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"Reduction of Supraharmonics using Fuzzy Controller"

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Abstract: *We will study the term discussed in the CIGRE/CIRED/IEEE joined working group C4.24 i.e. Supraharmonics and also about its reduction. The distortions in the current or voltage waveforms in the frequency range 2kHz-150kHz are termed as Supraharmonics. The characterization of Supraharmonics is gaining interest because of its increased occurance in power-line communication. Power Electronics is emerged as a pervasive technology which plays a vital role in almost all areas, but, is also an important factor behind harmonic distortion. Recent studies indicate that future problems to distribution grids may include supraharmonics and hence their mitigation becomes an essential aspect.To reduce these distortions we will design a system in MATLAB using Fuzzy Logic Controller, which will be reducing the Supraharmonic content from the output waveform of a three phase inverter.*

Keywords: *Supraharmonics, 2kHz-150kHz distortions in power line communications, Fuzzy logic controller.*

I. Introduction

The CIGRE/CIRED Joint WG C4.24 "Power quality and Electromagnetic Compatibility Issues associated with future electricity networks", (C4.24 in short) obtained its mandate in 2013 and is expected to deliver its final report in2017. The C4.24 cooperates with the IEEE working group "Power quality Issues with Grid Modernization" both with similar scope and objectives. The outline of the new developments in power electronics (PE) and their related impact in power quality (PQ) are currently discussed in those international groups. An important conclusion is now already that the conventional PWM techniques employed in PE inject emission in the high frequency (HF) range 2 to 150 kHz, (also referred to as "supraharmonics"). The topic of supraharmonics is also treated at CIGREC4/C6.29, "Power quality aspects of solar power" . Potential interference issues in relation to power-line communication (PLC) are discussed in CIGRE C4.31 in the HF band 9 to 150 kHz. The latest draft of IEC 61000-4-30 "Testing and measurement techniques -Power quality measurement methods" includes a definition of PQ indices to determine the emission in this HF band. IEC 61000-3-8 "Signaling on low-voltage electrical installations – Emission levels, frequency bands and electromagnetic disturbance levels" considers the HF range from 3 to 148.5 kHz. Also standards CISPR 14 and CISPR 15 are within this framework. The current EN 50561-1 on PLC equipment for connecting in LV grids considers the HF range 1.6065 to 30 MHZ. Within IEEE, supraharmonics have been debated in IEEE P-1250 and are an important part of the scope of TC-7 of the IEEE EMC Society. Supraharmonics are also part of IEC/TS62749 "Assessment of power quality– characteristics of electricity supplied by public networks". In CENELEC, supraharmonics is also considered by the WG in charge of EN 50160. The necessity of supraharmonics standards is also stated in the application guide for EN 50160. CENELEC TC-210 is collecting examples of interference with PLC originated by supraharmonics. IEC TC77A covers this HF range through some working groups. The 9 kHz limit border between TC77A (LF) andTC77B (HF), only has historical motive. In point of fact, advances in the direction of standards in the range 2-150 kHz are presently emerging within IEC TC77A, but not in TC77B. After very hard work and intense discussions, SC77A WG8 got a consensus regarding compatibility levels in the HF range 2-30 kHz. Consequently, SC 77A WG8 decided to proceed with the IEC 61000-2-2 Ed. 2 AMD. 1 and to circulate a draft for voting (CDV) as a next step. For non-intentional emissions in the range 30-150 kHz, no consensus has been achieved in SC77A WG8, leading to proceed with further investigations in this HF range to get a better view on the situation.Although the presence of supraharmonics in the grid is not new, and for several decades the related problems have been considered, the term supraharmonics was coined during the 2013 IEEE PES-GM. Emission below 2 kHz, low frequency (LF) harmonics, is a widely explored area where as HF emissions in the range of 2 kHz to 150 kHz, (supraharmonics), have caught recent attention mainly due to the use of large parts of this HF band for PLC as well as PE converters with active switching. Research and papers spanning that range go back to a decade, but this HF range has attracted more attention from researchers, and work is nowadays ongoing around the world.

II. System Structure

The configuration of proposed system for reduction of Supraharmonics is as shown in fig.1.

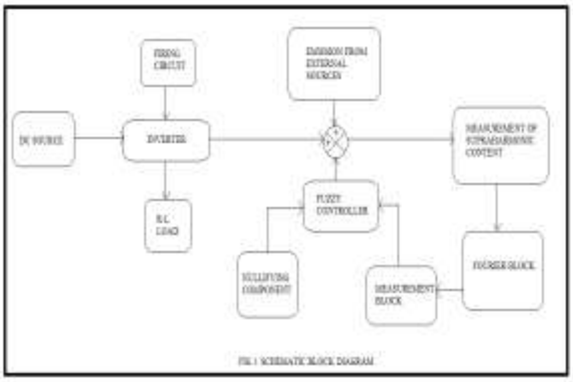

Fig.1. Schematic Block Diagram

DC Source:
A DC source which can be either a battery or a rectifier is given to a three phase Inverter. Here, we are using a battery which acts as a source for the inverter. A supply of 1 p.u. is given to the inverter through the battery.
Three phase inverter:
An inverter is a device that converts DC supply into AC supply. Here we are using a six pulse inverter which consists of IGBT's. IGBT is the acronym for Insulated Gate Bipolar Transistor. As the name suggests it is a gate turn-on and turn-off device that means it starts or stops its conduction only when a gate pulse is provided. The IGBT's are numbered as S1,S1'S2,S2',S3 and S3' where S1 and S1' conducts at a time, then S2 and S2' and after that S3 and S3' are conducts.
Firing circuit:
IGBT starts conduction after a pulse is given to its gate terminal. Thus, we require a firing circuit to fire a gating pulse.The model for generating a gating pulse is shown in fig.2.1. A three phase supply is given to the firing circuit along with a carrier signal. For comparison a relational operator is used along with a Boolean function (here NOT). If the supply voltage of either phases is greater then the upper devices of the leg of that particular phase will conduct and if the carrier signal is of a greater value then the lower devices of that particular leg will conduct simultaneously.
R-L Load:
The output from the inverter is fed to an R-L load. It consists of branch of resistor and inductor connected in series.
Emission from external sources:
These are mainly the emissions in the frequency range of 2kHz-150kHz.For this a DSP will be used.
Fourier Block:
To observe the harmonic content in the output waveform of the inverter a Fourier block is used.
Fuzzy Controller:
Fuzzy controller is used to reduce the harmonic content from the output waveform of the inverter by Fuzzy logic.

III. System Design

An appropriate design of the system plays an important role in the operation of this project. The simulation type will be Discrete and the sample time we are considering as Ts.We will be considering the p.u. system and thus we will assume some base values. Here; Base Power=100MVA, P-Q tolerance (p.u.)= 1e4, Maximum iterations=50, Voltage units = kV and Power units= MW.

Table I: Inverter Design

$V_{D.C.}$		1 p.u.
I.G.B.T.	Internal Resistance R_{ON} (ohms)	1e-3
	Snubber Resistance R_S (ohms)	1e5
	Snubber Capacitance C_S (F)	inf

Table II: DSP Specifications

	150kHz	**200kHz**
Amplitude	0.2	0.5
Frequency (Hz)	150000	200000
Phase Offset (rad)	0	0
Sample Mode	Discrete	Discrete
Output Complexity	Real	Real
Computation Method	Trignomet-ic Form	Trignomet-ic Form
Sample time	0.0000001	0.0000001
Sample per Frame	1	1

Table III: Gate Signal Specifications

	V_A	V_B	V_C	**3rd Harmo-nics**
Sine Type	Time based	Time based	Time based	Time based
Time (T)	Use Simula-tion time	Use Simula-tion time	Use Simula-tion time	Use Simula-tion time
Amp-litude	0.5*mi	0.5*mi	0.5*mi	1/6*0.5* mi
Bias	0	0	0	0
Frequ-ency (rad/sec)	2*pi*f	2*pi*f	2*pi*f	6*pi*f
Phase (rad)	0	-2*pi/3	2*pi/3	0
Sample Time	0	0	0	0

The load connected is R-L Load, the specifications for the same are; Resistance= 10 ohms, Inductance= 100e-3 H, initial inductor current= -7.4e-22.

IV. Simulink Model

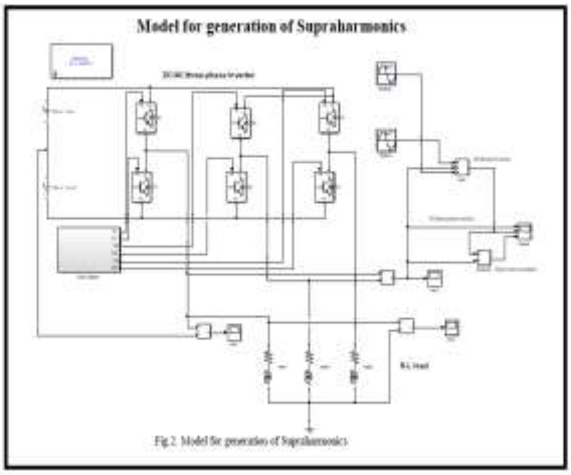

Fig.2. Model for generation of supraharmonics

First we will consider the model for generation of Supraharmonics which is as shown in fig.2. Here, a p.u. supply is given to a three phase inverter through a DC battery.The gate pulse is provided through a firing circuit as shown in fig. 2.1. The output of the inverter is fed to an R-L load. As we have to reduce the Supraharmonic content we will require external emission of frequency ranging in the supraharmonic range. Here, we will take emissions of 150kHz and 200kHz. We are providing this extra arrangement because supraharmonics are observed in practical system and the cause for the same is still not exactly known and as we know in MATLAB occurance of no such phenomena can be expected. Hence, DSP blocks are used for ejecting emissions of 150kHz and 200kHz.

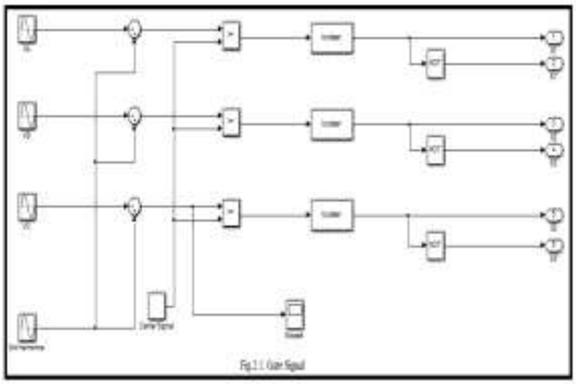

Fig.2.1. Gate Signal

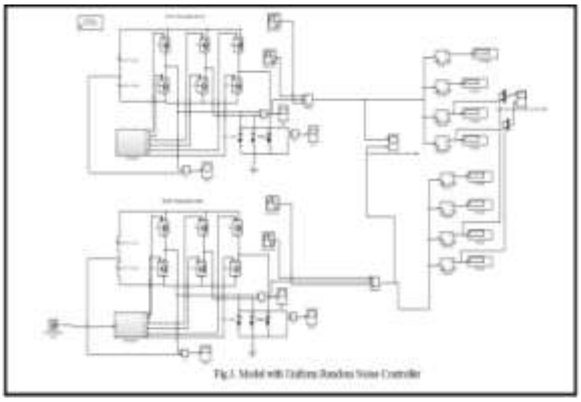

Fig.3. Model with Uniform Random Noise Controller

In this model, we insert a Uniform random noise in the gate signal of similar model as of generation of supraharmonics.This generates any random value between 0-1, which act as a nullifying component, because of which the supraharmonic component somehow gets reduced.

Then we insert Fuzzy Controller for reduction of Supraharmonics as is shown in fig.4. The controller will act after a certain time delay which is given by unit delay function in the model. The output if the system is given as a feedback to the controller and some rules are set according to which the it acts. A nullifying component is given as an output by the controller and accordingly particular supraharmonic content is reduced.

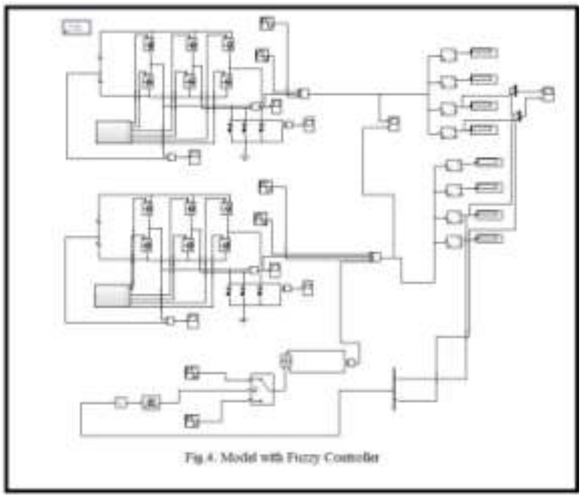

Fig.4. Model with Fuzzy Controller

V. Simulation Results

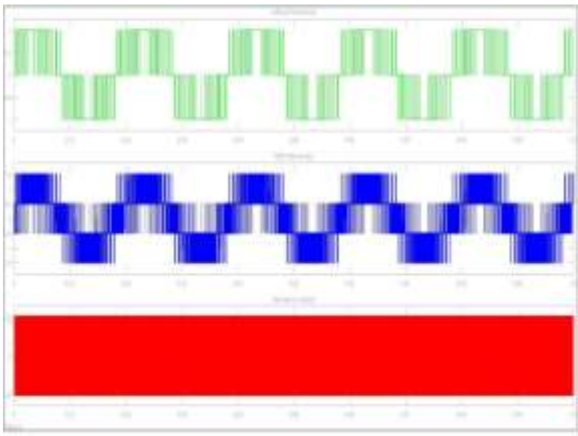

Fig.5. 1. Without Harmonics

Fig.5.2. With Harmonics

Fig.5.3. Harmonic Content

The waveforms in fig.5 shows the scope result of the model after generation of Supraharmonics. Fig.5.1. shows the waveform of without harmonics which are same as the scope results of V_{AB}. Then after adding a high frequency signal from DSP the same voltage waveform becomes as is shown in fig.5.2. The Harmonic content that gets added up because of DSP is as shown in fig.5.3.

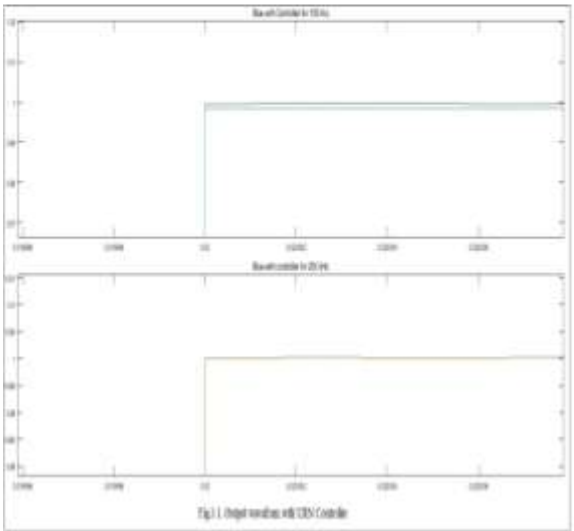

Fig.6. Output with Uniform Random Noise Controller

Using Uniform Random Noise Controller, the Supraharmonic content is reduced by approximately 0.2% as shown in fig.6. whereas, from fig.7, we can see that for 150kHz, the supraharmonics is reduced by 60% and for 200kHz, it is reduced by 40%.

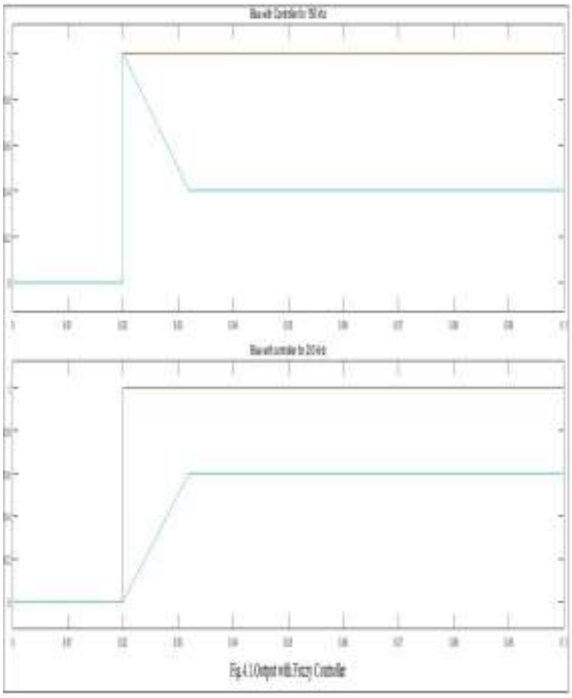

Fig.7. Output with Fuzzy Controller

VI. Conclusion:

Though reduction of Supraharmonics by using Fuzzy Controller is a time consuming method we can prefer it over Uniform Random Noise controller as it gives more accurate results and also the Supraharmonic content is reduced by 40%-60%.

VII. Future Scope:

Research and development is non-stopping process.For any research work there are possibilities for improvement. Here we can use different more technologies for the reduction of Supraharmonics.

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