

Research and Development on Hybrid Simulation Model of Modular Power System

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Abstract. with the increase in power demand, maximally guaranteeing normal and stable operation of power system has become the key point. HVDC and FACTS contains plenty of high-power electronics, and it has important effect on stable and transient operation of power system. As the member of multilevel converter, modular multilevel converter has universal application in the field of high voltage and high power. This paper makes research and summary on hybrid and simulation model of AC and DC power system based on modular, firstly, it introduces characteristics and topology structure of MMC technology. Secondly, it constructs mathematical model and hybrid simulation model of MMC-HVDC, and it makes corresponding mathematical computation, which determines its function in processing and expanding each kind of new power system element, increasing simulation efficiency.

Introduction

Power system is the unified system of electricity production, transmission and conversion which is composed of power plant, state grid. While HDVC and FACS contains plenty of high-power power and electronic equipment, enabling dynamic process reflects different physical characteristics mutually interweaves together in the operation process, which makes stable state and transient state of power system become increasingly complicated, and it appears plenty of problems which requires immediate solutions. In view of the particularity and safety of power system, it is proper to adopt system simulation to deal with these problems, it uses expert technology such as system, information, simulation as base and computer system, physical effect equipment, emulator as tool, using model to make comprehensive research on system.

Power system simulation mainly means the process of establishing mathematical model on physical process of power system, and it also establishes simulation model applicable to computer, and then it chooses proper numerical calculation method and preparation simulation process to make test, research or training on computer. In order to ensure the smooth simulation process, this paper puts forward one kind of DC and AC power system hybrid simulation algorithm based on modular, it uses partitions network segmentation to make modular procession on dynamic elements and controller of system, which quickly and precisely simulates stable state and transient state of power system.

Introduction to MMC technology and topology structure

MMC is the short term of modular multilevel converter, it is applicable to high voltage and high power field and it can reduce the voltage born by system elements, which has low harmonic number, low high-frequency noise, low switch frequency and low consumption. In addition, it has common DC bus without requirements on filter as well as high modular software, hardware, high flexibility and economic benefit. Meanwhile, because it has the same work principle on bridge arm of every phase, all can be independently controlled. When AC side of MMC has unbalanced fault (such as single-phase fault), the other 2 phases can still transmit energy with full power, transmission capacity of system reduces by 1/3, which guarantees stable operation of MMC and it can recover from fault state in the short time, it has obvious capacity in fault crossing and recovery capacity, this

can greatly reduce the maintenance period of major elements and guarantee good power output. The details of MMC topology structure and sub-modular are indicated by the following figure 1 and 2.

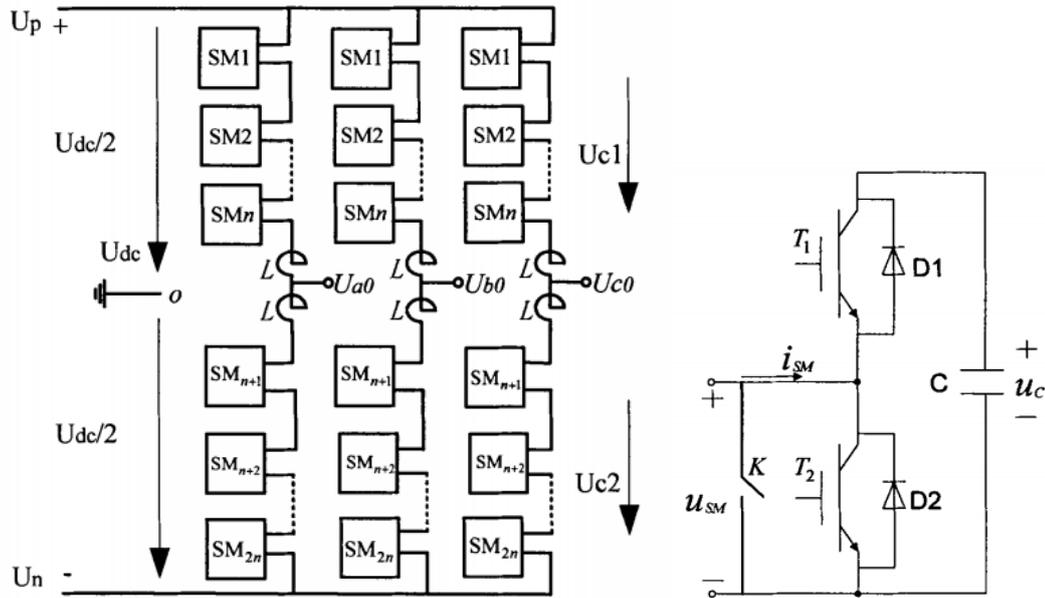


Figure 1 Topology structure of MMC converter Figure 2 Sub-modular structure of MMC

Modular processing method of power system

The key point of modular hybrid simulation model depends on construction of Tree hierarchy model of power system, which is partition network segmentation of power system. It needs to make network segmentation before determining tree hierarchy construction according to detailed area and topology condition of power grid. The construction principles are as follows: the tie line among different partitions on the same hierarchy is classified as father node of tree structure, the corresponding inter-bus is divided into 2 and they are respectively classified as father node and child node, the split inter-bus is connected through visual impedance branch. The internal inter-bus of every partition is classified as child node of tree structure. The node of tree hierarchy model is composed of sub-network, while the individual units such as synchronous machine, motor load, FACTS etc are regarded as individual unit to make processing, while many elements such as synchronous machine and its assorted excitation system, prime motor, speed regulating system etc compose one node. DC power transmission system, FACTS series or parallel compensator and corresponding control loop generally compose one node.

MMC-HVDC mathematical model

The active power and reactive power transmission of HVDC is controlled by voltage phase difference and amplitude difference on both sides voltage of system, and it also follows the principle of power balance between input and output. The difference between active power received from AC system of transmitting end and active power output from transmitting end is the power consumed by VSC-HVDC system. Whether the transmitting end is active load or passive load, all can adjust exchange of active power and active power between VSC and grid by controlling phase and amplitude of voltage output from converter station, and it has the following equation:

$$P = \frac{U_s U_c}{X_c} \sin \delta \quad (1)$$

$$Q = \frac{U_s (U_s - U_c \cos \delta)}{X_c} \quad (2)$$

In equation (1) and (2), U_c is the output voltage of converter station, U_s is AC of grid, X_c is circuit and module impedance, δ is the phase difference of U_c and U_s .

While stable state of HVDC and mathematical model of control system are mainly composed of converter, inverter and DC power transmission circuit, the single line diagram of double end DC system is indicated by figure 3:

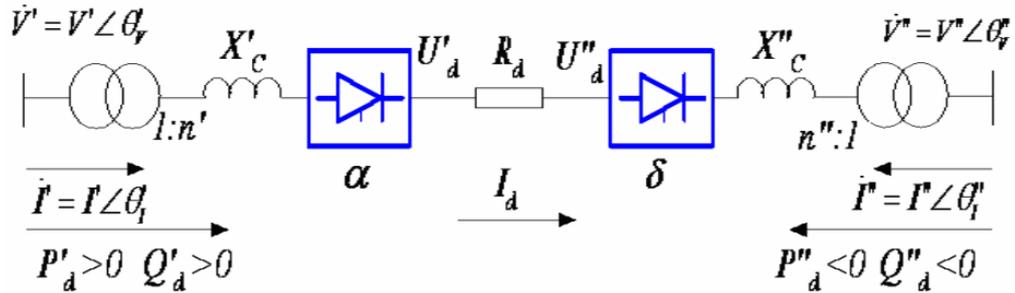


Figure 3 Single line diagram of double DC power transmission system

Of which, V' and V'' are respectively voltage of AC side between rectifier and inverter. The transformation ratio of converter transformer is respectively $1:n'$ and $n'':1$, it neglects internal resistance, internal reactance is X'_c and X''_c . Of which, α is the fire angle of valve bridge point, $\beta = \pi - \alpha$ is gating advance angle, $\delta = \beta - \gamma$ is turn-off advance angle or extinction angle. Its stable state model and mathematical model of control system is indicated by formula (3):

$$\left. \begin{aligned}
 U'_d &= n'V' \cos \alpha - 3X'_c I_d / \pi \\
 U''_d &= n''V'' \cos \beta + 3X''_c I_d / \pi \\
 U'_d - U''_d &= R_d I_d + L_d P I_d \\
 \cos \varphi' &= U'_d / n'V' \\
 |\cos \varphi''| &= U''_d / n''V'' \\
 \theta'_i &= \theta'_v - \varphi' \\
 \theta''_i &= \theta''_v - \varphi'' \\
 I' &= n' I_d \\
 I'' &= n'' I_d
 \end{aligned} \right\} (3)$$

Research on hybrid simulation model of HVDC power system

By combining with the actual condition of HVDC power system, it realizes the hybrid simulation process, step length of EMTDC is 50 microsecond, simulation step length of TSP is 20 millisecond. EMTDC and simulation interface of TSP exchanges data every 400 steps, the details are indicated by the following figure 4:

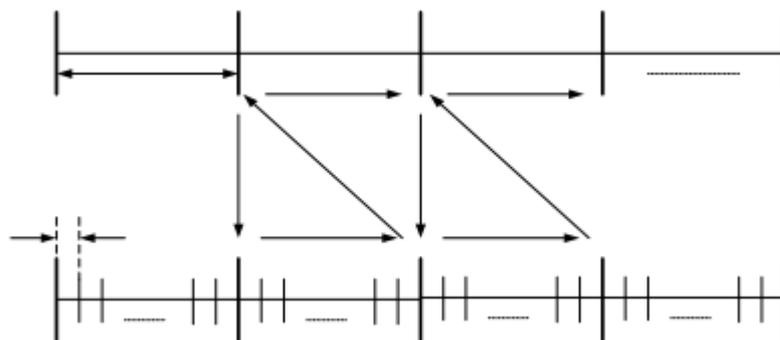


Figure 4 Hybrid simulation process diagram of HVDC power system

Here it mainly uses transient and stable simulation program as main program structure, including the following sub-program module: (1) modular processing of system initialization; (2) simulation

sub-program of EMTDC sub-system, it transfers ENTDC engine to make electromagnetic transient simulation on HVDC part, (3) gets conversion sub-program of TSP and EMTDC interface, (4) use bidirectional iteration method to get transient stable simulation.

According to simulation curve comparison (see figure 5, 6 and 7), it finds that the voltage, current and trigger angle obtained by adopting using modular hybrid simulation and TSP interface accords with result obtained by adopting electromagnetic transient simulation, which demonstrates that it can use this algorithm to make hybrid simulation.

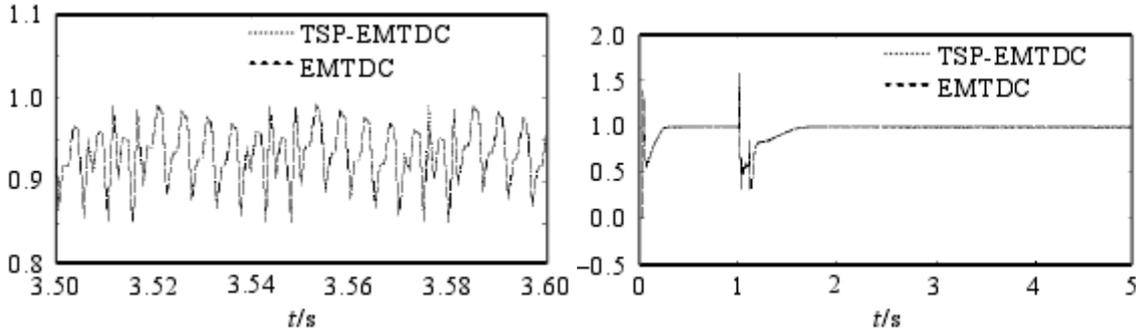


Figure 5 DC voltage on inversion side after fault Figure 6 Curve comparison of DC current on

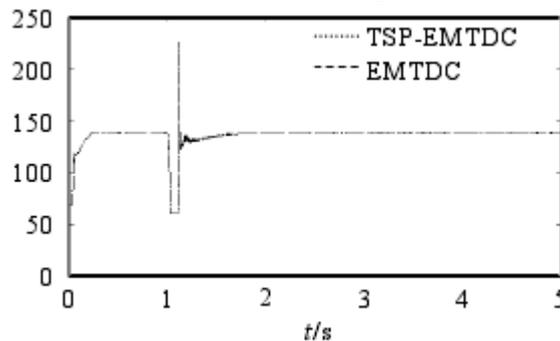


Figure 7 Comparison on trigger angle conversion on inversion side

Meanwhile, this paper uses hybrid simulation algorithm and voltage, instantaneous value of current obtained by making electromagnetic transient simulation on the whole grid as well as active power curve are basically the same, which has greatly increased the simulation efficiency of power system.

Conclusion

In a word, modular multilevel converter is one kind of new voltage converter topology structure which is put forward in recent years; it is one important breakthrough in multilevel converter topology structure. MMC-HVDC, the DC and AC hybrid simulation algorithm based on modular can make mechanical and electrical simulation on mutual effect between regional grid, large area and local area system, and at the same time it can conveniently and correctly reflect internal dynamic state of fast control device such as HVDC etc. Start from the perspective of protecting safe operation of system, constructing hybrid simulation model of modular power system can greatly reduce the calculation amount of using Newton method to make simultaneous solution on power system equation, it is convenient to process and expand new element of power system, which greatly increases simulation efficiency and it has huge practice and application values.

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