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RESEARCH ARTICLE

PREDICTION of POWER SYSTEMS HARMONIC USING FUZZY LOGIC

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ABSTRACT

This paper presents a new approach for predicting the Voltage Total Harmonic Distortion (THD_V) in power systems. We benefit from a power system with nonlinear dynamic load belonging to an Iron and Steel Industry. In this power system the nonlinear load consist of DC motor drives, high frequency welding machine, thyristor controlled AC chopper, rectifier and invertor. Especially high frequency machines used in heating and welding process in an iron and steel industry are playing rol in voltage distortions. Basic relationships about harmonics, effects of the harmonics and ways for the THD_V measurement are described in the firstly and prediction of THD_V using Fuzzy Inference Systems (FIS) are examined in the secondly part of the paper. Power Factor (PF), and 3rd phase current (IL3) values are measured for an example system. After FIS is designed for prediction of THD_V and method is tested using both FIS simulation and field measurements, the proposed fuzzy prediction approach is successfully applied to predict THD_V

Keywords: *Harmonic, Fuzzy Inference System, Power Factor, Active Filter, Distortion Factor*

1. INTRODUCTION

Today, in industrial facilities that make serious contributions to the economy; It is aimed to operate the equipment in the safest environment, especially the continuity of production. While establishing an industrial facility, it first seeks to investigate whether the energy need, which is the basic infrastructure needs, can be met. The next step is to increase the quality of the energy to be received. Industrial facilities can connect to distribution or transmission networks depending on power and generation. In addition to providing continuous and uninterrupted energy, it is among the biggest goals of the relevant transmission and distribution network operators to provide quality energy and to prevent all kinds of disruptive effects from the facilities [1].

Non-linear loads cause current and voltage waveforms to form far from sinusoidal forms on the system. Elements such as power electronics, transformers, converters and arc furnaces are commonly known as nonlinear loads. Energy losses on the system, defects in insulation and heating problems in materials are the harbingers of harmonics. Active and passive filtering systems have been developed in order to prevent the negativities that may occur on the network due to harmonics such as these.

These systems aim to eliminate the disruptive effects in the event of harmonics or by staying on continuously.

Active filters are divided into series active filters, shunt active filters, combined power quality regulators, while passive filters are divided into series passive filters and shunt passive filters. Active filters based on advanced power electronics are more costly than passive filters. Active filters can eliminate harmonics by destroying frequencies other than the fundamental frequency. The working principle of the active filter is to apply the current other than the fundamental component that the non-linear load will draw to the load in a suitable phase. Passive filters consist of a series-connected capacitor and an inductance block. If necessary, ohmic resistor can be added to this block. The working principle of passive filters is to ensure that the harmonic waveform, which is the multiple of the fundamental component, is connected to the ground over L and C values without applying it to the load. In order to eliminate each harmonic component, L and C values must be determined separately [2].

Today, it is aimed to predict and intervene the harmonics that create a disruptive effect on the networks before a certain period of time. With the estimation studies, the filtering systems, which are constantly in operation, will be activated during the times when harmonics will occur, which will provide significant gains in terms of cost and equipment life [3].

This paper presents THD_V method was used for harmonic analysis instead of FIS based studies.In this study, the differences between normal and abnormal harmonics and particularly high level harmonics in a power system with nonlinear dynamic loads are determined using a new technic that uses Fuzzy Inference Systems.

2. MATERIAL AND METHOD

2.1. Harmonics in Power Systems

In power networks, non-linear load means load that has no relationship between current and voltage. The voltage and current curves that are the load source are not sinusoidal. According to Fourier analysis, these non-sinusoidal terms are called harmonics. In energy distribution systems, when a sinusoidal voltage source is applied to a non-linear load such as an arc furnace, transformer, sinusoidal waveform distortions will occur. The reason for the distortion of the current waveform, which should be in the sine form or close to the sinus form, is the sine waves that occur outside the basic network frequency. These currents in the form of other sinuses originating from the non-linear load other than the network frequency (50 Hz) are called harmonics [4].

The presence of harmonics in the system requires a redefinition of their electrical magnitude. Below are some definitions necessary to determine the quality of power systems. The smaller these values are, the higher the quality of the energy drawn by the consumers from the power plants and the closer to the sinusoidal waveform.
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Effective current (I) and Current Total Harmonic distortion (THD_1) are described as below;

$$\mathrm{I} = \sqrt{\left(\frac{1}{T}\int_0^T i^2(t).dt\right)} = (I_0^2 + I_1^2 + I_2^2 + \cdots)^{1/2} \tag{1}$$

JSR A
Journal of Scientific Reports

Kuru, E. and Tekin, L., Journal of Scientific Reports-A, Number 50, 98-105, September 2022.

$$\mathrm{THD}_I = \frac{\sqrt{\sum_{n=2}^{\infty} I_n^2}}{I_1} \tag{2}$$

2.2. Effects Of Harmonics on Power Factor (PF)
The use of parallel capacitors reduces voltage shape distortions and increases the power factor. It also has a significant effect on harmonic levels. Capacitors do not generate harmonics but provide grid networks for possible resonance conditions. If the added capacitors are tuned to a harmonic frequency in the system voltage or current, in the resonant frequency range, large currents or voltages will occur. This may lead to dielectric failure or capacitor breakdown. Fuse blows in capacitors are a symptom of the harmonic problem. The resonance frequency of capacitor banks with a low voltage system can be found as follows [5].

Active Power, Power Factor and Apparent Power are represented as P, PF, S.
Active power calculation is given at below:

$$\mathrm{P} = P_1 = \mathrm{V}I_1 cos\varphi_1 \tag{3}$$

The angle between voltage and load current is shown as φ1. When the average power is examined, it consists of current and voltage.

$$\mathrm{S} = \mathrm{VI} \tag{4}$$

Power Factor (PF):

$$\mathrm{PF} = \frac{P}{S} = \frac{VI_1|cos\varphi_1|}{VI} = \frac{I_1||cos\varphi_1|}{\sqrt{\sum_{n=1}^{K} I_n^2}} \tag{5}$$

The distortion factor is expressed as I_1 / I. When the power factor is rearranged;

$$\mathrm{PF} = |\, cos\varphi_1| * DF \tag{6}$$

The baseline distortion factor must be less than 1 possible. The more sinusoidal the waveforms, the closer the power factor value is to 1.

3. RESULTS

Fuzzy logic is a model that enables the use and representation of human knowledge. Fuzzy logic represents information in a simpler way than the interpretation of the human brain, which has the ability to interpret information at an advanced level [7, 8]. An important issue, especially in the electrical energy sector, is the analysis of power quality [6].

In this study, we benefit from a power system with nonlinear dynamic load belonging to an Iron and Steel Industry. Figure 1. In this power system the nonlinear load consist of DC motor drives, high frequency welding machine, thyristor controlled AC chopper, rectifier and invertor. Especially high frequency machines used in heating and welding process in an iron and steel industry are playing role

JSR A
Journal of Scientific Reports

Kuru, E. and Tekin, L., Journal of Scientific Reports-A, Number 50, 98-105, September 2022.

in voltage distortions. Therefore this plant is very suitable for our study. Firstly, Power Factor (PF), cosφ, 3rd phase Current (IL3) and THD_V values must be measured. This values are measured from the busses illustrade in Figure 3. The results of these measuremnets are shown respectively in Figure 5, Figure 6 ve Figure 7.

This study introduces a system design that can achieve the target between power factor and other electrical parameters.

Figure 1. Nonlinear loods in Iron and Steel Factory.

Figure 2. High frequency welding machinery.

There are four inputs and one output in total in the system. Inputs of system are Power Factor (PF), cosφ, difference (D), 3rd Phase Current (IL3), Output of system is THD_V. Fuzzy Logic Toolbox on the Matlab platform was used to design this system. The system design is highly estimated THD_V with high accuracy.

Figure 4, 5 and 6 show output membership functions (MFs), According to the figures, it was decided to create one MF for each of the inputs and 3 MFs for THD_V. Table 1 shows the value ranges for MFs. By means of Mamdani fuzzy inference, the fuzzy space includes 15 (5 MFs x 3 MFs) parts.

Figure 3. Measurement point.

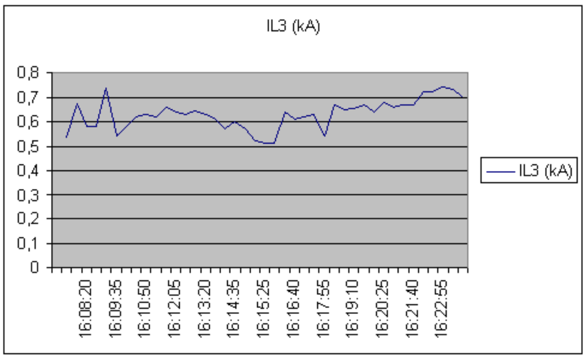

Figure 4. Real time current measurement values.

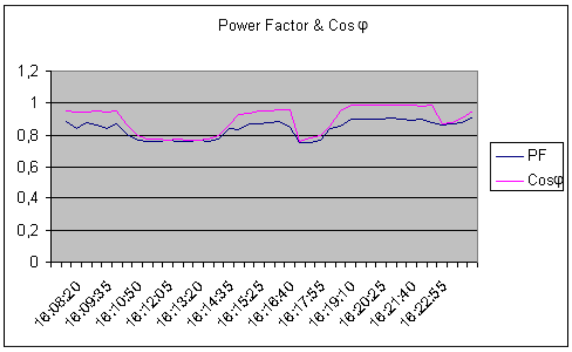

Figure 5. Real time power factor and cosφ measurement values.

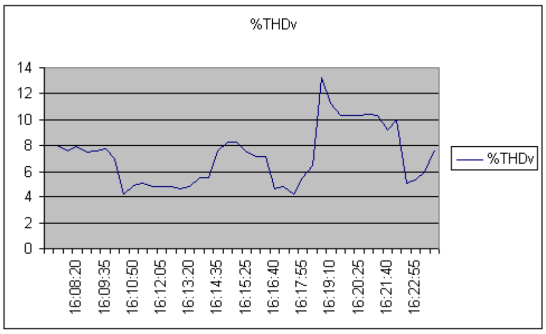

Figure 6. Real time harmonic measurement values.

MFs of input and output variables are designed according to Figures 4, 5 and 6. THD_V values vary between 4.2 and 13.2. In the membership function, these values are divided into three parts and named "LOW", "NORMAL" and "HIGH". Power factor, cosφ, membership functions are named as “LOWLOW”, “LOW” and “NORMAL”. The current membership functions in Figure 4 consist of three parts as “LOW”, “NORMAL” and “HIGH”. Membership function range values are given in Table 1.

Table 1. Membership Function Intervals.

PF	Cos	D	IL3	%THD_v
0,751-0,88	0,764 0,905	0-0,031	540-740	0-6,5
0,805-0,915	0,865-0,955	0,06-0,108	510-735	6,5-10
0,88-0,905	0,977-0,991	0,08-0,110	640-680	10-13,2

After the FIS design, the rules within the method had to be tested. The FIS Test was performed with the real harmonic measurements in Table 1. The measurement of the actual data was taken at 15 sec intervals. It also means that it includes voltage harmonics under varying load conditions. In this way, real THD_V estimations, which are the output of the system, can be made.
An increase in the difference between PF and cosφ causes an increase in THD_V. Within the scope of the application, it is seen that there is an increase in the harmonic level with the decrease in the power factor. Figure 7 shows the FIS architecture, which establishes a relationship between PF and harmonics.

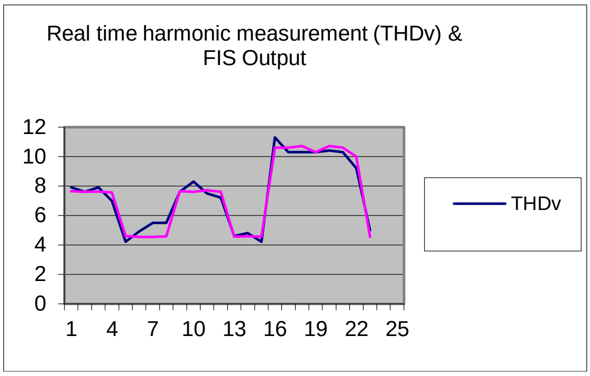

Figure 7. Real time harmonic measurement and FIS Output.

4. CONCLUSION

In this study, it is seen that fuzzy logic systems for THD_V extraction are quite successful. The proposed fuzzy logic inference method has achieved quite peaceful results in estimating THD_V. In this way, cosφ, power factor and phase current values can be estimated with very little error. FIS structures in THD_V systems can make accurate predictions. With the proposed method, an effective method in harmonic analysis is used in real time. At the same time, this fuzzy logic based harmonic filter design seems to be more economical.

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