

THYRISTOR NEURO-CONTROLLED VAR COMPENSATOR

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Abstract: A new technique for reactive power compensation "neuro-control" is proposed. The application of such technique overcomes the step-wise voltage compensation associated with switched capacitors. The simulation results show effective compensation of fast power system voltage transients. The proposed technique was found better compared with that which is using classical thyristor switched capacitor.

1. INTRODUCTION:

The power supply utility is usually bound to maintain supply voltages within defined limits. These limits may vary from typically $\pm 5\%$ averaged over a period of few minutes or hours, to the much more stringent constraints imposed where large, rapidly varying loads could produce voltage dips hazardous to the operation of protective equipment, or flicker annoying to the eye [1]. Compensating devices have a vital role to play in maintaining supply voltages within the specified limits, and to avoid voltage collapse [2]. Several types of VAR compensators are applied in power systems [3]; thyristor controlled reactors are applied for damping over-voltages while mechanical or thyristor switched capacitors are used to overcome under-voltage situations. Switched capacitors were introduced unit by unit as near as possible to the voltage peak resulting in integral cycles of reactive current. This method was assumed to be transient free [4], this may be partially true in the case of mechanically switched capacitors, but it becomes far from true when considering thyristor switched capacitors due to the uncertainty of the firing instance exact location with respect to the voltage crest. Furthermore, even for a simple mechanically switched capacitor, transients will occur when switching a new capacitor unit onto an already switched one. It is thus obvious that in addition to a practically transient non-free switching, the resulting voltage correction will assume a stepwise shape. In this work, the switching characteristics of a single unit capacitor compensator is identified by an artificial neural network to provide continuous VAR control. The resulting transients are analyzed and different transients damping measures are considered. The proposed neuro-controller technique was applied to a simulated real-time power system test to show its effectiveness.

Manuscript received from Dr . Ahmed Lotfy

Accepted on : 10 / 4 / 2002

Engineering Research Journal Vol 25, No 3, 2002 Minufiya University, Faculty Of
Engineering , Shebien El-Kom , Egypt , ISSN 1110-1180

2. THYRISTOR SWITCHED CAPACITOR (TSC) MODEL:

The firing instances of each thyristor switch with respect to the bus voltage will be used to provide the needed capacitive current. An inductor is added in series to the capacitor to limit the inrush transients of the capacitor to an acceptable level. Inrush current limiting is needed to down size the capacitor and the thyristor ratings.

The effect of the firing delay angle and the TSC elements on the reactive current is highly non-linear. Furthermore, it does not provide a direct means of controlling the current through the firing angle. The presence of inductance and capacitance together makes the transients oscillatory. The natural frequency of the transient is a key factor in the magnitude of the voltages and currents after switching, yet it is not entirely under the designer's control because the total series inductance includes the supply-system inductance and that of the step-down transformer if any.

3. NEURO-CONTROLLER DESIGN:

The switched capacitor compensator's current versus thyristor firing delay angle relation can be solved only by iterative methods. Such methods are time consuming and may even not converge. It is also possible to solve such non-linear relation off-line for various values of conduction angle and then store the results in a large look-up table. In this case there may be some granularity in the solution when the controlling parameters fall in between the table entries. As a result, a PID controller will not be effective to control a switched capacitor due to its poor performance and uncertainties when directly applied to nonlinear systems [5]. On the contrary, artificial neural networks allow for a quick on-line calculation of the required conduction angles [6]. There are numerous artificial neural network approaches with different structures, transfer functions, and training algorithms [7, 8]. The back-propagation algorithm was chosen for its relative simplicity and maturity in regards to the present application [9]. The structure of the neural network is very important, where the number of layers are chosen due to the performance index of the back-propagation algorithm; mean square error. A sequential training algorithm is adopted for a fast convergence training process. The construction of the applied neural network is shown in figure (1).

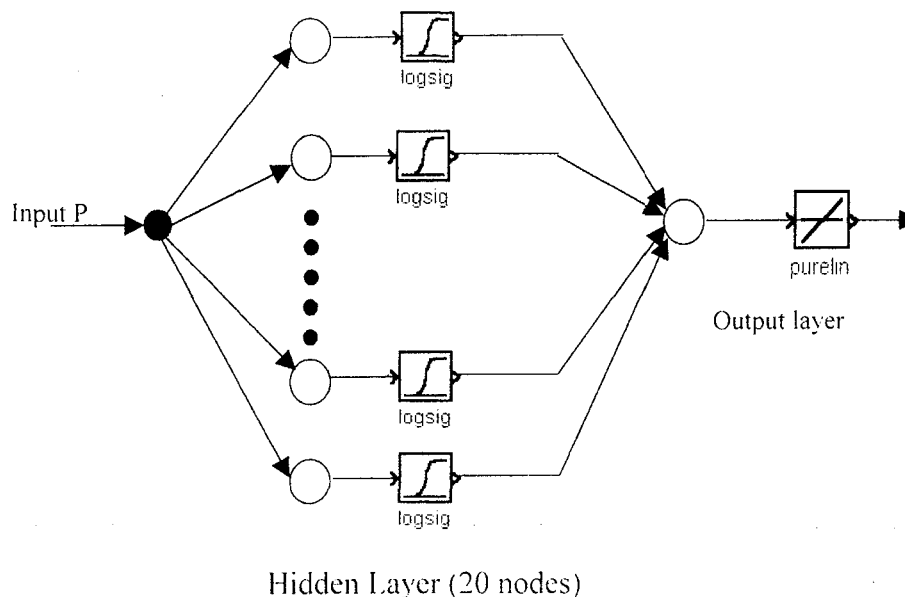


Figure (1): The designed TSC Neural Network

Figure (2) shows a portion of the actual nonlinear relation and the artificial neural network test response on the same graph. It is clear that the artificial neural network simulated the switched capacitor current characteristics perfectly.

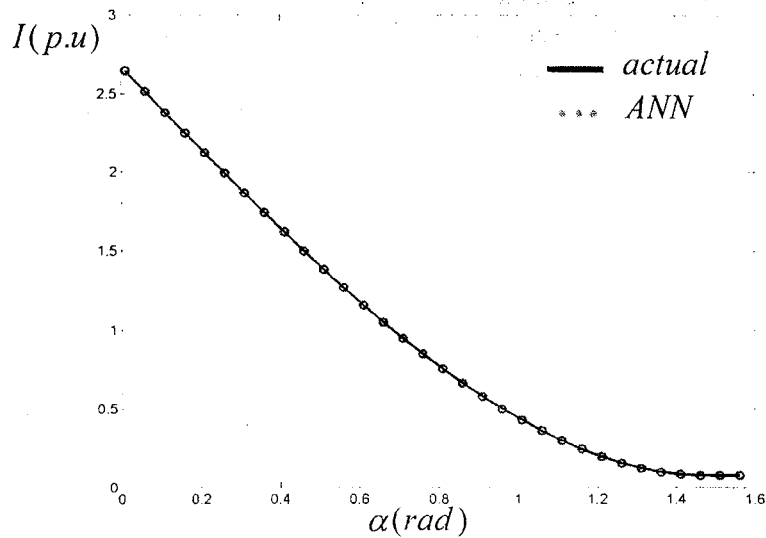


Figure (2): The characteristics of the actual system and the ANN

4. THYRISTOR CONTROLLED REACTOR (TCR) CONTROL:

The design of a TCR controller is by itself not a main objective in this work, mainly because of the difficulties associated with that of the switched capacitor method are not present. Still the performance of the proposed switched capacitor control has to be analyzed in view of the presence of a TCR, as the coordinated performance of both compensators is needed to maintain an acceptable voltage profile. A rather simple PID controller was adopted for being a suitable choice [10]. Figure (3) shows the responses for a bus experiencing an over-voltage situation; the resulting performance shows the adequacy of the PID controller parameters.

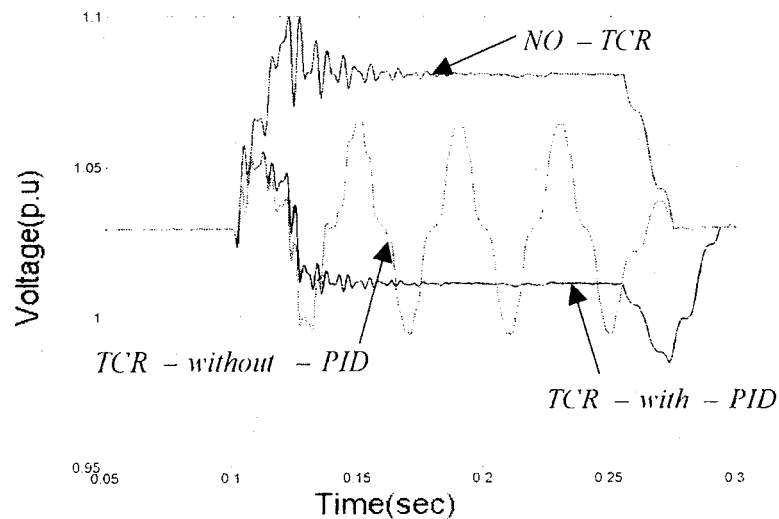


Figure (3): Effect of TCR on over-voltage Transients

5. OVERALL SUPERVISORY CONTROLLER:

The selection of the supervisory control action should take advantage of the newly proposed capacitor switched neuro-controller performance; there is no need now for the TCR to interpolate between capacitor characteristics with the possibility of dead-bands existence. The supervisory controller should read the power system Voltage State and specify the voltage to be within limits, above limits or under limits. The action to be taken depends on the static VAR compensator's actual operating state at the instance of voltage disturbance. Figure (4) shows the overall control system schematic representation.

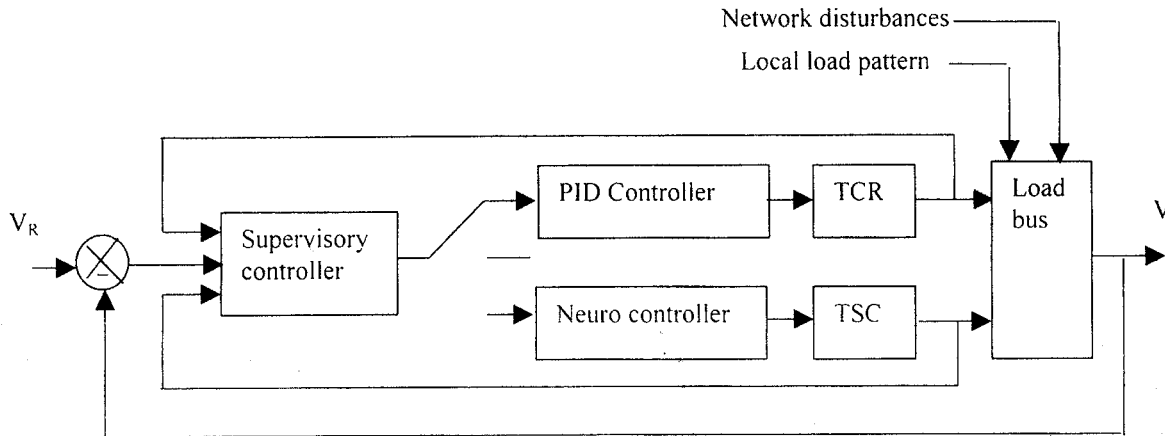


Figure (4) Schematic representation of overall control system

The supervisory control objectives may be realized by digital control or using an offline trained neural network, the former is suitable for hardware control circuit implementation while the latter remains a better choice for software driven overall control. Figure (5) shows the artificial neural network architecture proposed for the supervisory controller; the back-propagation algorithm was applied for training.

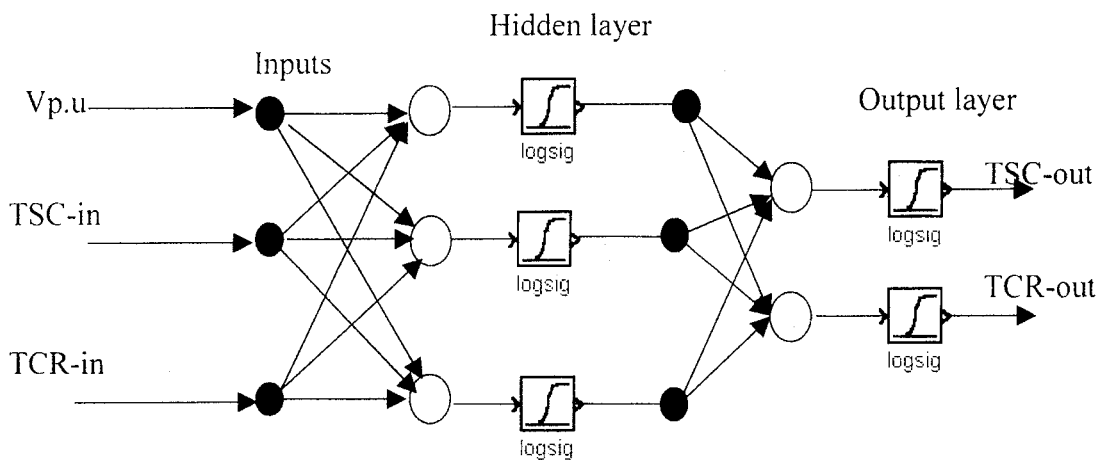


Figure (5): ANN architecture for the supervisory controller

The performance of the static VAR compensator was tested by introducing voltage disturbances through sudden heavy loading and dropping or faults.

Figure (6) shows the voltage profile of a bus enduring different sequential disturbances with and without compensation.

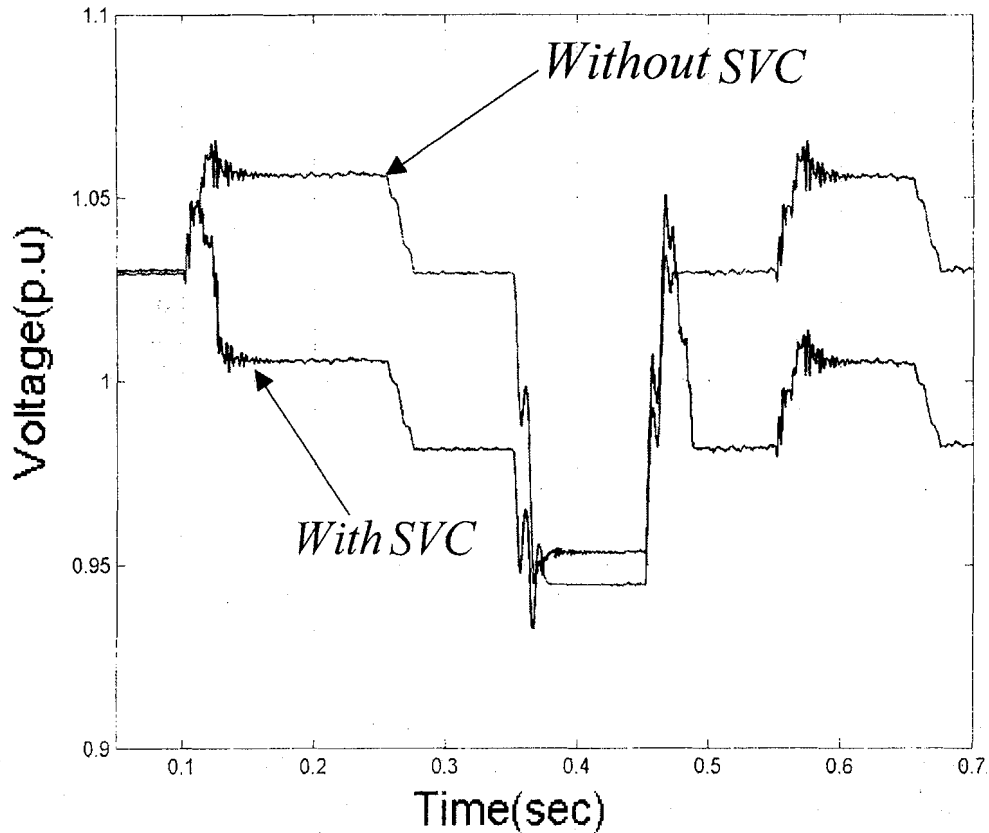


Figure (6): Disturbed voltage profiles with and without compensation

An over voltage disturbance lasting 0.15s was introduced. The TCR initially damped the voltage to 1.01 p.u., a further drop in the voltage followed the disturbance clearing due to the over-damping of the TCR. Nevertheless, the supervisory controller did not alter the compensator status as the voltage remained within acceptable limits. Following the under voltage disturbance introduced at 0.35s, the Supervisory controller inhibits the gating signals of the TCR. The disturbance severity - being beyond the former over damping TCR action range - implied enabling the TSC gating signals when the voltage reached its lower acceptable limit. The dropping of disturbing load caused a sudden over voltage that inhibited the TSC and re-operated the TCR. A further final injected over-voltage disturbance will not alter the control system operation due to the still operating TCR.

CONCLUSIONS:

The proposed reactive power neuro-control technique was shown to be effective in damping non-permitted voltage variations originating from faults, load patterns or network inadequate reactive power control. The voltage was fastly restored to permissible level following any injected disturbance. The new achieved extra-fast response compared with the classical techniques makes it possible to co-ordinate the static VAR system's operation with other kinds of special and / or conventional protection schemes.

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التحكم بالخلايا العصبية فى معوض استاتيكي للقدرة الغير فعالة

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ملخص

يتناول البحث موضوع التحكم فى فى المعوض الاستاتيكي للقدرة الغير فعالة لتحسين تغيرات الجهد الناشئة عن دخول أو خروج الأحمال أو حدوث أعطال فى خطوط النقل حيث أن الجهد يجب أن يظل داخل حدود مقننة لضمان عدم تشغيل أى جهاز حماية فى الشبكة الكهربائية أو حدوث انهيار للجهد و تغذية الأحمال على جهود و قدرة عالية الجودة. و قد تم استحداث طريقة جديدة للتحكم فى المعوض الاستاتيكي للقدرة الغير فعالة عن طريق استخدام الخلايا العصبية . و تعتمد التقنية المستحدثة على استخدام الخلايا العصبية للتعرف الدقيق على حالة معوض القدرة الغير فعالة و مقدار تلك القدرة اللازمة لنظام القوى لاستعادة حدود الجهد المقننة. و يستتبع ذلك تفعيل التحكم بالجزء الحثى أو الجزء السعوى للمعوض أو ابقاء الحال على ما هو عليه وفقا للحاجة. ويوفر التحكم بالخلايا العصبية تعويضا غير متقطع للقدرة الغير فعالة. و قد تم تطبيق التقنية على نموذج محاكى نظام قوى لاثبات فاعليتها.