Power Flow Control In Multi-Terminal VSC-HVDC By Using ANN Controller

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Abstract- *This article deals with the transmission of HVDC power in between the two converter stations by using matlab simulation. This paper mainly focuses on the reduction of power loss in the HVDC system. The power flow control method is applied to reduce the power losses. This power flow control method can be done by controlling the rectifier and inverter stations with PI Controller which does not give better power flow. Artificial Neural Network Controller method is employed for controlling power flow. The Performance of HVDC system with ANN controller is compared with the PI controlled HVDC system and results are presented.*

Keywords- HVDC Transmission , Conventional controller ,Voltage Source Converters,Artificial Neural Network

I. INTRODUCTION

In early days HVDC schemes were developed by by means of mercury arc valves. The thyristor valves was demonstrated with the initial back–to-back asynchronous interconnection at the Eel River between Quebec and New Brunswick in 1972. Ever since the thyristor valve technology have absolutely put back the mercury arc technology. The revival of direct current (dc) for long distance power transmission began in 1954 when ASEA, a predecessor of ABB, from island of Gotland to mainland Sweden by means of high voltage direct current (HVDC) lines. In 1890’s it is proved that AC was more efficient at transmitting electricity over long distances and hence Thomas Edison lost the war of dc against alternating current (ac). Now a days DC has gained more importance because of many advantages.One of the reason is the increase in electricity consumption throughout the world. In Europe, total electricity utilization has increased by 32.8% from 1990 to 2007.Consequently the European high-voltage alternating-current (HVAC) grid is operating very close to its maximum values. These days, there are many projects in operation worldwide. By 2008, the installed capacity in over 100 projects worldwide is 100,000 MW HVDC and more than 25,000 MW HVDC is under construction in 10 projects, and an further 125,000 MW HVDC transmission capacity have been designed in 50 projects[2]. It became necessary to take account of the HVDC transmission system into the power system for the fast development of DC transmission system and its. To transmit power for long distances with less amount of losses the tradition HVDC classic technology is employed. Recently HVDC technology based on voltage source converters (VSC) is more advantageous ie., VSC-HVDC systems address issues about the transmission of power, asynchronous network interconnections and stability[3]. The HVDC transmission systems can be classified into two-terminal and multi-terminal HVDC transmission systems. A mono polar link with ground return is generally employed in HVDC submarine cable scheme.

An HVDC transmission system consists of three basic parts which are:

1) A rectifier station used for converting AC to DC
2) A DC transmission line and
3) An inverter station used for converting DC to AC.

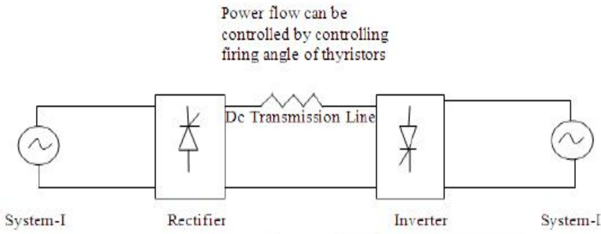


Fig1.Schematic diagram of an Multi-terminal VSC-HVDC transmission system

II. HVDC SYSTEM MODEL

A high capacity multifunctional MATLAB/SIMULINK software has numerical computation system functions with application development. Power System Blockset (PSB) tool is used for modeling and simulation of electric power systems using SIMULINK. It includes library block where devices are found which are based on electromagnetic and electromechanical equations. PSB/SIMULINK can be used for modeling and simulation of both power systems and control systems.The HVDC system shown in Fig.2.The system is monopolar 500 KV, 1000 MW HVDC link which has 12-pulse converters on rectifier and inverter sides each, connected to weak ac systems ie., short circuit ratio of 2.5 at a rated frequency of 50 Hz. Damped filters and capacitive reactive compensation are also provided on each side of rectifier and invereter. The power circuit of the converter consists of the following sub circuits.

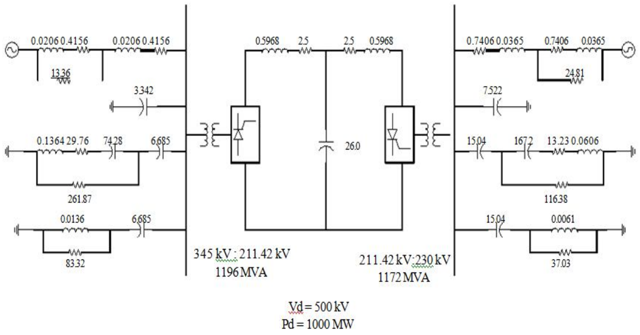


Fig 2.Schematic diagram of an HVDC transmission system

A. AC Side

The ac sides of the HVDC system consist of supply network, filters, and transformers on both sides of the converter[5]. The Thevenin’s equivalent voltage source with equivalent source impedance represents an AC network. The harmonics of the converter are reduced by using AC filters.

B. DC Side

The converter dc side consists of smoothing reactors on each rectifier and the inverter side. The smoothing reactor can have either an air-core or an iron-core. It helps to smooth the direct current. The dc transmission line is represented by an equivalent T network and it can be adjusted to a standard fundamental frequency to provide a resonant condition for the modeled system[1].

C. Converter

A converter station consists of basic converter unit, converter valve, converter transformer, smoothing reactor, AC filter and DC filter so on. Basic converter unit can be classified as 6-pulse converter unit and 12-pulse converter unit. Usually HVDC schemes utilize the 12-pulse converter unit as a basic converter unit [1]. To structure a 12-pulse converter unit, two 6-pulse converters units should be connected in series on the DC side and two 6-pulse converters in parallel on the AC side. In a converter, each valve is formed with a number of thyristors in series and has (di/dt) limiting inductor, and also each thyristor has parallel RC snubbers.

D. Power Circuit Modeling

The rectifier and inverter are 12-pulse converters which are constructed by two series universal bridge blocks. 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 all the way through a T-network

1) Universal Bridge Block: A universal three phase power converter is implemented by universal bridge block which consists of six power switches connected as a bridge. the dialog box is used for the selection of the type of power switch and converter configuration. Series RC snubber circuits are connected in parallel with each switching device. The vector gating signals are six-pulse trains equivalent to the natural order of commutation.

2) Three Phase Source:
A three-phase ac voltage source in series with a R-L combination is used to model the source.

3) Converter Transformer Model:
The three-phase two winding transformers models are used with the tap position is at a fixed position determined by a multiplication factor applied on the primary nominal voltage of the converter transformersie.,1.01 on rectifier side and 0.989 on inverter side[1].

III. RECTIFIER AND INVERTER CONTROL

The control model mainly consists of generation of firing signals for rectifier and inverter and (α/γ) measurements [3]. The PLO is used to build the firing signals and its output signal is a ramp, synchronized to the phase-A commutating.

Following are the controllers used in the control schemes:

1. Extinction Angle (γ) Controller
2. DC Current Controller
3. Voltage Dependent Current Limiter (VDCOL).

1) Rectifier Control:

The Constant Current Control (CCC) technique is employed in rectifier control system uses. The reference is obtained from inverter side for current limit to ensure the protection of the converter when inverter side does not have sufficient dc voltage support or does not have enough load requirement .The reference current in rectifier control depends on dc voltage at the inverter side. Proper transducers are used to measure dc current on the rectifier side and is passed through necessary filters to produce the error signal [1] .The error signal is then passed through a PI controller, which is used to produce t necessary firing angle order.

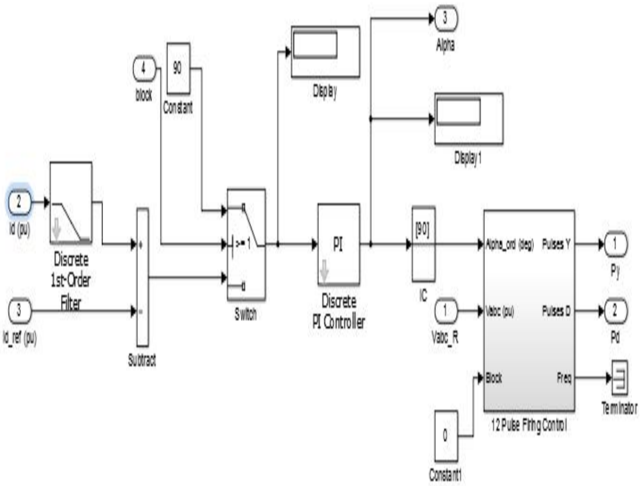


Fig 3. Rectifier control with PI

*2) Inverter C*ontrol:

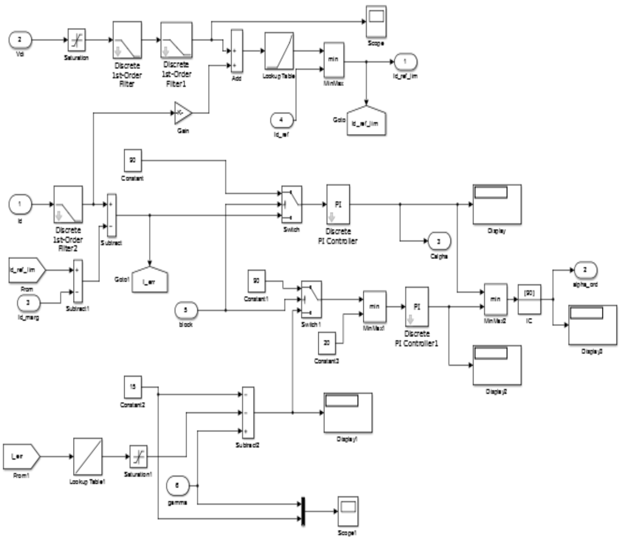


Fig 4. Inverter control with PI

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) is used through PI controllers[1]. The reference limit for the current control can be produced through comparison of the external reference and VDCOL output. The produce error signal is produced by subtraction of measured current from the reference limit and it is sent to the PI controller to produce required angle order.

IV. DESIGN OF ARTIFICIAL NEURAL NETWORK

Neural Networks, which are the simplified model of the biological neuron system, is a massively parallel distributed processing system made up of highly interconnected neural computing elements that have the ability to learn and thereby acquire knowledge.

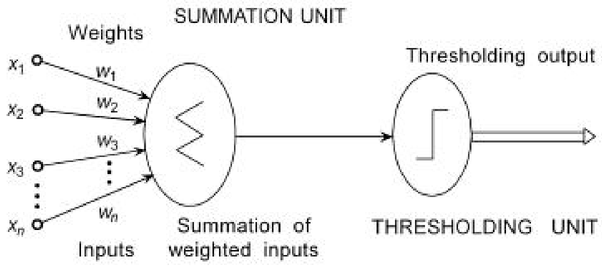


Fig 5. Simplified model of Artificial Neuron

Neural Network architectures are classified into different types depends on their learning mechanisms. Here, we are using Supervised learning.

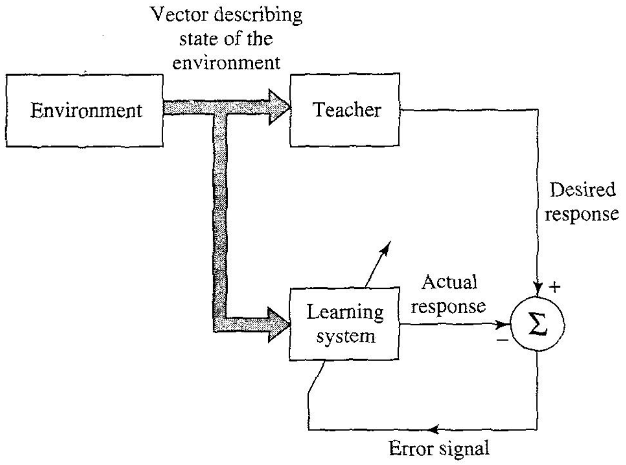


Fig 6. Supervised Learning

In the Supervised learning every input pattern which is used to train the network is coupled with the output pattern, which is target or desired output pattern. Assume a teacher is be present during the learning process, when comparison is made between the networks, the correct expected output and to determine the error.The error can be used to change network parameters, results an improvement in performance. The set of data which enabled the training is called “training set”.

The main steps to simulate NN on MATLAB are

1) Creating the network (defined type, structure &parameter)
2) Training the network (input, output)
3) Testing the network.

Here, we consider the feed forward neural network with one input layer, 15 hidden layers and one output layer. Transigmoidal and positive linear functions are considered as activation function. The network is tested with least square method.

1) Rectifier Control

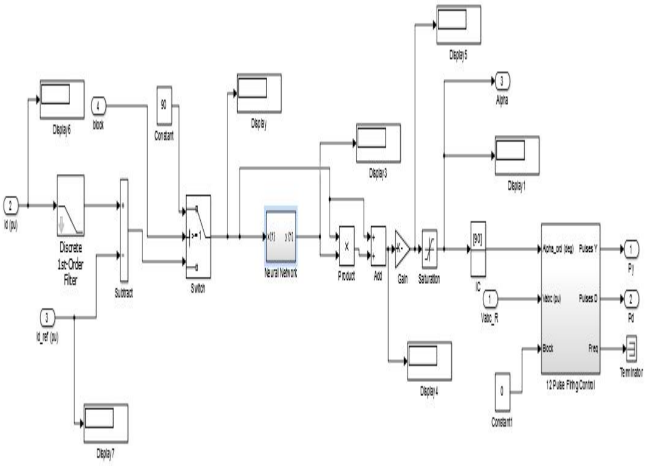


Fig 7.Rectifier control with ANN

2) Inverter Control

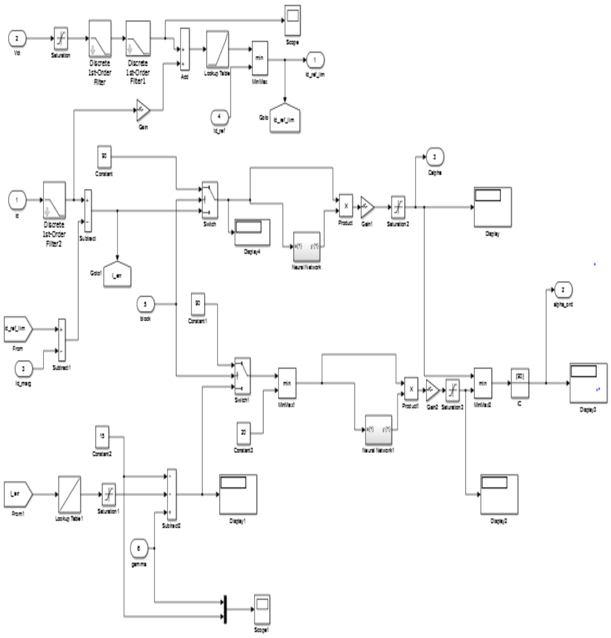


Fig 8. Inverter control with ANN

V. SIMULATION RESULTS AND DISCUSSION

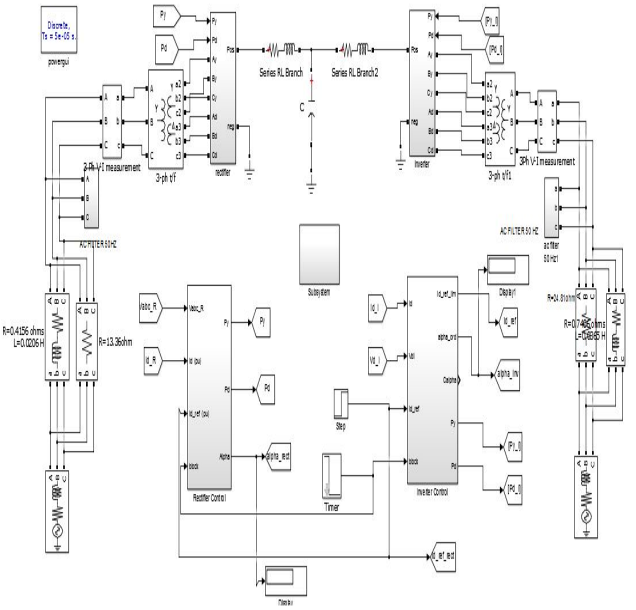
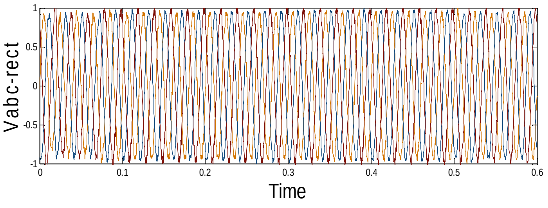


Fig 9. Simulink model of HVDC System



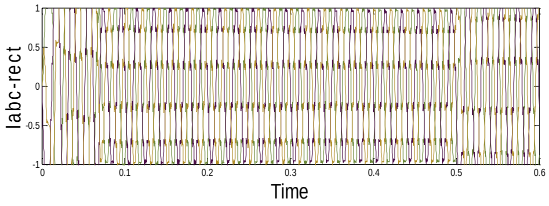


Fig 10.Rectifier side AC Voltage and AC Current

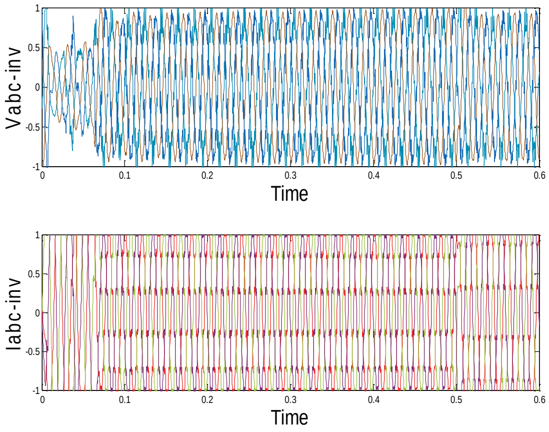


Fig 11.Inverter side AC Voltage and AC Current

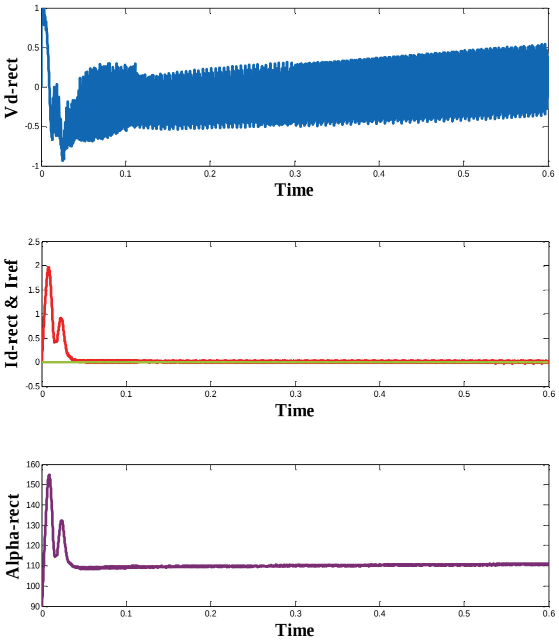


Fig 12. Rectifier side DC Voltage, DC Current and firing angle order with PI controller

From fig 12 By comparision Id-rect and Iref produces an error signal which gives a firing angle order α=15.5 deg.

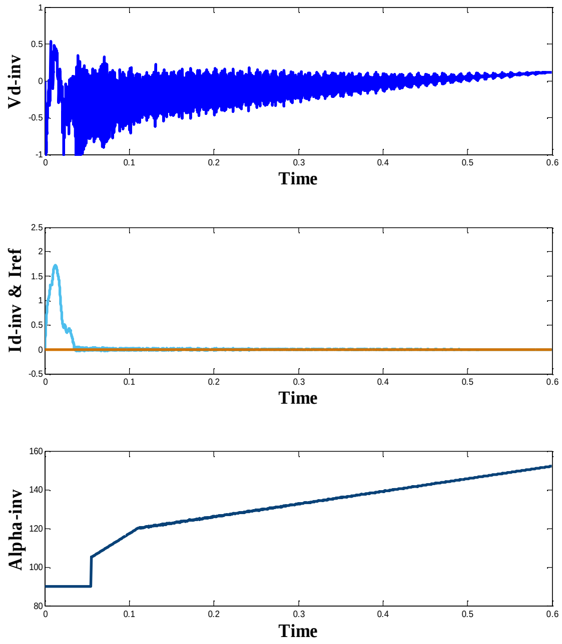


Fig13.Inverter side DC Voltage, DC Current and firing angle order with PI controller

From fig 13 By comparision Id-inv and Iref produces an error signal which gives a firing angle order αinv==134 deg.

The simulation results for the ANN controller is as follows:

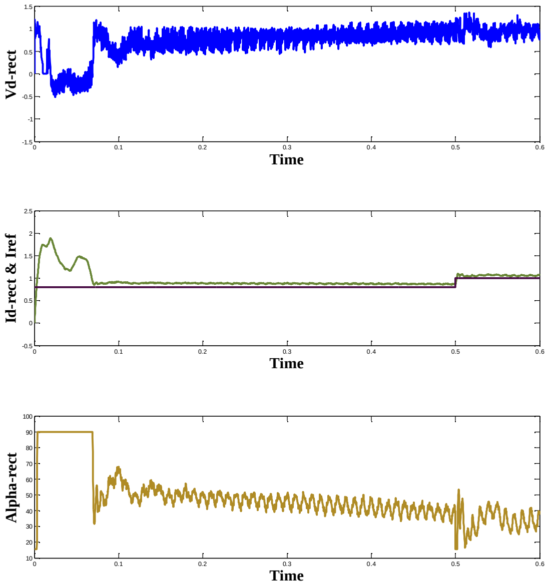


Fig 14. Rectifier DC Voltage, DC Current and firing angle order with ANN

From fig 14, By comparison Id-rect and Iref produces an error signal which gives the firing angle order α=15.5 deg.

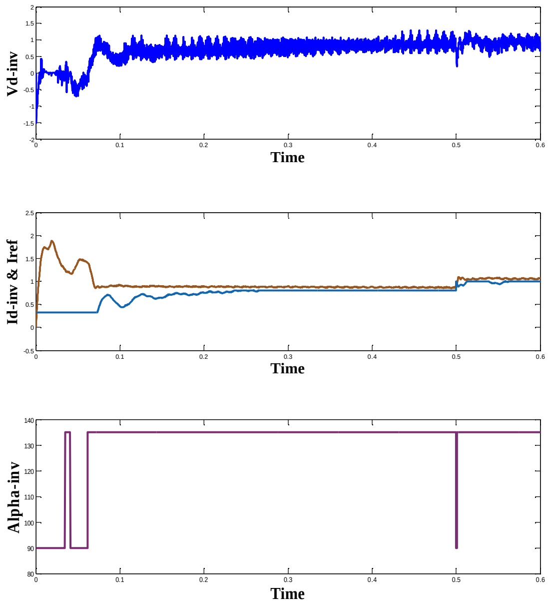
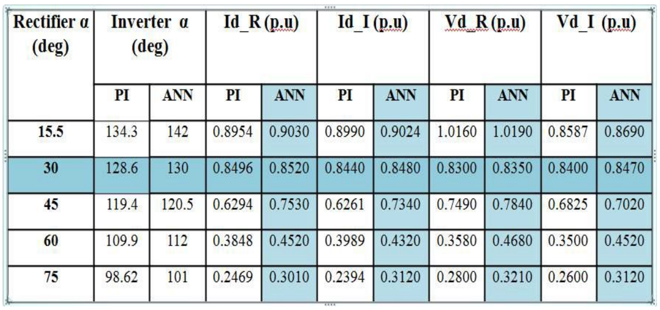


Fig 15. Inverter DC Voltage, DC Current and firing angle order with ANN

From fig 15, By comparison Id-rect and Iref produces an error signal which gives the firing angle order αinv=142deg

This error signal produced is send through Artificial Neural Networks and PI controller. It creates the essential firing angle order which can be used to produce the pulses to control devices in the converter station.



Rectifier α (deg)	Inverter α (deg)		Id_R (p.u)		Id_I (p.u)		Vd_R (p.u)		Vd_I (p.u)	
	PI	ANN	PI	ANN	PI	ANN	PI	ANN	PI	ANN
15.5	134.3	142	0.8954	0.9030	0.8990	0.9024	1.0160	1.0190	0.8587	0.8690
30	128.6	130	0.8496	0.8520	0.8440	0.8480	0.8300	0.8350	0.8400	0.8470
45	119.4	120.5	0.6294	0.7530	0.6261	0.7340	0.7490	0.7840	0.6825	0.7020
60	109.9	112	0.3848	0.4520	0.3989	0.4320	0.3580	0.4680	0.3500	0.4520
75	98.62	101	0.2469	0.3010	0.2394	0.3120	0.2800	0.3210	0.2600	0.3120

Table-1 : Comparision of ANN and PI controllers at different firing angles

Table-1 shows the comparison between artificial neural networks and PI controller at different firing angles.At this instant Artificial Neural Networks is designed for rectifier control and inverter control individually and its performance is compared with conventional PI controller.

VI. CONCLUSION

In this paper, a multi terminal VSC-HVDC system is designed to control the power flow between two converter stations with a conventional PI controller and artificial neural network. The performance of ANN controller with the PI controller is compared to assess the system ability. The PI controller shows a maximum overshoot and settling time with no steady-state error and we conclude that the ANN Controller absolutely conquer various drawbacks of PI Controller like set Point changes, load disturbances and variable Dead Time. The simulation results illustrates that the HVDC system with ANN controller gives improved power flow control for various firing angles.

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