

Dynamic Performance Comparison between STATCOM and SVC

مقارنة بين الأداء الديناميكي لمعوض القدرة الإستاتيكي ومعوض القدرة الغير فعالة

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ملخص

هذا البحث يقدم دراسة للأداء الديناميكي لمعوض القدرة الإستاتيكي الذي يتم التحكم فيه عن طريق نظام تحكم تكاملي متناسب وذلك تحت ظروف أخطاء تشغيل مختلفة وكذلك لنسب قصر متغيرة للنظام تحت الدراسة. علاوة على ذلك فإن أداء المعوض الإستاتيكي المقترح يتم مقارنته بأداء معوض القدرة الغير فعالة التقليدي. وقد تمت الدراسة باستخدام برنامج PSCAD/EMTDC. وأظهرت النتائج تفوق الأداء الديناميكي للمعوض الإستاتيكي المقترح وكذلك سرعة الأداء في معالجة الأخطاء المختلفة وكذلك في حالات تغير نسبة القصر بالنظام.

ABSTRACT

This paper presents an investigation to the dynamic performance of a PI-type controlled STATCOM for various faulty conditions as well as for different system short circuit ratios SCR. Furthermore, the performance of the STATCOM is compared with that of conventional static var compensator SVC. The study is thereby simulated using the PSCAD/EMTDC software. The obtained results reveal superior dynamic performance and fast fault recovery of the STATCOM through different fault conditions as well as with reduced system short circuit ratio SCR.

Keywords - STATCOM, SVC, SCR.

I. INTRODUCTION

The implementation of reactive power compensation devices in modern power systems is growing up for dynamic characteristic improvement. Reactive power compensation has a great influence on the dynamic performance of the voltage stability and helps to maintain a flat voltage profile, increases transmission efficiency and also reluctant to temporarily overvoltages that arise from different faulty conditions that may damage power system equipments [1]. There are many other factors that increase the risk of voltage stability problems in power systems such as the growing use of induction motors and the use of HVDC links that are connected to weak ac systems [2]. Weak ac systems are

characterized by their wide range of voltage and short circuit ratio, SCR, variations and are usually found in remote areas where the feeders are long [3].

In the literature, various techniques and different power electronic devices are employed and used to improve the dynamics of power systems specially those connecting large industrial loads and weak systems [2]. Traditionally, the use of synchronous condensers, SCs, and/or static var compensators, SVCs, have been the most commonly employed techniques for the stability improvement of ac systems [3]. The disadvantages of the synchronous condensers systems are known as slow response and high losses [4]. Apart from being costly solutions, the use of SVCs has the disadvantage that it becomes

less effective when the ac voltage level is reduced, i.e. during faults and large disturbances [4].

STATCOMs are foreseen to be the better solution for modern power systems that suffer voltage stability problems and poor dynamic performance [2,5]. STATCOM is basically a voltage source converter, VSC, that converts a dc voltage at its input terminals into three-phase ac voltages at fundamental frequency of controlled magnitude and phase angle. VSCs use pulse width modulation, PWM, technology, which makes it capable of providing high quality ac output voltage to the grid or even to a passive load, [5]. Therefore, the STATCOM has the advantages of VSCs such as fast response and independent control of active and reactive powers. Moreover, STATCOM does not significantly alter the existing system impedance, which gives it an advantage over the SVC [5]. This paper presents a control scheme based PI type for a STATCOM used as a reactive power compensator for a test system that has some certain industrial loads. The dynamic performance during different fault conditions is investigated. Also, the performance of the STATCOM is compared with that of the conventional SVC. Thereby, the influence of the reduction of system SCR as usually found in remote areas is also considered.

II. TEST SYSTEM DESCRIPTION

Fig.1 demonstrates a schematic diagram of the proposed system after [1]. The system describes a factory whose main load consists of a set of 50 induction motors of 500 hp with 0.85 power factor, 10 kV with inertia constant of 2 s. The induction motors are attached to the 36 kV substation through 25 MVA transformer (10% leakage reactance, 36/10 kV). Also resistive and inductive loads of 32 MW and 24 Mvar are connected to the same 36 kV substation via 45 MVA transformer (10%, 36/10 kV).

The short circuit ratio, SCR, which is the ratio between the short-circuit power measured at

the 36 kV bus and the load total apparent power, is 5 which represents a strong system. At the 36 kV bus, a ± 35 MVar STATCOM is connected to provide reactive power compensation not only during steady state conditions (to keep the bus voltage at rated condition), but also for fast injection of reactive power to achieve high dynamic performance during different fault scenarios.

The STATCOM is attached to the 36 kV bus through 40 MVA transformer (10%, 36/13.8 kV). The ac network is 130 kV infinite bus connected to the 36 kV bus through two 200 km lines (X/R ratio of 15) and 70 MVA step down transformer (10%, 130/36 kV).

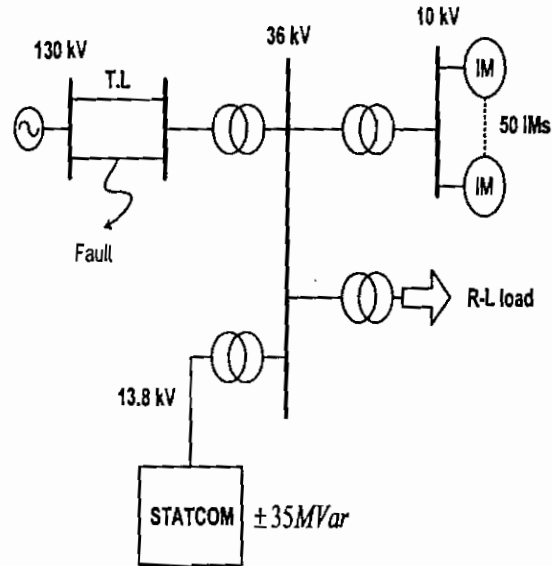


Fig. 1: System under study

III. PROPOSED CONTROL SCHEME

A. STATCOM Controller

The STATCOM connected to the 36 kV bus is modeled in this paper as three-phase two-level voltage source converter, VSC, with sinusoidal pulse width modulation control strategy. The proposed control system of the STATCOM, as illustrated in Fig. 2, is a PI-type controller. It is designed to provide reactive power support at steady state conditions as well as to achieve high dynamic performance during various interruption conditions. The control scheme of the

STATCOM consists of two control loops, namely the ac and dc voltage control loops. The ac voltage control loop is used to regulate the ac voltage while the dc voltage control loop is utilized to maintain a constant dc voltage across the VSC terminals.

The outputs of the control loops are the modulation index magnitude (m_a) and the phase angle α which is the phase difference between the fundamental components of the ac system voltage and the STATCOM output voltage. The outputs of the control loops (m_a , α) are used to generate the firing signals of the VSC switches. Furthermore, current limiters –which have been proved to be of great importance [6] - are integrated with the control loops to limit the higher values of the reference active and reactive currents (i_d^* , i_q^*) arising during different faulty conditions that may damage the converter switches [3,6].

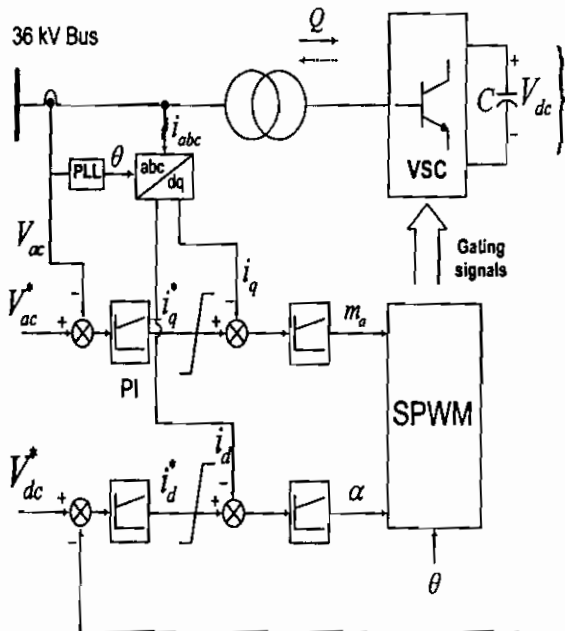


Fig. 2: Proposed control scheme of STATCOM based PI type.

B. Static Var Compensator SVC

Modeling and control of SVCs have been studied in many papers [1,7,8]. The main

construction of SVC, is thyristor-switched capacitor(s), TSC, and thyristor-controlled reactor(s), TCR, together with filters. The filters are used to remove low-frequency harmonics produced by the TCR and to produce reactive power. With proper coordination of the capacitor switching and reactor control, the reactive power output can be varied continuously between the capacitive and inductive ratings of the equipment to regulate the ac voltage [1].

VI. RESULTS AND DISCUSSION

The dynamic performance of the STATCOM along with the proposed control strategy is demonstrated and discussed in this section. Moreover, the performance of the STATCOM is compared with that of the conventional SVC during different faulty operating conditions and for different system strength SCR. The PSCAD/EMTDC software program is used for system modeling and simulation.

A. Single line to ground fault, SLGF

Figs.3-4 show the system response to a solid single-phase to ground fault (phase A) in the middle of one of the transmission lines (see Fig.1) for SCR = 5. The fault is applied at $t = 2$ s and removed at $t = 2.5$ s. Fig.3 shows the injected reactive power from the STATCOM and the SVC and the RMS voltage at the 36 kV bus. It can be noticed from the obtained results that both compensators respond instantaneously and inject the required amount of reactive power to regulate the ac voltage during the fault. Fig. 4 demonstrates the induction motors speed and the RMS voltage at the machine bus. As seen from Fig. 4, the induction motors speed and voltage recover quicker in this case. STATCOM and SVC do not differ greatly from each other in such a faulty case.

B. Double line to ground fault, DLGF

Another evaluating performance test is a solid double line to ground fault (phases A,B) which is also created at the middle of one of the transmission lines. The obtained results are displayed in Figs. 5-6.

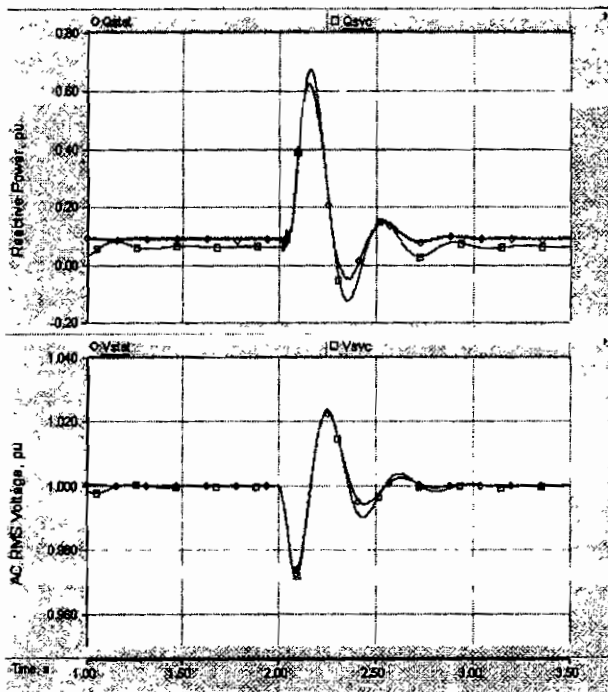


Fig. 3: Reactive power injected by STATCOM (o) and SVC (□) and RMS voltage of the 36 kV bus during SLGF (SCR=5).

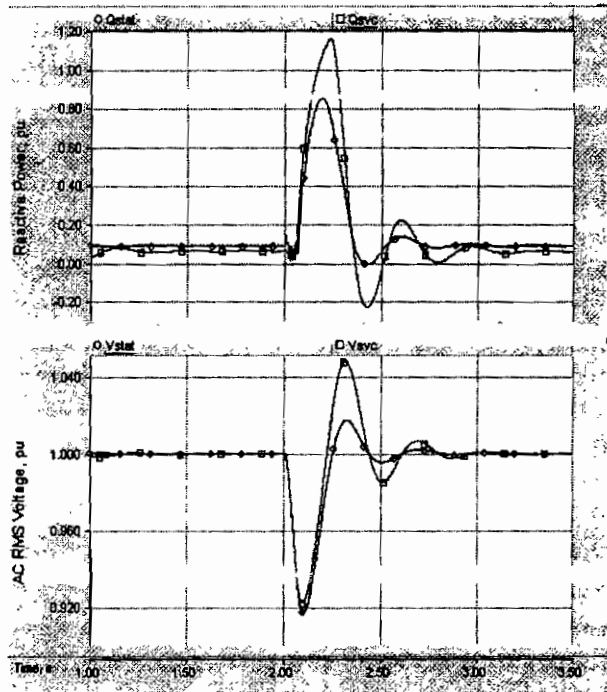


Fig. 5: Reactive power injected by STATCOM (o) and SVC (□) and RMS voltage of the 36 kV bus during DLGF (SCR=5).

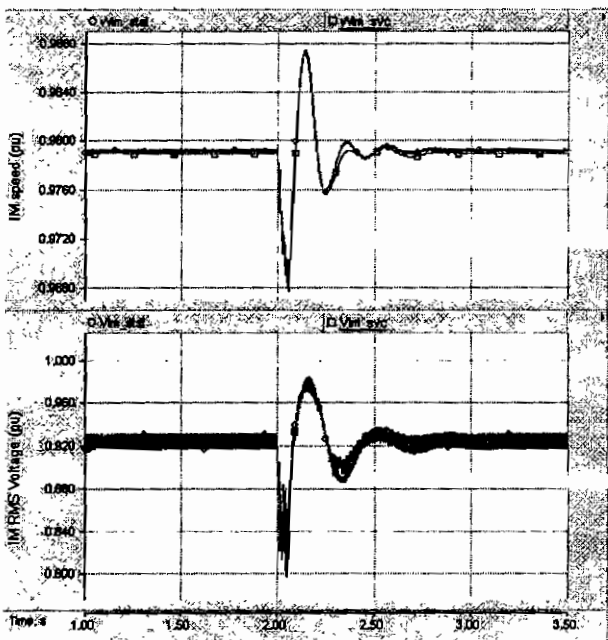


Fig. 4: Induction motors speed and RMS voltage at the machine bus during SLGF (SCR=5). STATCOM (o) and SVC (□).

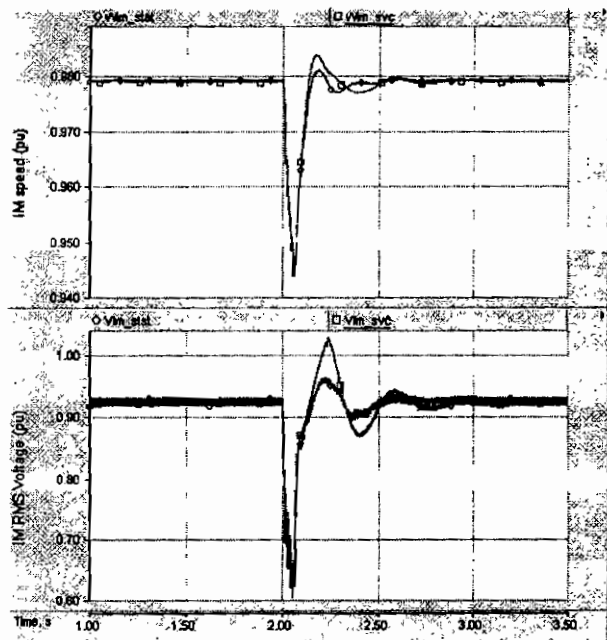


Fig. 6: Induction motors speed and RMS voltage at the machine bus during DLGF (SCR=5). STATCOM (o) and SVC (□).

Comparing the obtained results in Fig. 5 with that of Fig.3, it is evident that the ac voltage at the 36 kV bus has higher voltage drop as a consequence to the DLGF and that the compensators inject higher reactive power in this case to keep the ac voltage within acceptable limits. As seen from Fig.5, the STATCOM has better transient performance with lower overshoot of the RMS voltage at the 36 kV bus and also has fast fault recovery with damped performance and lower settling time.

Thereby, the ac voltage at the induction motors as well as the speed (Fig.6) recover quicker with better transient performance in case of the STATCOM.

C. Three phase to ground fault

The system response to a three phase to ground fault is depicted in Figs. 7-8. It is worth noting that in this type of fault, the SVC doesn't respond instantaneously compared with the STATCOM which responds quickly and injects higher amount of reactive power that ensures better transient performance of the ac voltage at the 36 kV bus as seen in Fig. 7.

This can be attributed to the fact that the SVC provides reactive power proportional to the square of its terminal voltage, therefore severe voltage drops on its terminals limit its reactive power injection capability [1]. Consequently, the speed of the induction motors drop more with the SVC compared with the STATCOM, which can be seen from Fig. 8.

D. Variation of SCR

To investigate the performance of the compensators to variation of the system strength SCR, the system SCR seen at the 36 kV bus is changed to be 2.5 (weak system) instead of 5 through using double line length to 400 km [1].

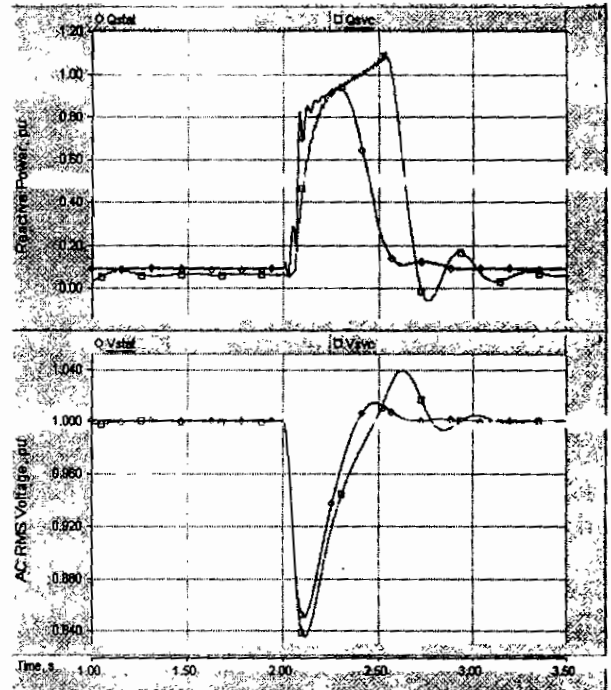


Fig. 7: Reactive power injected by STATCOM (o) and SVC (□) and RMS voltage of the 36 kV bus during three phase to ground fault (SCR=5)

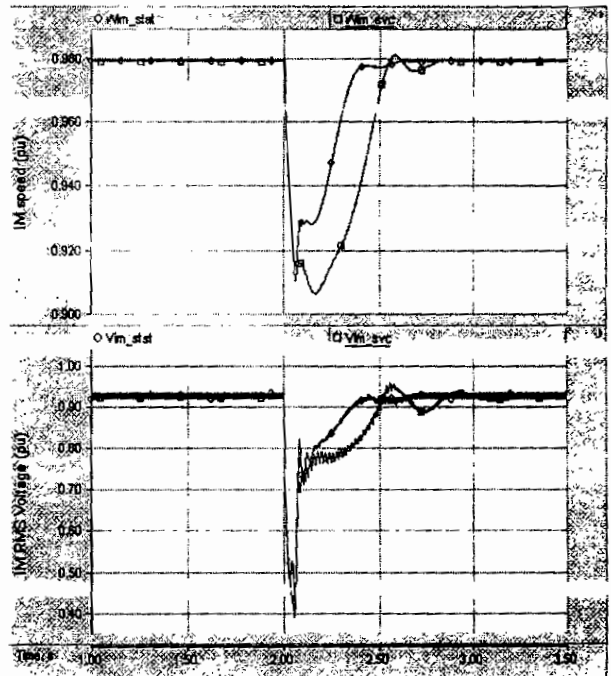


Fig. 8: Induction motors speed and RMS voltage at the machine bus during three phase to ground fault (SCR=5). STATCOM (o) and SVC (□)

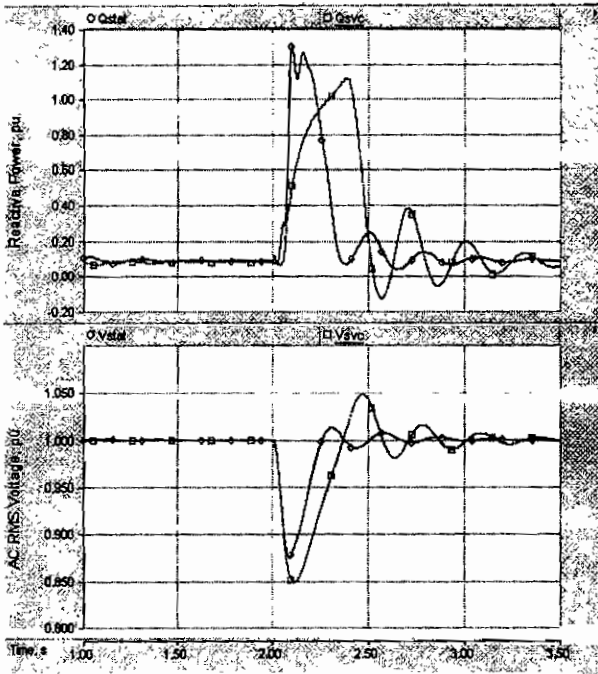


Fig. 9: Reactive power injected by STATCOM (o) and SVC (□) and RMS voltage of the 36 kV bus during three phase to ground fault (SCR=2.5).

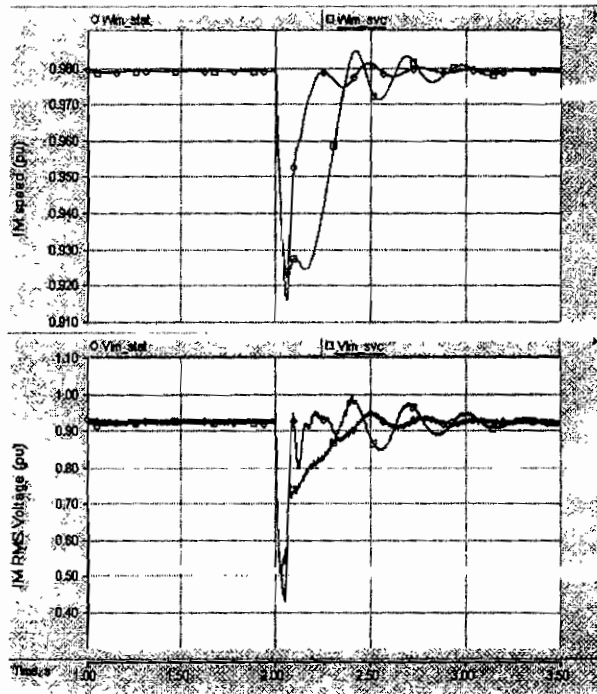


Fig. 9: Induction motors speed and RMS voltage at the machine bus during three phase to ground fault (SCR=2.5). STATCOM (o) and SVC (□).

V. CONCLUSION

The most severe fault (three phase to ground fault) is applied here to evaluate the system performance in this case. The obtained results are demonstrated in Figs. 9-10. It is evident from the results that the SVC has poor transient performance and suffers from oscillations after the fault clearance instant with long settling time while STATCOM still preserves its fast response and low overshoots.

The dynamic performance of a PI-type controlled STATCOM is investigated for various short circuit fault conditions and compared with that of conventional SVC. To this extend, a proposed PI-type controller is designed to provide high dynamic performance during system interruptions.

The more better transient response of the STATCOM against that of the SVC is clearly evident specially in cases of sever voltage drops as existing in cases of double line to ground and three phase to ground faults. Also, in case of weak grids (low SCR), the STATCOM showed faster response and lower overshoots compared with that of the SVC.

The superior dynamic performance of the STATCOM compared with that of the SVC encourages the authors to make more refinement in the control scheme to achieve more damped oscillation without enhancing the STATCOM reactive power capacity.

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