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Title

FREQUENCY CONTROL IN INTERCONNECTED A.C. SYSTEMS THROUGH HVDC LINK USING ARTIFICIAL INTELLIGENCE

Author(s)

Dr. Anil Kumar Sharma

Associate Professor,

Department of Electronics and Communication Engineering

Institute of Engineering and Technology, M.I.A.,

Alwar-301 030, Rajasthan, India

Dr. G. K. Joshi

Professor,

Department of Electrical Engineering

M.B.M. Engineering College, J.N.V.U.,

Jodhpur-342 011, Rajasthan, India

Abstract:

The Load frequency control in HVDC system has gained importance with the growth of interconnected systems. Hence greater reliance is being placed on the use of special control aids to enhance system security, facilities and economical design, and to provide greater flexibility of the system operation. Hence the need for bulk power transmission has shifted the interest to the HVDC transmission system viz-a-viz the EHV-AC system. Further it possesses the art of smart and useful application of controlled rectifiers and inverters. The controlled inverter operation can successfully modulate the power flow in HVDC link, leading to fulfillment of power demand in A.C. network, caused by sudden rise in loads. This in turn enables the restoration of power frequency in A.C. network. Due to frequent sudden loading and unloading of A.C. networks the frequency in the network continues to be always away from standard power frequency value. In this paper we have developed a controller which maintains the power frequency in A.C. network. Further there is a rich scope of saving of energy and yet maintaining the power frequency in A.C. networks by way of electronic switching of thyristors.

Keywords: Firing Delay Angle (α), Governor Control, HVDC Link, Power frequency, SCR.

Introduction:

Increasing load demand and widening geographical gap between the generation centre and the load centre are posing the need for bulk power transmission and interconnection of two and more A.C. networks. Sometimes A.C. networks with different power frequencies are also required to be interconnected for the purpose explained above. This objective can easily be fulfilled by using HVDC link/transmission system. Since every A.C. network is primarily controlled by the consumer's need for the power, the load keeps on varying every new moment. This in turn causes frequency of power supply to deviate from standard power frequency value. This state may lead to loss of stability and shutdown of plant besides being uneconomical. Further there is an indispensable need of maintaining frequency of supply at power frequency level. This kind of deviation may either be persistent or of divergently expanding nature, if the power demand is not met with equivalent power supply. A power matching state with load variation is the prime need for restoration of power frequency. In order to effectively utilize the generation point by point the controller is developed which will utilize every pint of power. The aim is to achieve firing delay angle (α) control so that governor settings are not disturbed till the power generation corresponding to given setting find passage through HVDC link to feed the load demand. In order to make firing angle (α) control in thyristors more dependable and realistic it has been implemented with Neuro-Fuzzy approach. The developed controller works successfully as proved by testing and illustration. The power matching after full opening of D.C. power flow corresponding to α_{min} state is achieved by changing the governor settings. This is enabled for $(P_{HVDC})_{max} < P_{demand} \leq P_{rated}$. Further when power demand exceeds the rated power of generator the only option left is to go for load shedding. This approach intends to provide a fine control for restoration of power frequency with a yield of financial resource savings for addition of new plants.

State of Art:

Power engineers have the responsibility to deliver economical, adequate and standard quality power to its consumers. The term standard power quality means the power supplied at a specified load should have characteristics such as standard sinusoidal voltage, current waveforms with standard frequency. But these attributes of power supply suffers sharp deviation from their standard values due to varying nature of the load which is in the hands of consumer. In order to overcome this, the power system must be maintained at the desired operating level by implementing modern control strategies. The HVDC link offers major advantages in meeting these requirements. The applications of power electronic devices in A.C. power systems provide attractive benefits of economics and innovative technologies. Due to unnecessary error in the past, conventional PI controller does not provide adequate control performance. The difficulty in obtaining the optimum settling time of previously said controller is mitigated by using Neuro-Fuzzy controller. The requirements of an optimal control of Load Frequency Controller (LFC) system for HVDC transmission are:

- Sufficient stability margins and control speed of response when the ratio between A.C. networks short-circuit capacity and transmitted power is low.
- Correct rectifier/inverter operation at frequency variations-very large frequency deviations may be obtained when the HVDC transmission is the only load to a power station.
- Low amount of abnormal harmonics generated by the converters- this leads to equidistant firing i.e. equal distances between all consecutive firing instants in steady state.
- Safe inverter operation with fewest possible commutation failures also at distorted alternating voltages e.g. due to earth faults.
- Lowest possible consumption of reactive power, i.e., operation with smallest possible delay angle α, and extinction angle γ, without increased risk for commutation failures.
- Smooth transition from current control to extinction angle control.

The Basic HVDC System:

The most commonly used configuration of HVDC power transmission systems is the bipolar circuit, which has two insulated conductors used as +ive and -ive poles. The two poles can be used independently if both neutrals are grounded. This increases the power transfer capacity. Under normal operation the currents showing in each pole are equal and there is no ground current. In case of failure of one pole power transmission can continue on the other pole, so its reliability is high. Most overhead line HVDC transmission systems are bipolar. Figure 1 shows a model of Bipolar HVDC Link.

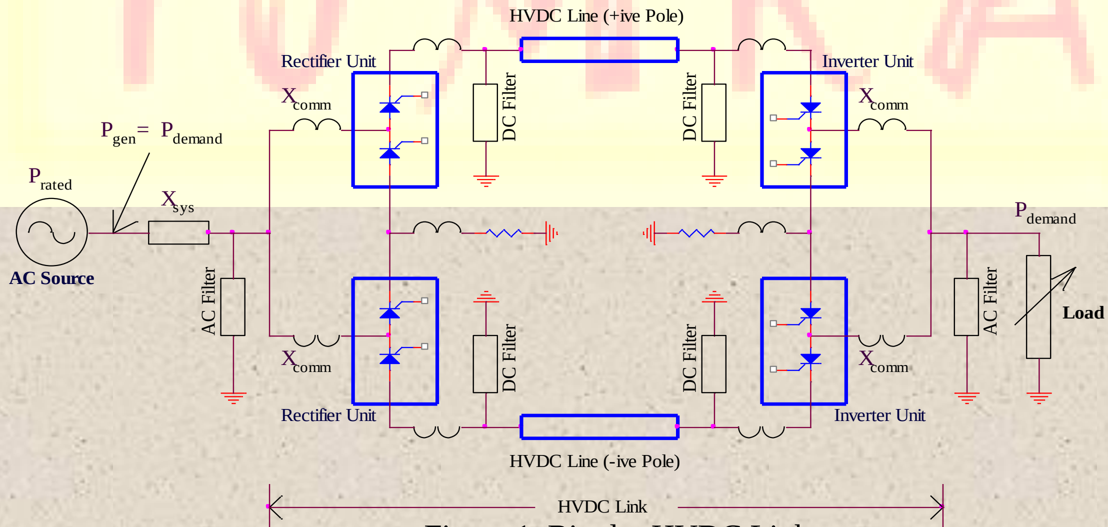

Figure 1. Bipolar HVDC Link

The HVDC converters are the heart of HVDC system. They convert A.C. into D.C. i.e. rectification at sending end and D.C. into A.C. i.e. inversion at receiving end. The 3-phase internal equivalent configuration of rectifier unit and inverter unit is as shown in Figure 2, Figure 3 respectively with its 3-phase A. C. Waveform in Figure 4.

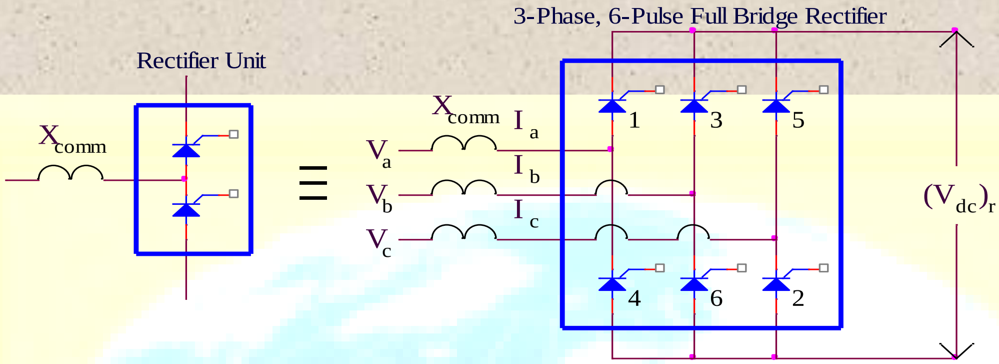

Figure 2. The Equivalent Rectifier Unit

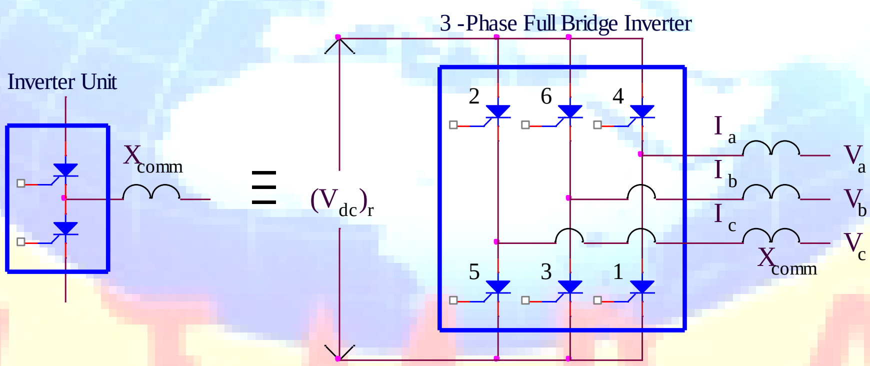

Figure 3 The Equivalent Inverter Unit

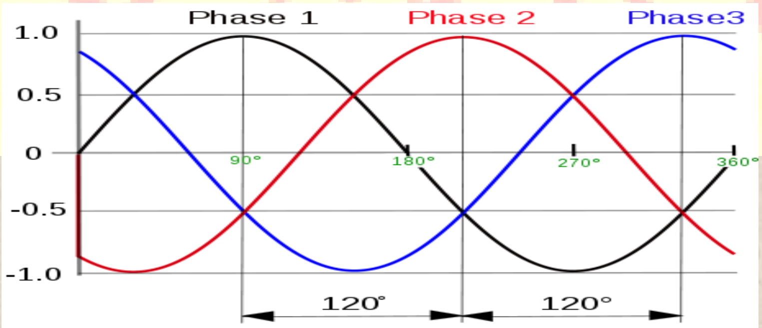

Figure 4. The 3- Phase A.C. Waveform

Causes of Loss of Frequency in HVDC system:

It is due to various changes occurring in the load such as sudden increase in load within capacity, sudden decrease in load within capacity, presence of transients due to switching and overload beyond capacity. The loss of frequency is observed between the periods when disturbance in the load starts and the generator resets with a new load demand. The crux of the problem is that the source will have to reset its dynamics of operation. This can firstly be adjusted without the source to disturb but the HVDC link to reset. It is intended that the source is not allowed to change its supply but to use the held up power within HVDC link. The objective is to utilize the reserve available in HVDC link without affecting the supply level upto certain limit. Further when HVDC link transmits full power the generation can be increased to meet the increasing load demand till its maximum capacity is reached. The objective is therefore to make optimum utilization of generation by regularly correcting power flow through HVDC link. This part works only till the generator works within its capacity. However when the load changes are beyond its capacity the controlling measure include driving of power from interconnected system where the load is quite low. This is understood in this part that all the possibility of governor and fuel settings for increasing the supply on the production of power demand has reached its maximum capacity, thus supporting the generation within its capacity. The role of the control provided to HVDC link through developed Intelligent Controller is to supplement the generator for meeting the increased power demand without making generator to reset its parameters..

The Proposed Frequency Controller and Simulation Results:

The model of proposed frequency controller is shown in Figure 5.

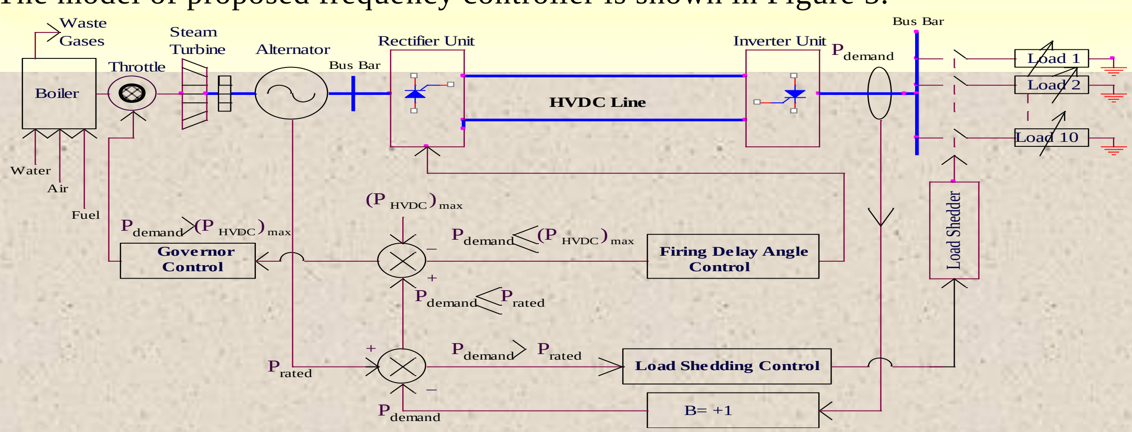

Figure 5. The Model of Proposed Frequency Controller

The power demand (P_{demand}) is sensed at the output and compared with the generation capacity (P_{rated}) of the generator. If $P_{demand} > P_{rated}$ the control gives command for load shedding. Then If $P_{demand} \leq P_{HVDC}$ the controller adjust the firing delay angle (α) to ensure $P_{demand} = P_{HVDC}$. This is done to arrange power matching and therefore restoration of power frequency. Thus the generator capacity is utilized to its optimum level thus this facility can be employed till P_{demand} is $\leq (P_{HVDC})_{max}$. If the power demand is such that $(P_{HVDC})_{max} < P_{demand} \leq P_{rated}$, the Governor control is executed to establish power matching leading to restoration of power frequency. The P_{HVDC} output has been obtained for Mathematical Model and Tested Using MATLAB. The values of Alpha Vs their corresponding P_{HVDC} value is shown in Table 1. and its corresponding graph in Figure 6. The restoration of power frequency is nothing but power matching. A most practical and significant logic for restoration of power frequency affected by load disturbance in HVDC transmission system lies in 3-stages to provide comprehensive control. This is shown in Table 2.

Table 1. Firing Delay Angle V_S P_{HVDC}

Sl.No.	Firing Delay Angle(α) Degrees	P_{HVDC} (MW)
1	5.0065	1455.4674
2	5.7287	1445.2584
3	6.5312	1432.3727
4	7.3336	1417.8926
5	8.1361	1401.8515
6	8.9385	1384.2866
7	9.741	1365.2387
8	10.5434	1344.7518
9	11.3459	1322.8736
10	12.1483	1299.6546
11	12.9508	1275.1487
12	13.7532	1249.4127
13	14.5557	1222.5063
14	15.3581	1194.4917
15	16.1606	1165.434
16	16.963	1135.4005
17	17.7655	1104.4607
18	18.5679	1072.6864
19	19.3704	1040.1513
20	20.1728	1006.9307
21	20.9753	973.1017
22	21.7777	938.7426
23	22.5802	903.933
24	23.3826	868.7538
25	24.1851	833.2863
26	24.9875	797.6128

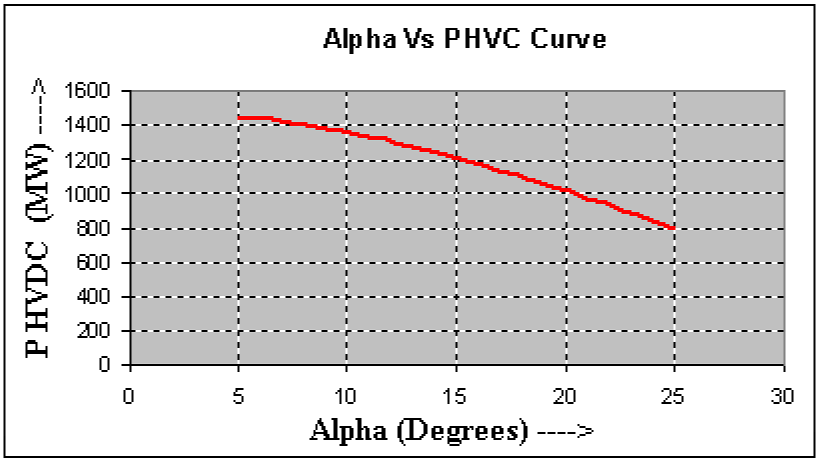

Figure 6. The Curve between Alpha Vs P_{HVDC}

Table 2. The 3- Stage Control of LFC

Stage	Condition	Control Action
Stage-1	$P_{demand} > P_{rated}$	Go for load shading Control
Stage-2	$P_{rated} \geq P_{demand} < (P_{HVDC})_{max}$	Go for α - Control
Stage-3	$P_{rated} \geq P_{demand} > (P_{HVDC})_{max}$	Go for Governor Control

The ANN model for P_{HVDC} vs α of proposed LFC was developed using MATLAB. For its training and testing we had used the data of 100 samples of daily load curves on 24 hours basis. A sample of daily load curve with its corresponding α is shown in Figure 7. The resulting error between the $\boldsymbol{\alpha}_{math}$ and $\boldsymbol{\alpha}_{ANN}$ is shown in Figure 8.

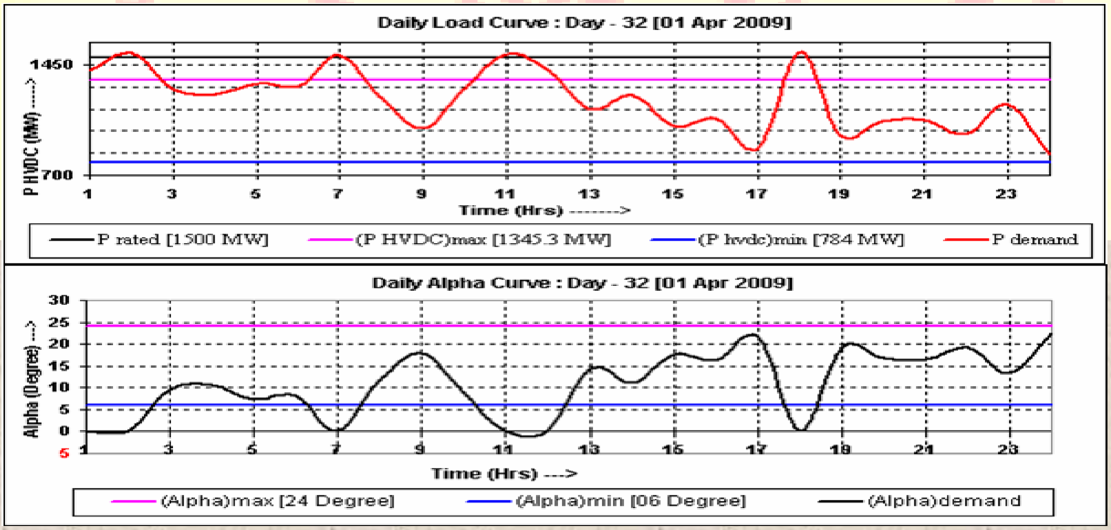

Figure 7. A Graph of Daily Load Curve Vs Required Alpha

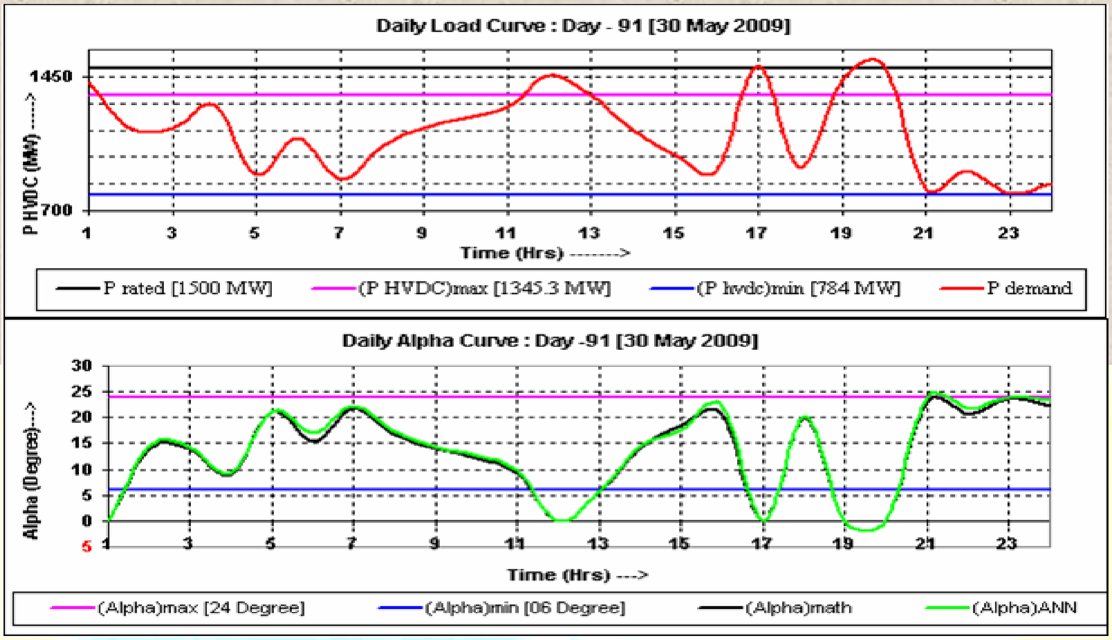

Figure 8. Graph showing the Actual and ANN obtained value of Alpha

Conclusions:

In the present paper the Frequency Controller has been successfully implemented and tested with ANN tool of Simulink on MATLAB. The smooth control of power frequency has been achieved with bulk power transmission. The results are highly encouraging. Further the proposed model can be tested and implemented on the National/International power grid.

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