Harmonic Reduction in Circulating Current for Modular Multi-Level Converter Using Repetitive Control Scheme and Fuzzy Logic

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ABSTRACT: In modular multilevel converter (MMC), the sub modules which perform switching actions, it may produce higher order harmonics when involved with fluctuating capacitor voltages and when it gets superimposed with the circulating currents, it will increase their magnitude which results into increased system losses. The proposed model is designed for three phase applications and the simulation results clearly define the effectiveness of the control mechanism.

Keywords - MMC, Fuzzy Logic, SIMULINK.

1.1 Introduction

In today's scenario, the need for a good quality power requirement is as much as important as its reliability. We need to maintain the voltage profile of the power system to be maintained, and this should be independent of the customer's load type and their demand.

Injection of harmonics in the circulating currents, will increase the circulating current magnitude and which can also lead to some special problems in three-phase systems:

- In a 3-phase system, four wire system, harmonic currents can lead to large currents in the neutral conductors, which may easily exceed the conductor rms current rating.
- Increased currents due to harmonics will cause more power loss, even instability due to transients.
- Power factor correction capacitors may experience significantly increased rms currents, causing them to fail.

1.2 Modular Multi-Level Converter

When we talk about converters, voltage source converters (VSC) are generally given preference as compared to current source counterparts because:

• It is more efficient

• It has low initial cost.

They could be expanded in parallel connection to augment their specific rating and the rate of switching can be improved if carefully controlled so as to ensure their individual switching times do not overlap.

1.3 Circulating Current in MMC

A unique characteristic of MMC out of the many advantages, is that its arm currents are continuous hence there is no need for a DC capacitor, but still there are circulating paths through which the currents could circulate within the three phases of an MMC. The AC and DC side of the converter is unaffected by the circulating current. However, if not controlled, it could raise the magnitude of current flowing through SM and can increase the chance of damaging the power electronic switches in SM.

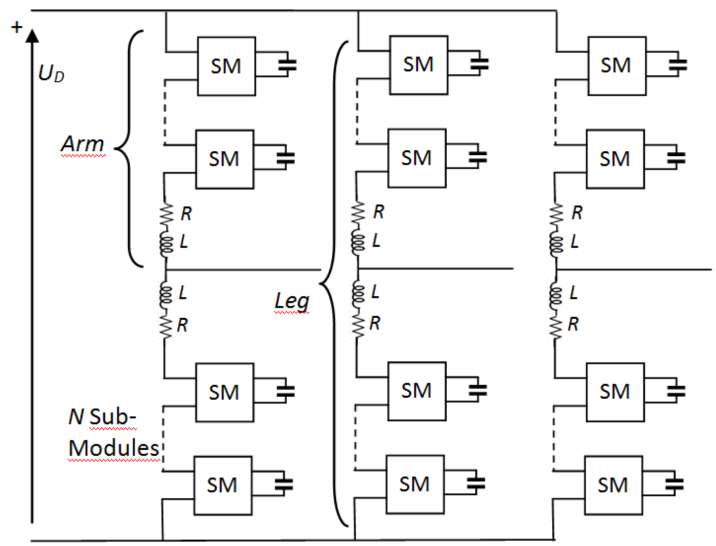

Fig 1.1: Schematic diagram of a three-phase MMC

Circulating currents hold such a name because they circulate within the converter circuit and have no effect on the currents on DC or AC side, however high values of the circulating current have two major effects on the converter:

1) it increase the loss of the system;

2) it makes the converter consist of higher-rate IGBTs, capacitors, and inductances.

1.4 Fuzzy Logic

Fuzzy logic has 2 completely different meanings in an exceedingly slim sense, symbolic logic could be a system of logic, that is an extension of multivalued logic. However, in an exceedingly wider sense symbolic logic (FL) is sort of synonymous with the idea of fuzzy sets, a theory that relates to categories of objects with unsharp boundaries within which membership could be a matter of degree.

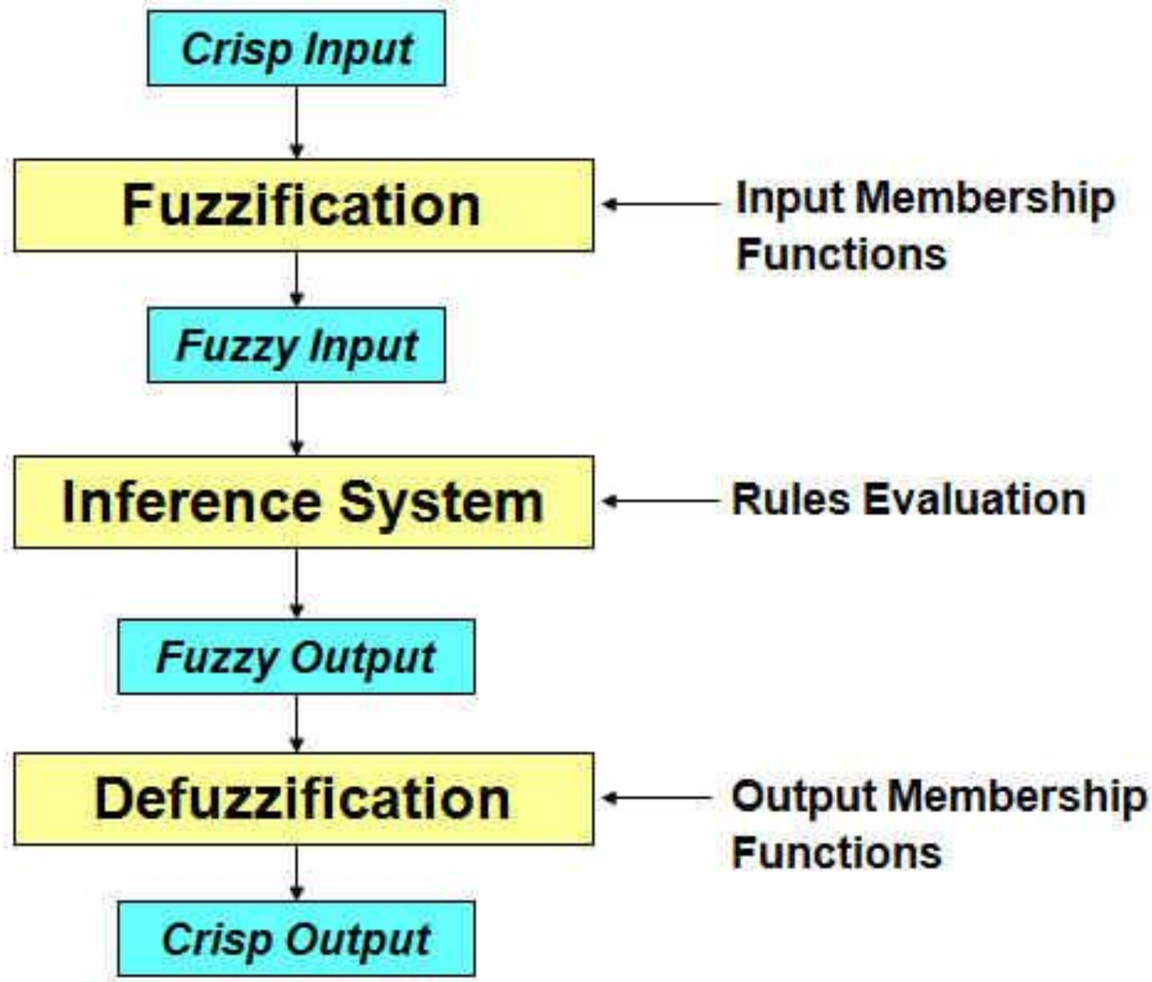

Fig 1.2: Flowchart of Fuzzy Logic

Fuzzy logic could be a convenient technique, mapping an input entity to an output entity and posses following benefits:

• Fuzzy logic is versatile, with any given system it is straightforward to layer on a lot of practicality while not beginning once more from basics.

• It is tolerant of inexact knowledge, as a result of it understands the method instead of jumping to the tip result.

1.5 Control System for Circulating Current

The block diagram for this repetitive scheme for control of circulating current is shown in fig 1.3. The proposed control system consists of the basic proportional-integral (PI) controller and a repetitive controller. This system is shown for the x-phase converter, here for the three phase MMC, three such control systems are needed.

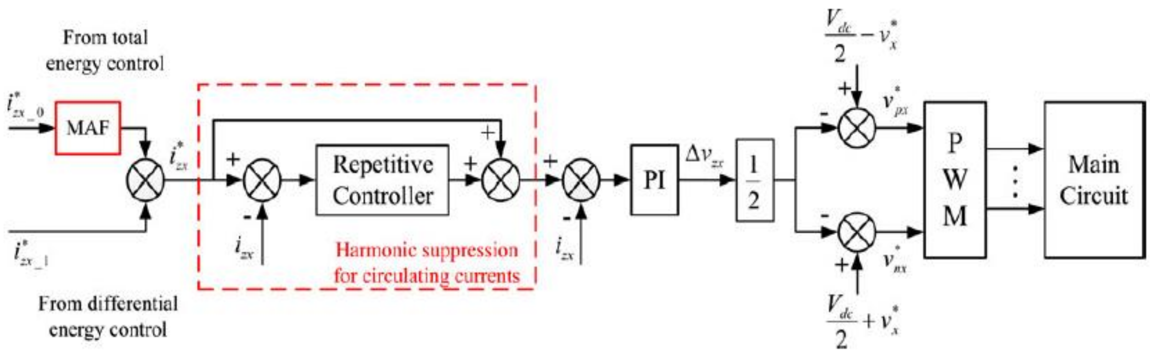

Fig 1.3. : Circulating Current Control for a x-phase MMC

The circulating current reference i_{zx} consists of a dc component coming from total energy control, and a component from differential energy control called fundamental component.

The repetitive scheme working here does not cause any hindrance to other components involved, it does not interfere with the transient response of the PI controller. Due to this arrangement of the controllers, the speed of the switching gets faster and second-order harmonics in the circulating current is cut out.

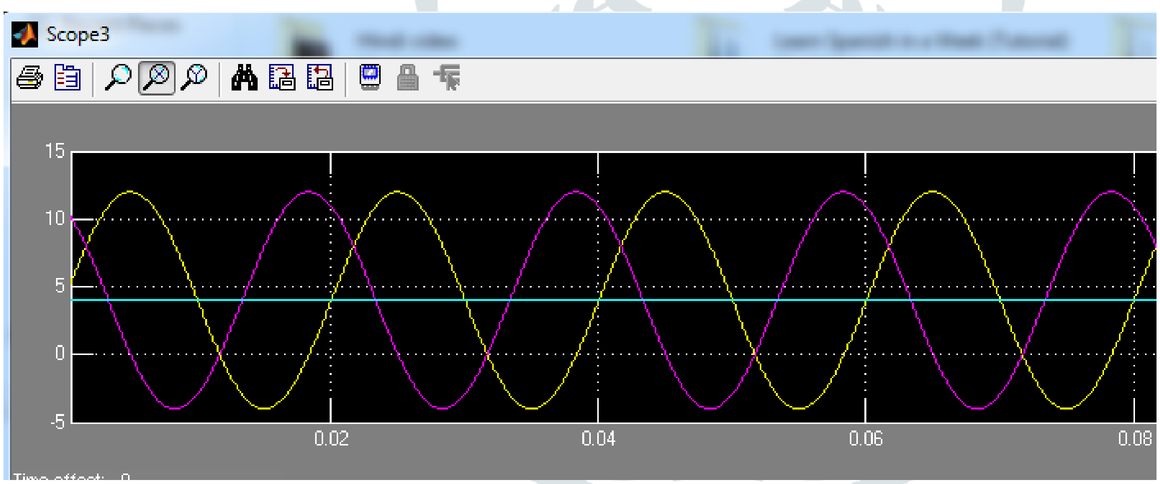

Fig 1.4: PI+MAF+ Repetitive controller waveform(magnitude of circulating current, (shown in blue) hence the harmonics has been settled)

The output waveform of the above figure with PI+ MAF+ Repetitive controller, shows that the waveform shape has been improved reason being the harmonics in the circulating current has been suppressed. It is applicable to both single-phase and three-phase systems.

CONCLUSIONS

With the application of the proposed repetitive controller, the circulating current waveform which was previously having different higher order frequency components or harmonics due to which its magnitude was higher has now been suppressed. Due to the harmonics suppression of this scheme, the reduced magnitude of the circulating currents will result into overall reduction in losses.

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