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Power Flow Control in HVDC Link Using PI and Ann Controllers

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Abstract:- In this paper, a HVDC system is designed to control the power flow between two converter stations with conventional controller and Artificial Neural Networks. For rectifier side current control is used and for inverter side both current and extinction angle control is implemented. Here Artificial Neural Networks is designed for both rectifier and inverter control and compared its performance with conventional PI controller. The MATLAB/SIMULATION results show that the HVDC with Neural network based controller have great advantage of flexibility when compared with PI controller.

Keywords:- HVDC transmission, modelling, simulation.

I. INTRODUCTION

The design, analysis, and operation of complex ac-dc systems require extensive simulation resources that are accurate and reliable. Ana log simulators, long used for studying such systems, have reached their physical limits due to the increasing complexity of modern systems. Currently, there are several industrial grade digital time-domain simulation tools available for modelling ac-dc power systems. Among them, some have the added advantages of dealing with power electronics apparatus and controls with more accuracy and efficiency. MATLAB/SIMULINK is high-performance multifunctional software that uses functions for numerical computation system simulation, and application development. The HVDC system [1,2] shown in Fig.1. The system is a mono-polar 500-kV, 1000-MW HVDC link with 12-pulse converters on both rectifier and inverter sides, connected to weak ac systems (short circuit ratio of 2.5 at a rated frequency of 50 Hz) that provide a considerable degree of difficulty for dc controls. Damped filters and capacitive reactive compensation are also provided on both sides. The power circuit of the converter consists of the following sub circuits.

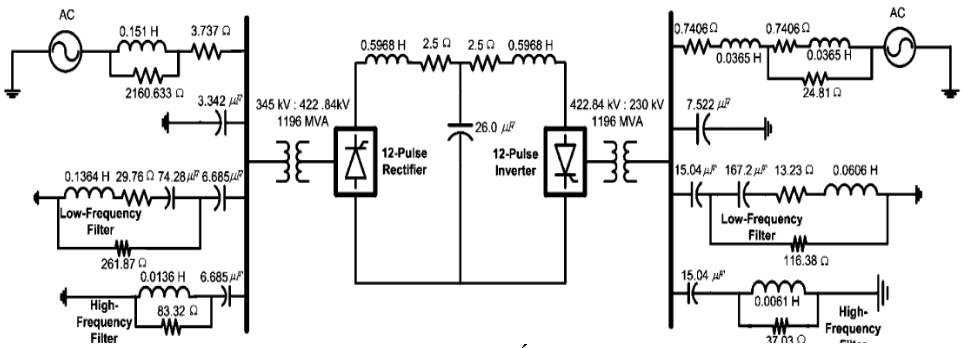

Fig:1Single-line diagram of the CIGRÉ benchmark HVDC system.

A. AC Side

The ac sides of the HVDC system consist of supply network, filters, and transformers on both sides of the converter. The ac supply network is represented by a Thevenin equivalent voltage source with an equivalent source impedance. AC filters are added to absorb the harmonics generated by the converter as well as to supply reactive power to the converter.

B. DC Side

The dc side of the converter consists of smoothing reactors for both rectifier and the inverter side. The dc transmission line is represented by an equivalent T network, which can be tuned to fundamental frequency to provide a difficult resonant condition for the modelled system

C. Converter

The converter stations are represented by 12-pulse configuration with two six-pulse valves in series. In the actual converter, each valve is constructed with many thyristors in series. Each valve has a (di/dt) limiting inductor, and each thyristor has parallel RC snubbers

D. Power Circuit Modelling

The rectifier and the inverter are 12-pulse converters constructed by two universal bridge blocks connected in series. The converter transformers are modeled by one three-phase two winding transformer with grounded Wye–Wye connection, the other by three-phase two winding transformer with grounded Wye–Delta connection. The converters are interconnected through a T-network.

E. Three Phase Source

A three-phase ac voltage source in series with a R-L combination is used to model the source.

F. Control Variables for Constant Power Flow Control

The control model mainly consists of (α/γ) measurements and generation of firing signals for both the rectifier and inverter. The PLO is used to build the firing signals. The output signal of the PLO is a ramp, synchronized to the phase-A commutating.

$$Id = ((Ar *Er/ Tr) \cos \alpha r - (Ai*Ei/ Ti) \cos \gamma i) / (Rcr + Rd- Rci)$$

$$Edr= (Ar *Er/ Tr) \cos \alpha r$$

$$Edi= (Ai*Ei/ Ti) \cos \gamma i)$$

Following are the controllers used in the control schemes:
1.Extinction Angle (γ) Controller
2.dc Current Controller;
3.Voltage Dependent Current Limiter (VDCOL).

G. Rectifier Control

The rectifier control system uses Constant Current Control (CCC) technique [3,4,5]. The reference for current limit is obtained from the inverter side. This is done to ensure the protection of the converter in situations when inverter side does not have sufficient dc voltage support (due to a fault) or does not have sufficient load requirement (load rejection). The reference current used in rectifier control depends on the dc voltage available at the inverter side. Dc current on the rectifier side is measured using proper transducers and passed through necessary filters before they are compared to produce the error signal. The error signal is then passed through a PI controller, which produces the necessary firing angle order. The firing circuit uses this information to generate the equidistant pulses for the valves using the technique.

H. Inverter Control

The Extinction Angle Control or γ control and current control have been implemented on the inverter side. The CCC with Voltage Dependent Current Order Limiter (VDCOL) have been used here through PI controllers. The reference limit for the current control is obtained through a comparison of the external reference (selected by the operator or load requirement) and VDCOL (implemented through lookup table) output. The measured current is then subtracted from the reference limit to produce an error signal that is sent to the PI controller to produce the required angle order. The γ control uses another PI controller to produce gamma angle order for the inverter. The two angle orders are compared, and the minimum of the two is used to calculate the firing instant. Gamma is the time expressed in degrees from the thyristor current extinction to the time when the thyristor commutation voltage becomes positive. The system frequency is used to convert time values in electrical degrees. The current extinction time is determined from the current threshold. The six gamma angles are determined using six thyristor currents and the six commutation voltages are derived from the three-phase-to-ground AC voltages measured at the 12 primary of the converter transformer. The minimum gamma value is considered for the control action. For a 12-pulse converter, two gamma measurement units are used, and the smaller of the two gamma outputs is compared with the reference gamma to produce the error signal. The firing angle orders from the CCC and from the gamma controller (CEA) are compared and the minimum is used to produce firing pulses for the valve. Appropriate voltmeters and ammeters are used to measure the DC voltages and currents, and three-phase VI measurement blocks are used to measure the three phase voltages and currents. Signals are routed using “From” and “Goto” blocks and displayed by the scope.

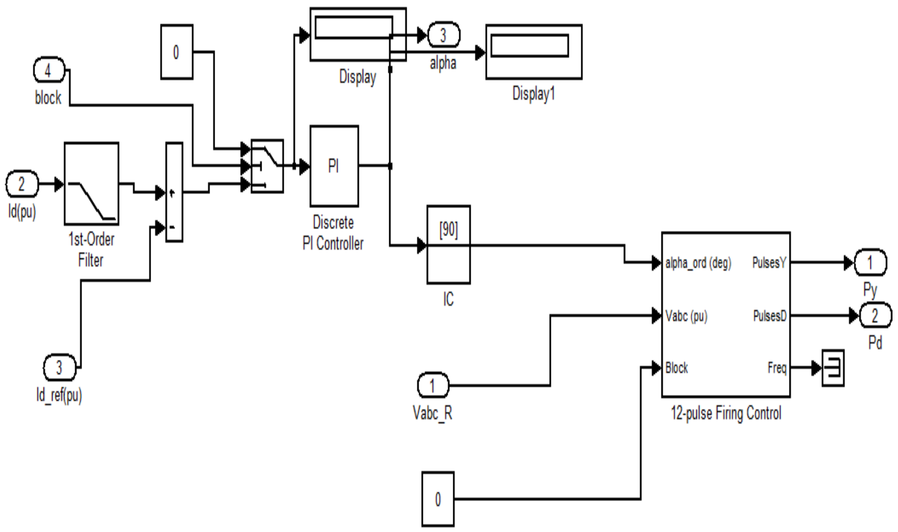

Fig: 2. Rectifier control with PI

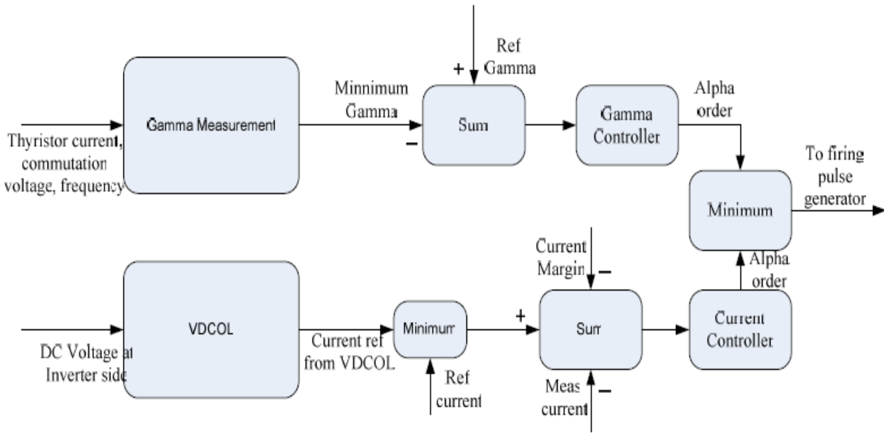

Fig: 3. Inverter control with gamma measurement technique

I. Artificial Neural Networks

An artificial neural network (ANN), often just called a "neural network" (NN), is a mathematical model or computational model based on biological neural networks. It consists of an interconnected group of artificial neurons and processes information using a connectionist approach to computation. In most cases an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase.In more practical terms neural networks are non-linear statistical data modelling tools. They can be used to model complex relationships between inputs and outputs or to find patterns in data.

Where x1, x2…..Xm are the m inputs
Wk1 , Wk2 ,…. Wkm are weights attached to the input links
For the above model
$Uk = \sum_{j=1}^{m}(\text{Wkj Xj})$
$\text{Vk} = Uk + \text{bk}$
The bias bk has the effect of increasing or lowering the input of the activation function.
$yk = \varphi(\text{Uk} + \text{bk})$

The weighted output signal vk is passed through an activation function and compared. If the output is greater than the activation function then vk is passed to the cell body (system) which is used to perform the required activity.

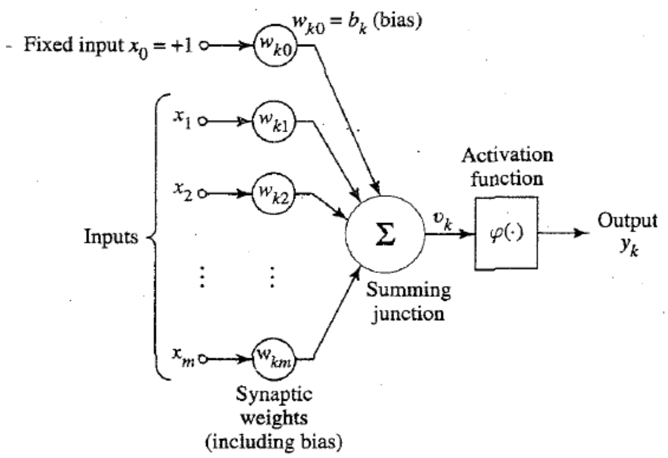

Fig: 4. Artificial Neural Networks

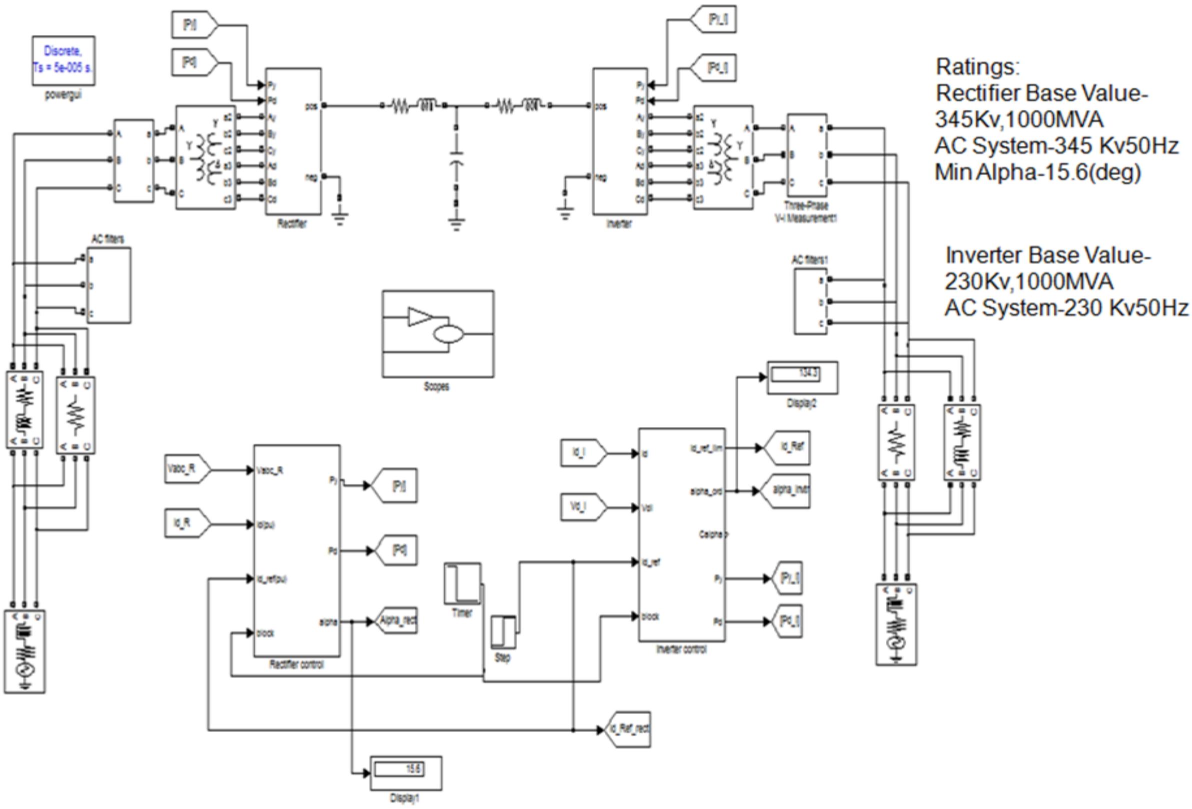

Fig: 5. Simulink model of HVDC System

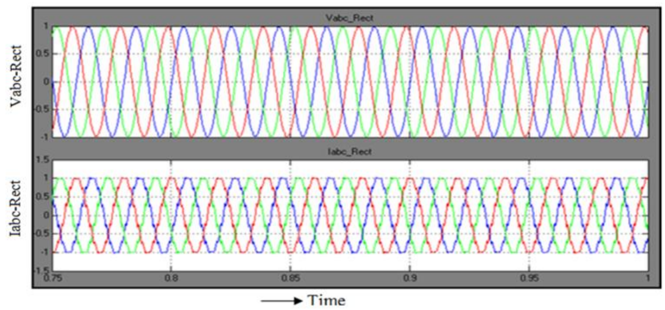

Fig: 6. Rectifier side AC Voltage and AC Current

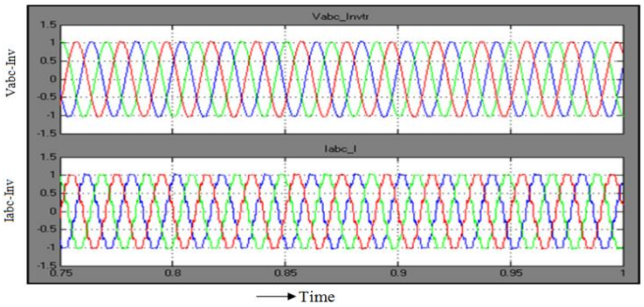

Fig: 7. Inverter side AC Voltage and AC Current

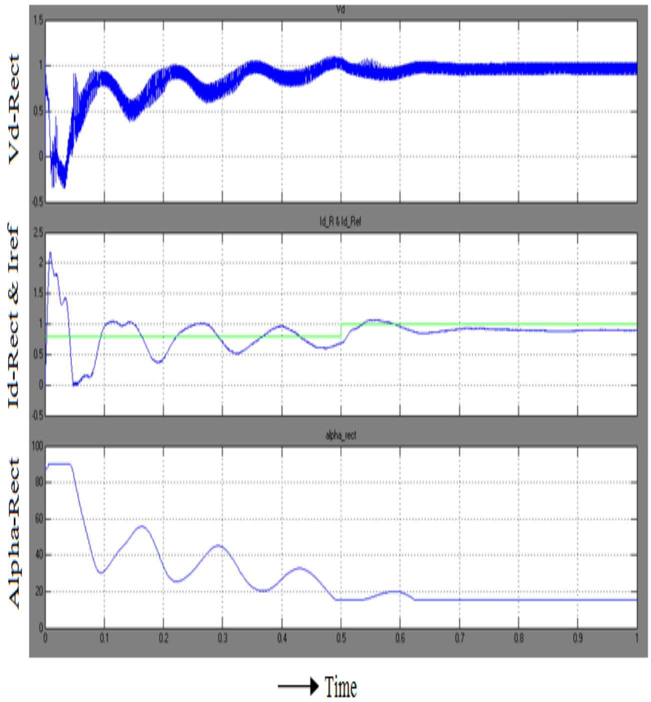

Fig: 8. Rectifier side DC Voltage, DC Current and Firing angle order with PI

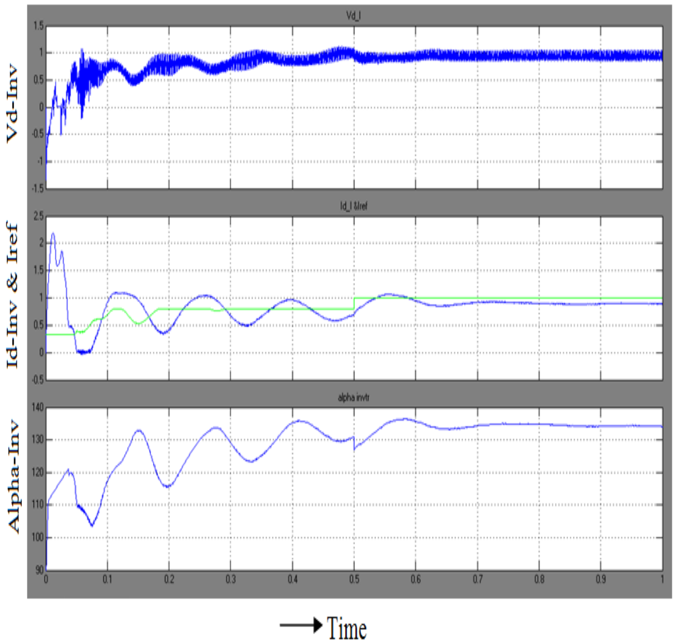

Fig: 9. Inverter side DC Voltage, DC Current and Firing angle order with PI

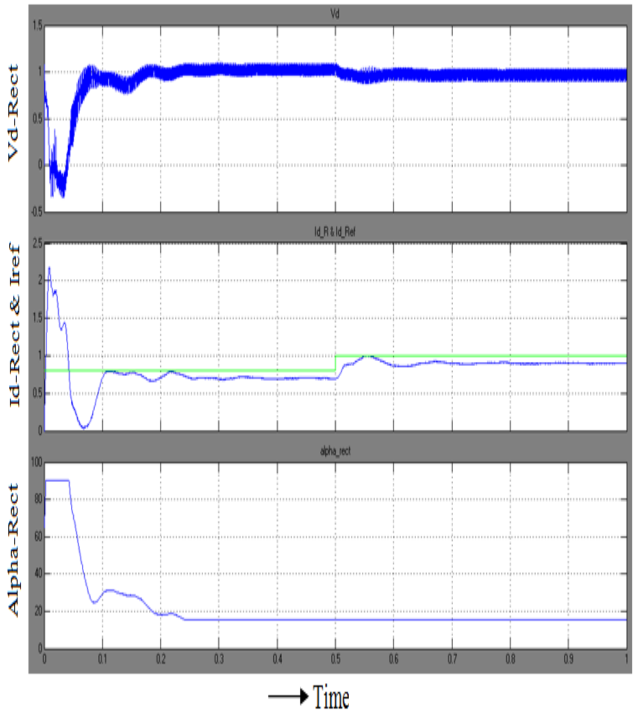

Fig: 10. Rectifier side DC Voltage, DC Current and Firing angle order with NN

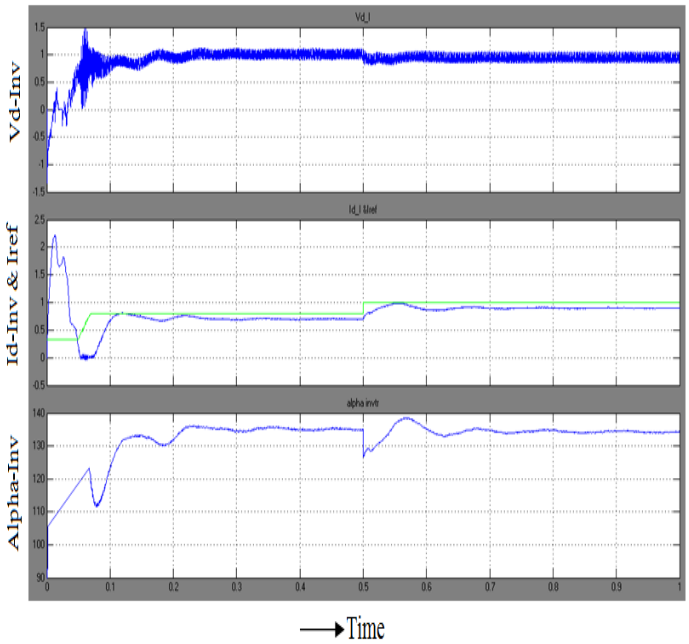

Fig: 11. Inverter side DC Voltage, DC Current and Firing angle order with NN

II. CONCLUSIONS

In this project, a HVDC system is designed to control the power flow between two converter stations with conventional controller and Artificial Neural Networks. For rectifier side current control is used and for inverter side both current and extinction angle control is implemented. In order to transfer maximum power in the dc link, we have to maintain minimum alpha. The error signal is passed through a PI and Artificial Neural Networks controller, which produces the necessary firing angle order. The firing circuit uses this information to generate the equidistant pulses for the valves in the converter station. Here Artificial Neural Networks is designed for both rectifier and inverter control and compared its performance with conventional controller. The simulation results show that the HVDC with Neural network based controller have great advantage of flexibility when compared with PI controller.

REFERENCES

[1]. Das, B.P.; Watson, N.; Yonghe Liu; , "Simulation study of conventional and hybrid HVDC rectifier based on CIGRÉ benchmark model using PLL-less synchronisation scheme," Power Engineering and Optimization Conference (PEOCO), 2011 5th International , vol., no., pp.312-317, 6-7 June 2011doi: 10.1109/PEOCO.2011.5970433.

[2]. Ashfaq Thahir, M.; Kirthiga, M.V.; , "Investigations on modern self-defined controller for hybrid HVDC systems," TENCON 2011 - 2011 IEEE Region 10 Conference , vol., no., pp.938-943, 21-24 Nov. 2011doi: 10.1109/TENCON.2011.6129248.

[3]. Das, B.P.; Watson, N.; Yonghe Liu; , "Comparative study between gate firing units for CIGRE benchmark HVDC rectifier," Industrial Electronics and Applications (ICIEA), 2011 6th IEEE Conference on , vol.,no.,pp.299-306,21-23June2011 doi: 10.1109/ICIEA.2011.5975598.

[4]. Sood, V.K.; Khatri, V.; Jin, H.; , "EMTP modelling of CIGRE benchmark based HVDC transmission system operating with weak AC systems," Power Electronics, Drives and Energy Systems for Industrial Growth, 1996., Proceedings of the 1996 International Conference on , vol.1, no., pp.426-432 vol.1, 8-11 Jan 1996doi: 10.1109/PEDES.1996.539653.

[5]. Kala Meah, A.H.M. Sadrul Ula, "Simulation Study of the Frontier Line as a Multi-Terminal HVDC System," IEEE PES General Meeting, July 20- 24, 2008, Pittsburg, PA, USA.

[6]. N.G. Hingorani, "Power Electronics in Electronic Utilities: Role of Power Electronics in Future Power Systems," Proceeding of the IEEE, Vol. 76, No. 4, April, 1988, pp. 481-482.

[7]. A. Ekstrom and G. Liss, "A Refined HVDC Control System," IEEE Transactions on Power Apparatus and Systems, Vol. PAS 89, No. 5, May/June 1970, pp. 723-732.