

# Applying Recurrent Neural Networks to Static VAR Compensator

Murtaza Farsadi<sup>1</sup>, Farzad Mohammadzadeh Shahir<sup>2</sup>, *Student Member, IEEE*, and Ebrahim Babaei<sup>3</sup>, *Senior Member, IEEE*

<sup>1</sup> Faculty of Electrical and Computer Engineering, Urmia University, Urmia, Iran  
m.farsadi@urmia.ac.ir

<sup>2</sup> Department of Electrical Engineering, Urmia Branch, Islamic Azad University, Urmia, Iran  
f.m.shahir@iaurmia.ac.ir

<sup>3</sup> Faculty of Electrical and Computer Engineering, University of Tabriz, Tabriz, Iran  
e-babaei@tabrizu.ac.ir

## Abstract

The purpose of this paper is to use recurrent neural networks (RNN) to control and adjust the switching of thyristor in a Static VAR Compensator (SVC) to adjust the voltage. In the new control scheme, instead of just using a feedback loop, same as neural network several feedback loop conventional recurrent are employed. In the proposed controller model RNN provides a sample of the connected system, and its output provides part of input for the RNN controller, then sends the control signals to SVC system. Three types of non-linear modes were selected for testing new control system operation for voltage regulation in IEEE Std 519-1992.

The test consists of three-phase power system fault that opens one of the transmission lines in a transitional two-track system and suddenly changes in load demand. The results show that the proposed control system is able to adjust voltage in desirable range.

## 1. Introduction

There are many factors that alters voltage value in bus load such as changing reactive power, fault in lines, wasting a line in double circuit transmission systems, etc., [1-2]. Before power electronic devices, large-capacity capacitors were regulating the voltage. But the main problem was the broad moving cylindrical body that wastes much energy [3-4]. In addition, these capacitors were able to transfer limited range of reactive power. Although the first flexible AC transmission systems (FACTS) was introduced in 1990 but in 1997 first FACTS device was installed in Oregon in North America [5-6], which had three phases of 60 Hz, 500 KV [7]. Their main advantage against conventional capacitors of that time was static time and immobile components. Accordingly, maintaining the power due to of lack inertia torque and without wasting energy, etc. increased. [8-9]. The static VAR compensator is a device in FACTS. Reactive power can be adjusted by controlling the firing angle of thyristors. Conventional control methods actually have been established based on conventional PID controller blocks [10]. Power system is a nonlinear process with unpredictable and unknown disorders that cannot be controlled and modeled with a linear system. Adaptive Artificial Neural Network (ANN) is used to control SCV since 1999 [11]. First control system consists of two two-layer feedback network [12].

Some ANN-based controllers are designed and delivery, but all of them were intended only for changes in load demand and no system faults had occurred. Faults are very important and common phenomenon in any power system and must be considered in any evaluation [13-14]. RNN is used in reactive power and voltage control in many power systems. RNN has many advantages over other types of ANN (such as FFN, etc.) [15-17]. Therefore, using RNN, ANN controllers' performance can be improved. The present method is superior compared to other RNN control methods due to provided construct for diagnose of system and generation of control signals, which are based on the model of internal control.

The proposed control scheme includes many feedback loops that are arranged for such a manner and increase the certainty of the response. Items tested opens a transmission line in two circuit transmission line that cause sudden changes in load demand and three-phase short-circuit fault.

## 2. Description of the Power System and SVC Modelling

SVC system, basically consists of coils, capacitors and thyristors. Fig. 1 shows an example of a typical SVC model that a TCR is connected to shunt with fixed capacitors. In this study, three coils are connected to  $\Delta$ , while each of them is in chain with back to back thyristors. SVC capacity is  $\pm 60$  MVar that means SVC can inject 60 MVar to system and to use it.

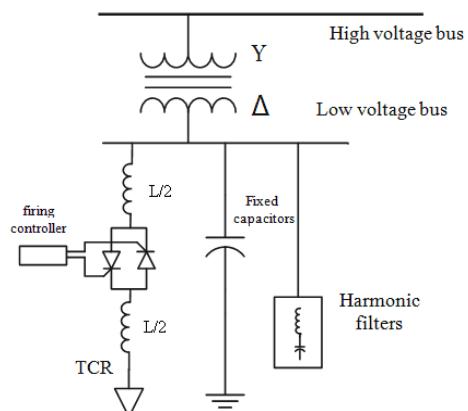
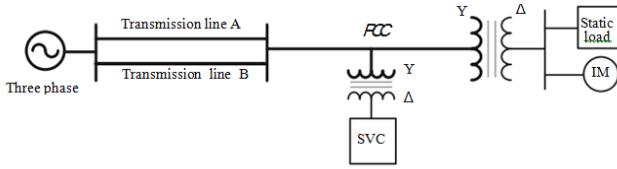


Fig. 1. Structure of a typical SVC model

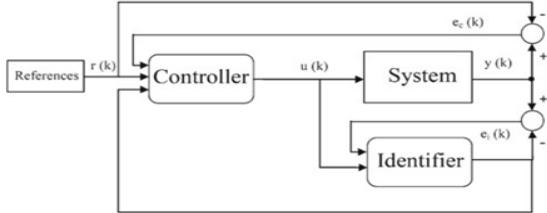
To test the proposed control system a radial power distribution system with a double-circuit transmission line was investigated as shown in Fig. 2. Line is 300 kilometers long and is used in the double-circuit transmission to be able to open one of them. Except for added SVC systems, the rest of the power system parameters are shown in Fig. 4 [16].

### 3. Description of Control Scheme

The design is based on the Internal Model Control (IMC). IMC is based on the internal model principle (IMP). Fig. 3 shows the general diagram of the structure of IMC model [15-17]. IMC is new structural model that using RNN as ID and controller is expressed in this paper.



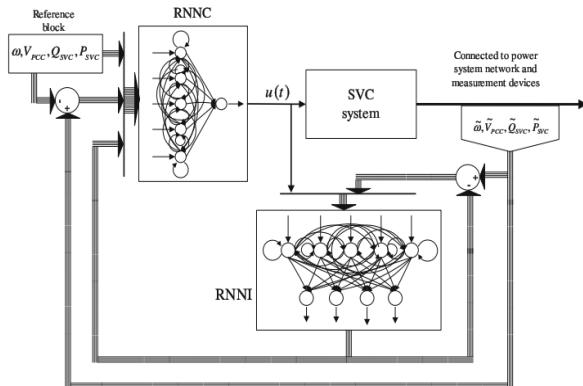
**Fig. 2.** Single-line diagram of the studied power system



**Fig. 3.** Diagram of the structure of IMC model

### 4. Application of RNN

Proposed RNN model includes a number of feedback loop. RNNI creates a sample of this design, which in effect feedback is sent to the control unit of RNN to create the signal. Power system diagram is shown in Fig. 4.  $\omega$  is the measured frequency of PCC per unit;  $V_{PCC}$  is measured voltage at PCC per unit; SVCQ is measured reactive power that is injected by the SVC to PCC per unit; SVCP is active power measured received per unit from the PCC by SVC.



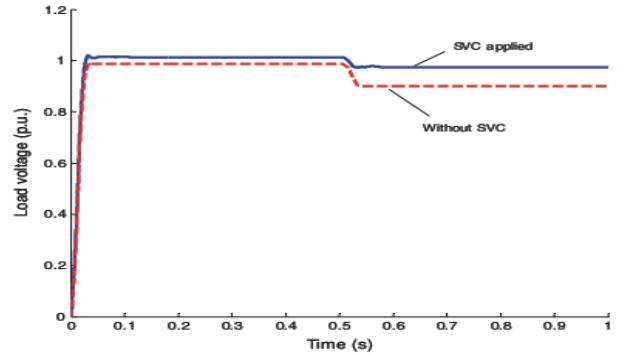
**Fig. 4.** Block diagram of control system based on RNN-IMC

## 5. Simulation Results

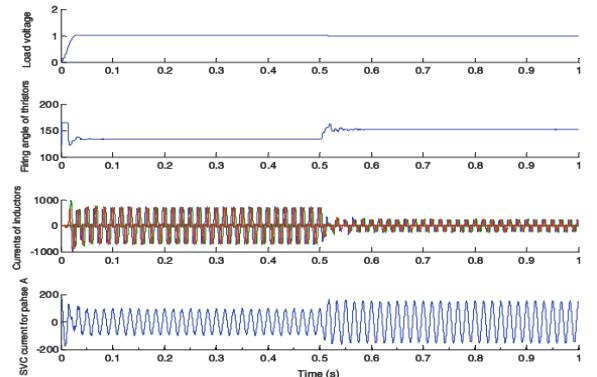
To evaluate the performance of the proposed control IMC scheme, three types of non-linear behaviors of the power system were simulated. By opening a transmission line of a double-circuit transmission lines, sudden changes in demand load three-phase short circuit fault are experiments that are simulated to demonstrate the feasibility of the proposed control system. Simulation model in MATLAB is shown in Fig. 7. IMC-RNN block in Fig. 7 is the most important control block that is used as a device. Block content shown in Fig. 8 shows that parameters are at the left and IMC-RNN is at right

### 5.1. Opening a Line of Power System

Since each transmission circuit forms a part of the transmission power, the waste of line reduce amount of a transmission power. It occurs when one of the lines is in fault. By reducing the reactive power transmission to the loads there may be a drop in the voltage, so regulation of system is essential. In this case, the transmission of line B, in Fig. 5, after a specified time of starting the simulation is ineffective. Fig. 5 shows difference between the two situations when suddenly one of the lines opens after 0.5 seconds after the start of simulation. The normal line shows voltage level in bus load when SVC is present in system, while the dotted line shows the voltage level in the absence of SVC system. In Fig. 5, the voltage level before use of SVC is 0.9 but after SVC voltage works well. The rest of the SVC system and controlling parameters are shown in Fig. 6.



**Fig. 5.** Comparison between presence and absence of SVC when a line is open



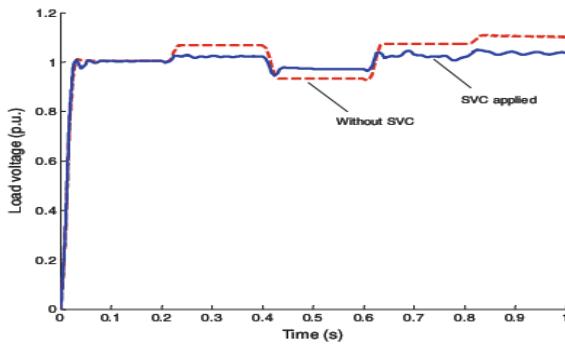
**Fig. 6.** SVC system parameters for an open line

## 5.2. Sudden Changes in Load Demand

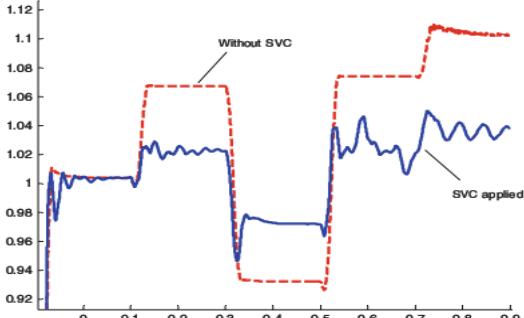
Variance of demand load is one of the reasons for changes in voltage level, especially when reactive power demand change [2]. Figs. 7 and 8 show differences of features of voltage at every unit. Voltage levels, without a system of SVC, is shown with dotted line

## 5.3. Three-Phase Short-Circuit Fault

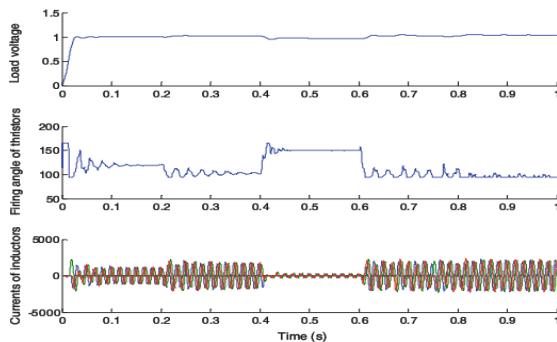
Three-phase short-circuit fault when stop the circulation of all power to loads can cause the most severe fault in a power system. Features of SVC parameters shown in Fig. 11 shows that SVC seeks to transfer the highest possible reactive power to the PCC for voltage regulation during the fault.



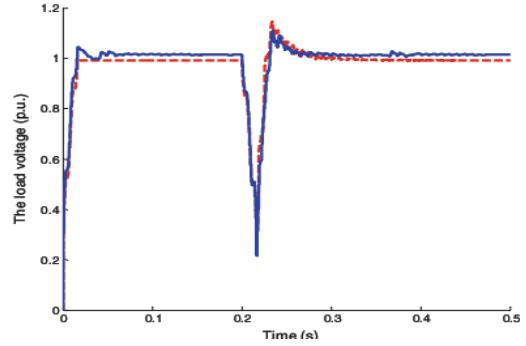
**Fig. 7.** Comparison between presence and absence of SVC in sudden changes in load



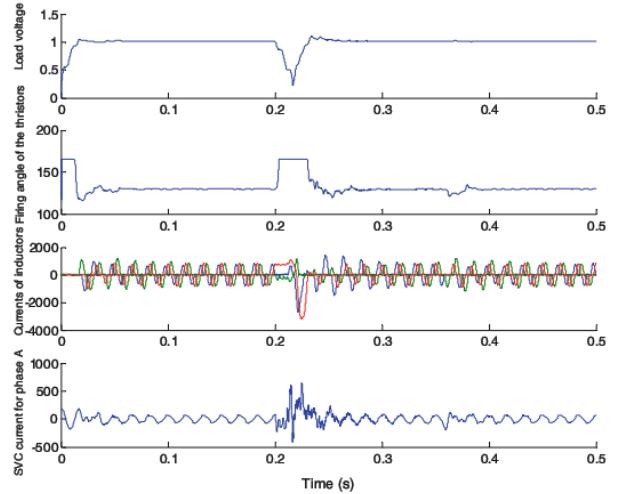
**Fig. 8.** voltage level of load with and without SVC in sudden changes in load



**Fig. 9.** SVC system parameters in a sudden change in load testing



**Fig. 10.** Comparison of presence or absence of SVC in three-phase ground fault



**Fig. 11.** SVC parameters for the three-phase ground fault test

## 6. Conclusion

In this paper, an internal RNN-base control model was introduced for control of release of thyristors in TCR of SVC system. The new methodology has been presented and clearly explained. Proposed SVC includes a TCR and fixed capacitors with a capacity of M Var to support a branch of transmission and distribution power system. System IMC - RNN system is a quick respond control system due to RNNC and RNNI ability to detect the change in system and adapt control signal in a short period of time. Designed system behavior was analyzed under a variety of different faults and the results showed the performance of this method for voltage regulation.

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