Research Article
Development of Inexpensive Static Var Compensator Using PIC

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Abstract: This study presents the design and construction of an economical static reactive power compensator using inexpensive Peripheral Interface Controller (PIC), with the aim to add dynamic response to local distribution power systems. As FACTS devices have been more prevalent to perform instantaneous power compensation providing the enhancement of transient voltage and system stability. For some distribution networks, its price and complicated operation make FACTS devices unfavorable. The PIC is programmed as the heart of the overall control system for monitoring voltage, generating controlled signal and modulating PI feedback-loop. Simulation was carried out to guide the control design. Experimental results show the performance of the system response. This implies that the proposed compensator can be used for real applications and envisages the future replacement of mechanical-switched capacitor/reactor.

Keywords: Inexpensive control system, PIC, static var compensator

INTRODUCTION

Voltage stability is classified as one of major problems in general power systems (Zang *et al*., 2006). Not only reflecting power quality directly, but also possibly leading to network stability concerns if system's protection sees the problem and consequentially does cut out parts of the network (Kundur, 1994). It will also be more worsen for sensitive loads if the voltage fluctuates or collapses instantly. Therefore, keeping the voltage in an acceptable range is the prioritised task for utilities and even for consumers themselves in order to maintain the desired quality. Mechanical-switched compensator can be applied for stabilising the voltage, but it is active only for steady-state reactive power compensation.

Adding the ability to overcome the instant power mismatches to power networks will depend on the network complexity and the investment. The bulky and complicated network will need more high performance devices such as Static Compensator (STATCOM), Dynamic Voltage Restorer (DVR) or Unified Power Factor Compensator (UPFC), which are power-electronically built with a noticeable budget (Song *et al*., 1999; Srithorn *et al*., 2008). However, Static Var Compensator (SVC), the device that is not too complicated to operate and not expensive to build, but with ability to provide reactive power support dynamically. SVC is then now finding its applications in power systems, especially to replace the traditional mechanical-switched compensator. Having the SVC
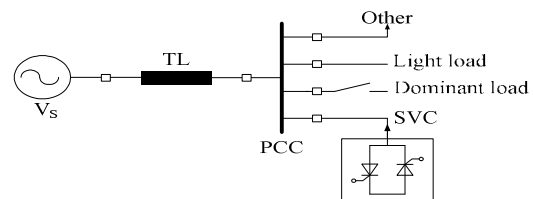

Fig. 1: Overall system for the proposed SVC application

inside is the convenient way to add more fine-tuned and fast response to the system operation.

Then, the objective of this study is to describe the design and construction of an economical static reactive power compensator using PIC as shown in Fig. 1, with the aim to add more dynamic response to local power networks envisaging the future replacement of mechanical-switched compensator.

METHODOLOGY

Simplified SVC operation: Thyristor Controlled Reactor (TCR) paralleled with a fixed capacitor is proposed here as the SVC which can provide continuous reactive power corresponding to the magnitude of the monitored voltage at the point of common coupling (V_{pcc}). An equivalent circuit of the proposed SVC application system is shown as in Fig. 2; the SVC is shunted to load at PCC which is linked to power source (V_S) through a transmission line (Z_T). The combination of TCR and C performs dynamic reactive power support continuously.

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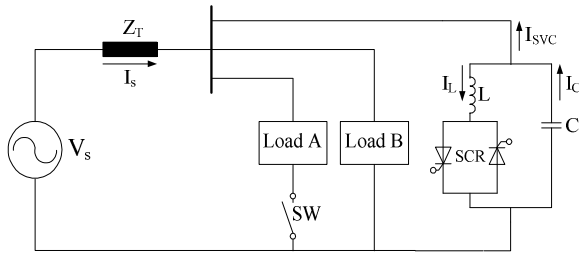
Fig. 2: Equivalent circuit of the proposed SVC application

Fig. 4: Control concept
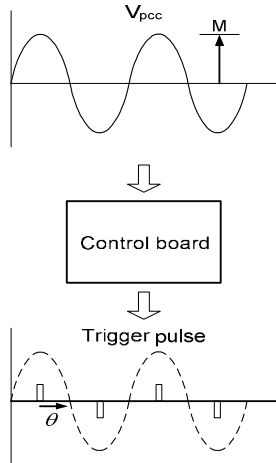

Fig. 3: Control target

Fig. 5: Flow-chart for PIC16F877 programming

In Fig. 1 and 2, the load and any impact interfered from the other networks will cause a current resulting in voltage drop across line Z_T and then the drop of load voltage (also V_{pcc}). If the current change abruptly, the magnitude of load voltage will also be dropped suddenly-possibly damage the load itself and nearby sensitive devices.

To regulate the voltage, the SVC shown in Fig. 2 will be operated to supply dynamic Var corresponding to V_{pcc} error. According to diagram shown in the figure, fixed capacitor C is designed based on the amount of rated reactive power (Q) the SVC can inject to the grid (related to loads), calculated using (1) as for traditional power factor correction. The inductor L is valued relating to impedance of the capacitor using (2), capable for cancelling each other in order to provide fine-tuned reactive power circulation:

$$C = Q/\omega V^2 \tag{1}$$

$$L = 1/\omega^2 C \tag{2}$$

When the load is switched on to the system, a sudden drop of the voltage will be occurred and seen as one of poor power quality. The control will command gating SCR to decrease inductor current. Therefore, the resulting SVC current (I_{SVC}) will then present a suita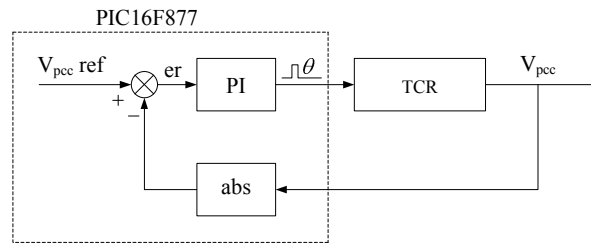ble V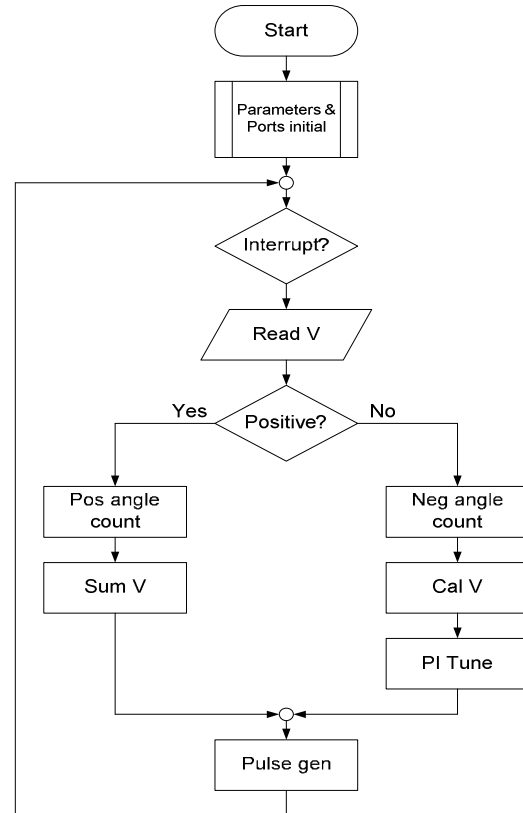ar transferring to the system and help levelling up the voltage magnitude to the desired value. Speed of this Var compensation is directly concerned with SCR gating system, which is proportional to the voltage error as described in the next section.

Control design: The aim of the control system is to provide proper response for the proposed SVC in order to regulate the voltage continuously. As mentioned in previous section, the control target is to generate the dynamic SCR gating-signal according to input voltage as illustrated in Fig. 3. The angle (θ) will be varied corresponding to voltage Magnitude (M) and synchronising with sinusoidal input voltage. Fine-tuning of the gating angle will be succeeded through the voltage feedback loop as of the control concept diagram shown in Fig. 4.
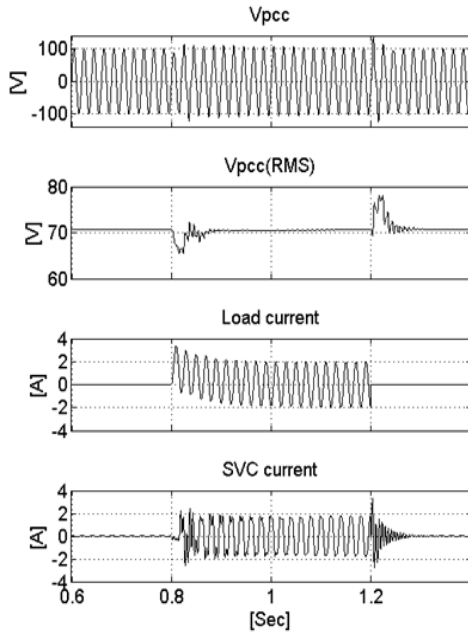
Fig. 6: V_{pcc} and load current of the system without SVC support (simulation)

Fig. 7: V_{pcc} and load current of the system with SVC support (simulation)

For the proposed inexpensive SVC, the control is implemented using PIC16F877. The built-in A/D converter of the PIC is programmed for V_{pcc} monitoring. Absolute value of the input voltage, V_{pcc} error and PI compensation and the resulting trigger pulse generation is processed inside the PIC. Loop controller is designed based on Ziegler-Nichols heuristic approach (Basilio and Matos, 2002; Hang *et al*., 1991). Flow-chart for programming the PIC is shown in Fig. 5.

SIMULATION RESULTS

The mentioned system shown in Fig. 1 with its control loop shown in Fig. 3 is modelled in MATLAB/SIMULINK and is carried out in order to simulate the overall system operation in order to validate the ability to compensate reactive power dynamically. System parameters are designed as given in the next section (experimental section).

M-file function block of the PIC is modelled digitally, which is similar to the same pattern as C programming for the real PIC16F887. The simulation also gave a convenient way to tune the loop controller. Two different experiments were carried out-system without the SVC inside and system with the SVC added at the PCC. Simulation results are shown in Fig. 5, 6 and 7.

Fig. 8, shows that, for the system without any support (no SVC current appear on the bottom trace), V_{pcc} will be dropped promptly when a sudden load is
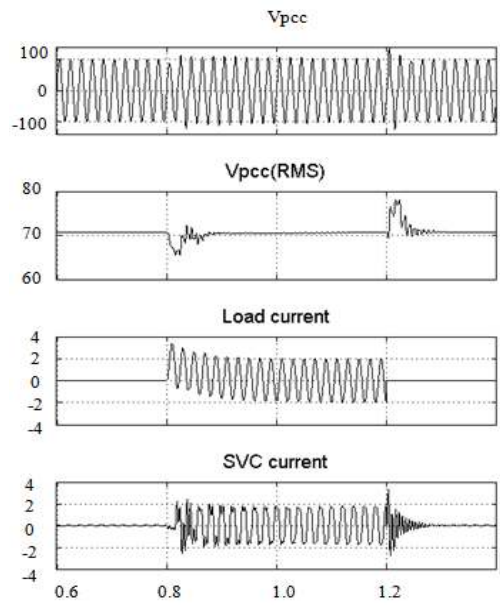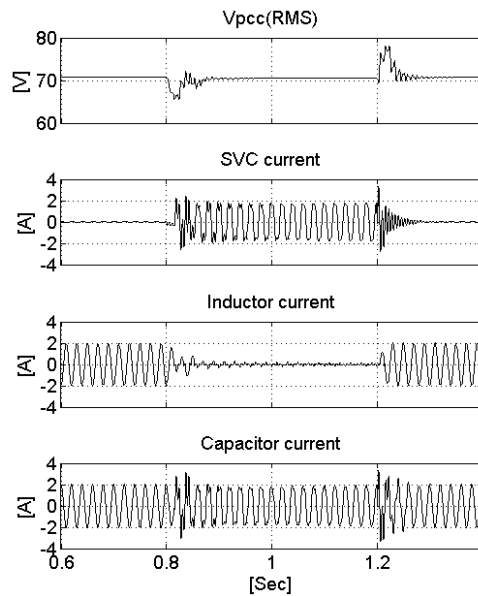

Fig. 8: V_{pcc} and the detailed SVC current (simulation)

connected to the system at PCC. However, when the SVC is added, this drop is levelled up automatically within a short period as shown in Fig. 6 and 7. From these figures, SVC current is the reactive power support current resulting from the combination of capacitor and controlled inductor current. This simulation confirms the component parameter of the proposed SVC system.

Experimental tests: According to diagram shown in Fig. 1, a laboratory scale system with the proposed SVC inside was setup. System parameters are designed
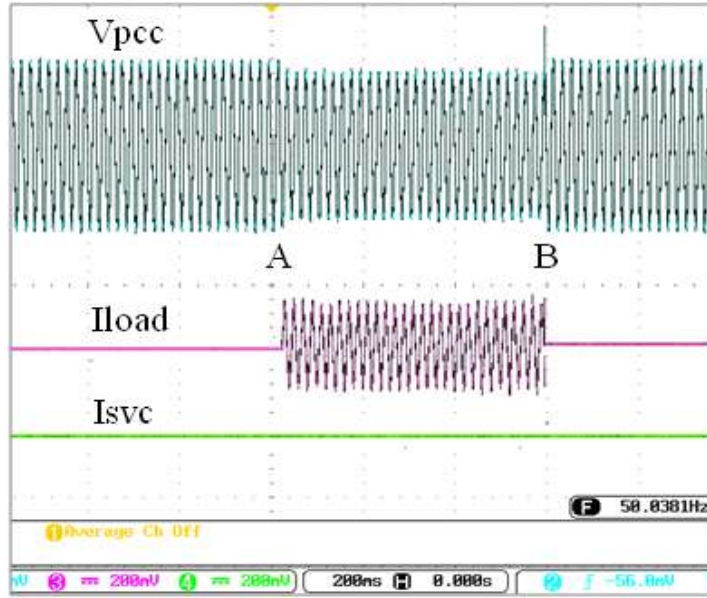
Fig. 9: V_{pcc} and load current of the system without SVC support (experimental)
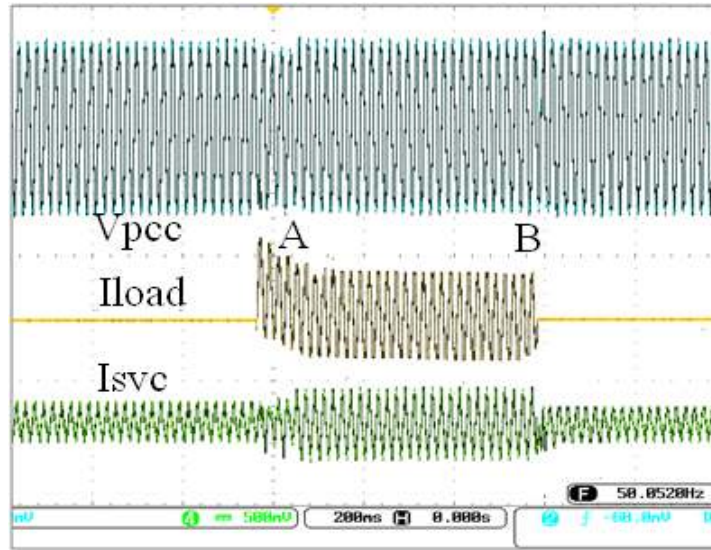

Fig. 10: V_{pcc}, load current and SVC current (experimental)

as-supply voltage $V_S = 100V$, inductance $L = 160$ mH, capacitance $C = 64$ uF and to highlight the voltage drop X_S is set to be 16 mH, with its 0.3 Ω internal resistance. A light load of about 20% of the main load was added to the PCC in order to make the system closed to the real sugar mill application. Similarly to simulations, system with and without the SVC inside were carried out comparatively. The results captured from oscilloscope are illustrated in Fig. 9 and 10.

The top trace of Fig. 9 shows that PCC voltage drops immediately after the load was switched on during the period marked by 'A' to 'B', which caused load current as shown by the middle trace. I_{svc} shows there was no any support for this event. The results also highlight voltage instability and poor power quality of the system during transient events. However, as previously mentioned, to increase system voltage stability, more fine-tuned reactive power compensation using SVC was installed at the main critical load point.

In Fig. 10, the top trace shows that the sudden drop of V_{pcc} was levelled up to normal value within 40 ms and was remained constant during the load period between 'A' and 'B'. The bottom trace shows that the SVC supplies some reactive power to the system to compensate the voltage drop at the line due to the light load. Then when the main load was connected, more SVC support can be seen promptly corresponding to the load period.

CONCLUSION

Although inexpensive PIC is the device that cannot be programmed to work in real-time fashion, satisfactory dynamic response of the SVC constructed with the PIC used as the main controller can be seen. It is validated with the experimental tests that the development of the control system described in this study can be used as the guide for future replacement of mechanical-switched compensators. For local power distribution systems which find that the other kinds of FACTS devices seem to be the expensive compensators, the mentioned SVC is a good choice.

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