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# COMPARISON OF PI AND ANN CONTROLLER FOR HVDC LINK

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**ABSTRACT**

This paper presents the HVDC system for power system to control the power flow between two converter stations. In this paper, rectifier side is used to control current and inverter side is used to control current as well as extinction angle. In power control system, proportional-integral (PI) controller is widely used. Here we compare its performance with conventional controller and artificial neural network controller. The MATLAB/SIMULINK shows that HVDC controller for power system.

**Keywords:** high voltage direct current (HVDC) transmission, modelling, simulation.

## 1. INTRODUCTION

In general most electricity is generated by using non-renewable energy sources i.e. natural resources such as natural gas, oil, coal, etc. But it is affected on nature or environment and also it depletes rapidly. By considering environmental issues now a day's researchers are considering renewable sources to generate electricity. Renewable energy resource means solar, wind, tidal, etc. Among these resources wind is most attractive resource to generate electricity. According to the U.S. department of energy (DOE) report, wind power installation in 2012 is 90% higher than in 2011 and 30% greater than according to the previous record in 2009. Cumulative wind power capacity grew by 28% in 2012, bringing a total of 60 GW in the United States [1].

An offshore site gives constant and continuous wind as compared to onshore site. Therefore, large wind farms are located in remote areas or offshore to fulfill the required demand. Different types of wind turbine are available in market but recently most popular turbine is doubly fed induction generator. Doubly fed induction generator gives maximum power and also economical than other wind turbines such as permanent magnet synchronous generator.

There are two methods to transmit the power that is High Voltage Direct Current (HVDC) and High Voltage Alternating Current (HVAC). Generally, for medium and short distance (i.e. 50-75Km) High Voltage Alternating Current (HVAC) transmission system is used and for long distance (above 100 Km) High voltage direct current (HVDC) transmission system is used. High Voltage Direct Current (HVDC) transmission is economical and highly efficient technology than High Voltage Alternating Current (HVAC) transmission system [2].

HVDC system is widely used and it plays more important role in long-distance power transmission, large scale power system interconnection, submarine cable transmission, etc. [1]. The operation of HVDC system is mainly depends on the controller and it is strongly controlled. The controller can improve the performance of HVDC system as well as AC parts of the power system.

## 2. CIGRE OF BENCHMARK POWER SYSTEM

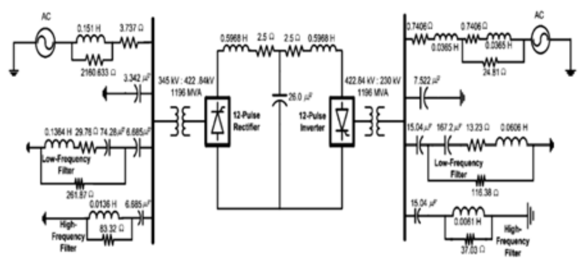


**Figure-1.** Single-line diagram of the CIGRE benchmark HVDC system.

Figure-1 shows first CIGRE HVDC benchmark power system model. This system is mono-polar with rating of 500KV, 1000 MW of HVDC link with 12-pulse converters at rectifier side and inverter side. Weak AC system is connected with converter to provide essential degree of difficulty for DC controls. Short circuit ratios of converters are 205 with rated frequency of 50 Hz. At the rectifier side and inverter side, damped filters and capacitors are connected for reactive power compensation. The power circuits of the converter consist of the following subcircuits.

### A. AC side

In HVDC system of AC side includes Supply network, filters and transformers at rectifier as well as inverter side of the converter. Thevenin equivalent voltage source with equivalent source impedance is used to represent AC supply network. AC filters are used to absorb the harmonics which is generated by converter and also to provide reactive power compensation to the converter.

### B. DC side

It consists of smoothing reactor on both side of the converter that is on rectifier side as well as on inverter side. To represent DC transmission line equivalent T network model is used. To provide a difficult resonant

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condition for the modeled system it is tuned to fundamental frequency.

**C. Converter**

Two six-pulse valves are connected in series to represent 12-pulse converter stations. Generally, each valve is built up with number of thyristor which is connected in series to represent the converter. In which all valve is a (di/dt) limiting inductor and all thyristor consists of parallel RC snubber circuit.

**D. Power circuit modeling**

Two universal bridge blocks are connected in series to model the 12-pulse converters of rectifier and inverter. The rectifier side consists of two converter transformer. In which one is modeled as three-phase two winding transformer with grounded Wye-Wye connection and other is modeled as three-phase two-winding transformer with grounded Wye-Delta connection. Similarly inverter side transformer is also modeled. The converters are interconnected through a T-network.

**E. Three-phase source**

The series combination of R-L circuit is used to model the three-phase AC voltage source.

**F. Control variables for Constant Power Flow Control**

Firing angle (α) / extinction angle (γ) are mainly considered in control model and also generation of firing signals for both the rectifier and inverter. The Phase Lock Oscillator (PLO) is used to generate firing signals. The output signal of the Phase Lock Oscillator (PLO) is a ramp and it is synchronized to the phase-A commutating.

$$Id = \left(\left(Ar*Er/Tr\right)\cos\alpha r - \left(Ai*Ei/Ti\right)\cos\gamma i\right)/\left(Rcr+Rd-Rci\right) \quad (1)$$

$$Edr = \left(Ar*Er/Tr\right)\cos\alpha r \quad (2)$$

$$Edi = \left(Ai*Ei/Ti\right)\cos\gamma i \quad (3)$$

In the control scheme following controllers are used such as:
1. Extinction Angle (γ) Controller, 2. Current Controller, 3. Voltage Dependent Current Order Limiter (VDCOL).

**G. Rectifier control**

Constant Current Control (CCC) method is used in rectifier control. From the inverter side reference is obtained for current limit. It is essentially used for protection of the converter for some situations such as due to fault occur it provide insufficient DC voltage support at the inverter side or due to load rejection, insufficient load requirement at the inverter side. In the rectifier control the reference current is used which is mainly depends upon availability of the DC voltage at the inverter side. Proper transducer is used to measure the DC current by passing through the error signal at the rectifier side. Firing angle order is produced by passing error signal through the PI controller. To generate equidistant pulses which are required for valves, above technique is used by the firing circuit which gives information.

**H. Inverter control**

At the inverter side, extinction angle (γ) control and current control is implemented. The combination of Constant Current Control (CCC) and Voltage Dependent Current Order Limiter (VDCOL) is used and it is passed through PI controller. By comparing Voltage Dependent Current Order Limiter (VDCOL) output and external reference, we get reference limit for current control. The angle order is obtained by subtracting the measured current and the reference limit. For inverter, gamma angle order is obtained from another PI controller which used in γ control. Firing instant is calculated by comparing two angle orders and minimum value is selected for measuring the firing instant. The time between thyristor current extinction and thyristor commutation voltage becomes positive which is denoted by gamma and it expressed in degree. To change the time value as electrical degree, we used the system frequency. The current threshold gives the current extinction time. At the converter transformer, three-phase-to-ground AC voltages gives six commutation voltages and six thyristors are gives the six gamma angles. In control action minimum value of gamma is considered. To obtain error signal by comparing gamma output and reference gamma. Gamma output is obtained from a 12-pulse converter which gives two values of gamma and selects a minimum value of gamma output for consideration of error signal. To obtain firing pulse by comparing firing angle order which is obtained from the constant current controller and from the constant extinction angle controller and select a minimum value for valves. To measure the DC voltages and current use proper voltmeter and ammeter. To measure three-phase voltages and currents use three-phase VI measurement blocks. “From” and “Goto” blocks are used for signal routing and scope is used to display.

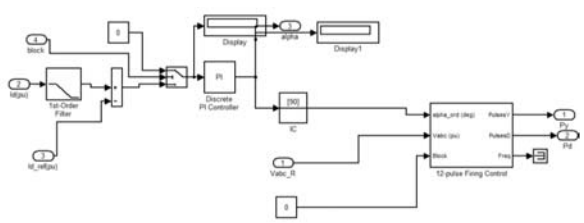


**Figure-2.** Rectifier control with PI.

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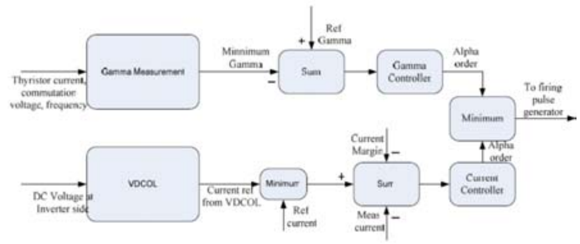


**Figure-3.** Inverter control with gamma measurement technique.

## 3. ARTIFICIAL NEURAL NETWORKS

An Artificial Neural Network (ANN) is also called "Neural Network" (NN). It is a mathematical model which is based on biological neural network. It contains interconnected group of artificial neural. This artificial neural network uses connectionist approach to process the information. An Artificial Neural Network has been an adaptive system which changes system structure. It is based on internal and external information which is obtained from network at the time of learning phase. ANN is a non-linear statistical data modelling tools. It is used to model complex relationship between inputs and outputs. Fig.4. shows Artificial Neural Network. In which $x_1$, $x_2$.....$x_m$ represents the m inputs, $w_{k1}$, $w_{k2}$......$w_{km}$ represents weight attached to the links.

For the above model

$$U_k = \sum_{j=1}^{m} \left( W_{kj} X_j \right) \quad (4)$$

$$V_k = U_k + b_k \quad (5)$$

The bias $b_k$ has the effect of increasing or lowering the input of the activation function.

$$y_k = \varphi \left( U_k + b_k \right) \quad (6)$$

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

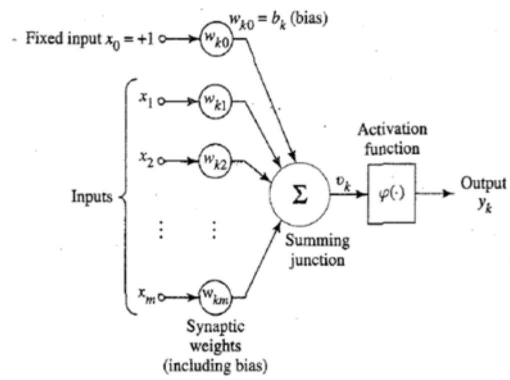


**Figure-4.** Artificial Neural Network.

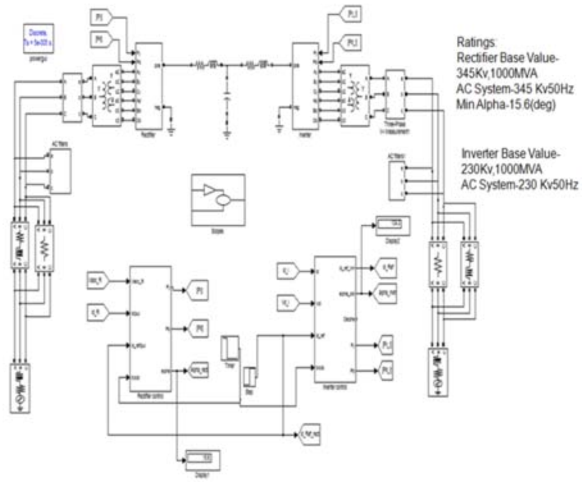


**Figure-5.** Simulink model of HVDC system.

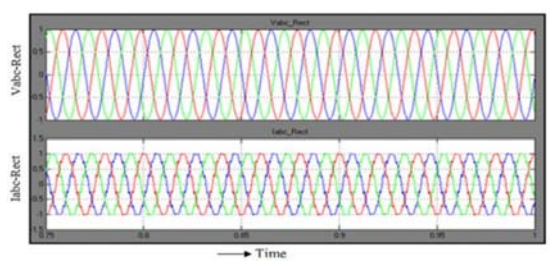


**Figure-6.** Rectifier side AC voltage and AC current.

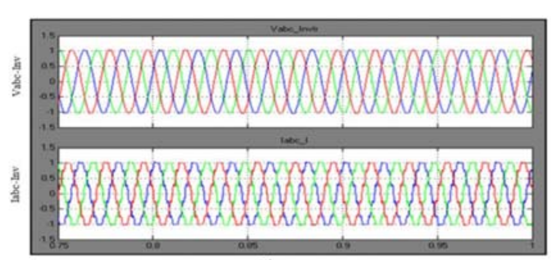


**Figure-7.** Inverter side AC voltage and AC current.

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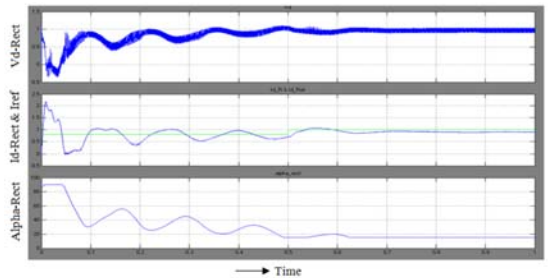


**Figure-8.** Rectifier side DC voltage, DC current and firing angle order with PI.

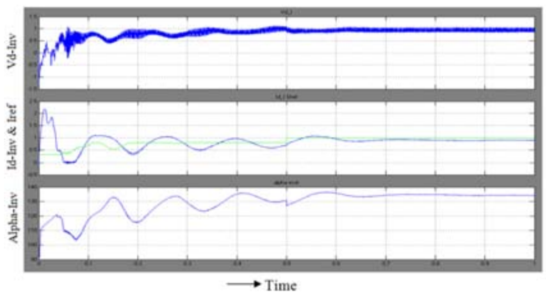


**Figure-9.** Inverter side DC voltage, DC current and firing angle order with PI.

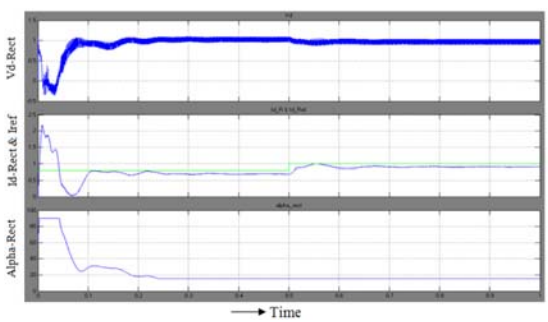


**Figure-10.** Rectifier side DC voltage, DC current and firing angle order with NN.

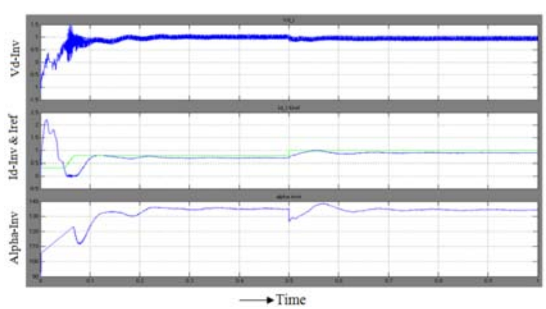


**Figure-11.** Inverter side DC voltage, DC current and firing angle order with NN.

## 4. CONCLUSIONS

This paper shows that HVDC system is constructed for power flow control between the two converter stations by considering conventional and artificial controller. Current control method is used for rectifier side. Current and extinction angle control method is used for inverter side. Alpha is maintained to minimum value to transfer maximum power in the DC link. Firing angle order is obtained by passing an error signal through proportional integral and artificial neural network controller. Here we design a HVDC link with PI controller and its performance compare with artificial network controller. By comparing above results it shows that artificial neural network controller gives better performance.

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