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Power factor correction technique based on artificial neural networks

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Abstract

This paper presents a novel technique based on artificial neural networks (ANNs) to correct the line power factor with variable loads. A synchronous motor controlled by the neural compensator was used to handle the reactive power of the system. The ANN compensator was trained with the extended delta-bar-delta learning algorithm. The parameters of the ANN were then inserted into a PIC 16F877 controller to get a better and faster compensation. The results have shown that the proposed novel technique developed in this work overcomes the problems occurring in conventional compensators including over or under compensation, time delay and step changes of reactive power and provides accurate, low cost and fast compensation compared to the technique with capacitor groups.

Keywords: Artificial neural network; Power factor correction; Synchronous motor

1. Introduction

In electrical systems, all inductive loads fed by alternating current draw active and reactive powers from the line. While the active power is converted into heat, light and mechanical energy or other types of energy, the reactive power cannot be converted. It causes the transformer, alternator, cable, protection relay and other equipment to be larger than their rated values. Therefore, reducing the capacities of production, transmission and distribution of the line is the result of the effects of lower power factor [1,2]. In order to get rid of this effect, the power factor needs to be corrected [3].

In practical applications, reactive power compensations have generally been achieved by employing constant capacitor groups using some relays, timers and contactors. These types of systems are known as classical methods and have some mechanical problems, slow responses, over or under compensation and harmonics

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in the line voltage due to step changes of the capacitor groups that occur during operation. The changes of reactive power produced by variation of the load or load switching on the line can cause adverse effects on voltage stability and system security [4–6]. Nevertheless, static volt-ampere reactive (var) compensators (SVCs) can give smooth reactive power compensation without step changes. SVCs can be classified in four categories [7–12]: thyristor controlled reactor (TCR), thyristor controlled capacitor (TSC), combinations of TCR and TSC with switched or fixed capacitor and advanced static var compensation (STATCOM). These are utilized to enhance the integrated voltage stability. TCRs (or TSCs) for reactive power compensation systems are faster and do not have any mechanical problems. However, they generate harmonics in the voltage and current and cause a stability problem in the system [13–18]. These problems can be overcome by using a synchronous motor (SM), if it is already available in the system [19]. Synchronous motors can operate at unity, lagging or leading power factor condition [20,21]. When the motor is operating at unity condition, its power factor is equal to 1.0, and it only draws active power from the line to compensate its mechanical losses. When it is operating at lagging condition, its power factor is less than 1.0, and it draws lagging reactive power from the line. When it is operating at leading condition, its power factor is again less than 1.0, but this time, it produces leading reactive power for the line.

Since the synchronous motor is operating at an over or under compensation condition, the transmission line can be over loaded by the reactive powers produced or drawn by the synchronous motor. The use of a synchronous motor as a reactive power compensator is a well known method, but if it is only used for reactive power compensation, the system will be very inefficient and expensive in comparison with a group of capacitors [1,5].

Synchronous motor operation is important to reduce the cost and var penalties, to improve the voltage stability of the system, it can be operated by exciting its field circuit either using a fixed DC supply for constant loads or a variable direct current (DC) supply for variable loads. The variable DC supply can be achieved either manually or automatically. Manual control requires a serial rheostat in the field circuit, which causes a step change of the field current, electrical arcs on the rheostat, over or under compensation and time delay for the compensation. To get rid of these problems, the field voltage of the SM has to be adjusted using different automatic control techniques. Proportional plus integral (PI), proportional plus integral plus derivative (PID), pulse width modulation (PWM) and fuzzy logic (FL) techniques have been used for improving the compensation [4,22,23]. If one of these automatic controllers is not used in operation, the system might be operating under the effects of potential pole slip, increasing the kVA loading on the plant transformer and reducing the system voltage. So, using an appropriate controller, the system voltage stability of the bus might be achieved or the requirement of the kVA loading for the plant transformer is decreased [5].

Artificial neural networks (ANNs) have been very popular for applying in many engineering fields because of their fascinating features, such as learning, generalization, faster computation and ease of implementation. ANNs have been recently applied for power system security, power system stability estimation and optimal SVC and controlling induction, direct current and synchronous motors [24–31].

This paper introduces a novel technique based on ANNs to correct the power factor using a dynamic reactive power compensator. The experimental data used to design, train and test the neural controller were achieved from the test rig. Using an ANN compensator totally removes the problems mentioned earlier. Moreover, the exact field current required by the load can be produced without any delay compared to the other methods presented in the literature.

2. Power factor correction

The electrical power produced by an alternator is transmitted, distributed and then used by loads. On a power line, besides the active power, reactive power must also be available for inductive loads. An alternator in the power station can produce the reactive power for the line, but the reactive power also can be supplied from any source, which can either be a synchronous motor or capacitor groups connected near the load. The source of the reactive power must be very close to the load for efficient operation of the system. If the reactive power of any load is supplied from a synchronous motor or a group of capacitors rather than the power line, this system is called a reactive power compensator [32]. So, the power factor of the system can be kept at a required value.