Harmonic Suppression of Circulating Current in Modular Multilevel Converters using Fuzzy Logic Controller

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ABSTRACT: Modular multilevel converters (MMCs) have emerged as the most promising topology for high and medium voltage applications for the coming years. However, one particular negative characteristic of MMCs is the existence of circulating current, which contains a dc component and a series of low- frequency even-order ac harmonics. If not suppressed, these ac harmonics will distort the arm currents, increase the power loses, and cause higher current stresses on the semiconductor devices. Repetitive control (RC) is well known due to its distinctive capabilities in tracking periodic signals and eliminating periodic errors. In this paper, a novel circulating current control scheme base on RC is proposed to effectively track the dc component and to restrain the low-frequency ac harmonics. The integrating function is inherently embedded in the RC controller. Therefore, the proposed circulating current control only parallels the RC controller with a proportional controller. Thus, conflicts between the RC controller and the traditional proportional integral (PI) controller can be avoided. The design methodologies of the RC controller and a stability analysis are also introduced. The validity of the proposed circulating current control approach has been verified by simulation And extension can be done using Fuzzy Logic Controller

Key Words: Modular multilevel converters (MMCs), Even-order AC harmonics, Repetitive control, Fuzzy Logic Controller, Stability Analysis.

1 INTRODUCTION: This lesson provides the reader the following:

(i) Create an awareness of the general nature of Power electronic equipment;

(ii) Brief idea about topics of study involved,

(iii) The key features of the principal Power Electronic Devices;

(iv) An idea about which device to choose for a particular application.

(v) A few issues like base drive and protection of PE devices and equipment common to most varieties.

Power Electronics is the art of converting electrical energy from one form to another in an efficient, clean, compact, and robust manner for convenient utilisation. A passenger lift in a modern building equipped with a Variable-Voltage-Variable-Speed induction-machine drive offers a comfortable ride and stops exactly at the floor level. Behind the scene it consumes less power with reduced stresses on the motor and corruption of the utility mains.

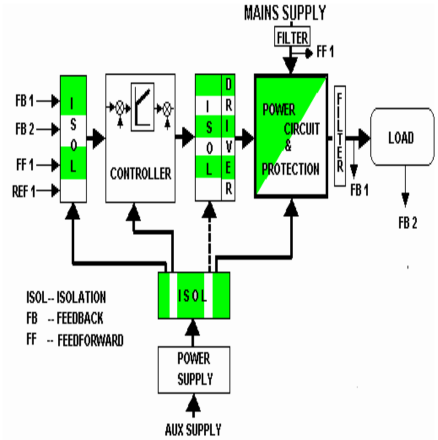


Fig. 1.1 The block diagram of a typical Power Electronic converter

1.1.Differentiate between Power electronics And linear electronics:

It is not primarily in their power handling capacities. While power management IC's in mobile sets working on Power Electronic principles are meant to handle only a few milliwatts, large linear audio amplifiers are rated at a few thousand watts.

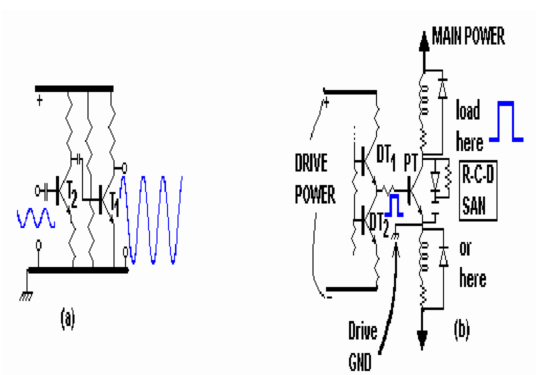


Fig. 1.2 Typical Bipolar transistor based

(a) linear (common emitter) (voltage)

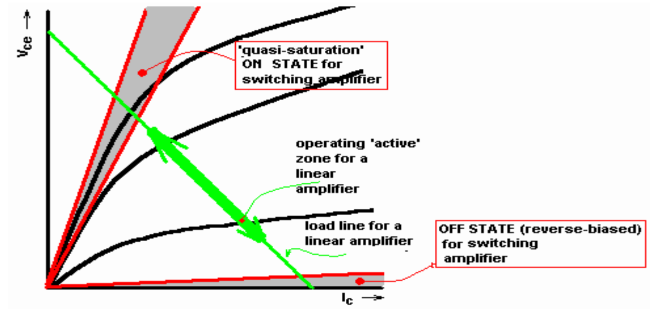


Fig 1.3 Operating zones for operating a Bipolar Junction Transistor as a linear and a switching amplifier

MOSPET:

The Power MOSFET technology has mostly reached maturity and is the most popular device for SMPS, lighting ballast type of application where high switching frequencies are desired but operating voltages are low. Being a voltage fed, majority carrier device (resistive behaviour) with a typically rectangular Safe Operating Area, it can be conveniently utilized. Utilising shared manufacturing processes, comparative costs of MOSFETs are attractive. For low frequency applications, where the currents drawn by the equivalent capacitances across its terminals are small, it can also be driven directly by integrated circuits. These capacitances are the main hindrance to operating the MOSFETS at speeds of several MHz. The resistive characteristics of its main terminals permit easy paralleling externally also.

THE IGBT:

It is a voltage controlled four-layer device with the advantages of the MOSFET driver and the Bipolar Main terminal. IGBTs can

be classified as punch-through (PT) and non-punch- through (NPT) structures. In the punch-through IGBT, a better trade-off between the forward voltage drop and turn-off time can be achieved. Punch-through IGBTs are available up to about
1200 V. NPT IGBTs of up to about 4 KV have been reported in literature and they are more robust than PT IGBTs particularly under short circuit conditions. However they have a higher forward voltage drop than the PT IGBTs. Its switching times can be controlled by suitably shaping the drive signal. This gives the IGBT a number of advantages: it does not require protective circuits, it can be connected in parallel without difficulty, and series connection is possible without dv/dt snubbers. The IGBT is presently one of the most popular device in view of its wide ratings, switching speed of about 100 KHz a easy voltage drive and a square Safe Operating Area devoid of a Second Breakdown region.

Power converter topologies:

A Power Electronic Converter processes the available form to another having a different frequency and/or voltage magnitude. There can be four basic types of converters depending upon the function performed:

2.3. HARMONIC

The typical definition for a harmonic is “a sinusoidal component of a periodic wave or\ quantity having a frequency that is an integral multiple of the fundamental frequency.” [1]. Some references refer to “clean” or “pure” power as those without any harmonics. But such clean waveforms typically only exist in a laboratory. Harmonics have been around for a long time and will continue to do so. In fact, musicians have been aware of such since the invention of the first string or woodwind instrument. Harmonics (called “overtones” in music) are responsible for what makes a trumpet sound like a trumpet, and a clarinet like a clarinet.

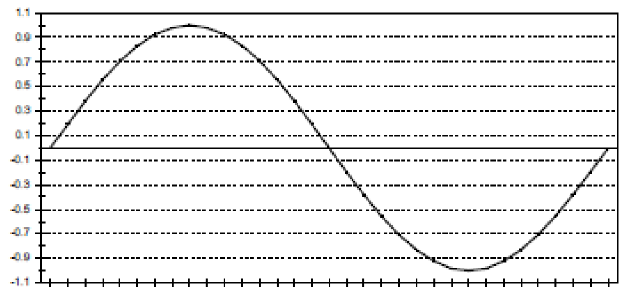


Fig1. Sine wave

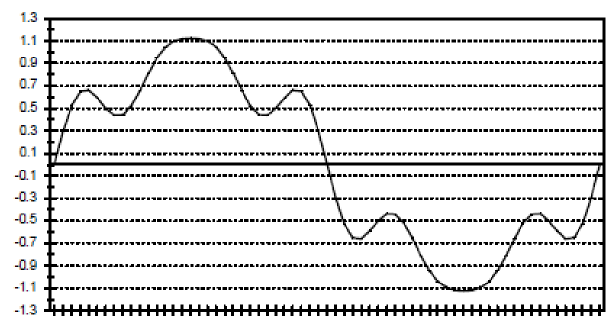


Figure2. Fundamental with two harmonics

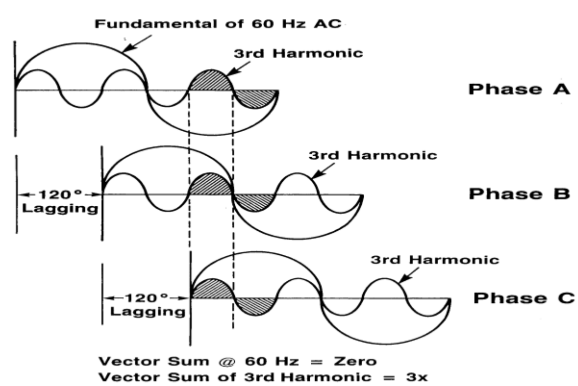


Figure3. Additive Third Harmonics

PROPOSED TECHNIQUE:

FUZZY LOGIC:

Fuzzy logic has two different meanings. In a narrow sense, fuzzy logic is a logical system, which is an extension of multivalve logic. However, in a wider sense fuzzy logic (FL) is almost synonymous with the theory of fuzzy sets, a theory which relates to classes of objects with unsharp boundaries in which membership is a matter of degree. In this perspective, fuzzy logic in its narrow sense is a branch of fl. Even in its more narrow definition, fuzzy logic differs both in concept and substance from traditional multivalve logical systems.

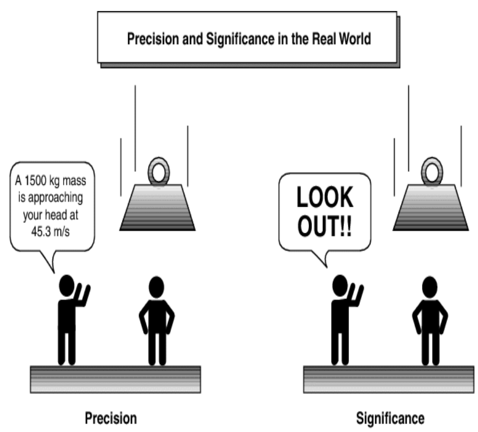


fig 5.1 fuzzy description

Building a fuzzy inference system:

Fuzzy inference is a method that interprets the values in the input vector and, based on user defined rules, assigns values to the output vector. Using the GUI editors and viewers in the Fuzzy Logic Toolbox, you can build the rules set, define the membership functions, and analyze the behavior of a fuzzy inference system (FIS). The following editors and viewers are provided.

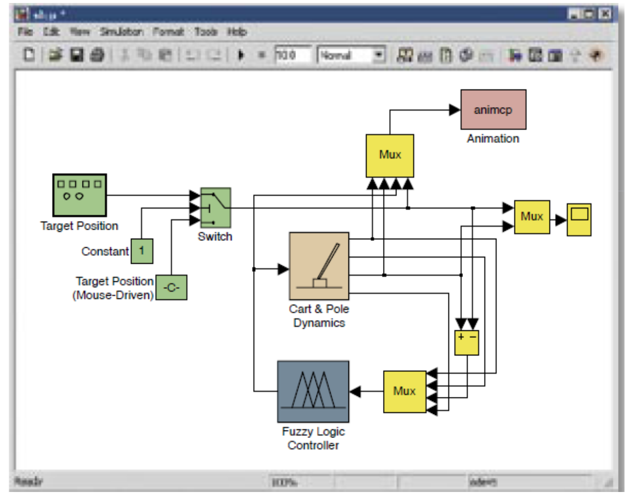


fig 5.2 fuzzy interference system

The FIS editor:

The FIS Editor displays general information about a fuzzy inference system. There's a simple diagram as shown in Fig.3 that shows the names of each input variable on the left, and those of each output variable on the right. The sample membership functions shown in the boxes are just icons and do not depict the actual shapes of the membership functions.

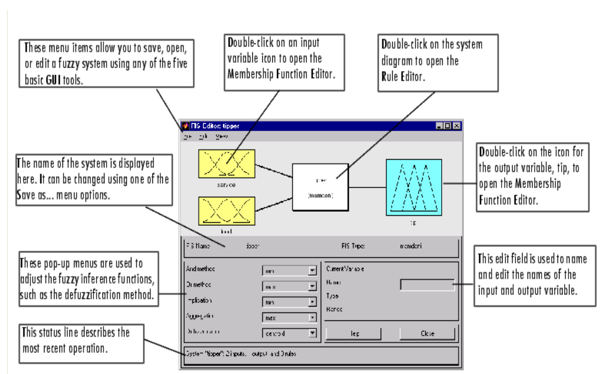
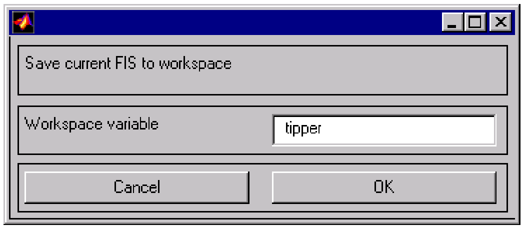


fig 6.3 The FIS Editor

You will see the diagram updated to reflect the new names of the input and output variables. There is now a new variable in the workspace called tipper that contains all the information about this system



WindowBy saving to the workspace with a new name, you also rename the entire system. Your window will look like as shown in Fig.5.

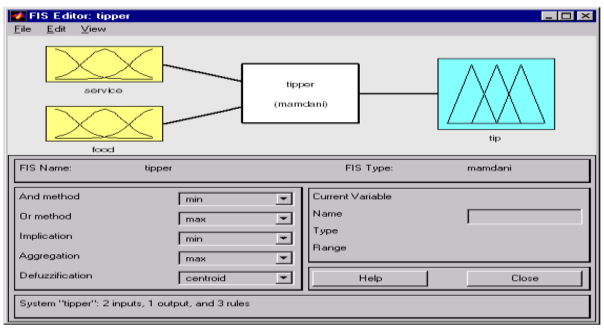
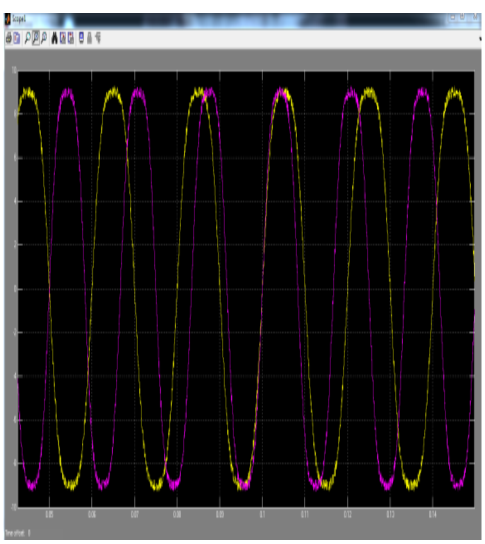


fig 6.5 The updated FIS Editor

RESULT:



CONCLUSION:

The second-order as well as other higher order harmonics in circulating current brings extra power losses and may affect stable operation of the MMC. This paper proposed a “Fuzzy + Repetitive” control scheme to suppress these harmonics in the circulating current. It greatly improves the harmonic suppression of the conventional Fuzzy controller. It is applicable to both single-phase and three-phase systems, and is able to eliminate multiple harmonics with a single controller. Compared with another “Fuzzy + Repetitive” control scheme in which the two controllers are paralleled, the control structure proposed in this paper results in amore friendly plant for the repetitive controller, and poses no design limit on the Fuzzy controller. Simulation and experiments are made on a single-phase MMC inverter. The results show good harmonic suppression of the proposed control scheme, and indicate that the plug-in repetitive controller does not affect the transient performance of the Fuzzy controller. The results also show that after the second-order harmonic in the circulating current is cut out, there is no significant increase of second-order ripple in the SM capacitor voltages.

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