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Fuzzy Logic Controller Based on Voltage Source Converter-Hvdc System

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Abstract— This paper suggests a Shrinking Span Membership function to be utilized in very fact changing system like VSC-HVDC system. The fast control capability of the VSC-HVDC and process of area mode oscillations are analyzed. An auxiliary Fuzzy Logic Controller designed in MATLAB/SIMULINK for the Voltage Source Converter based HVDC transmission system, to improve the stability by decreasing the deceleration energy of oscillation. VSC applications are not only used in HVDC but also includes in FACTS and Wind generators and Active filters. The VSC based HVDC system is very attractive an option for bulk power transmission over long or short distances and the grid integration of renewable energy sources in existing transmission and distribution systems. The precise control of active and reactive power flow to maintain the system voltage stability is the main requirement in a power transmission system. Here both active and reactive power can be controlled independently of one another. In the case of power reversal, there is no change in the DC voltage polarity for VSC based transmission system and it depends only on the direction of DC current. Furthermore, the reactive power flow can also be bi-directional depending on the AC network operating conditions. In this work, a3-phase, 2-level, 6-switch VSC connected to an active but weak AC system at both ends of HVDC link is developed using MATLAB/SIMULINK.

Index Terms—**Fuzzy logic controller, Phase reactors, Sinusoidal pulse width modulation (spwm), VSC-HVDC.**

I. INTRODUCTION

The electricity networks of today increasingly need control and stability at high levels of loading. Increasing the stability through adding more lines is not always an option due to restrictions in right-of-way or limits to acceptable short circuit current. The new HVDC system known as VSC-HVDC, has Voltage Source Converters and Pulse Width Modulation (PWM) at its core, different from current source converters in traditional HVDC. The necessity of HVDC technology arises to increase the efficiency of the transmission in a power system, as in the DC transmission line, the losses of equally rated lines are lower compared to AC lines. Two types of HVDC systems are used in this days namely Classic HVDC, which is line commutated, and VSC-HVDC, which is self-commutated. Classic HVDC is a Current Source Converter topology (CSC) where the direction of the current in the DC link does not change. For a VSC, the polarity of DC transmission system remains unchanged in the case of reversal of power. In contrast to Classic HVDC, which was introduced in the 1950s, VSC-HVDC is a relatively new technology and the first commercial system was implemented on Gotland in1999. Even if VSC-HVDC is less mature than Classic HVDC, the interest in VSC_HVDC is increasing as it offers several benefits including:

- Flexibility and controllability of the power flow.
- Multi terminal configuration.
- Fast response in case of disturbances.
- Possibility to control the reactive power independently of the active power.
- No risk of communication failures in the converter.
- Ability to connect to weak AC networks, or even dead networks.
- Faster response due to increased switching frequency (PWM).
- Minimal environmental impact
- Bi-directional power transmission without changing the polarity of DC link.

With the development of VSC-HVDC operation practice, a lot of research interests have been put on the study of modeling, controller design and influence to the grid connected of VSC-HVDC. Fuzzy logic control strategy doesn't depend on the detailed system model and is robust to different operating conditions. The VSC layout draws on a modular strategy. For any highest DC voltages the equipment is set up in architecture structures. The desired

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sizes f the site areas for that converter stations are usually compact. All equipment apart from the power transformer are indoors. Well-proven and tested equipment along at the factory make installation and commissioning speedy and efficient.

This paper designs a conventional and fuzzy controller for VSC-HVDC system with shrinking span membership function. Simulation results are provided in order to the performance of both the conventional and the modified controllers. The simulation results ensure that the control strategy has fast response, strong stability and reduction of losses.

II. PROPOSED SYSTEM

The main scope of this project is to build a VSC-HVDC transmission system model and study its operational performance using the MATLAB/SIMULINK software package. The control system for both rectifier and inverter stations is to be designed. Design of controllers and optimization of gains at both converter stations according to transmission of active and reactive power flow in either direction is also part of the scope. Detailed studies has to carry out regarding independent control of active and reactive power at sending and receiving ends which can be achieved.

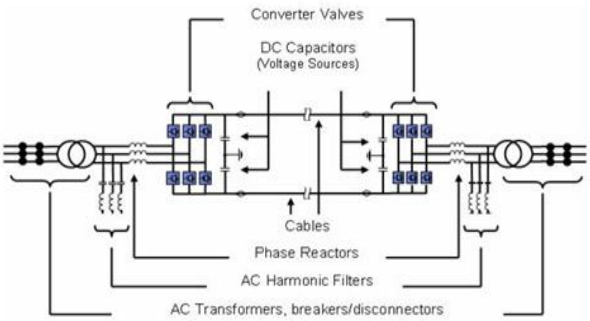

Fig 1. General VSC-HVDC system

In this paper the Voltage Source Inverter is designed in MATLAB/Simulink.

III. PULSE WIDTH MODULATION

Output voltage of the converter varies with several parameters such as- change in input voltage changes output voltage of the converter and as the load demand changes then also the output voltage changes. So output voltage has to be controlled for efficient operation of the network.

Pulse width modulation (PWM) techniques are commonly used techniques to control the output voltage of the converters. A modulation technique to generate the firing pulses for the VSC switches is necessary.
This technique offers to keep the input voltage constant, so that output voltage can be controlled by varying the Gain of the Inverter. Gain of an inverter is defined as-

$$GAIN = \frac{AC\ OUTPUT\ VOLTAGE}{DC\ INPUT\ VOLTAGE}$$

Practical Inverter waveform contains Harmonics. But the availability of high speed power semiconductors devices reduce the harmonic contents of output voltage can be minimized or reduced significantly by switching techniques. For the three phase system following four techniques are used-

- Sinusoidal pulse width modulation technique.
- 3^{rd} harmonic pulse width modulation technique.
- 60^0 pulse width modulation technique.
- Space vector modulation technique.

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Among these techniques the most common method used for three phase network is the Sinusoidal Pulse Width Modulation (SPWM) technique which uses a sinusoidal control(reference) wave and a triangular carrier wave to generate PWM signal which drives the switches.

In this, the width of each pulse is varied in proportion to the amplitude of a sine wave evaluated at the centre of the same pulse. The frequency of reference sine signal f_r determines the inverter output frequency f_o and its peak amplitude A_r controls the modulation index M. The number of pulses per half cycle depends on the carrier frequency. The rms output voltage can be varied by varying the modulation index M. Modulation index, M can be defined as-

$$MODULATION\ INDEX = \frac{AMPLITUDE\ OF\ SINE\ WAVE}{AMPLITUDE\ OF\ CARRIER\ WAVE}$$

By almost instantaneous change of PWM pattern, the creation of any phase angle or amplitude is enabled. Thus, PWM gives the possibility of separate control of active and reactive power, which makes this technology a very good choice for power transmission and also its control scheme is simpler compared to other PWM techniques with less switching losses.

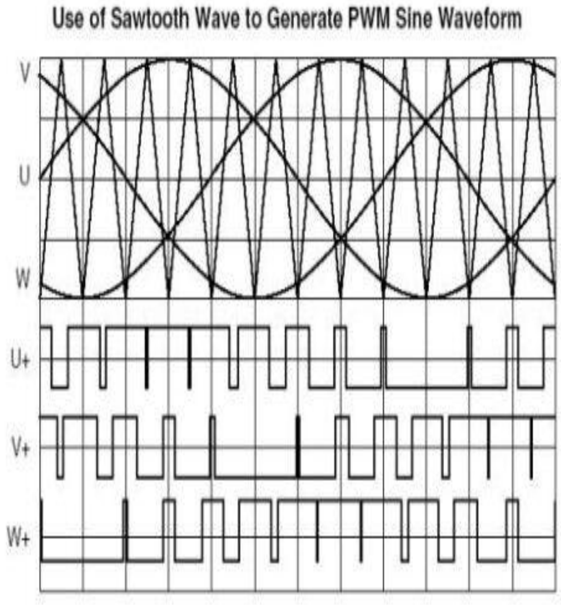

Fig 2 Waveform showing SPWM pulses.

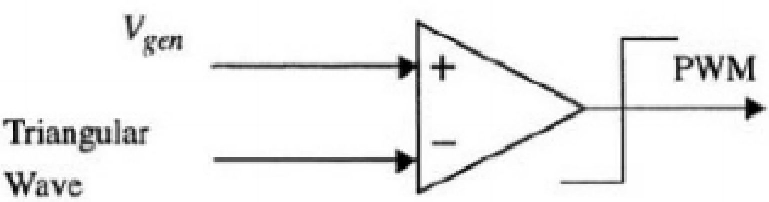

Fig 3 SPWM implementation

Fig. shows how the gating pulses are generated using sinusoidal pulse width modulation technique. In the fig, the width of each pulse is varied in proportion to the amplitude of a sine wave. The gating signals are generated by comparing a sinusoidal reference signal with a triangular carrier wave of frequency fc. The frequency of reference signal fr determines the inverter output frequency fo and its peak amplitude Ar controls the modulation index, M and then in turn, the rms output voltage Vo. SPWM technique together with AC voltage control will be used for achieving the desired control for our application . As seen in fig., a sine wave and a triangle wave are compared and the resulting pulses after comparison are fed to the IGBTs.

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IV. PROPOSED MODEL

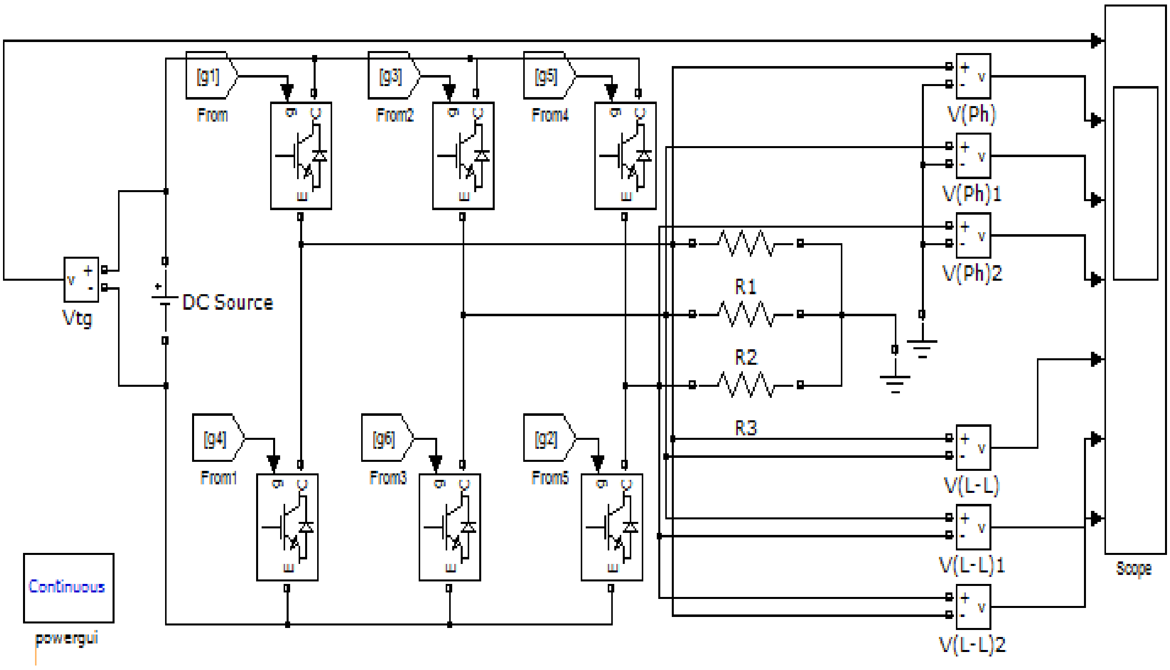

Fig 4 Phase voltage source Inverter model.

V. SIMULATION RESULTS

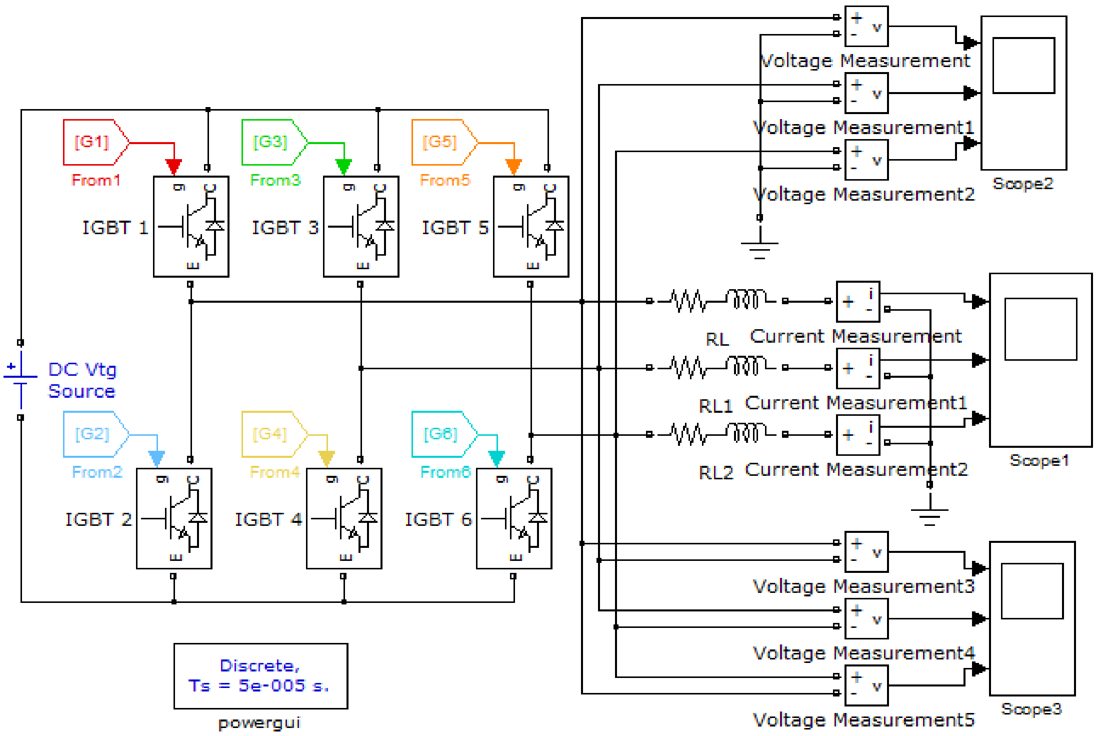

Fig 5 Three phase inverter simulation circuit

Fig 5 shows the simulation of three phase inverter circuit. In the simulation six IGBTs (3 arms) are used with antiparallel diode for freewheeling during inductive loads. Typically the output are designed get standard values like- 220 to 380v at 50Hz, 120 to 208v at 60Hz, 115 to 200v at 400Hz…,etc.

For an input of 100volts magnitude and for load of R=10ohm, L=10mH the three phase inverter is simulated to obtain a line voltage of 100volts and phase voltage of nearly 70volts. A discrete pulse generator is used to generate pulses for the six IGBTs, which is as shown below for time period of 50microsec. Gating pattern and their sequence of connections are shown in circuit simulation.

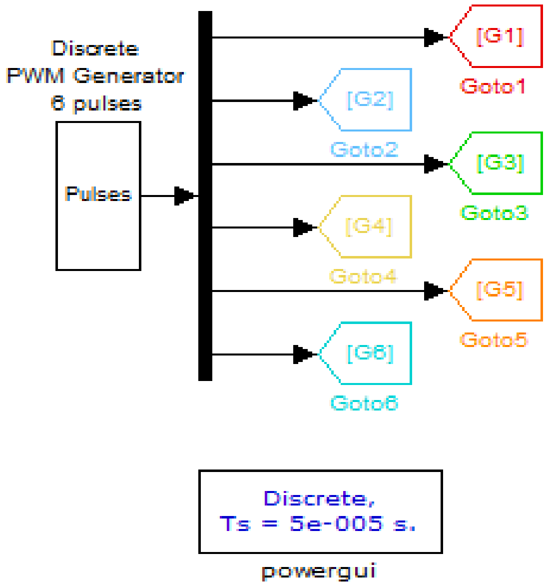

Fig 6 Discrete pulse generator orientation

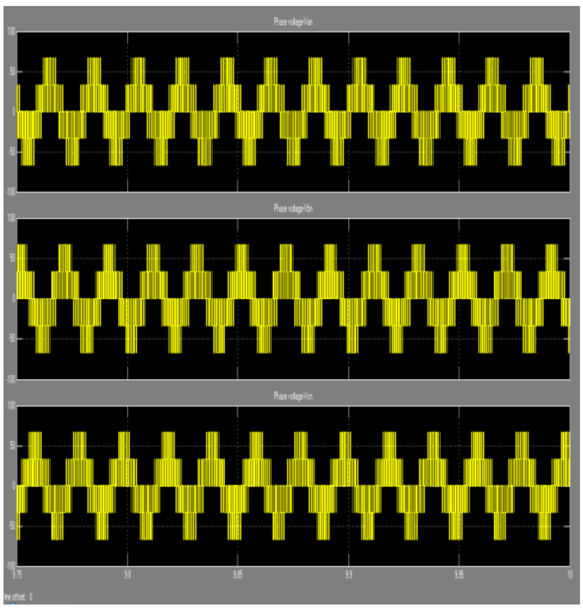

Fig 7 Phase voltage of three phase inverter

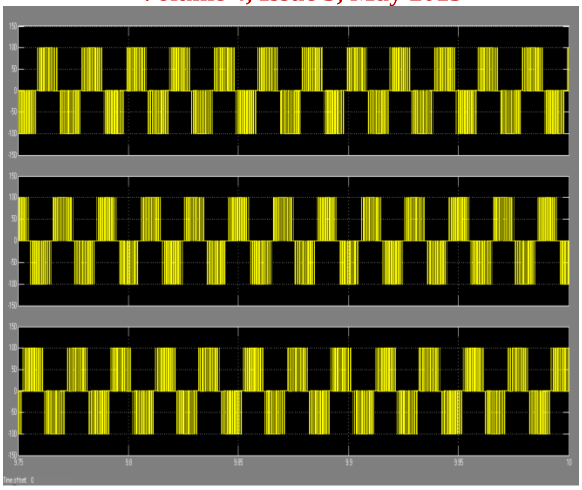

Fig 8 Line voltage of three phase inverter

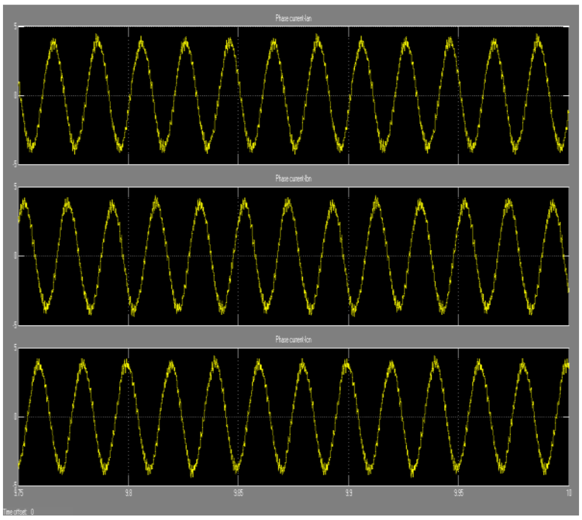

Fig 9 Phase current of three phase inverter

VI. CONCLUSION

The proposed work is aimed on the investigation of possible modeling and Fuzzy based control scheme for the VSC based HVDC transmission, with the purpose of identifying the impact of such modeling and control on the dynamics of the conversion system. A system consisting of 3-phase voltage source inverter is designed in the commercially available software packages MATLAB/SIMULINK using a detailed switching model of the inverter components.

VII. FUTURE WORK

Further Fuzzy controller for the rectifier model has to carry out with back-back to grid connection and the response of whole model has to compare with the PI-controller using MATLAB/SIMULINK model.

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