American Journal Of Applied Science And Technology
(ISSN – 2771-2745)
VOLUME 03 ISSUE 12 Pages: 14-18
SJIF IMPACT FACTOR (2021: 5. 705) (2022: 5. 705) (2023: 7.063)
OCLC – 1121105677
Crossref doi Google Scholar WorldCat MENDELEY

Publisher: Oscar Publishing Services

Journal Website: https://theusajournals.com/index.php/ajast

Research Article

REACTIVE POWER COMPENSATION TECHNOLOGIES

Submission Date: December 04, 2023, Accepted Date: December 09, 2023,
Published Date: December 14, 2023
Crossref doi: https://doi.org/10.37547/ajast/Volume03Issue12-04

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ABSTRACT

This article provides an overview of the current state of reactive power compensation technologies. The principles of operation, design characteristics and examples of the use of VAR compensators on thyristors and self-commutated converters are given. VAR static generators are used to improve voltage regulation, stability and power factor in AC transmission and distribution systems. Also described are examples obtained from the respective annexes describing the use of reactive power compensators implemented using the new static VAR technologies.

KEYWORDS

VAR, principles of operation, self-commutated.

INTRODUCTION

VAR compensation is defined as reactive power management to improve the performance of AC systems. The VAR compensation concept covers a wide and diverse range of problems for both the system and consumers, especially related to the quality of electricity that can be mitigated or solved by adequate reactive power management [1]. In general, the problem of reactive power compensation is considered from two sides: load compensation and voltage support. In load compensation, the goals are to increase the value of the system's power factor, balance the actual power consumed from an alternating current source, compensate for voltage regulation and eliminate the harmonic components of the current created by large and fluctuating nonlinear industrial loads [2], [3]. Voltage support is usually required to reduce voltage fluctuations at a given end of the transmission line. Reactive power compensation in transmission systems also improves the stability of the AC system by increasing the maximum active power that can be transmitted.

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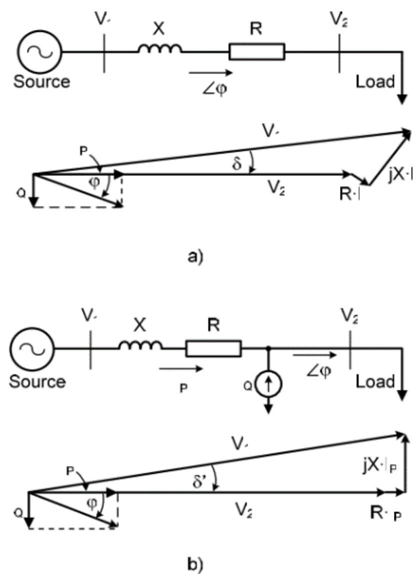

Fig. 1. Principles of shunt compensation in a radial AC system.

a) Without reactive compensation.

b) Shunt compensation with a current source.

Sequential and shunt VAR compensation are used to change the natural electrical characteristics of AC systems. Sequential compensation changes the parameters of the transmission or distribution system, while shunt compensation changes the equivalent load impedance [1], [7]. In both cases, the reactive power flowing through the system can be effectively controlled, improving the performance of the entire AC system. Traditionally, rotating synchronous capacitors and fixed or mechanically switchable capacitors or inductors have been used to compensate for reactive power. However, in recent years, static VAR compensators have been developed, which use thyristor-switched capacitors and thyristor-controlled reactors to provide or absorb the required reactive power [7], [8], [9]. In addition, the use of self-switching PWM converters with an appropriate control circuit allows the implementation of static compensators capable of generating or absorbing reactive current components with a time reaction faster than the main cycle of the power grid [10], [11], [12]. Selection of the structure model and boundary conditions. In a linear scheme, reactive power is defined as a component of an alternating current of instantaneous power with a frequency equal to 100/120 Hz in a system with a frequency of 50 or 60 Hz. The reactive power generated by an alternating current source is stored in a capacitor or reactor for a quarter of a cycle, and in the next quarter of the cycle it is sent back to the power source. In other words, the reactive power fluctuates between an alternating current source and a capacitor or reactor, as well as between them, with a frequency equal to twice the nominal value (50 or 60 Hz). For this reason, it can be compensated with VAR generators, avoiding its circulation between the load (inductive or capacitive) and the source, and thus improving voltage stability in the power system. Reactive power

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compensation can be implemented using VAR generators connected in parallel or in series.

As a rule, VAR generators are classified depending on the technology used in their implementation and the way they are connected to the power system (shunt or serial). Rotating and static generators were commonly used to compensate for reactive power. In the last decade, a large number of different static VAR generators using power electronic technologies have been proposed and developed [7].

There are two approaches to the implementation of VAR compensators based on power electronics: one uses thyristor-switched capacitors and reactors with branch-switching transformers, and the second uses static converters with automatic switching.

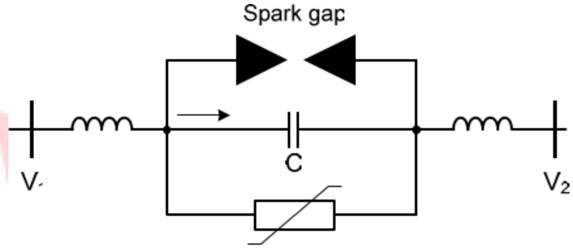

Fig. 2. Serial capacitor compensator and the corresponding protection system.

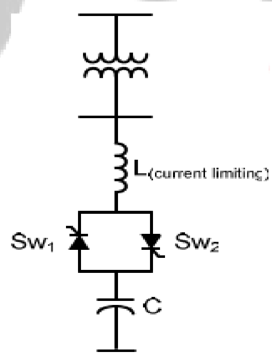

Fig. 3. Configuration of a capacitor with thyristor switching.

A brief description of the most commonly used bypass and sequential compensators is provided below. Regardless of the type of source or system configuration, various requirements must be considered for the successful operation of VAR generators. Some of these requirements are simplicity, manageability, dynamics, cost, reliability, and harmonic distortion. The following sections describe the various solutions used to generate VAR, as well as the associated operating principles and compensation characteristics.

The capacitor can be switched with a minimum of transients if the thyristor is switched on at a time when the capacitor voltage and the mains voltage have the same value. Static compensators of the TSC type have the following properties: stepwise control, an average delay of half a cycle (maximum one cycle) and the absence of harmonic generation, since the transient component of the current can be effectively attenuated [6], [7].

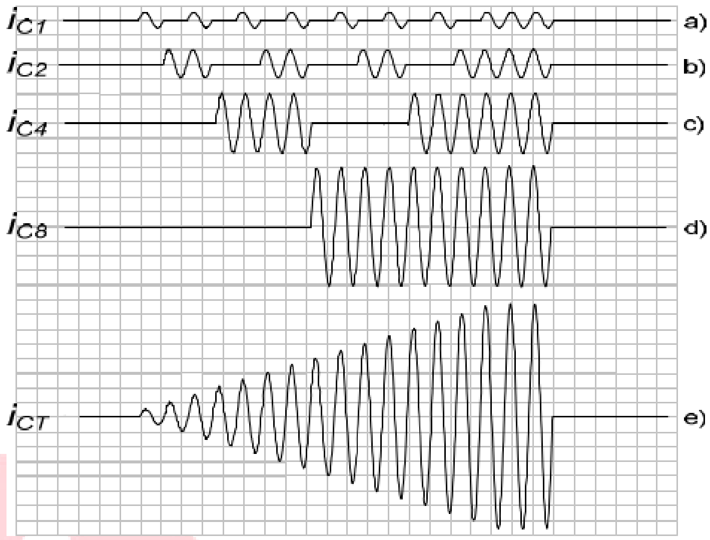

Fig. 4. Experimental compensating phase current of a thyristor-diode switching capacitor.

The advantages of this topology are that many compensation levels can be implemented with multiple branches, allowing continuous change without

distortion. In addition, the topology is simpler and more economical compared to thyristor-switched capacitors. The main disadvantage is that it has a time delay of one full cycle compared to the half-cycle of the TSC.

Conclusions. An overview of the technological development of VAR generators and compensators is presented. Based on the principles of VAR compensation, classical solutions using phase-controlled semiconductors were considered.

The introduction of self-switching topologies based on IGBT and IGCT semiconductors has significantly improved the characteristics of VAR compensators: they have faster dynamic behavior and can control a large number of variables. The introduction of new self-switching topologies at even higher voltage levels will enhance the impact of VAR compensation in future applications. Some relevant examples of projects have been described where it can be seen that modern VAR compensators improve the operation of power systems, helping to improve the reliability and quality of electricity supplied to consumers. These examples show that VAR compensators will be used on a much larger scale in the future, as network performance and reliability will become even more important factors. Better manageability of the energy system will allow utilities to reduce investments in the transmission lines themselves. The combination of modern management with real-time information and information technology will bring them closer to their physical limits. In addition, the development of faster and more powerful semiconductor valves will expand the possibilities of using VAR generators to higher limits.

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