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Ripple Controlling MMC For Circulating DC Current

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ABSTRACT: *MMC is an evolving topology that is capable of take care of high voltage and power rankings.Under the unbalanced circumstance, the principle subject matter of controlis to lower the bad-sequence line contemporary. Moreover,the circulating cutting-edge of a MMC includes now not most effective double-linenegative-collection thing, which appears below the balancedcondition, however also superb- and zero-series double-line components. Thus the controller have to be able to cast off all the ones components of the circulating cutting-edge. A proportional-resonantcontroller (PR controller) is applied to adjust the fine- andnegative-sequence components of circulating cutting-edge. In addition,the 0-series issue of circulating contemporary is controlledby a dc modern-day controller. The proposed manipulate approach isconfirmed in MATLAB/simpowersystem.*

KEYWORDS-Modular multilevel converter (MMC), Circulating Current Suppression Control, DC Current Ripple Control,Proportion Resonance Controller

I. INTRODUCTION

AC has been the preferred global platform for electric transmission to homesand companies for the beyond 100 years. And but high-voltage AC transmission hassome limitations, beginning with transmission ability and distance constraints, andthe impossibility of right now connecting two AC electricity networks of various frequencies. With the dawn of a ultra-modern strength technology and the need to construct a better grid,HVDC is predicted to develop far past its conventional feature as a complement to actransmission [2].

Excessive Voltage Direct current (HVDC) is the electrical energy transmission desire carried out in massive quantity of strength over lengthy distances with minimal losses. Thinking about the reality that in a traditional three segment gadget the energy delivered is conformed by way of its RMS charge, HVDC lets in transmitting energetic strength with higher voltagevariety. Moreover, the impedance created in AC transmission systems are avoidablelowering the power losses. Consequently, the initial set up fee of HVDC is betterthan HVAC systems but because of lower losses it turns into price powerful over the time.as an example, strength delivered from remote offshore wind farms may be successfully fedinto power grids onshore through HVDC technology. Moreover, HVDC systems are useful to interconnect asynchronous AC grids reliably. Using HVDC system lets in theopportunity of the use of underground and susea cables. Hence, HVDC is considered asa extraordinarily green alternative for transmitting massive amounts of energy over lengthydistances and for special reason packages. As a key enabler in the future strengthsystem based on renewables, HVDC is in reality shaping the grid of the future.this period includes a converter station wherein the AC device is transformed into DC then transmitted via a strength transmission cable after which converted lower back into AC. The cable connection can be overhead or every underground orsubmarine under water. An HVDC transmission system is depicted in figure 1.1.

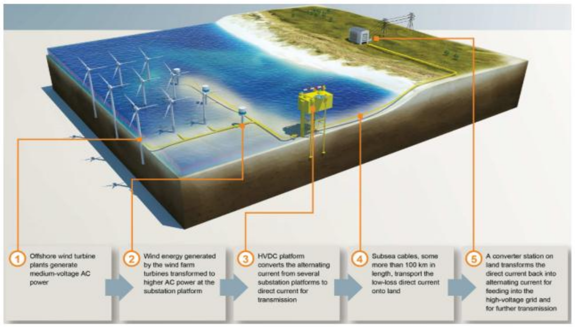

Figure 1.1: HVDC transmission system from an offshore to onshore grid [1]

Modular Multilevel Converters (mmcs) have received researcher's attention due totheir potential to deal with excessive voltage and energy rankings. VSC-HVDC is getting increasingly more essential for integrating renewable power assets together with large offshorewind farms, supplying flexible interconnection amongst vulnerable AC grid networkthe use of again-to-returned configuration, or actually transmitting power the use of undergroundcables. The VSC-HVDC moreover has fast and unique manipulate over the lively electricity-flowin addition to it is able to independently control the reactive energy injection on the close by acgrid. There are numerous operational MMC-HVDC duties which encompass HVDC PLUS(Siemens) with an 88km undersea transmission hyperlink among San Francisco's citycentre electric energy grid and a substation near Pittsburg. The crucial supporting functions HVDC PLUS gives are AC voltage Control, black-start functionality,compact converter station area utilization, four quadrant operation, repayment ofasymmetrical loads, flexible integration into HVDC multi terminal systems or future HVDC grids. Its primary going for walks principle and specific benefits each on thetechnical similarly to on the finances friendly issue can be described in [3] [4].

Another MMC-HVDC set up named HVDC Light with the aid of the use of ABB, is an versionof HVDC traditional used to transmit power in electricity ranges (50-2500MW) transmitted the usage of overhead strains and enviornmental first-rate underground and sub-sea cables.It is used for grid interconnections and offshore hyperlinks to wind farms. With hvdclight, it's far viable to transmit power in both instructions and to manual current acgrids an awesome manner to growth robustness, balance, reliability and controllability. Hvdclight offers many different advantages and may be utilized in awesome packages whichis defined in [5]. As stated before, the principle problem of the 2 degree converter is its immoderate switching losses due to pretty excessive switching frequency which necessitates excessive insulation necessities of the transformer, in addition to filters. The use ofmodular multilevel converters overcomes maximum of the aforementioned shortcomings,but at the rate of times as many semi-carrying out devices and a massive allottedcapacitor for each submodule. The principle concept of the hybrid VSC-HVDC, as usedin HVDC maxsine advanced by using Alstom, is to apply a stage converter as the principleswitching component with low switching frequency and an MMC to offer a voltagewave shaping function on the AC facet so you can take away the harmonics [6] [7].

II. PROPOSED SYSTEM

Multilevel converters are classified into diode-clampedmultilevel converters (dcmcs), flying-capacitor multilevelconverters (fcmcs), cascaded H-bridge converters (chbcs),and modular multilevel converters (mmcs). Mmcs havebeen broadly followed in VSC-HVDC systems. Fig. 1 showsthe shape of an MMC which include six hands. Each armis composed of an inductor and a series of linked halfbridge sub-modules (sms). HVDC-MMC systems requireseveral design strategies. (1) System parameter designincludes inductance and capacitance layout and switchingdevice cutting-edge capability design. (2) System control designincludes electricity (DC-link voltage) manipulate, AC-sidecurrent manipulate, circulating modern-day manage, and SM voltagebalancing [2-6].

A layout technique for the SM capacitance of the mmcwas delivered in [7]. This design technique calculated thedifference in input electricity consistent with the amplitude of thegrid voltage and the lively strength. The SM capacitance isdesigned by using the

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enter strength and the SM capacitor voltageripple on the idea of the restrict cost.

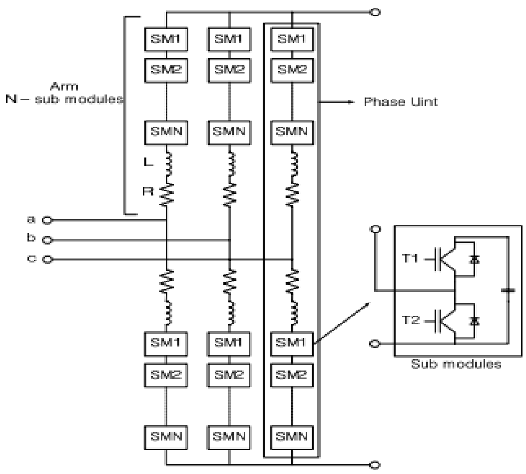

Fig. 1. Basic structure of MMC.

The SM capacitorvoltage ripple has line-frequency and double-line-frequencycomponents. However, this design method did not separateline-frequency and double-line-frequency components; thecapacitor voltage ripple was only calculated using integratedcomponents.

The output ofsub-module is either Uc or 0 depending on the gate statement.When N is big enough or the switching frequency is highenough, the voltage injection to each arm by sub-modules canbe considered as continuous. For DC side voltage, with bigDC-side capacitor, the dc-side voltage can be considered as aconstant value. Thus, the single phase-equivalent circuit of aMMC can be expressed as Fig. 2.

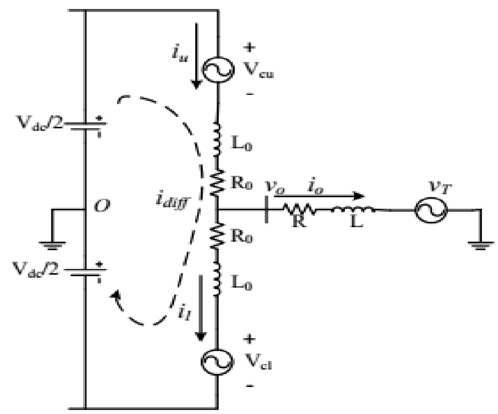

Fig. 2. Single phase equivalent circuit of MMC

In Fig. 2, The upper and lower arm current are named as $i_u$and i^l; the converter's output current and voltage are named asio and vo respectively. The circulating current flowing withinthe converter is denoted as idiff. Since the upper and lowerarm are symmetric, ideally both lower and upper arm currentscontain half of the converter output current.

II. CONTROL SYSTEM UNDER UNBALANCED VOLTAGE

A. PR Controller

PR control can achieve high bandwidth at certain resonantfrequency. Through PR control, measurement signal can trackthe reference signal without steady-state error at the resonancefrequency.

B. Outer Loop Power Control

When the grid side voltage is under unbalanced condition,the line current and power flow are separated in positive-, negative- and zero-sequence components. With a zero-sequence current controller, thezero-sequence current can be reduced to zero. Therefore theobjective of the unbalance controller is the negative componentof line current.

C. Inner Loop Current Control

Different control objectives have been set for MMC underunbalanced condition. Reference [15] tried to

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reduce thenegative components of the line current to zero.

D. Grid-side Zero-Sequence Current Control

The overall control structure is shown in Fig.4. The zerosequence current occurs during the unbalanced condition. AY−to−Δ transformer can stop the zero sequence current.However, when the fault happens on the transformer or between the transformer and MMC, zero-sequence current willnot be stopped by transformer.

E. Circulating Current Control and Dc Current Ripple Control

In an MMC, the difference between each phase's totalsub-module capacitor voltage leads to the circulating current. Under balanced condition, it has been evaluated thatcirculating current consists of only negative-sequence doubleline frequency component, since the instantaneous power foreach phase has a negative-sequence double line frequencycomponent.

When the ac-side voltage has negative component, theinstantaneous power of each phase consist not only negativesequence but also positive- and zero-sequence double-linefrequency components. Therefore, to eliminate the circulatingcurrent under unbalanced condition, the controller in positive- ,negative- and, zero-sequence are all needed.

It'sdc component is set as the reference of the PR controller. Theoutput of PR controller is the positive- and negative-sequencecomponents of the reference inner unbalanced voltage, whichis noted as $e_{diff;abc}$ in Fig. 3.

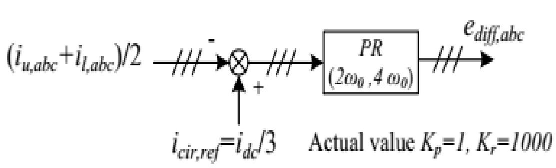

Fig. 3. Circulating current suppression controller.

For a three-phase system, the sum of positive- and negativesequence current are zero. However the sum of zero-sequencecomponent is not zero. And i_{dc} is the sum of three-phase current. Therefore, if the three-phase current has zero-sequencecomponent, then idc includes the zero-sequence componentripple. Normally, a Y-to-δ transformer can stop the zerosequence line current. However, when the fault happensbetween the transformer and MMC, or the system has notransformer, it is necessary to eliminate the zero-sequence linecurrent. The controller to eliminate zero-sequence current isshown in Fig. 4. As shown in Fig. 3, the output of the zerosequence line current controller is added to the output of theinner loop current controller as a zero-sequence component.

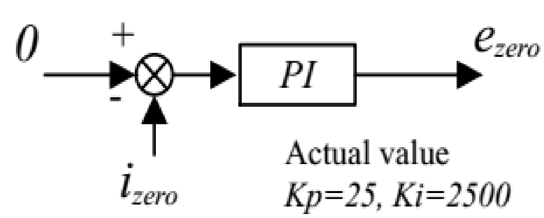

Fig. 4. Zero-sequence line current controller.

If we assume there is no power loss on MMC. Then theac-side power of MMC should be equal to the dc-side powerof MMC. So the dc component of the dc-side current can beeasily set as $I_{dc;ref}$ = P_{out}=V_{dc}. Where Pout is the ac-sideoutput power of MMC and V_{dc} is the dc supply voltage ofMMC. A PR controller is used to control the zero-sequenceof the inner difference current to $I_{dc;ref}$. The output of PRcontroller is the zero-sequence component of the referenceinner difference voltage. Beside the double-line frequencyripple, the dc current ripple controller can also cancel theresonance current caused by LC circuit resonant. A controlleris added to reduce the dc current ripple as shown in Fig. 5. Theoutput of the dc current ripple controller is added to the outputof the circulating current suppression controller as shown inFig. 3.

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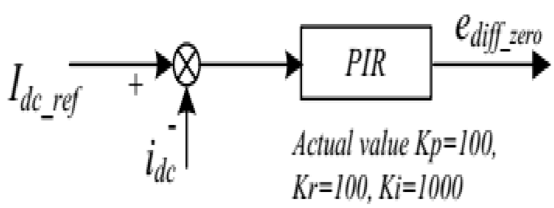

Fig.5. DC-side current ripple controller.

III. SIMULATION RESULTS

A simulation of the proposed system is conducted inMATLAB SimPowerSystem. The simulation environment andparameters are listed in table I. At t =0:2s the circulatingcurrent controller and the controller to eliminate the dc currentripple is activated. From t = 0:6s to t = 0:8s, there is a0:2pu negative-sequence component voltage on the grid side.Regardless of the start-up process, the capacitor voltages ofsub modules were charged at nominal value at beginning.

B. Performance of the control system

Fig.6 shows the output real power of the MMC. During the unbalanced voltage condition (t from 0:6 to 0:8), the output power has a double-line frequency component. When I− is zero, with a non zero V⁻g , The double-line frequency component of line power is not zero.

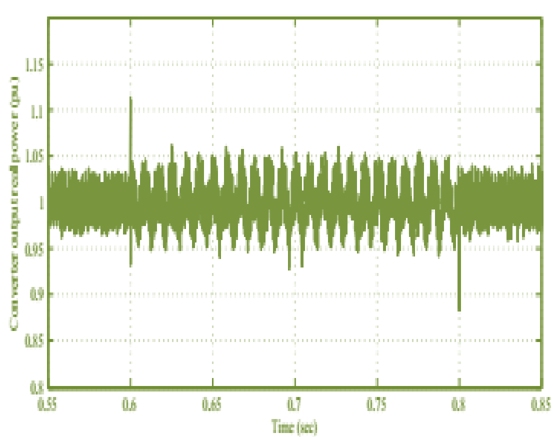

Fig. 6. Output real power of converter.

Fig.7 shows the output reactive power of the MMC. As thesame with the output active power. During the unbalanced gridcondition, there is a double-line frequency component appearon the converter output reactive power.

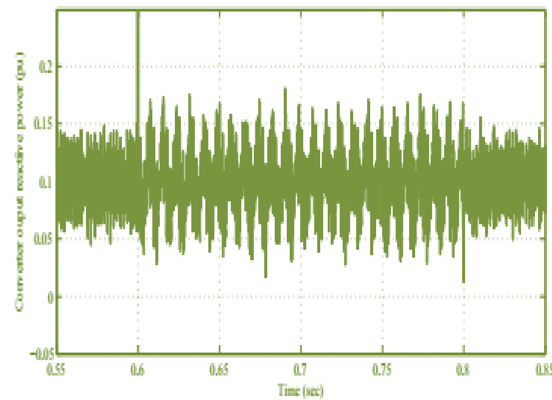

Fig. 7. Output reactive power of converter

Fig.8 is the grid current of MMC during the unbalancecondition. The ripple during the unbalanced condition is dueto the changing of the power and reactive power. The outloop power controller tries to regulate the converter powerto reference value. So the ripple of the power leads a ripplein current reference in dq frame, and the ripple for referencecurrent in dq frame causes a ripple of line current in abc frame.

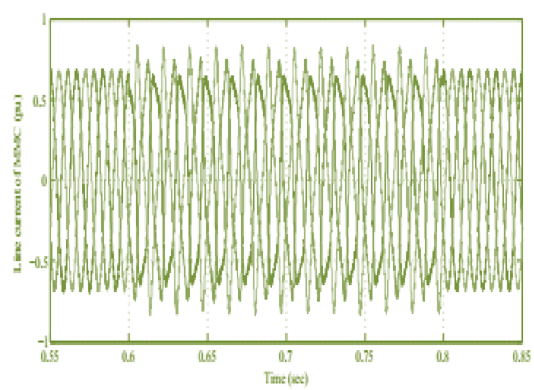

Fig. 8. Grid current of MMC

Fig. 9 is the zero-sequence component of line current. After applying the zero-sequence current controller at t = 0:1s,the magnitude of the zero-sequence current is reduced duringboth balanced and unbalanced condition.

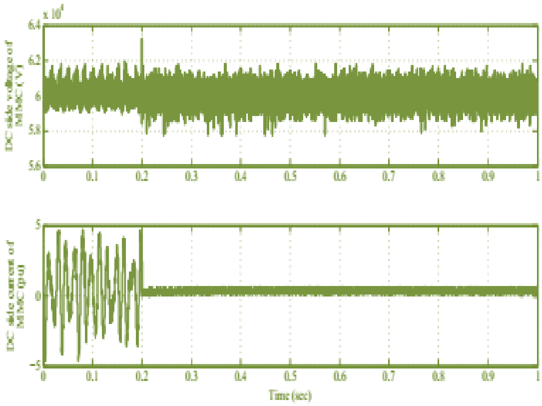

Fig. 9. Zero-sequence component of line current of MMC

IV. CONCLUSION

Investigative examine of the internal unbalances in an MMC has been authorized out.This unbalance can be a result of the asymmetries, non linearities and trade in the tolerances of the components as for instance arm inductors andsubmodule capacitors used in an MMC. When the poor-series componentof the line current at some stage in unbalanced circumstance is managed tozero, there may be a double-line frequency factor on the outputpower of MMC in the course of unbalanced condition. With right nonzero terrible-sequence line present day, the double-line frequencycomponent of the output actual strength may be removed. Thepr controller reduces both superb- and terrible-sequencecomponents of the circulating modern-day at some stage in the unbalancedcondition. In addition, a dc modern-day controller is appliedto reduce the 0-series of the circulating contemporary andresonance modern-day on the dc-facet of MMC.

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