AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING

EFFECT OF CONVERTER STATION REGULATIONS ON THE STABILITY OF AC/DC POWER SYSTEMS

THESIS

Submitted by

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NOMENCLATURE

Direct-Current Link

V_t	Converter a.c. line voltage
I_t	converter a.c. line current
I_d, I_q	direct and quadrature axis components of converter a.c. line current
P_{dc}, Q_c	active and reactive power input to conveter
V_{d_c}	d.c. line voltage
I_{d_c}	d.c. line current
X_t	converter transformer leakage reactance referred to bridge side
R	resistance of d.c. link
R_e	effective resistance of d.c. link
T	effective time constant of d.c. link
I_{d_r}	reference current for d.c. link
ϕ	phase angle between converter fundamental voltage and fundamental current
α	converter-valve firing-delay angle
β	converter-valve firing-angle advance $= 180^\circ - \alpha$
γ	estinction angle.

<u>Subscripts</u>

r, i rectifier and inverter quantities, respectively

<u>Alternating Current System</u>

V_f field voltage

$V_{fd} = \frac{M_d\, w}{r_f} V_f$ field voltage referred to stator.

V_d, V_q direct and quadrature axis components of machine terminal voltage V_t

i_d, i_q direct and quadrature axis components of machine terminal current i_t

i_f field current

X_d, X_q direct and quadrature axis synchronous reactances

X_d' direct axis transient reactance

M_d mutual inductance between field and direct axis winding

T_{d_o}' direct axis transient open circuit time constant

r_a armature resistance

δ , θ rotor angle with respect to infinite busbar and machine terminal voltages, respectively

V_o infinite busbar voltage

w synchronous speed, rad/sec.

X_e tie line series inductive reactance

X_c shunt capacitor reactance

M inertia constant

D system damping coefficient

P_e electrical power output from alternator

P_m prime-mover power

Regulators

K_{ov} voltage regulator gain

T_e voltage regulator time constant

K current regulator gain

K_1 current regulator gain corresponding to the derivative signal

T_1, T_d current regulator time constants

K_I inverter firing circuit gain.

A B S T R A C T

This thesis studies the effects of the converter station controls on the dynamic behaviour of parallel a.c./d.c. power systems.

A synchronous generator connected to an infinite bus through a d.c. line is considered at first. A parallel a.c. line is added to the system and the new combination is also studied.

Throughout the thesis, the inverter station is assumed to have constant extinction angle control with current control override. The rectifier station is considered with a constant current controller as well as constant power controllers.

The synchronous generator excitation control and speed governer are included in the system model.

The Domain Seperation criterion is used to analyize the performance of the two systems studied. The analysis produced the best values for the gains of the excitation and d.c. current control loops. The values range of these gains are obtained subject to prespecified value for the overall system damping coefficient.

The effects of varying various system and regime parameters on the allowable range for the controller gains are investigated. The results obtained give the best values of the controller gain for the given control configuration in order to achieve the best performance for the overall system.

It is found out that under constant power control a wider range of gain values for stable operation of the system is obtained.

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CHAPTER I

INTRODUCTION

GENERAL ASPECTS OF HIGH VOLTAGE DIRECT CURRENT TRANSMISSION

It is an established fact that alternating current holds a unique position both as far as the generation of electrical energy is concerned and also for the distribution of this energy to the ultimate consumers. This situation favouring alternating current, may be attributed to its commutator-free generators and above all to the ease with which the voltage at the generation side can be transformed up to the desired transmission voltage, just as it can be readily reduced again at the consumer side to the various voltage levels required. The stage, at which the application of direct current appears today to be favourable within the overall process of electrical energy production, transmission and distribution to the consumer, is thus limited to the transmission area.

In the case of modern d.c. plants the problem is therefore always one of transporting energy from one alternating current (a.c.) network to another, i.e. the energy from an a.c. network must be transformed into a high voltage d.c. system (rectification) and at the other end of the transmission system the d.c. energy must, in opposite manner, be returned back to a.c. form (inversion). The practical solution of this problem has, however, only become possible following decades of development work, which has led to the construction of mercury-arc valves that have fulfilled the necessary requirements both as regards voltage stresses and current loadings. Furthermore, the favourable position, which thyristors have attained in recent times within the low voltage fields, has encouraged their introduction into the high voltage fields and thereby a broadening of the range of available technology has taken place.

The amount of electrical energy transported over high voltage d.c. transmission has increased exponentially during the last half of this centuary (Fig. 1.1). This is due to the advantages offered by this mode of transmission over the a.c. one.

The map given in Fig.(1.2) shows over 25 h.v.d.c. transmission projects either in service, under construction or actively studied[1].

One naturally asks what limitations of the a.c. transmission has led to the use of d.c. transmission in some projects.

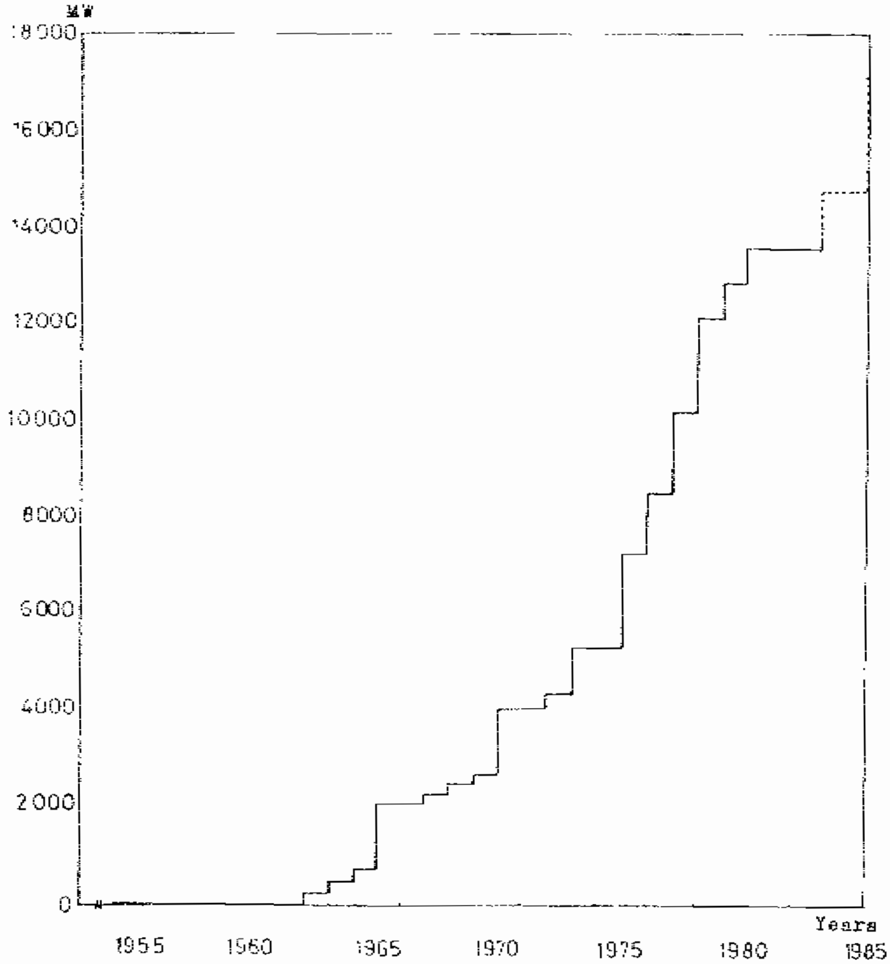

Fig.(1.1) The Growing up in the Transmitted d.c. Power During the Last Half of this Centuary.

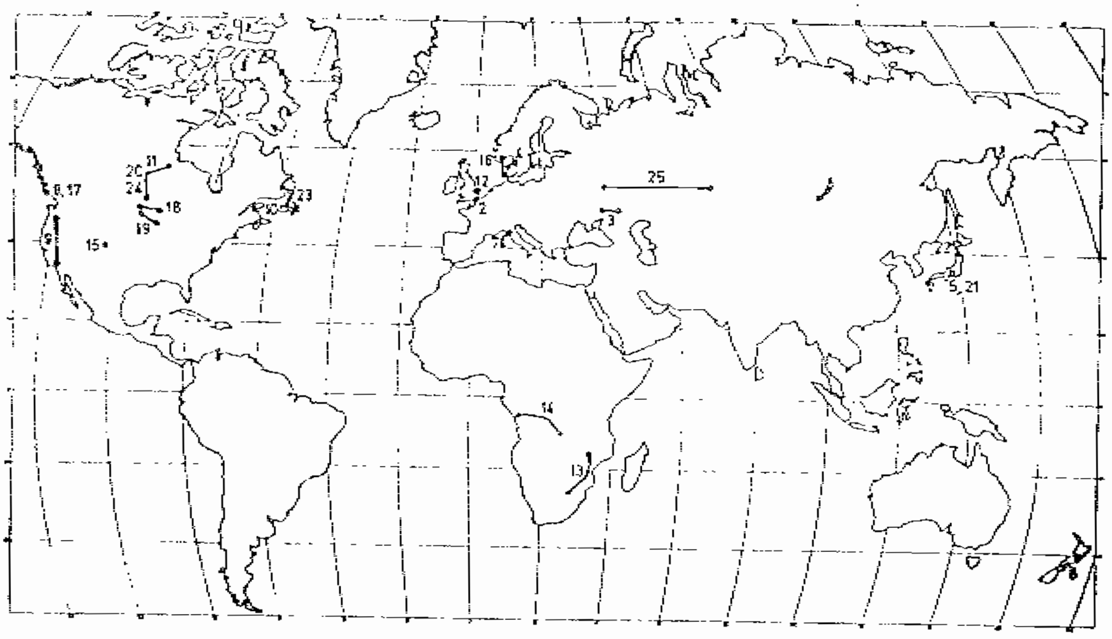

Fig. (1.2) H.V.D.C. Transmission Projects.