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Control of HVDC System with Reactive Power by using Multilevel Converter

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Abstract: Multilevel Voltage Source Converter (VSC) configurations have been presented as possible alternatives to Pulse Width Modulation-Voltage Source Converter Transmission, but their structural complexity has been the main obstacle to their commercial implementation. OWING to their structural simplicity and four quadrants power controllability pulse width modulation (PWM) conversion has so far been the preferred option for self-commutating medium power HVDC transmission. However, this technology is less suited to large power ratings and long distances, due to higher switching losses and to the rating limitations of its main components (namely the power transistor switch and underground cable). Thus the interchange of large quantities of power between separate power systems and the transmission of power from remote generating stations are still based on the principle of line-commutated current source conversion. A recent proposal, the multilevel current reinjection (MLCR) concept simplifies the converter structure and permits the continued use of conventional thyristors for the main converter bridges. This project describes a new concept applicable to large power converters consisting of two series-connected twelve-pulse groups. It is based on the use of a controllable shift between the firings of the two twelve-pulse groups in opposite directions, a new concept that provides independent reactive power control at the sending and receiving ends. PID Controller is used in this project and Simulation is carried out using MATLAB/SIMULINK software and results shows the Effectiveness of the proposed system.

Keywords: HVDC Transmission, Multilevel Conversion, Reactive Power Control.

I. INTRODUCTION

The back to back link has played an important part from the beginning of HVdc transmission in the interconnection of systems of different frequencies or incompatible frequency control. Its role is likely to increase in the market-oriented power system environment due to the greater control flexibility provided by self-commutating conversion. In this respect, the IGBT-based PWM voltage source conversion (VSC) is currently preferred to the multilevel conversion alternatives, despite the high switching losses involved. The conventional thyristor based current source converter (CSC) configuration still provides the more economical solution for large power dc interchange. Self-commutating CSC is not normally considered for HVdc transmission, because the converter terminals require a large interface capacitor to absorb the inductive energy stored in the ac system side during the commutation periods. A previous contribution has described a self-commutating MLCR scheme with a substantially reduced number of switching components. It uses the parallel converter con- figuration, which has no need for dc blocking capacitors (a requirement of the multilevel scheme when used with the series converter configuration [8]) and uses the inter-phase coupling reactor as the reinjection transformer. Moreover, the need for a large interface capacitance on the converter ac side is avoided by forcing a zero current region during the commutations.

The creation of a zero current switching condition is the most important property of the proposed configuration, because it makes it possible for the main bridges to commutate naturally without the need for gate turn off assistance; in other words permits the continued use of thyristor valves, without losing the control flexibility of the self-commutating process. Although the parallel converter configuration is not cost effective for long distance HVdc, where transmission efficiency requires the use of very high voltages (which favors the series connection), it can be competitive for back to back applications, where the magnitude of the dc voltage plays only a small part in the overall link efficiency Multilevel VSC configurations have been presented as possible alternatives to PWM-VSC Transmission, but their structural complexity has been the main obstacle to their commercial implementation. A recent proposal, the multilevel current reinjection (MLCR) concept, simplifies the converter structure and permits the continued use of conventional thyristors for the main converter bridges.

The main advantage of self over natural-commutation in HVDC transmission is the ability to control independently the reactive power at each end of the link, a property that cannot be achieved by MLCR-based (or any other multilevel) configuration when using only one double-bridge converter group. However, interconnections of large power ratings will normally use two or more 12-pulse converter groups and these can be controlled independently from each other without affecting the output voltage waveform. This fact constitutes the basis of the new control scheme proposed here. When the operating condition at one end of the link alters the reactive power balance at this end, the firings of the two groups at the other end are shifted with respect to each other in opposite directions to keep the power factor constant. The new control concept gives the MLCR configuration described in the flexibility until now only available to PWM–VSC transmission.

II. PROPOSED ALGORITHM

Fig1 shows a simplified equivalent of a bipolar self commutating HVDC link connecting a large power station to an ac power system. The CSC converter stations consist of two twelve-pulse groups. When the operating condition of the receiving end system requires an extra injection of reactive power from the converter, the converter firing angle increases. This action causes a dc voltage reduction and thus an increase of dc current. The latter, however, will be limited by a corresponding reduction of dc voltage at the sending end (implemented by an increase of firing angle) to maintain the specified power transfer. If, as is the case in conventional multi-group control, a common firing angle is used by the two groups, the extra reactive power injection at the receiving end will also result in an increase of reactive power injection at the sending end. As the ac and dc voltages across the converter are related by the cosine of the firing angle, the sign of this angle does not affect the dc voltage level. In the proposed control, the dc voltage correction at the sending end in response to a reactive power increase at the receiving end is implemented by varying the firing angles of the two converter groups in opposite directions. Accordingly, one group (say group A) will advance the firing angle (i.e. inject more reactive power) and the other (say group B) delay the firing angle (i.e. absorb reactive power). This will maintain the converter operation at constant power factor. The sending end converter groups can be set to operate with minimum firing angle (say zero) when the receiving end system requires minimum reactive power injection (i.e. for the case when the Short Circuit Ratio is largest).

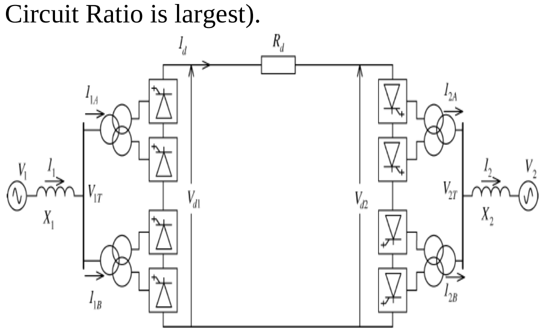

Fig.1. Simplified diagram of a dc link connecting two ac systems.

The generating station operates at its most efficient point when the generators are controlled to provide only active power to the link. PWM provides fully independent controllability of the converter voltages (and therefore reactive power transfers) on both sides of the link. This capability is not available to multilevel configurations under the present control strategies. For instance, if extra reactive power is needed at the receiving end to maintain the ac terminal voltage constant, the firing angle is increased and, therefore, the dc voltage reduced. To continue transmitting the specified power under this condition, the sending end station must also reduce its dc voltage. The dc voltage reduction is implemented by a corresponding increase in the firing angle of the two converter groups; this action will force an unwanted extra injection of reactive power and, thus, an increase of ac terminal voltage at this end. Such condition would not occur if some PWM control were to be added to the multilevel configurations. However the use of PWM is currently limited to three levels and is only used in voltage source conversion schemes. In multilevel CSC HVDC interconnections with two twelve pulse groups per terminal (such as shown in Fig. 1) the same current waveform is produced by each of the 12-pulse converter groups, and thus the total output current waveform remains the same if a phase-shift is introduced between the firings of the two groups constituting the converter station. When a change of operating conditions at the receiving end demands more reactive power from the converter, and thus reduces the dc voltage, shifting the firings of the two sending end converter groups in opposite directions provides the required dc voltage reduction, while maintaining the reactive power constant (due to the opposite polarity of the two firing angle corrections). A relatively small change of active power will be caused by the variation of the fundamental current produced by the shift, but this change can be compensated for by a small extra correction of the two firing angles.

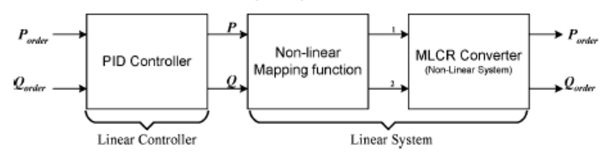

Fig.2. Block diagram of the nonlinear system control objective.

Fig2 illustrates a simplified block diagram of what the controller must achieve, the goal being a mapping function that translates to make the nonlinear converter appear linear. In doing this, then linear control theory may be used successfully. In Fig. 3, the controller has two separate channels, one for each of the If the matrix is nonsingular, and its inverse can be used to linearize the converter system behavior and components. For each channel, the theory is the same; the error is calculated by subtracting the measured power from the power order, and this is fed into the PID controller. As the reactive power circulation is confined to the ac system side, the magnitude of the ac current in each converter group determines the level of reactive power controllability in the ac system.

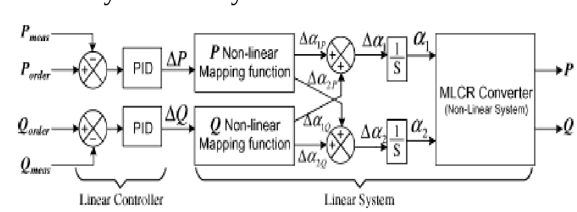

Fig.3. Implementation of nonlinear control theory.

III. SIMULATION RESULTS

As the secondary control objective is to maintain dc voltage constant, a maximum step of 100 MVAr is possible at the receiving end. This is because the receiving end terminal voltage decreases as more reactive power is required by the converter, which further contributes to the decrease in dc voltage for a given firing angle as shown in Figs.4 to 6.

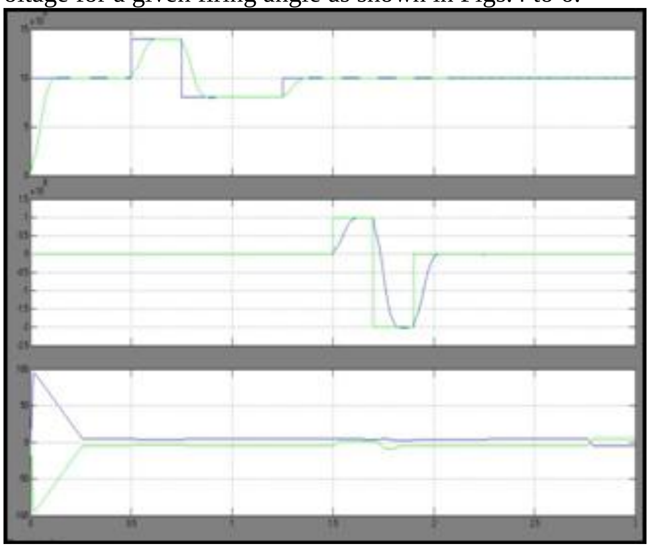

Fig.4. Real and reactive power changes at sending end.

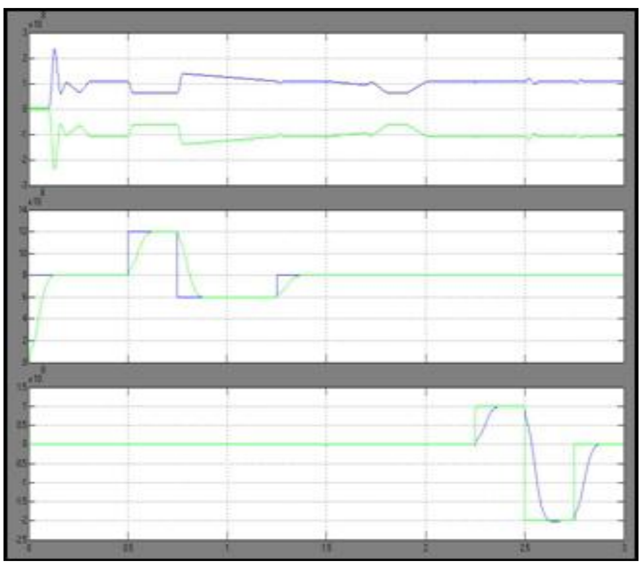

Fig.5 Real and reactive power changes at the receiving end.

The sending end correction is made from the point of view of the ac system, so the converter controller is configured to maintain the power factor of the main supply transmission line as well. In practice it may not be possible to calculate the impedance of the supply in all cases, and an approximation would have to be made about a "nominal" correction point. At the receiving end, the control of the terminal voltage should be easier to achieve, as the nominal supply voltage would be known, or could be calculated. This could also be adjusted manually by the system operator to provide additional voltage support as necessary.

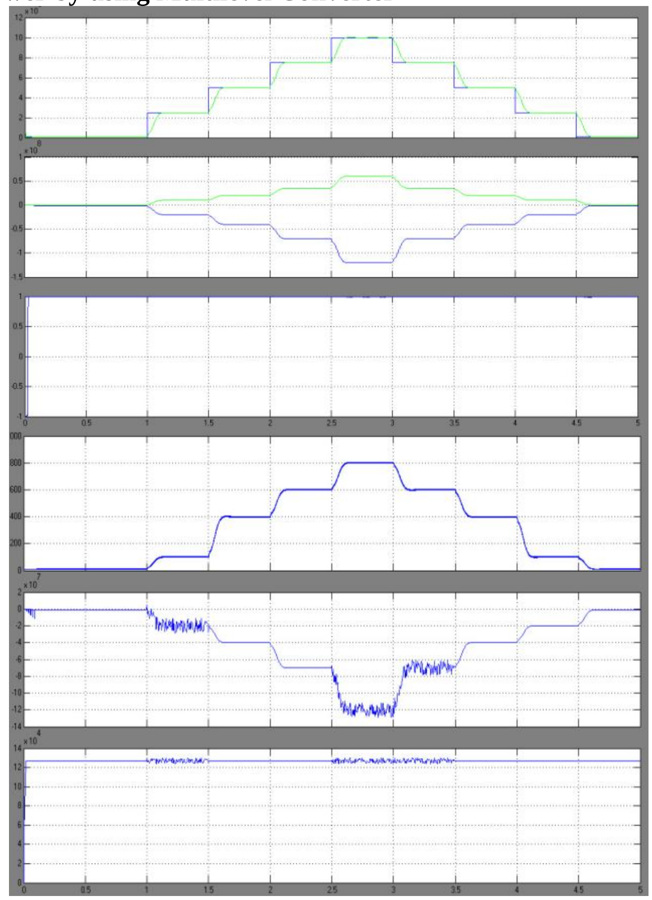

Fig.6 Reactive power responses under power factor and terminal voltage control for a series of step changes to real power.

IV. CONCLUSION

A new type of converter control has been developed, applicable to multilevel HVDC schemes with two or more 12-pulse groups per terminal. It has been shown theoretically, and verified by EMTDC simulation using an MLCR configuration, that the use of a controllable shift between the firings of the series connected converter groups permits independent reactive power control at the two dc link terminals. This provides four quadrant power controllability to multilevel current source HVDC transmission and, thus, makes this alternative equally flexible to PWM-controlled voltage source conversion, without the latter's limitations in terms of power and voltage ratings. It can be expected that MLCR, combined with firing-shift control, should compete favorably with the conventional current source technology for very large power applications.

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