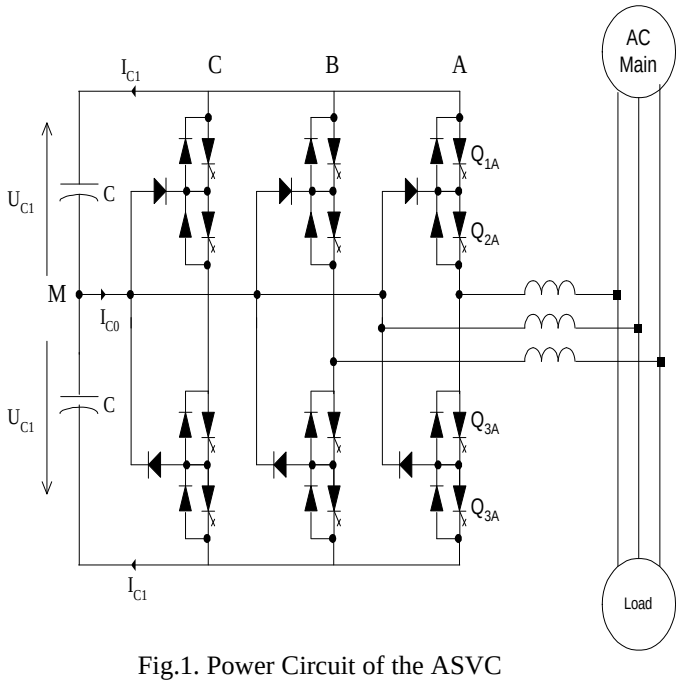

Fig.1. Power Circuit of the ASVC

connected to the three-phase supply through a reactor, X of small value. Two capacitors are connected to the dc side of the converter.
The structure of one leg of the inverter itself is made up of four pairs of diode-GTO forming a switch and two diodes allowing to have the zero level point of the inverter output voltage.

B. Operating principle

The operating principles of the system can be explained by considering the per-phase fundamental equivalent circuit of the ASVC system as shown in Figure 2.
In this figure, E_{a1} is the ac mains voltage source. I_{a1} and Va are the fundamentals components of current and output voltage of the inverter supply respectively.
The ASVC is connected to the ac mains through a reactor L and a resistor R representing the total loss in the inverter.

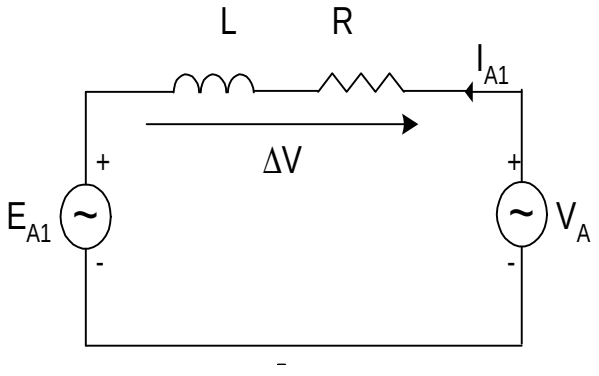

Fig.2. Per-phase fundamental equivalent circuit

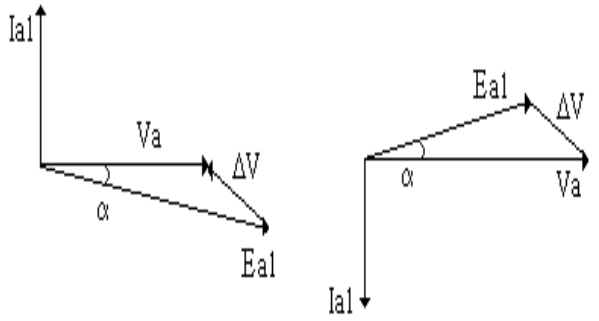

Fig.3. Phasor Diagram for leading and lagging mode

As shown in Figure 3, by controlling the phase angle 'α' of the inverter output voltage, the dc capacitor voltage U_c can be changed. Thus, the amplitude of the fundamental component E_{a1} can be controlled.

III. MODELLING

A. Mathematical model of the ASVC

Figure 4 shows a simplified equivalent circuit of the ASVC [4].

Using matrix form, the mathematical model is given by

$$\frac{d}{dt}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = \begin{bmatrix} -\frac{R}{L} & 0 & 0 \\ 0 & -\frac{R}{L} & 0 \\ 0 & 0 & -\frac{R}{L} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \frac{1}{L}\begin{bmatrix} v_a - e_a \\ v_b - e_b \\ v_c - e_c \end{bmatrix} \quad (1)$$

The model of the inverter output voltage is given by

$$\begin{bmatrix} e_a \\ e_b \\ e_c \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} \left\{ \begin{bmatrix} S_{1A}.S_{2A} \\ S_{1B}.S_{2B} \\ S_{1C}.S_{2C} \end{bmatrix} U_{c1} - \begin{bmatrix} S_{3A}.S_{4A} \\ S_{3B}.S_{4B} \\ S_{3C}.S_{4C} \end{bmatrix} U_{c2} \right\} \quad (2)$$

With:
S_{ki} : The switching function, is either 1 or 0 corresponding to on and off states of the switch Q_{ki} respectively.
K : Names of arms (A, B ,C).
i : number of switchs of one arm (*i* = 1,2,3,4)

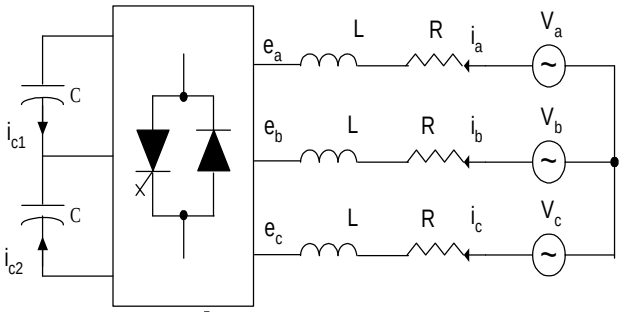

Fig.4. Equivalent Circuit of the ASVC

The DC side currents are given by

$$I_{C1} = S_{1A} \cdot S_{2A} \cdot i_A + S_{1B} \cdot S_{2B} \cdot i_B + S_{1C} \cdot S_{2C} \cdot i_C$$
$$I_{C2} = S_{3A} \cdot S_{4A} \cdot i_A + S_{3B} \cdot S_{4B} \cdot i_B + S_{3C} \cdot S_{4C} \cdot i_C \quad (3)$$

$$I_{C0} = I_{C1} + I_{C2}. \quad (4)$$

And the DC side capacitors voltages are given by

$$\frac{d}{dt}\begin{bmatrix} U_{c1} \\ U_{c2} \end{bmatrix} = \frac{1}{C}\begin{bmatrix} I_{C1} \\ I_{C2} \end{bmatrix} \quad (5)$$

Equations (1) to (4) represent the mathematical model of the Statcom in ABC Frame.

B. Modelling of the network

Figure 5 represents the ASVC connected to Network bus for regulating the local load reactive power .
The parts of Figure 5 centred by dash line are modelled using the PLECS Toolbox [5],[6] .

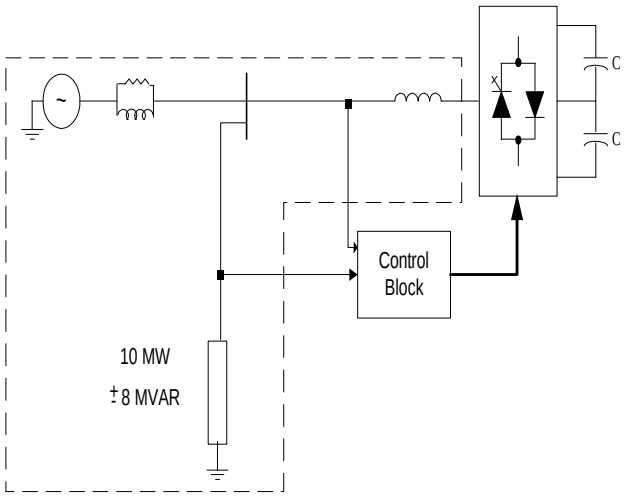

Fig.5. Statcom connected to the network

IV. REACTIVE POWER CONTROL

The control of the ASVC was designed to compensate the reactive power of the local load.
To achieve an easier design of the control , linearized transfer function was used to adjust the Fuzzy Logic PI membership Function. We used the regulator circuit as depicted in Figure 6 .

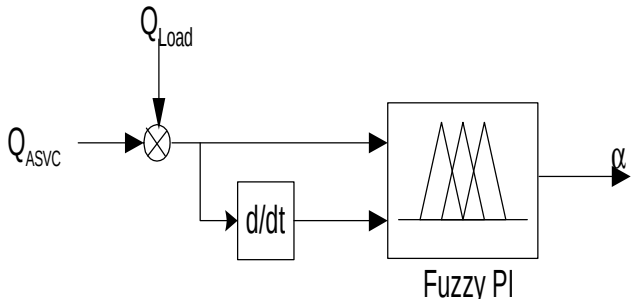

Fig.6 Fuzzy PI regulator circuit

V. TRANSIENT SIMULATION

Based on the modelling of the inverter and the network described in section III, we build the Simulink model as depicted by Figure7.

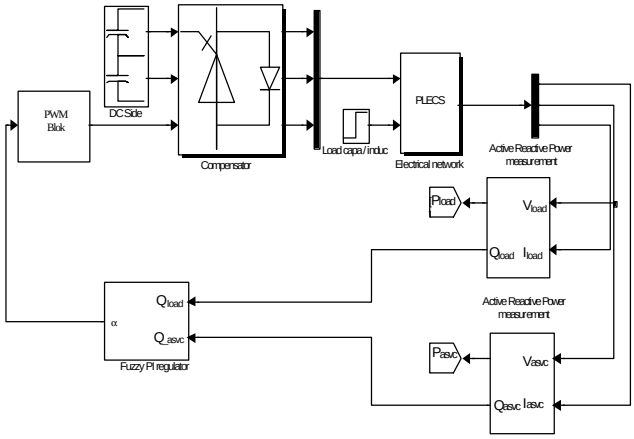

Fig.7. Simulink model of the system

Figures 8 to 10 represent the dynamic response of the compensator for switching from capacitive to inductive mode of reactive load [8].
Figure 8 illustrates the variation of load and ASVC reactive power. We have shown that the compensator have good response. At 0.5 sec we connect the ASVC to the line bus and absorbing inductive power, the load is in capacitive mode. At time 2 sec the ASVC is generating leading vars and the load is in inductive mode.
Figure 9 shows the variation of the active power. At time 2 sec active power flows through the ASVC to charge the capacitor. Thus, the amplitude of the inverter voltage becomes higher in Figure 10 and the ASVC are in capacitive mode.

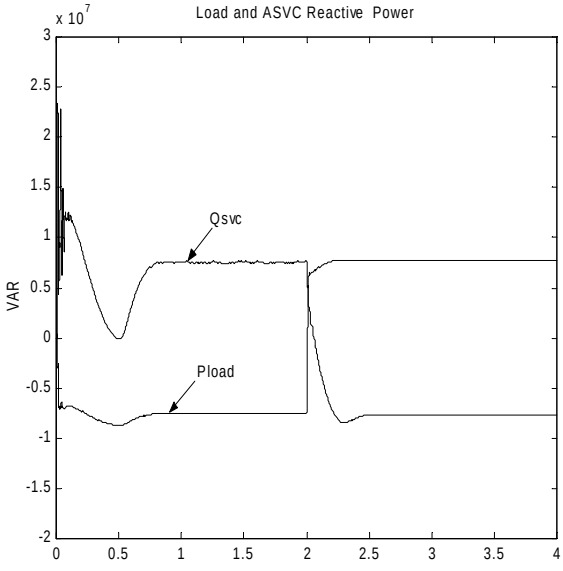

Fig.8. Variation of Load and Asvc reactive power

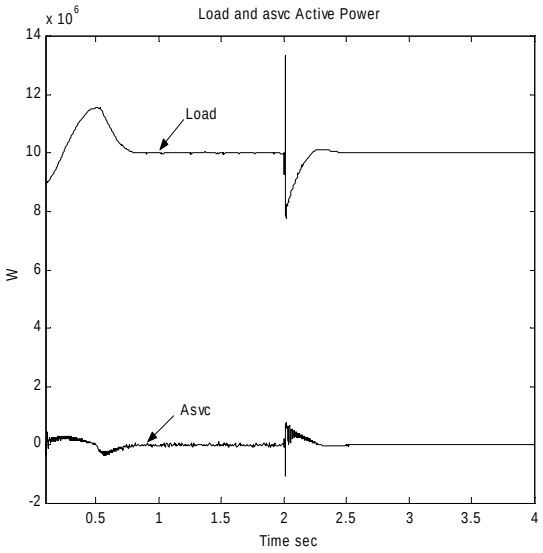

Fig.9. Variation of Load and ASVC active power

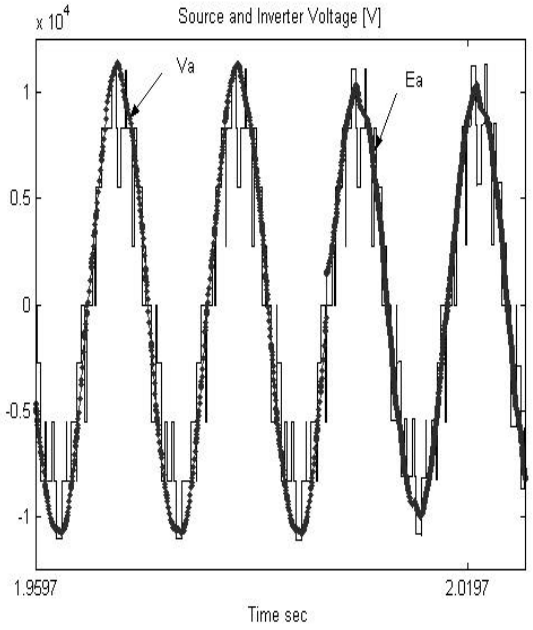

Fig.10. Source and inverter voltage waveforms

V. CONCLUSIONS

A study and mathematical modelling of the dynamic performance analysis of an Advanced Static Var Compensator (ASVC) using three-level voltage source inverter has been presented in this paper. The dynamic behaviour of the system was analysed with Simulink model in the case of reactive load power control using Fuzzy PI regulator. From the results of the simulations and the mathematical model developed in this paper, we will directe our future research work to control unbalanced loads.

VI. REFERENCES

[1] Jih-Sheng Lai, Fang Zheng Peng, , “Multilevel converter anew breed of power converters”, IEEE Transactions on Industry Applications, vol. 32, no. 3, May/June 1996, pp. 509-517

[2] G.C.Cho, N.S.Choi, C.T. Rim and G.H. Cho, "modeling, analysing and control of static var compensator using three-level inverter",IEEE ind.Soc.Annu.Meet., 1992,pp.837-843.

[3] Jost H. Allmeling and Wolfgang P. Hammer, “PLECS-Piece-wise Linear Electrical Circuit Simulation for Simulink”,

[4] A.Tahri, A.Draou member IEEE, and M.Benghanem, " A Fast Current Strategy of a PWM inverter Used for Var Compensation" proceeding vol. 1 IECON'98

[5] J. Allmeling, W. Hammer, "PLECS (Piece-wise Linear Electrical Circuit Simulation for Simulink) May 2000, User Manuel 0.3.

[6] M.Benghanem , A.Draou and A.Tahri “harmonics Elimination Technique Applied To an N.P.C Topology Three Level Inverter Used As Static Var Compensator”, ACEMP2001, Kusadasi-TURKEY

[7] Benghanem Mustapha, “Etude et Analyse d’un onduleur a Trois Niveaux Utilisé comme Compensateur Statique d’Energie Reactive”, (in Franch) , U.S.T.O, Department of Electrotecnics, Master Thesis, Oran, 2000

[8] K.V. Patil, R.M. Mathur, J. Jiang, S.H. Hosseini, “ Distribution System Compensation using a new Binary Multilevel Voltage source Inverter ” IEEE Transaction on Power Delivery, Vol 14, no 2 April 1999