International Journal of
Emerging Research in Management &Technology
ISSN: 2278-9359 (Volume-4, Issue-6)

Research Article

June 2015

Study of Fundamental Regulators for Control of HVDC Transmission System

[1]Amita, [2]Ramavtar Jaswal
[1]M.Tech(EE),UIET Kurukshetra University, Kurukshetra, Haryana, India
[2]Assistant Professor, Department Of EE, UIET, Kurukshetra University, Haryana, India

Abstract:

This document gives an overview of the HVDC Control System .Control of HVDC transmission is necessary so that the whole system work properly.The loss of transient stability in a power system is due to overloading of some of the lines (or due to severe line faults), as a consequence of tripping off of the other lines after faults or heavy loss of loads. By means of rapid and flexible control over the ac transmission parameters and network topology, HVDC controller can facilitate power control, enhance the power transfer capacity, decrease the line losses, increase power system damping and improve the stability and security of the power system.

Keywords: HVDC Transmission, , HVDC Control Voltage Dependent Current Order Limiter, Commutation FailurePrevention Control,master control,voltage controller

I. INTRODUCTION

There has been rapid development in the areas of controland protection equipment for power system applications in recentyears. This has been made possible mainly due to general electronic development. The power transmission through HVDC technology is now emerging and experiencing rapid increases in the voltage, power carrying capacity and length of transmission lines. While comparing with three phaseHVAC transmission systems, HVDC system is commendable in the following portions: (a) HVDC line cost and operating cost are less, (b) it need not to operate synchronously between two AC systems linked by HVDC and (c) it is simple to control and adjust the power flow . Generally, the HVDC system is composed of three major parts: (a) rectifier station to convert AC to DC, (b) transmission link and (c) inverter station to convert back to AC. Most of the HVDC systems have a line commutated converter. The LCC-HVDC system naturally absorbs a large amount of reactive power in rectifier stations and inverter stations. By means of filters and/or reactive power compensators connected to the primary side of the converter transformer, the reactive power is supplied to HVDC systems. Various control techniques are employed for the control and protection of the line and converter .

The major advantage of an HVDC transmission is its built in ability to control the transmitted power between the sending and the receiving converter terminals, the former called rectifie**r** and the latterinverter. This **c**ontrollabilitycan be utilized for the stabilization of the connected AC network,to control the frequency of a receiving, islanded network and to assist the frequency control of a generator, connected to the HVDC transmission rectifier. The reactive power, that the HVDCconverter consumes, is depending on the values of the control angles. Thus, the exchange of the reactive power between the converter and the AC network can be controlled and the AC voltage can be stabilized. Also, combined active and reactive power generation can be applied when foundadvantageous. The basic concept to control an HVDC transmission is the possibility to set the DCvoltage across the converter valve bridge and the transmitted power by varying the phase position of the gate control pulses to the converter valves.

The primary function of HVDC controls are:

1) Fast and flexible power control between the terminals under steady state and transient operation.
2) Better stability of ac system.
3) Fast protection of ac and dc system faults.

i) it minimizes over voltage across the valves
ii) it reduces the short circuit current through the valves and lines/cables
iii) it reduces the reactive power consumption
iv) avoids repetitive commutation failures

These above advantages are achieved by varying exact firing instant of valves. The converter firing control which determines the firing instants for each valve to determines the rated DC voltage. The input for the firing control system could be the output of current control, voltage control, gamma control.Traditionally rectifier controls the current and inverter operates with constant commutation margin under normal operation.

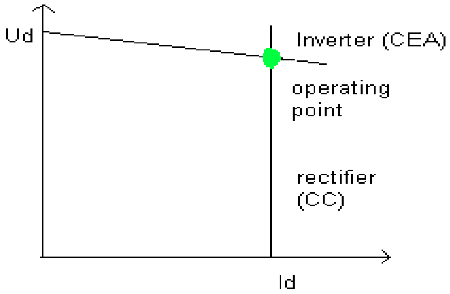


Fig.1 Ud Id characteristics of converter

Under steady state, typically rectifier would be act as constant current source i.e. constant current control and inverter will operate as constant counter voltage source i.e. constant extinction angle. The current order at the rectifier is determined by the manipulation of power order and inverter dc voltage. To maintain stability at rectifier, it is necessary to have less (Idref– Id) deviation in dc current and also (΄ϒmeas-΄ϒref) deviations should be keep as low aspossible for inverter stability. The intersection of two modes gives normal operation point.

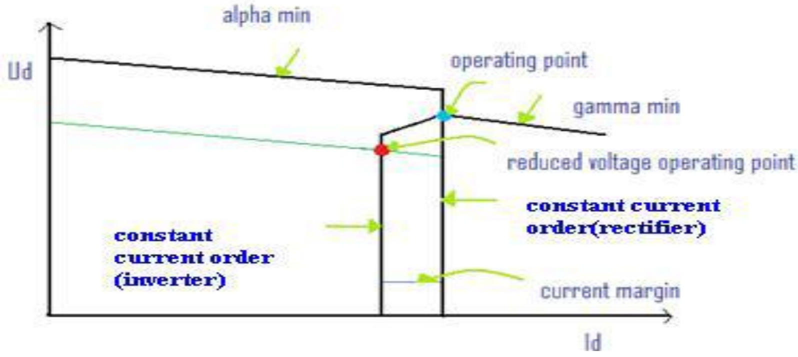
II. REGULATOR FUNDAMENTALS

Alpha-minimum characteristics at rectifier:

This characteristics is determined by the equation shown below, Udc = Udio cosα –(dxn+drn).(Udion/Idcn).Idc The above equation determines the dc voltage across the converter. If we assume practical minimum alpha of 5 degrees in order to have certain voltage across the valve before firing and transformer reactance (dxn + drn)cosαUdi0N/Idcnare also always constant. Hence, increasing dc current reduces the dc voltage i.e. negative slope determined by the transformer reactance and dc current (reduced voltage due to overlapping of valve currents).

Constant current characteristics at rectifier:

This characteristic could also be explained by the above same equation ,by assuming current as constant and alpha as variable. It can be seen from the figure 5.2 that higher dc voltage at minimum alpha and increasing of alpha decreases the dc voltage. The direct current is determined based on the current order, which could be selected between minimum current capability and the rated current of valves.



.

Fig.2 Ud-Id characteristics with VDCOL

Constant extinction angle characteristic:

Inverter is normally operating as alpha-max or constant commutation margin mode in order to have certain extinction angle to commutate the valves without fail. Under normal operation, inverter operates at γ=17 at 50Hz, it is not recommended to increase or decrease to limit reactive power consumption and avoid commutation failure. At steady state, inverter operates normally as constant dc voltage control mode.

Alpha minimum at inverter:

The power reversal could be obtained by increase the current order of the inverter higher thanrectifier. In case of dc line fault, it is recommended that both converters should operate as inverter to make the fault current in dc line to zero as fast as possible. If there is no minimum alpha limit at inverter, it could also operate as rectifier by reduced alpha cause feeding of dc fault. Therefore, always minimum alpha at the inverter is limited to 110 degree.

III. VOLTAGE DEPENDENT CURRENT CONTROL LIMITER (VDCOL)

This control, named Voltage Dependent Current Order Limiter (VDCOL), automatically reduces the reference current (Id_ref) set point when VdL decreases (as, for example, during a DC line fault or a severe AC fault). Reducing the Id reference currents also reduces the reactive power demand on the AC system, helping to recover from the fault.The Id_ref value starts to decrease when the Vd line voltage falls below a threshold value VdThresh. The actual reference current used by the controllers is available at the second controller output, named Id_ref_lim. IdMinAbs is the absolute minimum Id_ref value. When the DC line voltage falls below the VdThresh value, the VDCOL drops instantaneously to Id_ref. However, when the DC voltage recovers, VDCOL limits the Id_ref rise time with a time constant defined by parameter Tup.

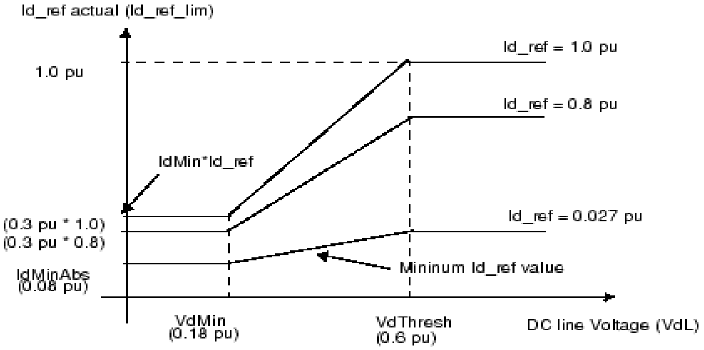


Fig.3Voltage dependent current order limiter

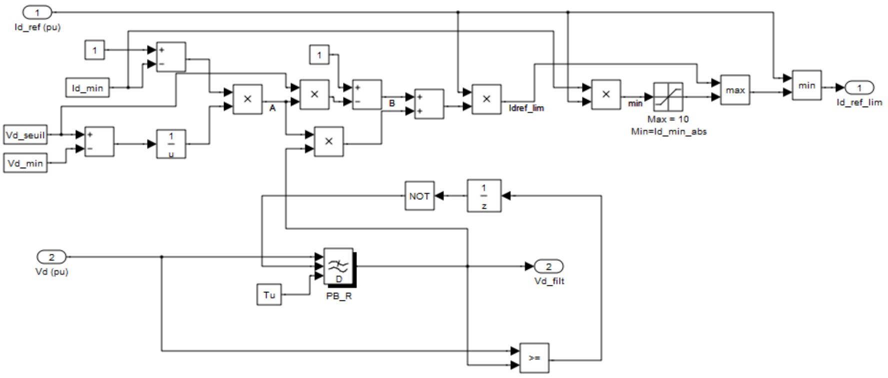


Fig.4 matlab model of VDCOL

CURRENT CONTROL AMPLIFIER (CCA):

The current control amplifier is used as the main function which used to control the firing angle of the converter under steady state and dynamics of HVDC system. The current controller is basically a Proportional and Integral regulator. As we all know the proportional part helps to give fast response with respect to the feedback and integral part is aslower part which used to make steady state error zero. The current error (Iorder-Idc) is send as input to the PI regulator. It gives out alpha order as output to the converter firing control. Traditionally, rectifier will operate as current controller in order to have optimal operation point with reduced consumption of reactive power. Direct current is indirectly regulated by controlling the firing angle of the thyristor.

During steady state, current order IoLIM from voltage dependent current order limiter (VDCOL) and measured dc current are same; hence the error of zero would be send to the saturated PI regulator in current control amplifier. In contrary, during transients IoLIMwould be varied as a function of dc voltage when the dc voltage hits the breakpoint of VDCOL, the error of IoLIM and measured current will be sent to PI regulator with maximum limit (AMAX =166) and minimum limit (AMIN = 5).

VOLTAGE CONTROLLER:

The input for the voltage regulator is measured direct voltage and reference voltage error. The maximum and minimum limits of PI regulator are determined by the direct current (ID low). If the direct current is less than Idlowref value, maximum and minimum limits are manipulated by normal dc voltage equation $\alpha = \cos{-1}(Ud/Udio)$.

GAMMA MINIMUM REGULATOR:

The Gamma minimum regulation mode at the inverter is used for dynamic stability purposes. The inverter's reactive power consumption depends on its Gamma angle. With weak AC systems, the Gamma regulation mode is essential to ensuring voltage stability, and at times Gamma angle modulation may also be used for reactive power regulation. With weak AC systems, a DC current variation at the rectifier will cause larger AC voltage variations at the inverter AC commutation bus. Since DC voltage is directly dependent on the inverter side AC voltage, such deviations may result in DC power flow perturbations, thereby causing dynamic stability issues. Using the Gamma regulation mode will reduce the probability of commutation failures since this mode helps prevent extinction angles (Gamma) from reaching a value that is lower than the specified minimum Gamma. Allowing for operation in Gamma minimum regulation mode will modulate power flow and contribute to overall system stability. For a given thyristor, the Gamma angle is defined asthe delay between the fall time of the thyristor current and the positive zero-crossing of thevoltage . All 12 thyristors of an inverter are monitored for individual Gamma angle measurement, and the minimum measured Gamma over one cycle is used as a feedback to the Gamma minimum regulator.

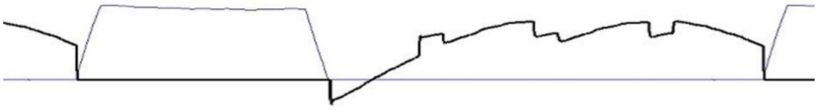


Fig.5- Gamma angle measurement principle

PULSE GENERATION UNIT:

The pulse generation unit is comprised of a 12-pulse generator that outputs sequentially firing pulses to the thyristor valves. A PLL is employed to synchronize the 12-pulse firing pulse generator, according to commutation voltage zero-crossings. The PLL is capable of precisely measuring the fundamental frequency and the instantaneous angle of the voltage. It outputs the sinusoidal waveforms of the three-phase voltages (with unitary amplitude) to the pulse generator that will synchronize on zero-crossings and activate the firing signals with a delay given by Alpha order (from the regulators). The PLL also outputs the measured frequency which is used by the Gamma measurement unit to convert the measured Gamma "time delay" to a Gamma "angle" value. The PLL can also adapt to phase and frequency variations on the AC network. The 12-pulse generator inputs the three-phase unitary sinusoidal signals given by the PLL and calculates all the instantaneous sinusoidal waveforms needed to synchronize each thyristor firing.

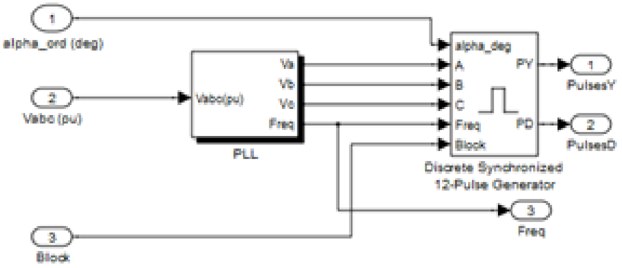


Fig.6 Matlab model of pulse generation unit

MASTER CONTROL:

Master control generates the reference currents for the Rectifieras well as Inverter. To avoid loss of margin these rectifier andinverter reference currents should be equal. The converter startingand stopping is ignited by the master controller and the currentreference can be ramped up or down. A current step can be addedto the current reference for testing purpose. At start up bothconverters are de blocked and ramped up to minimum currentallowed in steady-state with an adjustable time in the "Start/Stop&ramping unit" subsystem. After the system stabilization the current is ramped up to its final value with an adjustable rateand execution time. Before stopping the converters the current isramped down to the minimum reference.In the Master control, pulse generators are de-blocked and thepower transmission started by ramping the reference current at particular time.

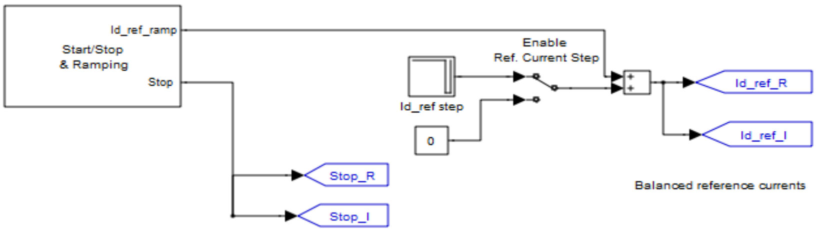


Fig.7 Matlab model of master control

COMMUTATION FAILURE PREVENTION CONTROL:

It is not possible at all to avoid commutation failure at inverter when sudden increase of dc current and decrease of commutating voltage. However, it could be possible to avoid subsequent commutation failures during the high remaining voltage fault at inverter ac network by advancing the firing angle in order to increase the commutation margin. This makes the system could transfer power during disturbance. There are two possibilities for commutation failure such as commutation voltage reduction or distortion and phase angle jump at unbalanced fault. Therefore, two different sets of control function used to avoid consecutive commutation failure caused by balanced and unbalanced fault. Since the reduction of voltage at single phase fault is not severe as three phase fault, but creates phase shift. So the unsymmetrical fault is detected by zero sequence voltage detection, then it compared with pre-defined voltage level, if zero sequence voltage is lower than predefined level, it advances the firing angle and keeps it for whole fault duration. Symmetrical fault will not give zero-sequence, therefore it directly compared with predefined value and voltage (prefault voltage – fault voltage) difference, it will decrease the firing angle if the difference is higher than predefined value. In brief, the three phase voltages are transformed to dc quantity by alpha-beta transformation; it gives dc output only when the three phases are symmetrical. However, three phase fault will not decrease the voltage instantaneously in all the phases, it decrease the voltage phase by phase hence creates negative sequence the same happens when clearing the fault.

Therefore, oscillations will occur in alpha-beta output. It is not possible to compare the oscillating waveform with pre-fault voltage, so max-hold function is used here tokeep the maximum value for half cycle.

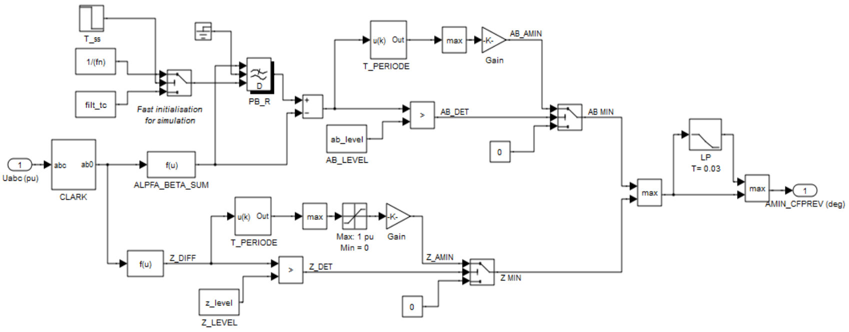


Fig.8 Matlab model of CPREV

IV. COCLUSION

This document gives an overview of the HVDC Control System**.**The key for understanding how an HVDC transmission operates is to knowthe basic principles of the HVDC Control system functions. The HVDC controlsare modeled in detail in MATLAB .

REFERENCE

[1] TorbjörnKarlsson, Mats Hyttinen, Lars Carlsson and Hans Björklund , "Modern control and protection for HVDC".
[2] A.Tirupati Rao, P.Ramana, P. Kanata Rao, "Modeling of CIGRE HVDC Benchmark System in MATLAB/ SIMULINK".
[3] D.Madhan Mohan, BhimSingh ,B.KPanigrahi"HVDC Technology for Power Transmission", July 2008, ElecticalIndia
[4] Lidong Zhang, Lars Dofnas,"A Novel Method to mitigateCommutation Failures in HVDC systems", Internationalconference on power systems technology 2002, proceedings.Poercon -2002, Vol. 1.
[5] K.R.Padiyar,"HVDC power Transmission Systems".
[6] E.W.Kimbark, "Direct Current Transmission, vol.I, Wiley-Interscience",1971.
[8] Dr. M. Davies, A. Kölz, M. Kuhn, D. Monkhouse, J. Strauss, "Latest Control and Protection Innovations Applied to the BasslinkHVDC Interconnector"
[9] J.Arrillaga, Y.H.Liu, N.R:Watson ,"Flexible power transmission- the HVDC options"
[10] Kundur, P. "Power system stability and control" Newyork: McGraw-Hill Publications.