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Design of Modular Multi Level Converter for HVDDC Using Multi Loop Control Strategy

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ABSTRACT:

This paper presents an application of Multi loop controller for Modular Multi Level Converter High Voltage DC Current(MMC-HVDC).The AC currents are controlled and transformed .With this control method the ac currents are kept balanced and dc link voltages are maintained under unbalanced fault conditions. The effectiveness of the control strategy is verified through a simulation case of 11-level MMC-HVDC transmission system using MATLAB/Simulink.

Keywords:

MMC-HVDC, Multiloop control, circulating currents, unbalanced voltages,

1. INTRODUCTION:

High voltage direct current (HVDC) has been applied widely to increase the capability of power transmission and link different ac networks together. Normally, an HVDC system can be either voltage-source converter (VSC) based or current-source converter based. VSC-based HVDC systems can control the active and reactive power separately. Unlike the conventional CSC-based HVDC systems where acres of land are used for filter installation; VSC-HVDC requires only small sized filters on the ac side of the converter. Compared with a two-level VSC, multilevel voltage-source converters have much less harmonics in the output voltage, which significantly reduces the size of grid-side filters. Among the different multilevel converters, modular multilevel converter (MMC) has extensibility for several hundreds of output voltage levels.

Therefore, MMC is ideal for high voltage high-power applications, e.g., HVDC transmission, high-voltage motor drives and electric railways. Fig. 1 is the topology of a three-phase MMC. For an N + 1 level MMC, there are N sub modules on each arm of the converter. Each sub module is a half bridge dc-dc converter. The modular multilevel converters (MMC)-based high voltage direct current (HVDC) system is a new type of voltage source converter (VSC) for medium or high voltage direct current power transmission. Recently, it has become more competitive because it has advantages over normal VSC-HVDC system such as low total harmonic distortion, high efficiency, and high capacity.

The operation of the MMC-HVDC system has been investigated by many authors over the world. In the authors presented the control strategies for eliminating the circulating currents and maintaining the capacitor voltage balancing of the MMC. The dynamic performances of the MMC-HVDC system have been analyzed. Similar to other HVDC systems, the stable and reliable operation of the system must be researched carefully, especially when the system operates under fault conditions. In the authors showed out the control methods of the MMC- HVDC system under the unbalanced voltage conditions. Almost all of them only focus on the use of proportional-integral (PI) current controllers in the synchronous rotating reference frame (dq-frame) for enforcing steady-state error to zero. However, the use of these PI current controllers will be difficult under the unbalanced voltage conditions because of the complex control of the positive and negative sequence components of the

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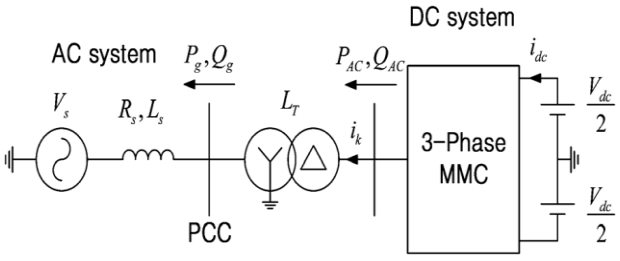
currents . Recently, the multi loop controllers have been developed to overcome this problem.

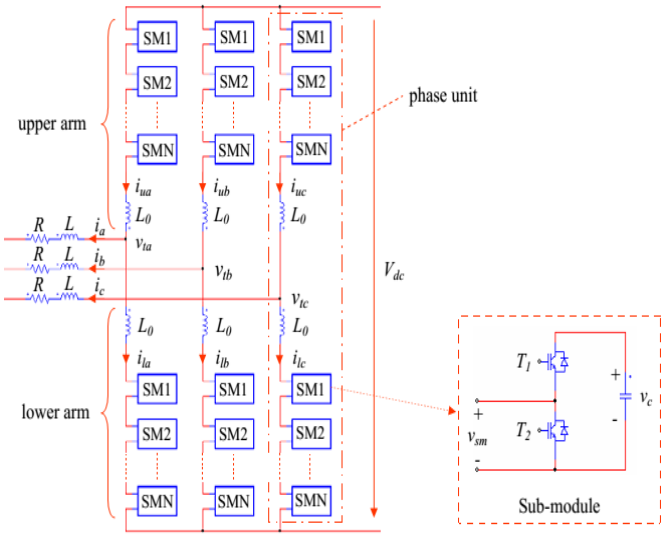
The most important performance of multiloop controllers is that the currents are controlled directly. This paper addresses main issues of MMC(ac current control, dc link current, circulating current and SM capacitor voltage balancing).Compared to the other published control strategies. The new strategy has the following advantages: reduced number of required controllers, improved ability to adapt to frequency fluctuation, reduced calculation load and effective control both MMC-HVDC terminals under unbalanced grid conditions.

2. CONFIGURATION OF MMC -HVDC SYSTEM:

The configuration of MMC-HVDC system is depicted from Fig1.A single line MMC-HVDC system. Each MMC consisting of six arms Fig1(b). Each arm has a total of N sub modules(SM) connected in series and a series inductor which provides current control within the phase arms and limits fault currents. Two arms in the same leg comprise a phase unit. A SM is a half-bridge cell which consists of two IGBTs, two anti-parallel diodes, and a capacitor. The ac side of each MMC is connected to a unity grid through a series-connected resistance and inductance and a three-phase transformer. The output voltage of each SM, vsm, has two values: (i) vsm= vc if T1 is switched on and T2 is switched off, (ii) vsm = 0 if T1 is switched off and T2 is switched on. The charging or discharging of the capacitor depends on the direction of the current. If the current flows into the SM, the capacitor is charged. If the current flows out of the SM, the capacitor is discharged.



(a)



(b)

Fig 1: Configuration of MMC-HVDC (a) Single line diagram (b) Circuit Configuration

3.THE PROPOSED METHOD FOR MMC-HVDC SYSTEM:

A. Multiloop control strategy

The MMC converter consists of three independent H-bridges that are connected to a common dc-link capacitor**.** VSCs are connected in series to the supply grid through a single phase transformer. The proposed Fault Current Interruption(FCI) consists of independent and identical controllers for single phase VSC of the MMC. The fundamental frequency components of supply voltage V_s, load voltage V_l and injected voltage V_{inj}

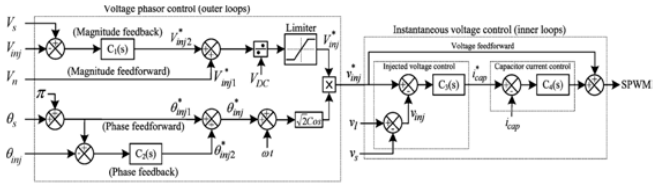


Fig 2: Block diagram of multi loop control strategy

$$\upsilon_s = V_s \times \cos(\omega t+\theta_s) \quad (1)$$

$$\upsilon_l = V_l \times \cos(\omega t+\theta_l) \quad (2)$$

$$\upsilon_s = \upsilon_s - \upsilon_l = V_{inj} \times \cos(\omega t+\theta_{inj}) \quad (3)$$

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The FCI function requires a phasor parameter estimator (digital filter) which attenuates the harmonic contents of the measured signal. To attenuate all harmonics, the filter must have a full-cycle data window length which leads to one cycle delay in the MMC response. Thus, a compromise between the voltage injection speed and disturbance attenuation is made.FCI performs satisfactorily under fault conditions where the measured voltages and current signals are highly distorted. Fig. 2 shows a per-phase block diagram of the proposed MMC control system corresponding to the FCI operation mode, where V_n is the is the nominal rms phase voltage. The control system of Fig. 2 utilizes , the dc-link voltage V_{DC} and the harmonic filter capacitor current i_{cap} as the input signals. The study in this paper is based on the fault current detection method.

The fault detection mechanism for each phase is activated when the absolute value of the instantaneous current exceeds twice the rated load current. The proposed multiloop control system includes an outer control loop (voltage phasor control) and an inner control loop (instantaneous voltage control). The inner loop provides damping for the transients caused by the MMC, and improves the dynamic response and stability of the MMC.When a downstream fault is detected, the outer loop controls the injected voltage magnitude and phase angle of the faulty phase(s) and reduces the load-side voltage to zero, to interrupt the fault current and restore the PCC voltage.

B. VOLTAGE PHASOR CONTROL:

In the FCI operation mode, the required injected voltage phasor is equal to the source voltage phasor. Performance of the voltage phasor control, in terms of transient response, speed, and steady-state error, is enhanced by independent control of voltage magnitude and phase, and incorporating feed forward signals to the feedback control system. Parameters of each controller are determined to achieve a fast response with zero steady-state error. The output of the phasor control system is a reference phasor denoted by

$V_{inj}^{*} = V_{inj}^{*} x\theta inj$

To eliminate the effects of the dc-link voltage variations on the injected voltages, V_{inj}^{*} is normalized by V_{DC}.

C.INSTANTANEOUS VOLTAGE CONTROL:

Under ideal conditions, a voltage sag can be effectively compensated if the output of the phasor-based controller is directly fed to the sinusoidal pulse-width modulation (SPWM)unit. However, resonances of the harmonic filter cannot be eliminated under such conditions. Therefore, to improve the stability and dynamic response of the MMC, an instantaneous injected voltage controller and a harmonic filter capacitor current controller are used to attenuate resonances. The generated reference signal for the injected voltage V_{inj}^{*} is compared with the measured injected voltage V_{inj}. and the error is fed to the voltage controller. As shown in Fig. 2, the output of the voltage controller i_{cap}^{*} is the reference signal for the filter capacitor current control loop.

The steady-state error of the proposed control system is fully eliminated by the PI controllers in the outer control loop(i.e C_1 and C_2) which track dc signals (magnitude and phase angle).Therefore, there is no need for higher order controllers in the inner control loop which are designed based on sinusoidal references. A large results in amplification of the MMC. Filter resonance and can adversely impact the system stability [18]. Thus, the transient response of the MMC is enhanced by a feed forward loop, and a small proportional gain is utilized as the voltage controller. A large damps the harmonic filter resonance more effectively, but it is limited by practical considerations (e.g., amplification of capacitor current noise, measurement noise, and dc offset [18]). Therefore, the lowest value of the proportional gain which can effectively damp the resonances is utilized .The output of the current controller is added to the feed forward voltage to derive the signal for the PWM generator. The proposed FCI method limits the maximum fault current to about 2.5 times the nominal value of the load current and interrupts the fault currents

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in less than 2 cycles.depicts variations of thedc-link voltage during the FCI operation, and indicates that the dc-link voltage rise under the worst c ase (i.e., a severe three phase fault) .

4.MATLAB/SIMULINK

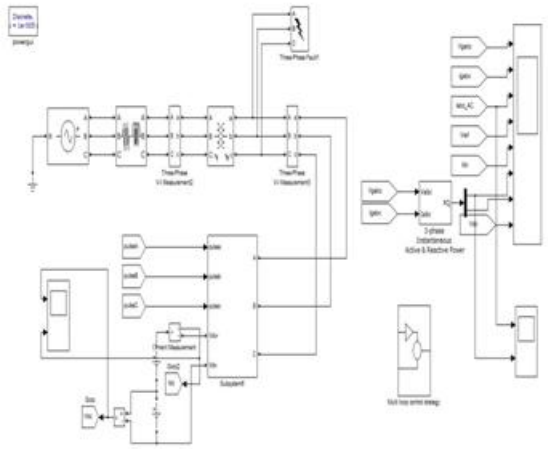

FIG 3: SIMULINK MODEL OF THE PROPOSED SYSTEM

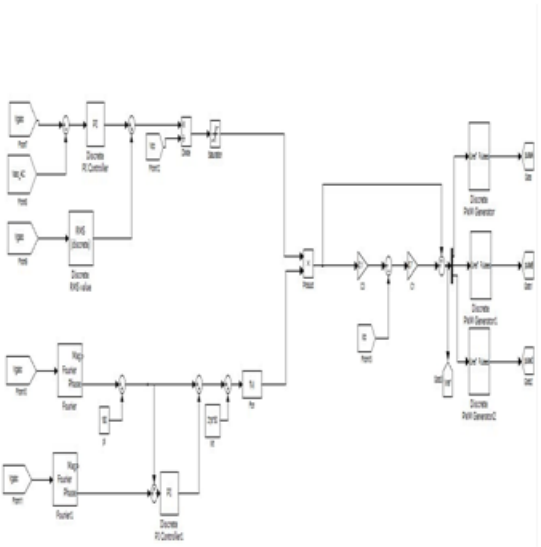

FIG 4: SIMULINK MODEL OF MULTILOOP CONTROL

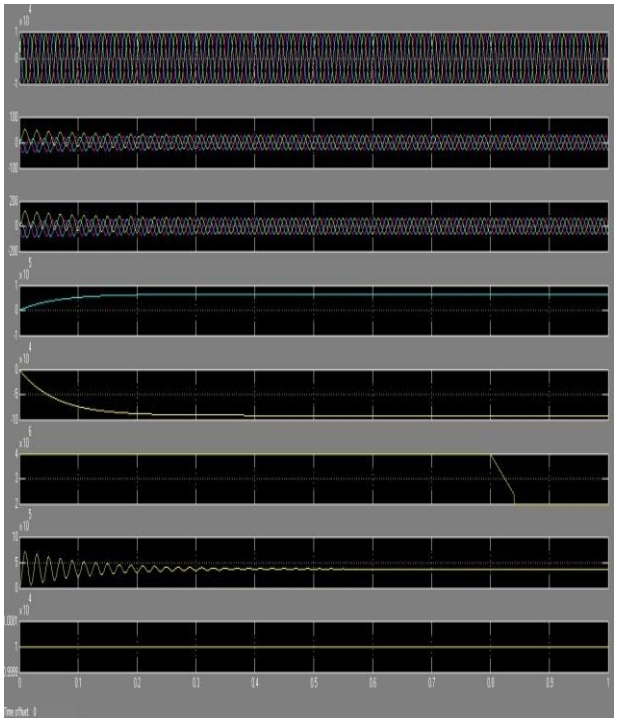

FIG5:SIMULATION RESULTS UNDER UNBALANCED GRID CONDITIONS:A) GRID CURRENT B) GRID VOLTAGE C)ACTIVE POWER D) REACTIVE POWER E)REFERENCE VOLTAGE F)DC LINK CURRENT G)DC LINK VOLTAGE

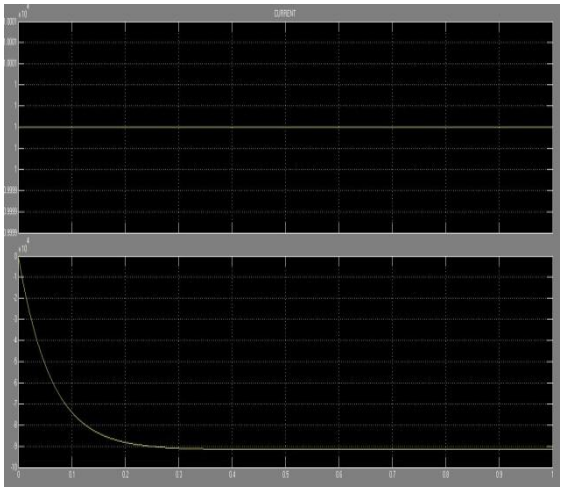

FIG 6: SIMULATED OUTPUTS OF DC VOLTAGE AND DC CURRENT

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5. CONCLUSION:

This paper presents an application of the Multi loop controller for 11 level MMC-HVDC system under the unbalanced voltage conditions. With the Multi loop controller co, the complicated analysis of the positive and negative sequence components are not necessary. The currents are controlled directly. The simulation results have demonstrated that the ac currents are kept balanced and the dc-link voltage is constant under the unbalanced voltage conditions. Besides that Sm capacitor voltage balancing is done using FCI Multi loop control Strategy.

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