

Ain Shams University
Faculty of Engineering
Electrical Power and Machines Department

REACTIVE POWER CONTROL IN ELECTRIC POWER SYSTEMS

Dissertation For the Degree of Doctor of Philosophy
In Electrical Power Engineering

By

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M.Sc. in Electrical Power Engineering 1990

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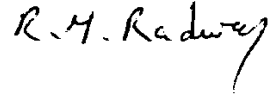
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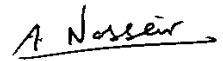
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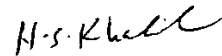
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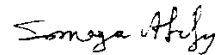
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Statement

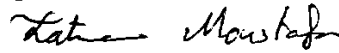
This dissertation is submitted to Ain Shams University for the degree of Doctor of Philosophy in Electrical Power Engineering.

The work included in this thesis was carried out by the author in the Department of Electrical Power and Machines.

No part of this thesis has been submitted for a degree or qualification at any other university or institution.

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ABSTRACT

REACTIVE POWER CONTROL IN ELECTRIC POWER SYSTEMS

The determination of the requirements of high voltage transmission networks for reactive power compensation remains an area of concern, mainly, because of the use of large load centers and continuous variations in loads, continuous occurrence of abnormal events on the bulk power transmission networks, extensive use of long transmission lines, and bulk transmission of electric powers. Investigations reported in the last four decades have shown that reactive power compensation can control the system voltage with acceptable limits, improve the system stability, minimize system losses, and provides more economical transmission of electric energy.

Reactive power compensators are classified into:

- (i) Shunt capacitors and shunt reactors,
- (ii) Series capacitors,
- (iii) Synchronous condensers, and
- (iv) Static Var Compensators (SVC)
- (v) Static synchronous compensator

Static Var Compensators (SVCs) are now widely used for their numerous advantages. They have fast response. Also they are fully controllable and capable of continuous adjustment of their reactive powers over an unlimited range. On the other hand, SVCs with thyristors controlled reactors (TCR) are nonlinear elements which produce harmonics.

The 500 kV Egyptian network is characterized by ultra high voltage long transmission lines of total length of approximately 2340 Km, and large power of about 1500 MW to be transmitted from the High Dam generating station downstream to Cairo to feed the load centers. This power is accompanied by a considerable amount of reactive power due to the length of transmission lines. The network is equipped with fixed and variable reactors as well as a synchronous condenser at Cairo 500 kV substation.

The synchronous condenser is now out of service because of its performance deterioration and many other deficits. The candidate suggests the replacement of the synchronous condenser by static var compensators (of the TCR/FC type) installation.

The thesis presents a study on the requirements of the Egyptian 500 kV network for reactive power compensation. The investigations carried out by the candidate include the following:

(1) load flow analysis, which is performed to find out the need for reactive power compensators (inductive and/or capacitive), the optimum size of compensator and the best site in order to maintain the voltage profile within the acceptable limits. The results are determined for different loading conditions and for two stages of system development.

(2) dynamic stability analysis for the system when subjected to 3-phase faults. The aim is to investigate the effect of the SVC on the system dynamic performance. The results of the voltage and frequency variations during the transient period will be presented. This type of analysis is carried out for different fault locations in the system.

(3) Analysis of harmonics generated by the SVC in the system. A good deal of the investigations is devoted to:

- (a) Analyze the voltage and current waveforms and determine the level of their harmonics,
- (b) Investigate the effect of SVC transformer winding connections, and firing angle asymmetries of the thyristors of the TCR.
- (c) Identify the resonant frequencies of the system and determine whether significant magnification of the TCR harmonics is possible.

The thesis presents important results which illustrate the effect of SVC on system voltage regulation and dynamic stability.

The results also show the level of harmonics generated in the network and there is no risk of the magnification of these harmonics.

