AN ADAPTIVE POWER FACTOR CONTROLLER FOR VARYING LOADS

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Dedicated

to

My Parents

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by

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THESIS

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ABSTRACT

The operation of a static reactor compensator using a triac controlled inductor for improvement of the power factor of single-phase loads is investigated. The system power factor is measured by the computer and compared with a predetermined reference value. Then the computer software adjusts the power factor to get the predetermined value which is achieved by controlling the firing angle of the triac. The system power factor is measured by the computer at every supply cycle, and the above sequence is repeated. A laboratory model of the reactive power compensator was built and tested. The control scheme and associated control circuitry are explained in detail, and results showing the supply power factor with and without the compensator are presented. The proposed scheme achieves both accurate measurement and adjustment of the system power factor.

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CHAPTER I

INTRODUCTION

The supply power factor is critical in the economic design, and efficient and reliable operation, of a power system. Industrial loads account for most of the reactive power drawn from the supply and the power factor of most of the industries are low not exceeding 0.8. This low power factor causes supply voltage dip and increases transmission and distribution losses. The lagging VAR drawn by the loads is either reduced partly or cancelled completely by external compensating devices which draw the leading VAR from the supply. These devices are also known as shunt reactive power compensators since they are installed across the supply lines at industrial service inputs.

The use of fixed capacitor bank is well known and dates back to as early as 1914 [1]: but this leads, especially when the VAR requirement of the load is changing over a wide range, to over-compensation or under-compensation. Dynamic VAR compensation is achieved partially by a bank of switched capacitors - the required number is switched into or out of the system depending upon the compensation required at different instants of time.

With the advent of high-power thyristors, mechanical switches are being replaced by solid-state switches, thereby reducing the possibility of switching surges and improving the reliability of the system. Thyristor switching of static capacitors has made it possible to achieve virtually continuous control of

reactive power generation on a large scale and the smoothness of control is solely dependent on the number of capacitor switching units used.

Continuous and very fast control over the entire VAR range is possible following the development of the static reactor compensator. This consists essentially of a controllable reactor in parallel with a shunt capacitor. By choosing suitable values for the capacitor and the inductor, it is possible to achieve smooth and stepless control of KVAR from lagging to leading over a wide range, by continuous control of the effective fundamental reactance of the inductor. In this thesis, the operating principles of the shunt rector compensator using a triac controlled reactor as the controllable reactance are discussed.

The thesis is organized in the following manner. The mathematical analysis of the adaptive power factor controller, other methods of power factor control and harmonics and its effects are discussed in Chapter 2. The hardware and the control circuitry is described in Chapter 3. The software for the control is discussed in Chapter 4. In Chapter 5 the results of the experimental work are discussed and in Chapter 6 the conclusions are made.

CHAPTER II

THEORETICAL AND MATHEMATICAL ANALYSIS OF THE ADAPTIVE POWER FACTOR CONTROLLER AND HARMONICS

2.1 Introduction

The supply and consumption of electrical energy were relatively obscure matters to most people two decades ago. They were, in fact, functions largely taken for granted. The shortages and higher prices that arrived with the oil embargo in the early seventies inspired, among other things, a great appreciation of the need of energy conservation. The originally perceived form of conservation was simply "doing without". However, "doing without" often carries with it the burden of curtailed production which in turn decrease the overall profits.

A survey taken in the late seventies indicate that $55 billion was spent on energy in one year. Out of this amount 35% was spent for machine drive from electric motors, and 2% for space conditioning and heat. It is the cost of these functions that must be managed and controlled [2].

2.2 Energy and Power

Consider the network in figure 2.1. Energy and power relationships for this network apply for elements which are linear or non-linear, active or passive. The energy absorbed by the network from time t_1 to t_2 is

$$W = \int_{t_1}^{t_2} v(t)\,i(t)\,dt \quad joules \qquad (2.1)$$

The rate at which energy is being absorbed is the power and it is given by

$$P = \frac{dW}{dt} = v(t)\,i(t) \quad watts \qquad (2.2)$$

The convention for the reference direction for the flow of energy is shown in

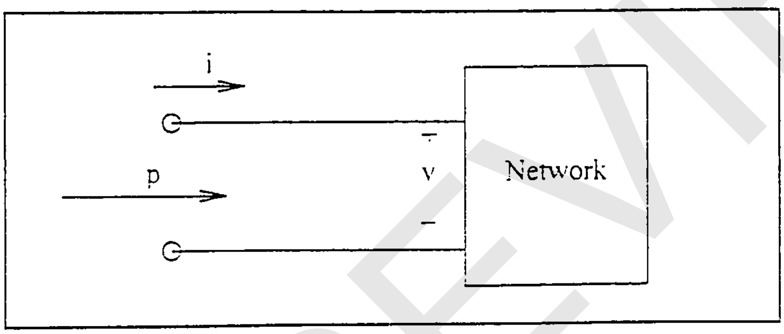

Figure 2.1 Network with reference directions for v and i to define positive p

Figure 2.1. For the voltage and the current references shown, a positive *P* indicates a flow of energy into the network, negative *P* out of the network. The direction of flow may change with time, of course, and will depend only on the sign of *P*. If either the voltage or current reference is reversed, so is the reference for the flow of energy. The network of figure 2.1 may be characterized by a driving point impedance, assuming it contains no independent sources. This impedance is

$$Z(j\omega) = R+jX = |Z|e^{j\theta z} \quad (2.3)$$

Here we see that

$$R = Re\ Z(j\omega) = |Z|\cos\ \theta_z \quad (2.4)$$

If the network has only a resistor then the average power for the resistor can be shown as equal to

$$P_{av} = I_{eff}^2 R = \frac{V_{eff}^2}{R}\ watts \quad (2.5)$$

Substituting the value of R from equation (2.4) in equation (2.5) we get

$$P_{av} = I_{eff}^2\ |Z|\ \cos\ \theta_z \quad (2.6)$$

In this equation cos θ_z is defined as the power factor. The convention is that the power factor is said to be leading if the current leads the voltage and lagging if the current lags the voltage. Let the voltage and the current phasors be

$$\mathbf{V} = V\,e^{j\beta} \text{ and } \mathbf{I} = I\,e^{j\alpha}$$

So that

$$Z = \frac{V}{I} = \frac{V}{I}e^{j(\beta-\alpha)} \quad (2.7)$$

Comparing the equation (2.4) and (2.7) we get

$$\beta - \alpha = \theta_z \quad (2.8)$$