VOLUME-4, ISSUE-4

INVESTIGATION OF AUTOMATIC REACTIVE POWER COMPENSATION IN POWER SUPPLY SYSTEMS

B.M.Husanov[1], M.A.Namozov[2]

[1)] PhD, Toshkent davlat texnika universiteti, Toshkent, 100095, O'zbekiston;
husanovbaxtiyor7@gmail.com

[2)] Magistr, Toshkent davlat texnika universiteti, Toshkent, 100095, O'zbekiston;
makhmudnamozov777@gmail.com

Introduction

At present, improving the efficiency of electricity use at industrial enterprises is one of the most important tasks. In production processes, the widespread use of asynchronous motors, transformers, welding units, compressors, and other inductive electrical consumers causes a significant increase in reactive power consumption. The growth of reactive power leads to an increase in current in electrical networks, higher active power losses, voltage drop, overloading of network elements, and deterioration of the power factor. As a result, the technical condition of the power supply system worsens, the risk of emergency operation increases, and energy use becomes economically inefficient.

In many enterprises, capacitor banks are used to reduce reactive power consumption. However, under conditions where the load changes during the day, within shifts, or according to technological cycles, simple uncontrolled capacitor banks do not always ensure high efficiency. In some cases, compensation is insufficient, while in others overcompensation occurs. This may cause voltage rise above permissible limits, overheating of equipment, and a reduction in the service life of capacitor installations. Therefore, the issue of automatically controlling reactive power in accordance with real operating conditions is highly relevant.

Main Part

Reactive power compensation is based on supplying part of the reactive demand of inductive loads locally, near the point of consumption. This reduces the transfer of reactive power over long distances, thereby decreasing line current, reducing active power losses, improving voltage stability, and increasing the effective utilization of network capacity.

The considered system operates in a three-phase, four-wire 0.4 kV low-voltage network supplied by a 10/0.4 kV transformer. To ensure automatic control, the regulator receives voltage and current signals from measuring transformers and continuously evaluates the main electrical parameters, including active power, reactive power, apparent power, and power factor. The control strategy is formed on the basis of these real-time measurements.

As shown in Fig. 1, the automatic reactive power compensation system consists of a measuring unit, a discrete control module, a power supply unit, a microcontroller, a relay, and a capacitor bank switched through electromagnetic contactors. After processing the measured network parameters, the microcontroller generates switching commands for the capacitor bank stages. This enables stepwise regulation of compensation power and ensures maintenance of the required power factor under variable load conditions.

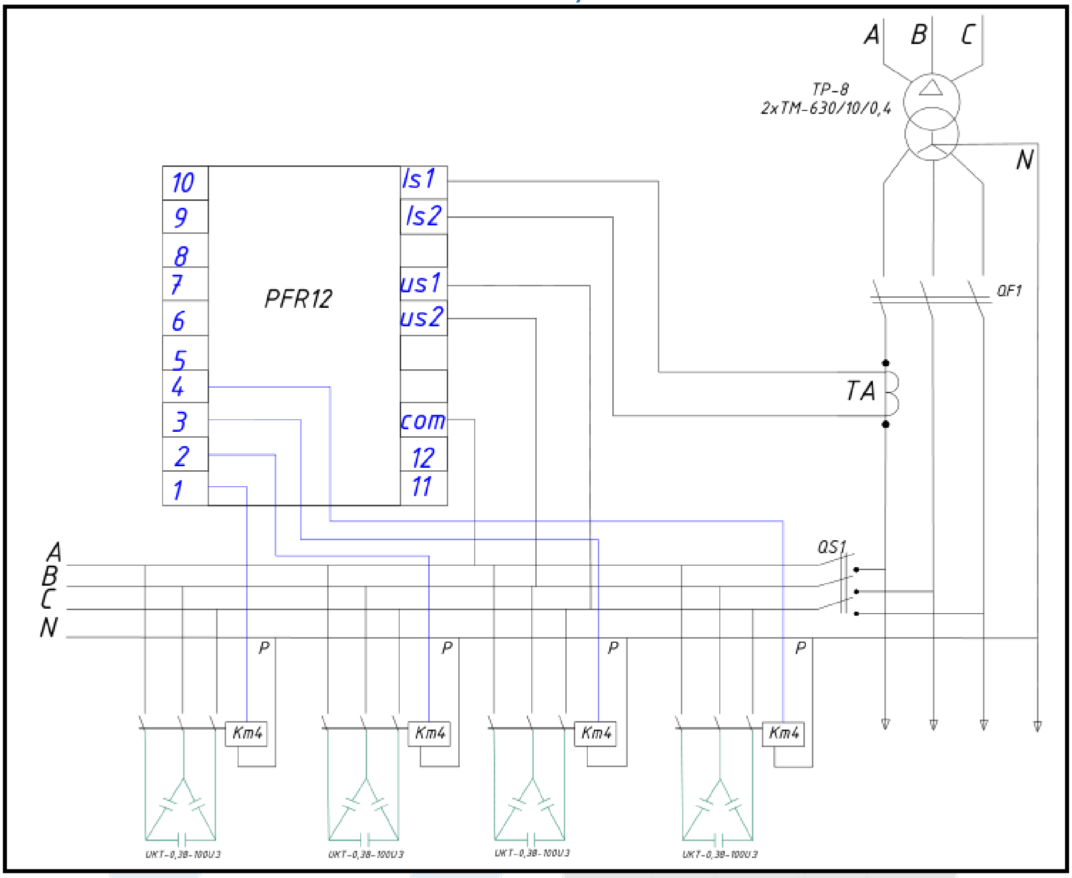

Fig.1. Structural diagram of an automatic reactive power compensation system based on a microcontroller regulator and capacitor bank.

In practical systems, capacitor banks are divided into several stages, each switched by a separate electromagnetic contactor. This allows stepwise regulation of reactive power according to load conditions. When the power factor decreases under inductive operation, the regulator sequentially connects capacitor stages; under overcompensation, the corresponding stages are disconnected. Therefore, compensation is performed dynamically rather than statically.

Such an automatic system reduces not only reactive power flow, but also line current, active power losses, voltage deviations, and the loading of transformers and cables. Microprocessor-based regulators further improve reliability through functions such as sequential switching, overcompensation protection, voltage monitoring, and switching frequency limitation.

However, capacitor-bank compensation is less effective in networks with rapid load variations or high harmonic distortion. In such cases, FACTS-based devices such as STATCOM and SVC are more suitable. As shown in Fig. 2, STATCOM provides fast and continuous reactive power control through a voltage source converter, making it effective for dynamic load conditions and improved voltage stability.

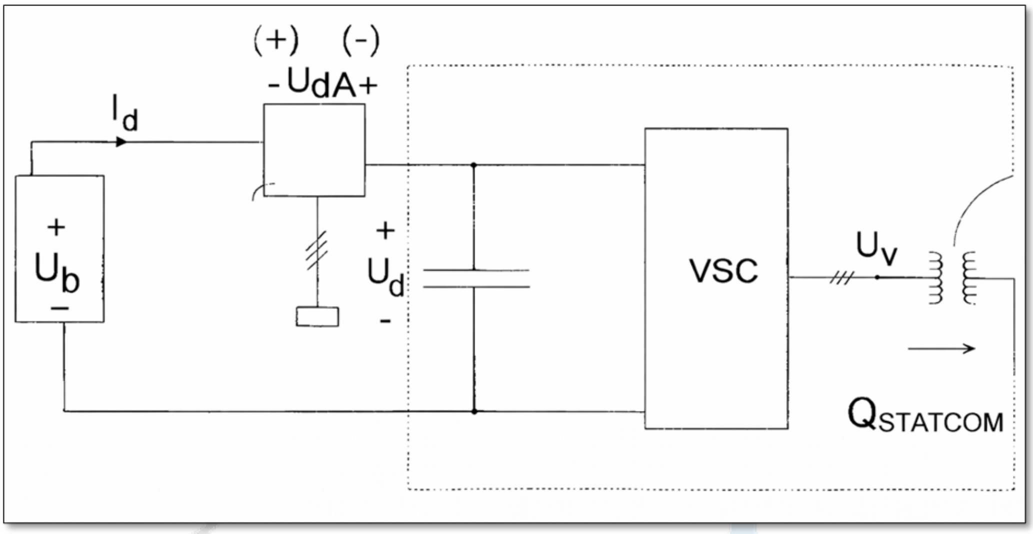

Fig.2. Simplified functional diagram of a STATCOM based on a voltage source converter (VSC).

A comparison of conventional capacitor-bank compensation and STATCOM indicates that each solution is effective under specific operating conditions. For most 0,4 kV industrial power supply systems, regulator-controlled multi-stage capacitor banks represent a technically practical and economically efficient option. In contrast, STATCOM is more suitable for networks with rapid load variations, continuous compensation requirements, or significant voltage disturbances. Therefore, the selection of compensation technology should be based on technical, economic, and operational considerations.

For low-voltage industrial networks, automatic compensation using a multi-stage capacitor bank and a microprocessor regulator remains one of the most rational solutions. Its simplicity, reliability, and ease of operation ensure high practical efficiency. Moreover, locating reactive power sources close to load nodes improves performance by reducing reactive power circulation in the main network and enhancing the utilization of existing infrastructure.

Conclusion

Reactive power compensation is essential for improving power quality and energy efficiency in industrial power supply systems. In networks with a high share of inductive loads, excessive reactive power flow causes voltage deviations, higher active power losses, and overloading of network elements. An automatic compensation system based on a microprocessor regulator and multi-stage capacitor banks effectively mitigates these problems by maintaining the power factor at the required level in real time. As a result, energy losses are reduced, voltage quality is improved, equipment loading is lowered, and overall system reliability is enhanced. Therefore, the application of automatic reactive power compensation in industrial enterprises is both technically and economically justified.