CLASSIFICATION OF HARMONIC DISTORTIONS AS A FUNCTION OF ANGLE (α) USING FUZZY CLASSIFICATION IN FULL-BRIDGE, SINGLE-PHASE INVERTER AND ACTIVE FILTER

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Abstract: In this article first of all normalized fundamentals and harmonic voltage output and total harmonic distorsions as a function of Angle (α) in full-bridge, single-phase inverters are explained. Then fuzzy classification is explained. After, it is explained how we can use the fuzzy classification to classify harmonic distortion. So it is shown that we can classify hormonic distortion level as a function of α using the fuzzy classification technic. Finally, a new active filter control scheme has been improved using fuzzy classification system outputs and fundamental current I_1. This research shows that fuzzy classification approach can be successfully applied to classify hormonic distortion level and active filter control scheme.

I. Full-bridge, single-phase inverter control by voltage cancellation

This type control is feasible only in a single-phase, full bridge inverter circuit. It is based on the combination of square-wave switching and PWM with a unipolar voltage switching. In the circuit of figure 1, the switches in the two inverter legs are controlled separately. But all switches have a duty ratio of 0.5, similar to a square-wave control [1].

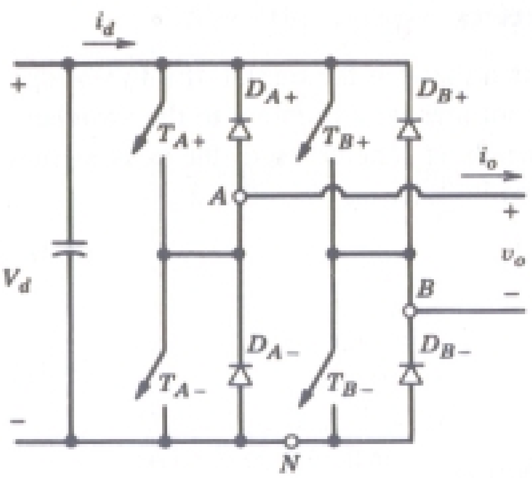

Figure 1. Power circuit of full bridge, single-phase inverter

This result in waveforms for V_{AN} and V_{BN} shown in figure 2, where the waveform overlap angle α can be controlled. During this overlap interval, the output voltage is zero a consequence of either both top switches or both bottom switches being on. With α=0, the output waveform is similar to a square-wave inverter with the maximum possible fundamental output magnitude [1].

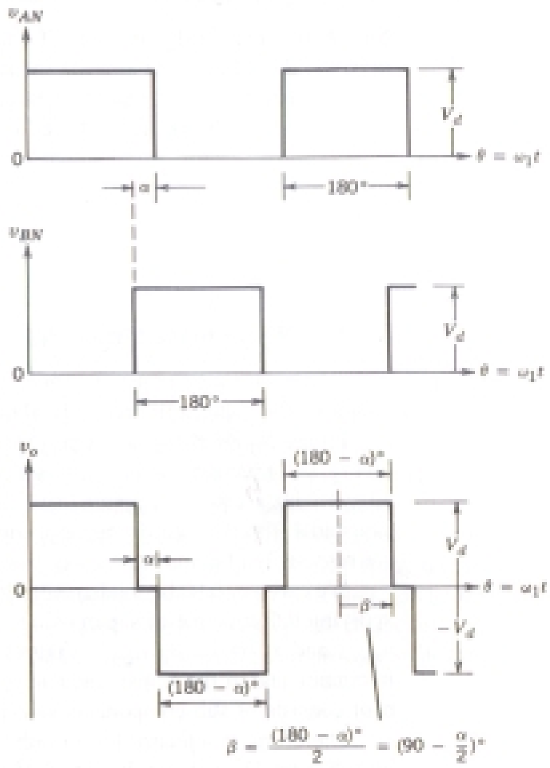

Figure 2. Waveforms of full bridge, single-phase inverter

It is easier to derive the fundamental and the harmonic frequency components of the output voltage in terms of $\beta = 90^0 - \frac{1}{2}\alpha$, as is shown in figure 2.

$$\left(\hat{V}_0\right)_h = \frac{2}{\pi}\int_{-\pi/2}^{\pi/2} V_0 \cos(h\theta).d\theta$$

$$= \frac{2}{\pi}\int_{-\beta}^{\beta} V_d .\cos(h\theta).d\theta$$

$$\therefore \left(\hat{V}_0\right)_h = \frac{4}{\pi h} V_d \sin(h\beta)$$

where $\beta = 90^0 - \frac{1}{2}\alpha$ and h is an odd integer.

Figure 3 shows the variation in the fundamental-frequency component as well as the harmonic voltage as a function of α. These are normalized with respect to the fundamental-frequency components for the square-wawe (α=0) operation . The total harmonic distortion, which is the ratio of the rms value of the harmonic distortion to the rms value of the fundamental-frequency component, is also plotted as a function of α. Because of large distortion, the curves are shown as dashed for large values of α [1].

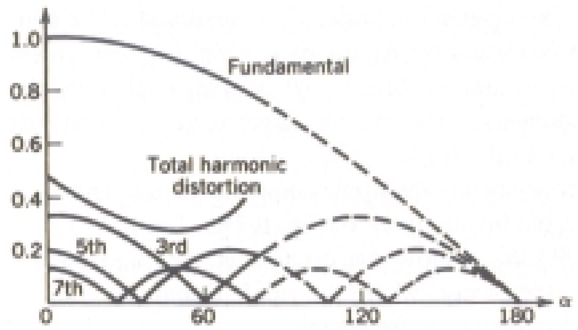

Figure 3. Normalized fundamental and harmonic voltage output and total harmonic distortion as a function of α

II. Fuzzy Classification

Fuzzy logic is an attempt at the representation and utilization of knowledge but in a way more comparable to the way humans think. "Crisp" variables and crisp knowledge are elements in the knowledge-domain that have an exat "truth value" ; either TRUE or FALSE. Another definition of fuzzy logic is that it is a method for easily representing analog processes on a digital computer. These processes are concerned with continuous phenomena that are not easily broken down into discrete segments, and the concepts involved are difficult to model along mathematical or rule-based lines [3-4]

Major issue of concern in the electric power quality industry is classification of power quality problems [2]. This article involves the development of several fuzzy inference systems that accomplish the following objective:

- Identify and classify hormonic distortion level as a function of α in full-bridge, single-phase inverter using the fuzzy classification technic.

III. Fuzzy Classification of 3th, 5th and 7th current harmonics

MATLAB Fuzzy Logic Toolbox is used for identification and classification of fundamental and harmonic voltage output and total harmonic distortion as a function of α.

In the first part of this research, input variable α, output variable 3th, 5th and 7th current harmonic levels are defined. Membership functions (MF) are also defined for input variable α, output variables 3th, 5th and 7th current harmonics using figure 3. After defining the MF, we defined fuzzy rules in MATLAB Fuzzy Logic Toolbox Rule Editor. Finally fuzzy system is tested using different α values. Figure 4 shows the complete classification algorithm we proposed.

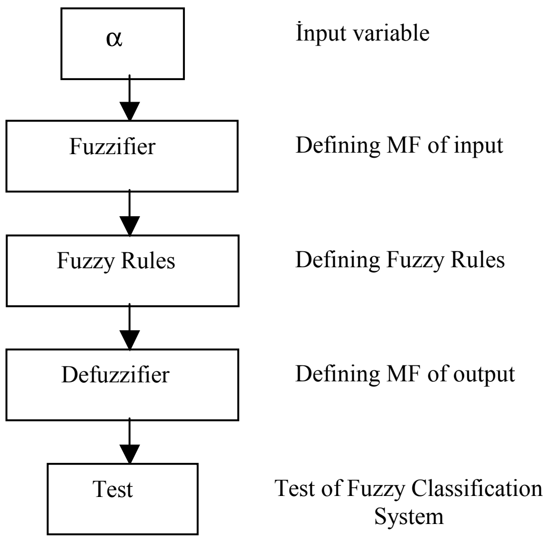

Figure 4. Classification algorithm

IV. Fuzzy Classification System Design

In this application there is one input and three outputs. Input variable is α and output variables are 3th, 5th and 7th current harmonic levels. They are defined using MATLAB Fuzzy Logic Toolbox as shown in figure 5. After defining Fuzzy Inference System we tested the system. Finally we shown that 3th, 5th and 7th current harmonics can be classify by using fuzzy classification. After classification of harmonics we can design a new Active Harmonic filter.

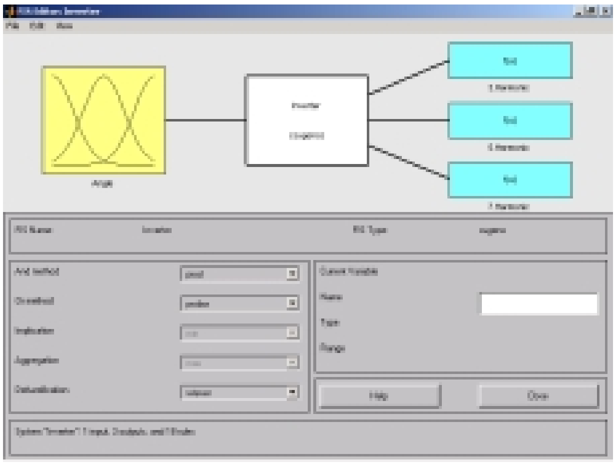

Figure 5. Definition of angle and harmonic levels

After defining input and output variables we defined also MF for input variable α and output variables 3th, 5th, 7th harmonic levels using figure 3. When defining MF of an angle MFs per 10^0 will be defined. So optimization has done for defining of MFs. Similarly when defining MFs of 3th, 5th and 7th current harmonic levels, harmonic levels output takes only one value for every 10^0. As it is shown in figure 6 variable angle has 18 MFs.

Figure 6. MF of angle

3th, 5th and 7th current harmonics as a function of angle will be decided as "if then" fuzzy rules. There are 18 rules and this rules are defined in Matlab Fuzzy Rules editor as shown in figure 7.

Rule1: If Angle=1 then 3.Harmonic=1 and 5.Harmonic=1 and 7.Harmonic=1

Rule2: If Angle=2 then 3.Harmonic=2 and 5.Harmonic=2 and 7.Harmonic=2

Rule3: If Angle=3 then 3.Harmonic=3 and 5.Harmonic=3 and 7.Harmonic=3

Rule18: If Angle=18 then 3. Harmonic=18 and 5. Harmonic=18 and 7.Harmonic=18.

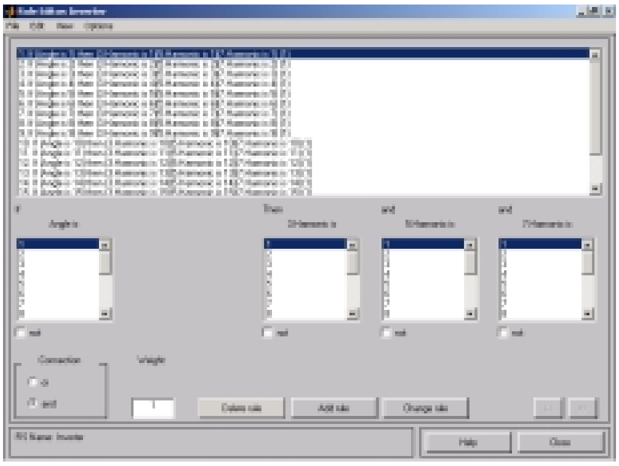

Figure 7. Fuzzy rules

Finally fuzzy classification system will be tested using Rule Viewer for different α values as shown in figure 8.

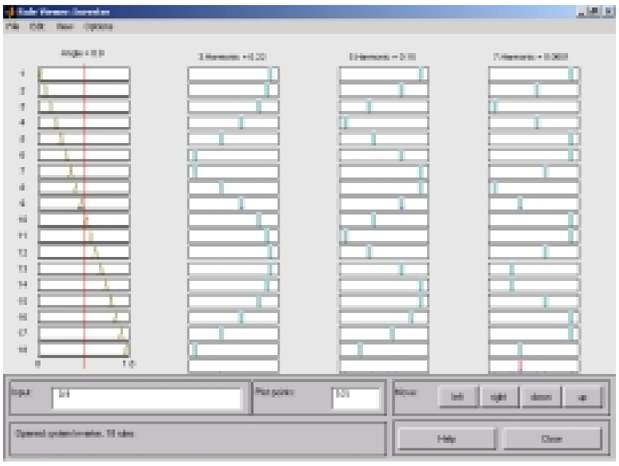

Figure 8. Rule Viewer of fuzzy classification system

Table 1. Fuzzy system outputs for different angles

	Harmonics (%)			Analaysis		
Angle	**3 th**	**5 th**	**7 th**	**1.Highest Harmonic**	**2.Highest Harmonic**	**3.Highest Harmonic**
5	32	19	12	3	5	7
15	31	15	8	3	5	7
25	28	8	3	3	5	7
35	22	3	8	3	7	5
45	15	9	12	3	7	5
55	6	15	12	5	7	3
65	6	19	9	5	7	3
75	15	19	3	5	3	7
85	22	15	6	3	5	7
95	28	9	12	3	7	5
105	31	3	12	3	7	5
115	32	8	9	3	7	5
125	32	15	5	3	5	7
135	31	19	5	3	5	7
145	28	19	9	3	5	7
155	22	17	12	3	5	7
165	15	13	12	3	5	7
175	6	6	6	3,5,7	3,5,7	3,5,7

We can get the fuzzy system outputs for different α values using matlab rule viewer. The Fuzzy system outputs for different α values are shown in table 1. According to this table harmonic degrees of 3th, 5th and 7th current harmonics and highest harmonics can be determined as a function of angle α.

V. An Active Filter Design

We can calculate also %THD (Total Harmonic Distortion) using 3th, 5th and 7th current harmonics which are given in table 1.

$$\%THD = \sqrt{\sum_{h=2}^{\infty}\left(\frac{I_h}{I_1}\right)^2} \qquad (1)$$

For example we can calculate %THD for 5^0 angle using equation 1;

$$\%THD = \sqrt{(32)^2 + (19)^2 + (12)^2} = 40$$

We can say that if %THD value is high it has to be use a filter. If we would like to use an Active Filter, we must find the active filter compansation currents.

For example, 3th, 5th and 7th current harmonics are given in table 1 as % for angel 5^0. If we can measure the fundamental current (I_1) then we can calculate the I_3, I_5 and I_7 harmonic currents as it is shown below.

$I_3=0,32*I_1$

$I_5=0,19*I_1$

$I_7=0,12*I_1$

3th, 5th and 7th current harmonics are shown in figure 9 as bar graphs.

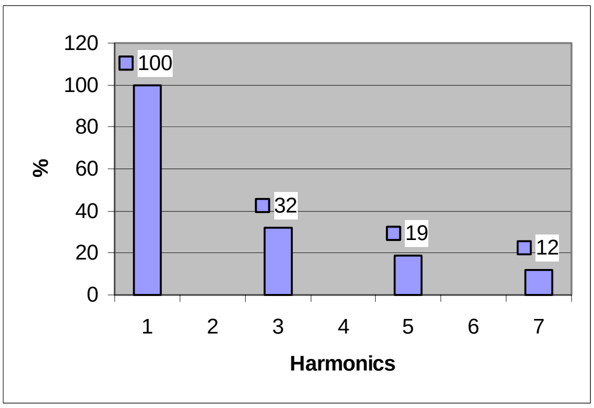

Figure 9. 3th, 5th and 7th Current Harmonics for angle 5^0

For the filtering of the 3th, 5th and 7th currents harmonic, AF has to produce - I_3, - I_5 and - I_7 compansation currents which are shown in figure 10

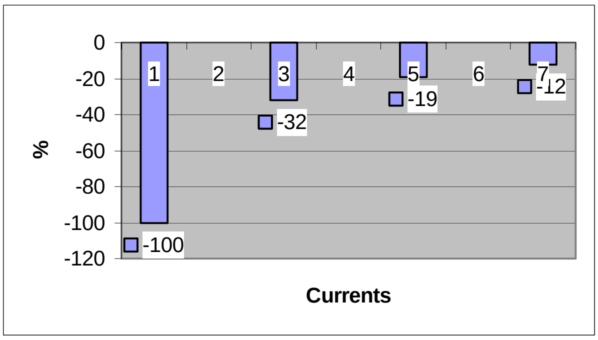

Figure10. Active filter compansation currents

Figure 11 shows the control scheme of the AF. According to this figure, pulse angle of the single phase inverter and fundamental current value are used for implementation of control scheme. In real time implementation of the AF fuzzy classification system plays an impotant role. After classification of 3th, 5th and 7th current harmonics, 3th, 5th and 7th harmonic currents can be calculated. In this condition AF compansation currents can also be calculated. So the control algorithm of the AF provides reference supply currents.

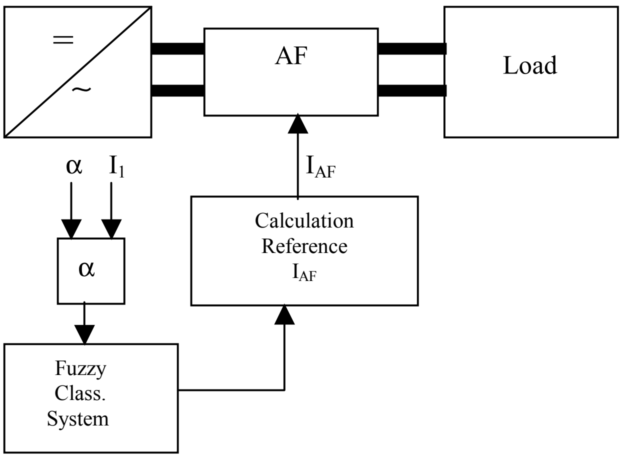

Figure 11. Control scheme of the active filter

VI. Conclusion

This research shows that classification of 3th, 5th and 7th current harmonics and THD in Full-bridge, single-phase inverter using fuzzy classification system is satisfied.

The proposed fuzzy classification approach has been successfully applied to classification hormonic distortion level as a function of α in full-bridge, single-phase inverters. In addition an improved control algorithm of the active filter system has been implemented for harmonic elimination of full-bridge, single-phase inverter

VII. References

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VIII. Biographies

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