Ain Shams University
Faculty of Engineering
Electrical power and Machine Department

Steady State and Dynamic Performance of Unsymmetrical Power Systems Interconnected By HV AC/DC Link

Thesis
for the degree of
Doctor of Philosophy
In Electrical Power Engineering

By

Girgis Rizk Migalla
M. Sc. In Electrical Power Engineering

Supervised By

Prof. Dr M. A. El-Sharkawy
Dr. A. S. Emarah
Ain Shams University

Dr. M. A. Swidan
Dr. I. Yassin
Egyptian Electricity Authority

Cairo - 1997

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بسم الله الرحمن الرحيم

Approval Sheet

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The Dissertation for the degree of Doctor of Philosphy In Electrical Power Engineering Presented by Eng. Girgis Rizk Migalla has been approved by :

Name	Signature
1. Prof. Dr. Muhammed A. Choudhry West Virginia University - U.S.A	
2. Prof. Dr. Mohammed . K. El-Sherbiny Assiut University - Egypt	
3. Prof. Dr. Metwally Awad El-Sharkawy Ain-Shams University - Egypt	M.A. El-Sharkawy
4. Dr. Adel Sedkey Emarah Ain-Shams University - Egypt	A. S. Emarah

Ain Shams University
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Electrical Department

Thesis for : Doctor of Philosophy In Electric Power Engineering

By : Girgis Rizk Migalla
B.Sc In Electrical Power Engineering - Ain Shams Universty 1969
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Egyptian Electricity Authority (EEA)

Thesis Title :

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Under Supervision of :

From Faculty of Engineering
- Prof. Dr. Metwally Awad El Sharkawy
- Dr. Adel Sedkey Emarah

From Egyptian Electricity Authority
- Dr. Moustafa Aly Swidan
  EEA Chairman
- Dr. Ibrahim Yassin
  Management Director for Studies

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To the Soul
of my Late Father...
I Dedicate my Thesis

ABSTRACT

Girgis Rizk Migalla, Steady State And Dynamic Performance Of Unsymmetrical Power Systems Interconnected By HV AC/DC Link, Doctor of Philosophy Thesis, Faculty of Engineering, Ain-Shams University, Cairo, Egypt, 1997.

In this work a three-phase mathematical model has been developed for full representation of six valve converters operated under voltage unbalance and controlled with IPC or EPC firing scheme. Investigation of the developed converter model shows that the commutation periods and extinction angles of different valves are not equal under the conditions of voltage unbalance even the EPC firing scheme is used. However, it has been shown that under these conditions the fundamental components and harmonic content of converter ac currents are unbalanced only when the IPC firing scheme is used. It has been also found that the dc voltage drop due to the commutation process is not affected by ac voltage unbalance.

An existing three-phase unsymmetrical ac load flow algorithm and program have been modified by including the developed converter model to offer the possibility of handling systems including dc links. The modified program is applied to investigate the behavior of two ac systems interconnected by ac, dc or ac/dc tie-lines under unbalanced loading conditions. The obtained results show that the load unbalance at the receiving end of tie-lines strongly affects the degree of unsymmetry of phase active and reactive powers and currents supplied by the tie-lines especially in the case of the ac/dc tie-lines. The load

unbalance strongly also affects the performance of the dc line and converters especially in the case when the dc line stands alone.

A traditional constant extinction angle controller has been modified by adding a new signal called "Gamma Supplementary" to make it capable of operating in steady state conditions at lower values of extinction angle (gamma). High values of gamma will be set by the suggested controller only during abnormal conditions caused by symmetrical or unsymmetrical faults or severe load unbalance loading. A dynamic simulation program is modified and applied to investigate the capability of the modified controller in improving the dynamic behavior of ac/dc systems. The obtained results prove that the suggested "Gamma Supplementary Controller" has a significant effect in limiting commutation failures during fault and fault recovery periods.

This work discusses also the effect of voltage waveform distortion, likely to appear in weak ac systems due to harmonics, on the ac/dc system performance especially when the inverter CEA controller which requires a healthy sinusoidal voltage wave shape is used. A "Filter Phase-Shift Compensator" is designed and used to modify the traditional CEA controller that uses the IPC firing scheme. The performance of the modified controller has been tested for an inverter connected to a weak ac system. The obtained results prove that the modified controller is capable to reducing the harmonic instability problems appearing at the weak ac bus during normal and fault conditions. The modified controller is also capable of limiting commutation failures following fault clearing.

A "Differential Logical Controller" has been designed in this work to detect the dc fault occurrence and to coordinate the operation of rectifier and inverter controllers to bring their voltages and currents to zero during the fault period. A dynamic simulation program has been developed, to simulate a dc fault clearing technique based on converter control, and used to study the dynamic behavior of an ac/dc system when the proposed and traditional methods are used to clear the dc fault. It is found that the proposed controller has the capability of clearing the dc fault faster and smoother than the traditional method.

Key Words

Dynamic Performance - Unsymmetrical - DC Link

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