VGPI Control of Multilevels STATCOM

Hamza Tédjini, Messaoud Fatima zahra

Abstract—**In this paper a synchronous compensator (STATCOM) based multilevels converter is used is to compensate of a power network. The STATCOM when it is under a very complex structure state such as the nine levels NPC topology may suffer from the association of many capacitors at the DC link bus. The variable gain PI controller (VGPI) is introduced to improve stability of the DC link bus.**

Keywords— FACTS, STATCOM, Multilevels inverter, variable gain PI controller (VGPI).

I. Introduction

Reactive power compensation is an essential part of a power system and the static synchronous compensator (STATCOM) plays an important role in controlling the reactive power flow over the transmission line [1], [2]. The basic building block of the STATCOM is a voltage source inverter (VSI) that generates a synchronous sinusoidal voltage.

In 1981, a prototype of an advanced static var compensator, based on force-commutated thyristor technology, was fit reported in the literature [l].

From this prototype, a few units of the STATCOMs based on gate-turn-off thyristors (GTOs), rated around 100 Mvar, have been in service as demonstration models in Japan and in USA [2-4]. Anticipating the days when GTOs can switch at a faster rate, other research groups, mainly from universities, have explored STATCOM concepts based on pulse-width modulation (PWM) techniques [5,6l.

The traditional 2-level VSI is not viable for high voltage applications. In order to be used in such high voltage applications each main switch of the 2-level converter is formed by many semiconductor devices connected in series.

Recently, there has been a recognition that the multilevel converter [7,8] has distinct advantages over the conventional two level converter and several research groups have begin studies to apply it to make the STATCOM more compact and economical [9]. To date, the studies have assumed the availability of equal, regulated, dc voltage sources which feed the multilevel converter.

The variable gain PI controller is a solution allow overshoot elimination proposed by A. Miloudi, it is very efficiency in speed control of motors; it is based on the transformation of the gain Kp and Ki from constants values to a variable functions.

In this paper, we will examine the role of the Multilevels STATCOM in damping power network oscillation, and the impact of VGPI in DC link of Multilevels converter control.

Hamza Tédjini is with
SGRE Laboratory University tahri mohamed Bechar, Algeria.
(e-mail: tidjini.hamza@univ-bechar.dz).
Messaoud Fatima Zahra is with
SGRE Laboratory University tahri mohamed Bechar, Algeria.
(e-mail: messaoud.fatima@univ-bechar.dz).

II. STATCOM operation

Fig.1 shows the principle of STATCOM which has the advantage of reacting more quickly and it can respond in less than one cycle to changes in voltage. Also, when the voltage is low, it can produce more reactive power, especially at a time when we need a reactive power. STATCOM is used of PWM converters operate at switching frequencies of some kilohertz and using IGBT or GTO [9].

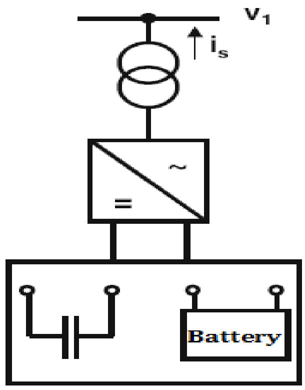

Fig. 1. Principle of STATCOM

The advantage of the STATCOM is that both active and reactive powers are independent and that the current and voltage are limited in an area controlled as shown in Fig. 2 [10].

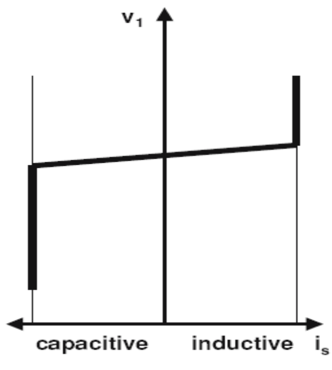

Fig. 2. Current voltage characteristic of STATCOM

The STATCOM is designed for many uses an industrial scale such as:

- ✓ Increasing the capacity of transmission.
- ✓ Reducing voltage variations.
- ✓ Improvement of damping power swings.

- ✓ The dynamic load balancing.
- ✓ Improving the quality of energy.
- ✓ Support for the steady state voltage.
- ✓ Improving the stability phase.

III. NINE LEVELS NPC VSI

Fig.1 shows the structure of the neutral point clamped nine levels voltage inverter arm. It consists of eight secondary sources of DC voltage, sixteen IGBT switches and diodes ten looping [11][12].

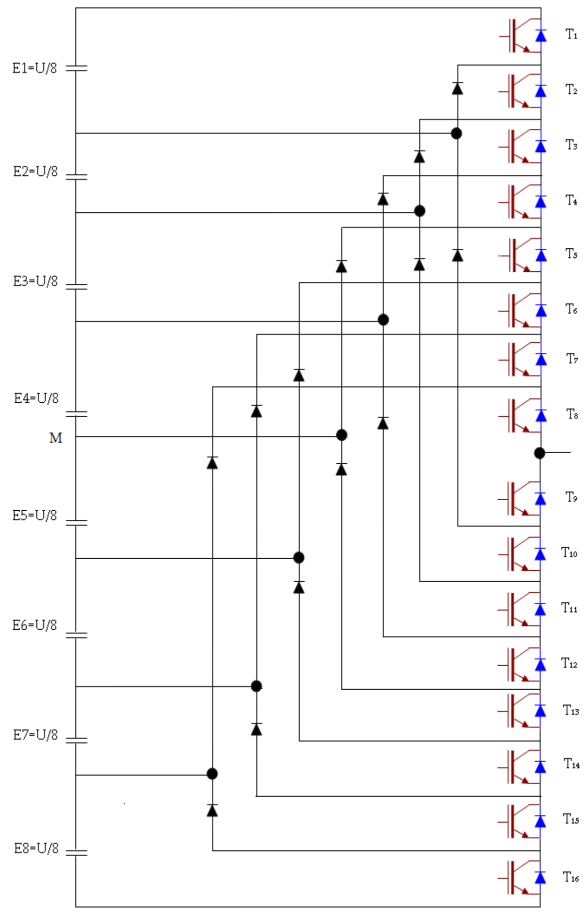

Fig. 3. Nine levels bridge VSI NPC structure

The function of connecting half - arms defines the relation are as follows:

$k = 1, 2, 3.$

$$\begin{cases} F^{b}_{k1} = F_{k11}F_{k12}F_{k13}F_{k14}F_{k15} \\ F^{b}_{k0} = F_{k16}F_{k17}F_{k18}F_{k19}F_{k110} \end{cases} \quad (1)$$

The potentials of nodes A, B and C of the inverter compared to the midpoint "M" are expressed as shown in equation 2.

$$\begin{aligned} & k = 1,2,3 = A,B,C \\ & V_{kM} = F_{k1}F_{k2}(1-F_{k3})U_{C1} \\ & + F_{k1}F_{k2}F_{k3}(1-F_{k4})(U_{C1}+U_{C2}) \\ & + F_{k1}F_{k2}F_{k3}F_{k4}(1-F_{k5})(U_{C1}+U_{C2}+U_{C3}) \\ & + F^{b}_{k1}(U_{C1}+U_{C2}+U_{C3}+U_{C4}) \\ & - F_{k6}F_{k7}(1-F_{k8})U_{C5} \\ & - F_{k6}F_{k7}F_{k8}(1-F_{k9})(U_{C5}+U_{C6}) \\ & - F_{k6}F_{k7}F_{k8}F_{k9}(1-F_{k10})(U_{C5}+U_{C6}+U_{C7}) \\ & - F^{b}_{k0}(U_{C5}+U_{C6}+U_{C7}+U_{C8}) \end{aligned} \quad (2)$$

IV. CONTROL OF MULTILEVELS STATCOM

Among the methods used in the control of the STATCOM, the method of instantaneous power control is based on a cascade control based two loops: external in order to stabilize the DC link voltage; this last pilot that controls the inner loop control currents which are images of powers.

A. *Identification of references*

The transformation of Concordia can bring this system to a balanced three phase to a diphase system.

This transformation applied to the network voltages and currents of the line leads to:

$$\frac{d}{dt}\begin{bmatrix} V_{p\alpha} \\ V_{p\beta} \end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix} 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \sqrt{\frac{3}{2}} & -\sqrt{\frac{3}{2}} \end{bmatrix}\begin{bmatrix} V_{pa} \\ V_{pb} \\ V_{pc} \end{bmatrix} \quad (3)$$

$$\frac{d}{dt}\begin{bmatrix} i_{p\alpha} \\ i_{p\beta} \end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix} 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \sqrt{\frac{3}{2}} & -\sqrt{\frac{3}{2}} \end{bmatrix}\begin{bmatrix} i_{pa} \\ i_{pb} \\ i_{pc} \end{bmatrix} \quad (4)$$

The real and imaginary instantaneous powers denoted and defined by the following matrix relation:

$$\begin{bmatrix} P_p \\ Q_p \end{bmatrix} = \begin{bmatrix} V_{p\alpha} & V_{p\beta} \\ -V_{p\beta} & V_{p\alpha} \end{bmatrix}\begin{bmatrix} i_{p\alpha} \\ i_{p\beta} \end{bmatrix} \quad (5)$$

$$\begin{bmatrix} i_{p\alpha} \\ i_{p\beta} \end{bmatrix} = \frac{1}{V_{p\alpha}^{2} + V_{p\beta}^{2}}\begin{bmatrix} V_{p\alpha} & -V_{p\beta} \\ V_{p\beta} & V_{p\alpha} \end{bmatrix}\begin{bmatrix} P_p^{*} \\ Q_p^{*} \end{bmatrix} \quad (6)$$

This expression allows the identification of current references in the coordinate α-β. The triphase currents are obtained from biphase currents and the inverse transformation of Concordia:

$$\begin{bmatrix} i_{pa}^{*} \\ i_{pb}^{*} \\ i_{pc}^{*} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ \frac{-1}{2} & \sqrt{\frac{3}{2}} \\ \frac{-1}{2} & \sqrt{\frac{3}{2}} \end{bmatrix} \begin{bmatrix} i_{p\alpha} \\ i_{p\beta} \end{bmatrix} \quad (7)$$

V. Variable Gain PI Controller VGPI

Overshoot elimination setting will cause a poor load disturbance rejection, and rapid load disturbance rejection setting will cause important overshoot or even instability in the system.

VGPI controller proposed par A.Miloudi [13], which is based on the classical PI, the gains Kp and Ki are not constants values or more mathematically constants functions but they are variables functions.

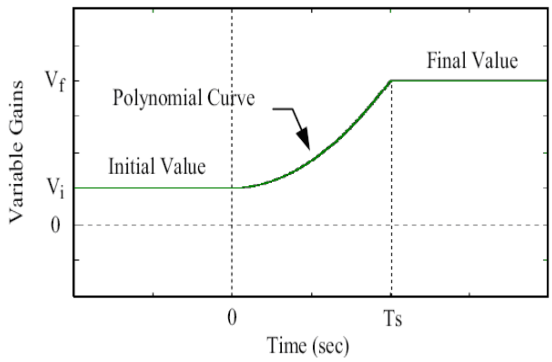

Fig. 4. Variable PI Gains Tuning Curve

Each gain of the proposed controller has four tuning parameters:

- Gain initial value or start up setting which permits overshoot elimination.
- Gain final value or steady state mode setting which permits rapid load disturbance rejection.
- Gain transient mode function which is a polynomial curve that joins the gain initial value to the gain final value.
- Saturation time which is the time at which the gain reaches its final value.
- The degree n of the gain transient mode polynomial function is defined as the degree of the variable gain PI controller.

If e (t) is the signal input to the VPGI controller then the output is given by:

$$y(t) = K_p e(t) + \int_0^{\tau} K_i e(\tau) d\tau \quad (8)$$

Where:

$$K_p = \begin{cases} (K_{fp} - K_{dp})\left(\dfrac{t}{T_s}\right)^n + K_{dp} & \text{if } t < T_s \\ K_{fp} & \text{if } t \geq T_s \end{cases} \quad (9)$$

$$K_i = \begin{cases} (K_{fi} - K_{di})\left(\dfrac{t}{T_s}\right)^n + V_{di} & \text{if } t < T_s \\ K_{fi} & \text{if } t \geq T_s \end{cases} \quad (10)$$

Where K_{dp} and K_{fp} are the initial and final value of the proportional gain K_p, and K_{fi} is the final value of the integrator gain, K_{di}. The initial value of Ki is taken to be zero. It is noted that a classical PI controller is a VGPI controller of degree zero [13].

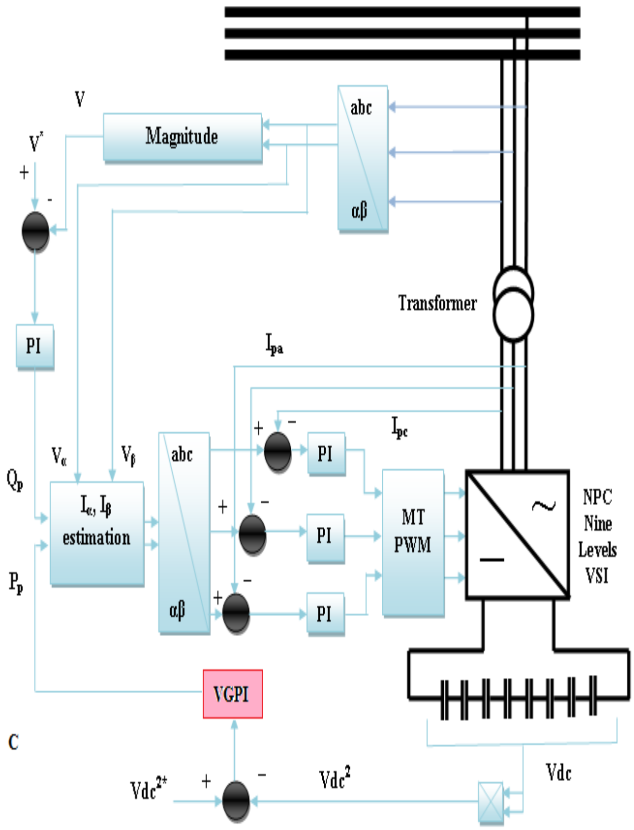

Fig. 5. Schema of nine levels STATCOM control

VI. Studied System

A power network (V_{base}= 10kV, I_{base}= 110A) is connected to a three phases line (r=4.8Ω, L=0.1552H) feeding three phases load. As an instability case, an 1320KVAR inductive overload is applied between t_1=0.3s and t_2=1s. The studied system is represented in Fig.6.

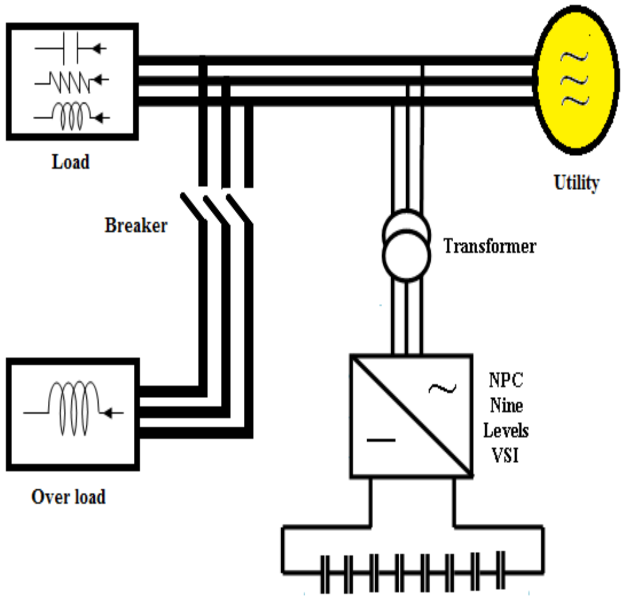

Fig. 6. General representation of studied system

- *Load side*

Fig.7 shows an increase of reactive power almost 1.42pu. Which is imposed by a current rise; the voltage of the region does not change.

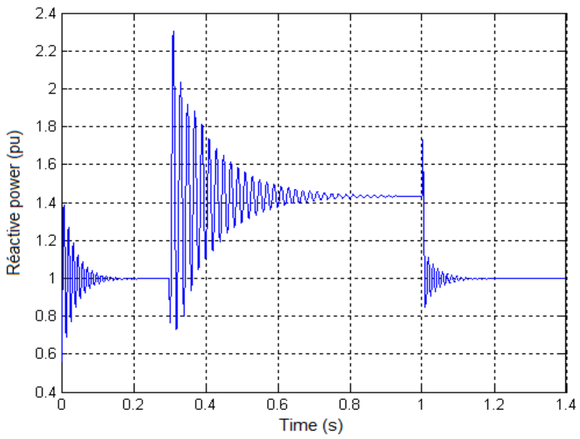

Fig. 7. Reactive power of load

- *STATCOM bus*

The multilevel voltage of STATCOM is presented in fig.9.

We use the pulse wave modulation control based multi carriers technic MCPWM, in our case we have to use eight carriers to generate pulses for each transistor.

The multi carrier PWM technique is presented in fig.8.

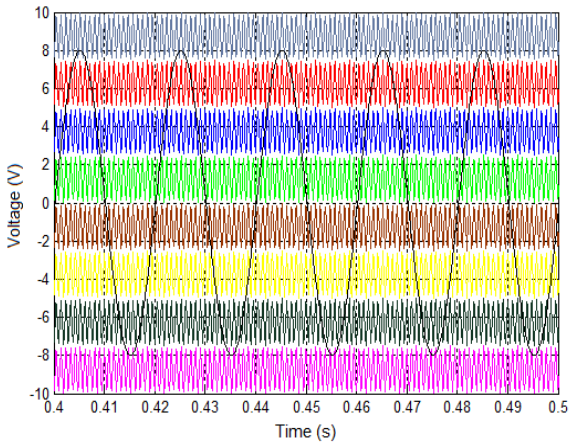

Fig. 8. MCPWM control

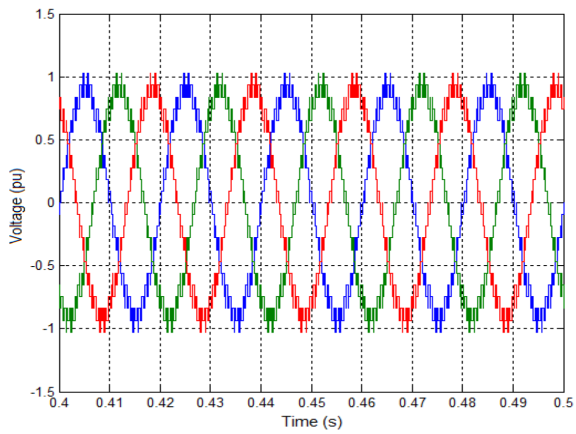

Fig. 9. Fig.19 STATCOM voltage

The introduction of the VGPI controller allowing for removal of the excess with a very short response time, it can be seen on fig. 10.

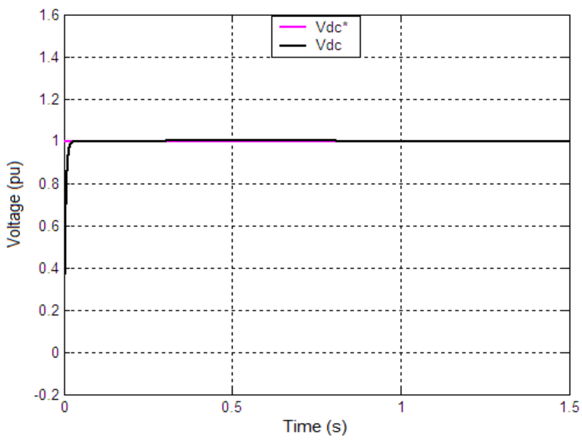

Fig. 10. DC link voltage control

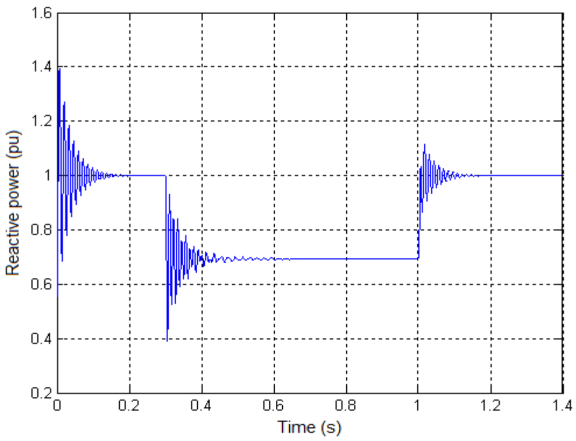

Fig. 11. Reactive power of STATCOM

Fig. 11 and fig.12 shows that the STATCOM absorb reactive power during the fault to stabilize reactive energy. Hence we see that the reactive power and current were are diminishing during this period.

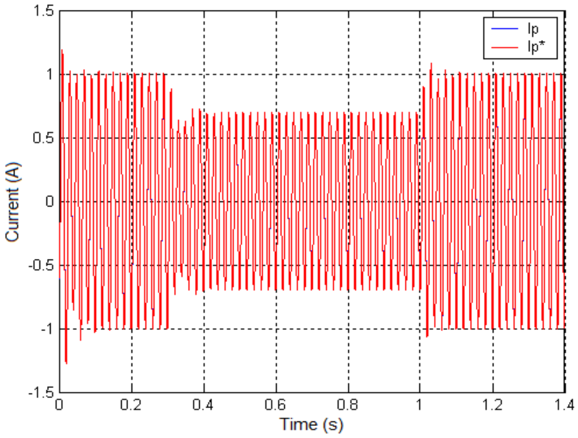

Fig. 12. Control of current (Phase A)

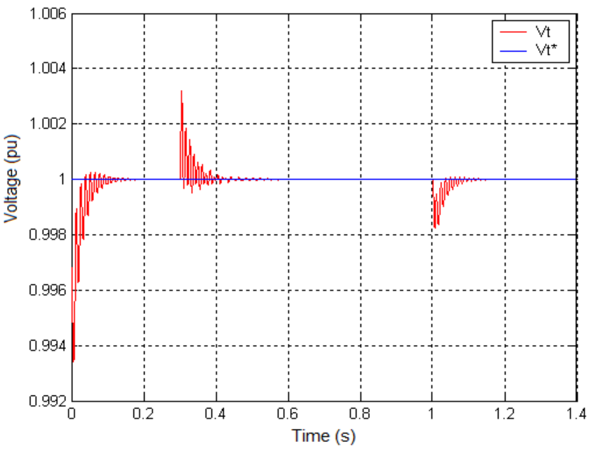

Fig. 13. Voltage magnitude control

- *Source side*

As noted in fig.14 that the reactive power is oriented towards stability.

So we can conclude that the STATCOM absorb all the fault consequences and keep the stability of the network.

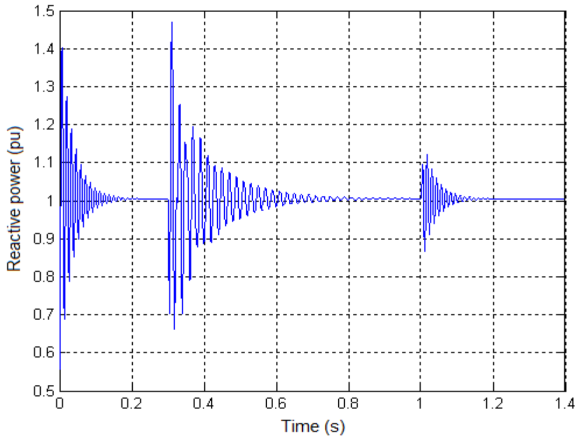

Fig. 14. Reactive power in source side

VII. CONCLUSION

We brought this study on the STATCOM which has several advantages:

- Good damping of power swings.
- Support voltage in disturbed operating.
- Help the early return to stability.

The multi-level structure appears as a solution to the limitation of the voltage of IGBT components as well the economic side particularly with regard to the transformer.

The results obtained using the VGPI control indicates good performances can solve the problem of DC voltage instability.

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