ESTIMATION OF HARMONICs IN DISTRIBUTION SYSTEM USING FUZZY ESTIMATION METHOD

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ABSTRACT – In the present power system the significance of power quality increases day by day and has positioned an important factor in energy system. In this work the power distribution system harmonic estimation with Fuzzy Estimation Method is propose and the Fuzzy estimation technique is used widely for the estimations of the harmonics. In this research paper, the id-iq values of residential and industrial zones were analysed. To estimate the value of id-iq, Fuzzy Estimation method was used. These estimated values can be used to choose the required filter system. Using the proposed method, equipment that improves the power quality can be preselected while planning energy distribution systems. This model can be used for the planning the energy systems which has the high Power Quality.

Keywords: *Power Distribution System, Fuzzy Estimation, Harmonic, Power Quality, THD,*

1. INTRODUCTION

With the increasing the technology the nonlinear loads are applied in Power distribution system widely. Devices that using semiconductor switching elements caused to increase grid connected non-linear load. Household devices like television, computer ,air conditioning;Industrial type load like UPS, Speed control device, welding machine , can be given as an example to this type of non-linear load. This type devices that generates harmonic, negatively effects the power quality. Harmonics make adverse effects in transmission lines, loads and electrical equipment because of this effects. Harmonics cause power quality problems [1]. Harmonics causes the power quality problems such as losses in transformers, trenches, disruption in communication systems, sudden release, losses in power distribution [2], [3]. Total Harmonic Distortion (THD) is used as an indication of current and voltage distortion values. Harmonic limitations are described in the IEEE 519 standard [4], [5]. In addition, reference [6] and [7] describes the harmonic distortion limit values in IEC standards. The frequency estimation were made by the fuzzy logic in reference [8]. The design, modeling and estimation of the financial indicators, fuzzy logic modeling and estimating method were used [9]. In reference [10] fuzzy logic estimation method were used for the motion estimation. In reference [11] fuzzy logic estimation method were used for the water quality estimation with limited number of water samples. Fuzzy logic estimation method were used in reference [12] for footprint estimation without depending on gait dynamics. In reference [13] power system fault estimation were made by the Fuzzy Logic estimation method. In reference [14] fuzzy logic estimation method were used for project planning and management. Fuzzy Logic application is proposed to estimate the DC motor parameters in reference [15]. New angle estimation scheme were made with Fuzzy Logic method in reference [16]. In reference [17] fuzzy logic method were proposed for estimation frequency response in aviation from experimental data. Fuzzy Logic method have been proposed for the identification of harmonic components in reference [18]. In reference [19] Fuzzy Logic method have been proposed for estimation of the reliability index of the power system. In reference [20] fuzzy logic-based angle estimation method is proposed for switched reluctance motor.The harmonic producng loads are wideley modeled by various techniques.In reference [21] the sensitivies of these models are evaluated for the system. Ali Idri and Laila Kjjri [24] proposed the use of fuzzy sets in the COCOMO, 81 model [25]

In this study Fuzzy estimation method is proposed for the estimation of energy distrubution system harmonic estimation.

Power system harmonıcs and measurements described in the second section . Fuzzy logic modelling and the simulation was made in the third section.

2. POWER SYSTEM HARMONICS AND MEASUREMENTS

Power systems harmonıcs

Harmonics causes the distortion in the energy system. The increase in nonlinear loads and circuit elements, could cause to unstable and low quality grids. Harmonic voltages and currents in an electric power system result of non-linear electric loads. Because of nonlinear loads in the system, sinusoidal waves can occur at different frequencies. Harmonics and harmonic analysis are needed the determination to reduce the negative effects of nonlinear loads to power systems. If there are Nonlinear loads on systems it is necessary to redefine the electrical parameters.

Total Harmonic Distortion THD is a common measurement of the level of harmonic distortion present in power systems. THD is defined as the ratio of total harmonics to the value at fundamental frequency. values can be calculated with using following equations, [22] .

Total current harmonic distortion can be expressed as,

$$□□□□ = \frac{\sqrt{\sum_{n=2}^{\infty} I_n^{\ 2}}}{I_1} \qquad (1)$$

Total current harmonic distortion can be expressed as,

$$□□□□ = \frac{\sqrt{\sum_{n=2}^{\infty} V_n^{\ 2}}}{V_1} \qquad (2)$$

Harmonic currents causes the voltage drop across the impedance of the electrical system. This voltage drops are added fundemantal voltage and this causes voltage distortion or an increase in effective voltage. One of the major effects of power system harmonics is to increase the current in the system. Non sinusoidal power system currents (harmonic currents) causes a distortion of voltage waveform.. Therefore, power quality distortion and the resonance risk in the system is increasing. Therefore, this study focused on the current harmonics. In the next section □□□□ measurements locations and the □□□□ measurement values are given.

Power systems harmonıcs measurement

Manisa's energy distribution system is supplied from different transformer centers. The input voltage of distribution system is 154 kV. 154 / 34.5 kV transformers are used to turn voltage value to 34.5 kV in secondary distribution bus. □□□□ values was measured at the 34.5 kV side of the transformer. □□□□ values taken from residential areas and industrial zones are used in the Fuzzy model to harmonic estimation. Single-line diagram of the distribution system is given in Figure 1. Residential areas □□□□ measurements are given in first section, industrial zones □□□□ measurements are given in second section .

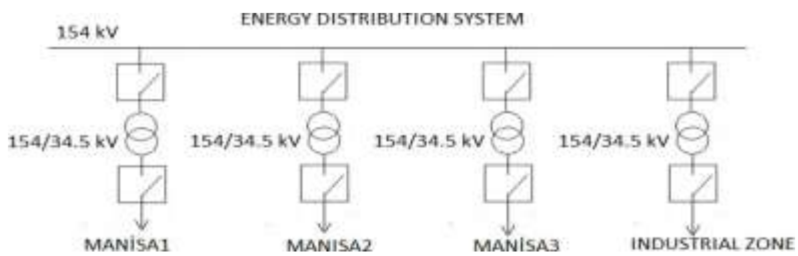

Figure 1. Single-line diagram of the energy distribution system

2.1.1 Harmonic Measurements in Residential Areas

Single-line diagram of the Residential Areas distribution system is given in Figure 2. Six different power line are connected to Manisa1 distribution line. Main transformer transforms the voltage from 154 kV to 34.5 kV, secondary distribution transformer transforms the voltage from 34.5 kV to 400 V. □□□□ values was measured at the 34.5 kV side of the transformer. These measured □□□□ values have been used by Fuzzy for training and testing purposes. The load current and □□□□ measurements were recorded 24 hour period.

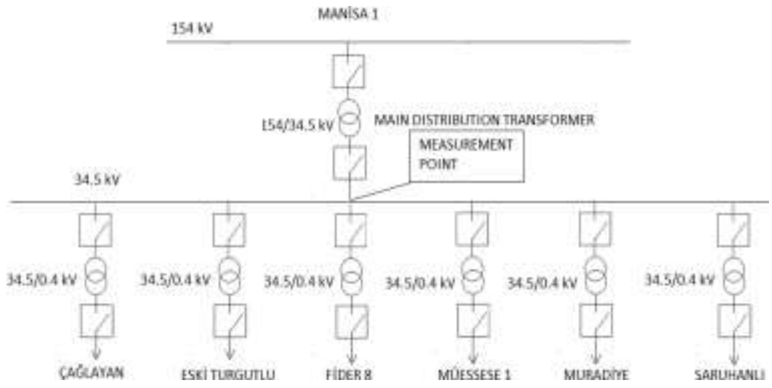

Figure 2. Single-line diagram of the Residential Areas energy distribution system

Harmonic Measurements in Industrial Zone

Single-line diagram of the Industrial zone distribution system is given in Figure 3. Four different power line are connected to Industrial zone distribution line. Main transformer transforms the voltage from 154 kV to 34,5 kV, secondary distribution transformer transforms the voltage from 34,5 kV to 400 V. □□□□ values was measured at the 34,5 kV side of the transformer. These measured □□□□ values have been used by Fuzzy for training and testing purposes. The load current and □□□□ measurements were recorded 24 hour period.

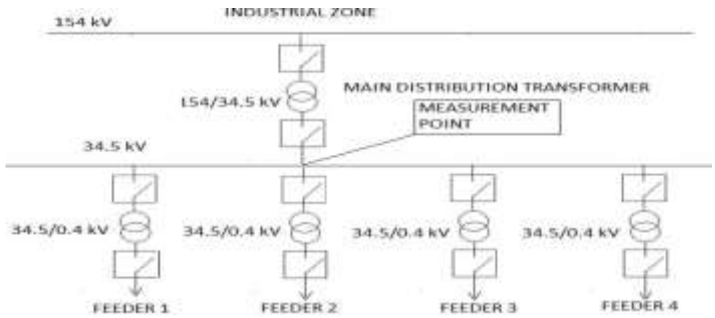

Figure 3. Single-line diagram of the Industrial zone energy distribution system

3. FUZZY ESTIMATION METHOD

Fuzzy logic idea is similar to the humanbeing's feeling and inference process. Unlike classical control strategy, which is a point-to-point control, fuzzy logic control is a range-to-point or range-to-range control. The output of a fuzzy controller is derived from fuzzifications of both inputs and outputs using the associated membership functions.

To implement fuzzy logic technique to a real application requires the following three steps:

1. Fuzzification – convert classical dataor crisp data into fuzzy data or Membership Functions (MFs)

We take the input as size S, output as effort E, then a triangular fuzzy number, K(S), is defined as follows:

2. Fuzzy Inference Process – combine membership functions with the control rules to derive the fuzzy output .

3. Defuzzification – use different methods to calculate each associated output and put them into a table: the lookup table. Pick up the output from the lookup table based on the current input during an application. The single output, fuzzy estimate of E, can be computed as a weighted average of the optimistic (□□□) , most likely (□□□) and pessimistic estimate (□□□) [23].

E=□1(□□□)+□2(□□□)+□3(□□□) / □1+□2+□3

The classical set has a sharp boundary, which means that a member either belongs to that set or does not. Also, this classical set can be mapped to a function with two elements, 0 or 1. Compared with a classical set, a fuzzy set allows members to have a smooth boundary. In other words, a fuzzy set allows a member to belong to a set to some partial degree.

Residential areas

The residential areas load current measurements and □□□□ values are shown table 1. Measured data between 1 and 15 were used to train the Fuzzy model, and the data between 16 and 24 were used to test the Fuzzy model, Measured Load Current (□□) values were used as the input, the □□□□ values were used as the output in the Fuzzy model. □□□□ values were estimated with this Fuzzy model.

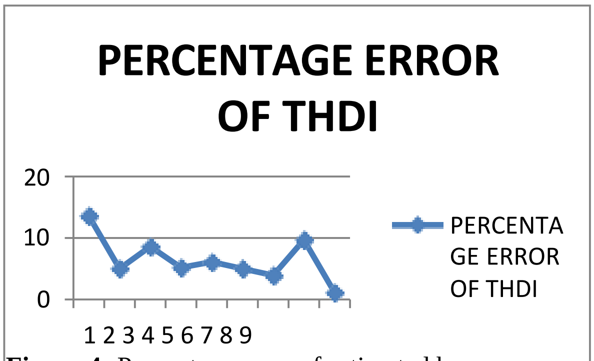

Figure 4: Percentage error of estimated by Fuzzy method □□□□ values

Table 1. Measured Load Current (□□) and □□□□ values

MEASUREMENT NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
LOAD CURRENT (IL)	370	330	270	250	240	220	290	365	447	465	470	480	490	475	238
MEASURED THDI	8,4	8,7	11	12	13	18	12	8,8	7	6,8	6,6	6,7	6	5,8	14

MEASUREMENT NUMBER	16	17	18	19	20	21	22	23	24
LOAD CURRENT (IL)	425	440	477	448	410	360	260	300	380
MEASURED THDI	7	7,1	5,8	6,8	7,8	9	12	12	8,4

Table 2. % error, measured □□, estimated □□□□ values

MEASUREMENT NUMBER	1	2	3	4	5	6	7	8	9
MEASURED THDI	7	7,1	5,8	6,8	7,8	9	12,2	11,8	8,4
ESTIMATED THDI	7,95	7,45	6,3	7,1	8,28	8,54	11,71	10,64	8,5
PERCENTAGE ERROR THDI	13,6	5	8,7	5,23	6,18	5,08	3,96	9,8	1,24

Table 2 gives the information about percentage error between the measured and estimated □□□□ values. The □□□□ values in this table are used for testing the Fuzzy model. Percentage error value is expressed as percentage of the difference between the measured □□□□ and estimated □□ .

Figure 4 shows the % error of estimated by Fuzzy method □□□□ values. The highest estimation error in test data is 13.6% ; the lowest estimation error in test data is 1.24. The avarage error for Residential areas is 6,5 % .This indicates estimation has been done with the accuracy 93,5.

Industrial Zone

Measured three-phase current (□□) and □□□□ values from Industrial Zone are shown in table 3. These values were used in order to train Fuzzy Model. The □□ values were used as the input, the □□□□ values were used as the output in the Fuzzy model. □□□□ values were estimated with this Fuzzy model.

Table 4. Measured three-phase current (□) and □□□ values

MEASUREMENT NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
THE LOAD CURRENT PHASE 1 I_LN 1	215	202	211	223	207	199	203	192	242	251	250	253	234	232	237
THE LOAD CURRENT PHASE 2 I_LN 2	218	205	212	224	205	199	206	190	241	253	250	253	232	233	236
THE LOAD CURRENT PHASE 3 I_LN 3	220	206	216	227	210	201	208	192	245	255	253	257	236	235	235
MEASURED THD_I 1	8,2	8,4	8,8	7,9	9,7	9	8,3	9,5	7,2	6,5	5,9	7,3	5,9	6,3	6,4
MEASURED THD_I 2	7,6	8,4	8,8	7,7	10	9	8,3	9,4	7,1	6,4	5,9	7,3	5,8	6,1	6,2
MEASURED THD_I 3	7,9	8,1	8,6	7,8	9,5	8,5	7,8	8,8	7,9	6,4	5,7	7,7	5,6	6,1	6,3

MEASUREMENT NUMBER	16	17	18	19	20	21	22	23
THE LOAD CURRENT PHASE 1 I_LN 1	238	213	205	191	193	214	219	215
THE LOAD CURRENT PHASE 2 I_LN 2	237	213	205	189	197	216	219	215
THE LOAD CURRENT PHASE 3 I_LN 3	241	216	207	190	197	220	224	220
MEASURED THD_I 1	5,3	7,1	7,6	8,5	8,1	8,2	7,4	8,2
MEASURED THD_I 2	5,3	7	7,3	8,3	7,5	8,1	7,2	8
MEASURED THD_I 3	5,1	6,8	7,4	8,1	7,4	7,8	7,2	7,9

Table 4 indicates three phase load current and □□□ measurements. Measured data between 1 and 15 were used to train the Fuzzy model and the measured data between 16 and 23 were used to test the Fuzzy model .

Table 6 gives the information about % error, the measured □□□ values and estimated □□□ values. The □□□1, □□□2, □□□3 values in this table are used for testing the Fuzzy system. Percentage Error value is expressed as percentage of the difference between the measured □□□ and estimated □□□.

Table 6. Percentage error, measured □□□, estimated □□□ values.

MEASUREMENT NUMBER	1	2	3	4	5	6	7	8
MEASURED THD_I 1	5,3	7,1	7,6	8,5	8,1	8,2	7,4	8,2
MEASURED THD_I 2	5,3	7	7,3	8,3	7,5	8,1	7,2	8
MEASUREDTHD_I 3	5,1	6,8	7,4	8,1	7,4	7,8	7,2	7,9
ESTIMATED THD_I 1	6,06	8,15	8,7	9,26	9,26	8,15	8,14	8,15
ESTIMATED THD_I 2	6,46	8,13	8,94	9,4	9,04	7,64	7,64	7,64
ESTIMATED THD_I 3	6,81	8,51	8,08	8,85	8,64	7,79	7,79	7,79
PERCENTAGE ERROR THD_I 1	14,4	14,8	14,5	8,9	14,3	0,6	10	0,6
PERCENTAGE ERROR THD_I 2	21,9	16,1	22,5	13,3	20,5	5,66	6,12	4,46
PERCENTAGE ERROR THD_I 3	33,6	25,2	9,2	9,3	16,7	0,08	8,2	1,36

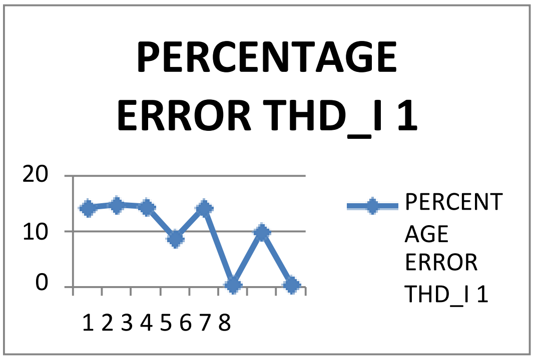

Figure 5 . The % error between measured □□□□ 1 and estimated □□□□ 1 values

Figure 5 shows the percentage error of estimated by Fuzzy estimation method □□□□ 1 values. . The highest estimation error in test data is 14,8% ; the lowest estimation error in test data is 0.6. The avarage error for □□□□ 1 is 9.76 % .This indicates estimation has been done with the accuracy 90.24 for □□□□ 1.

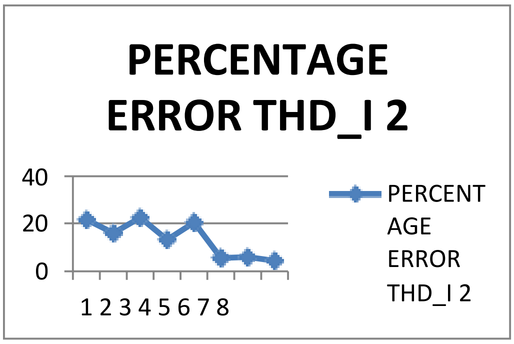

Figure 6. The % error between measured □□□□ 2 and estimated □□□□ 2 values

Figure 6 shows the percentage error of estimated by Fuzzy estimation method □□□□ 2 valuesThe highest estimation error in test data is 22,5 % ; the lowest estimation error in test data is 4,46. The avarage error for □□□□ 2 is 13.8 % .This indicates estimation has been done with the accuracy 86,2 for □□□□ 2.

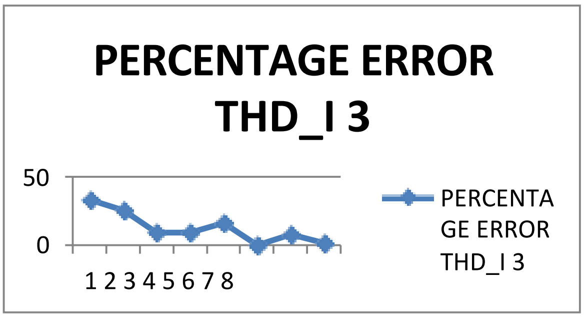

Figure 7 . The Percentage error between measured □□□□ 3 and estimated □□□□ 3 values

Figure7 shows the percentage% error of estimated by Fuzzy estimation method. The highest estimation error in test data is 33,6% ; the lowest estimation error in test data is 0,08. The avarage error for □□□□ 3 is 12,9 % .This indicates estimation has been done with the accuracy 87,1 for □□□□ 3.

4. DISCUSSION

Fuzzy model was used to estimate the □□□□ values. We can use this values to increase the power distribution system power quality. Different region data can be collected and models can be enhanced.

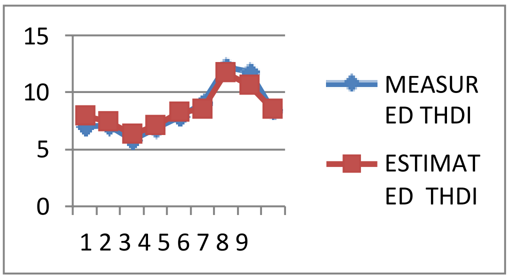

Figure 8. The measured □□□□ and estimated □□□□ values for residential areas

Figure 8 illustrates the information about measured □□□□ and estimated □□□□ values by Fuzzy Logic method. Fuzzy Logic method reached the best estimation in the nineth measurement. Where measured □□ is 8,4 and the estimated □□□□ value is 8,5. The worst estimation is the first estimation. Where measured □□ is 7 and the estimated □□ value is 7,95. For the residential areas estimated □□ values are close to measured □□□□ values.

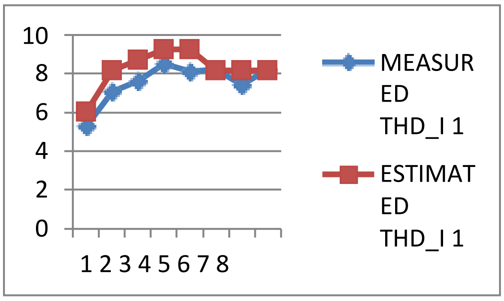

Figure 9. The measured □□□□ 1 and estimated □□□□ 1 values for residential areas

Figure 9 illustrates the information about measured □□ 1 values and estimated □□□□ 1 values by Fuzzy Logic method. Fuzzy Logic method reached the best estimation in the 6'th measurement where measured □□□□ 1 is 8,2 and the estimated □□□□ 1 is 8,15. The worst estimation is the second estimation. Where measured □□□□ 1 is 7,1 and the estimated □□□□ 1 value is 8,15. For the industiral areas sixth and eighth estimated □□□□ 1 values are close to the measurement. However, the first, second and the third estimations are significantly different from the measured value.

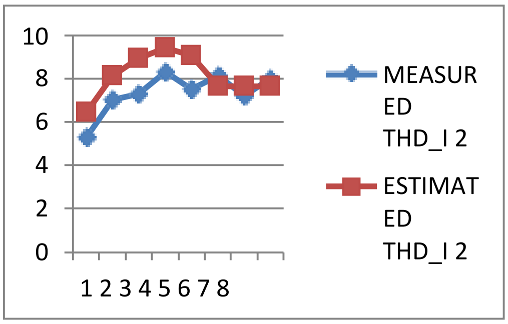

Figure 10. The measured □□□□ 2 and estimated □□□□ 2 values for residential areas

Figure 10 illustrates the information about measured □□□□ 2 and estimated □□□□ 2 values by Fuzzy Logic methods. Fuzzy Logic method reached the best estimation in the 8'th measurement where measured □□□□ 2 is 8and the estimated □□□□ 2 is 7,64. The worst estimation is the first estimation. Where measured □□ 2 is 5,3 and the estimated □□□□ 2 value is 6,46. For the industrial areas sixth, seventh and eighth estimated □□□□ 2 values are close to the measurement. However, the first second and the third estimated estimations are significantly different from the measured value.

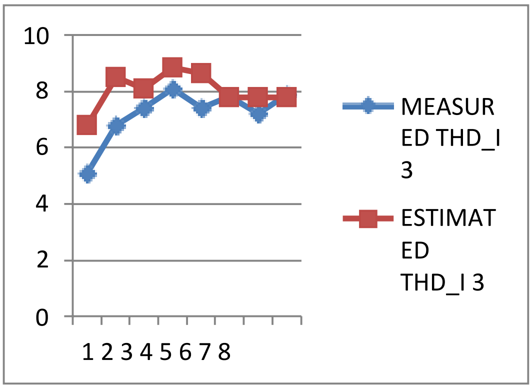

Figure 11. The measured □□□□ 3 and estimated □□□□ 3 values for residential areas

Figure 11 illustrates the information about measured □□□□ 3and estimated □□□□ 3 values by Fuzzy Logic methods. Fuzzy Logic method reached the best estimation in the sixth measurement where measured □□□□ 3 is 7,8 and the estimated □□□□ 3 is 7,79. The worst estimation is the first estimation. Where measured □□ 3 is 5,1 and the estimated □□□□ 3 value is 6,81. For the industrial areas sixth and eighth estimated □□□□ 3 values are close to the measurement. However, the first and second estimated values is significantly different from the measured value.

5. CONCLUSION

In this study, the power distribution system harmonics were estimated by Fuzzy Logic estimation method. With this proposed method, harmonics which is one of power quality problem can be estimated previously to improve power quality. Especially harmonic analysis and the estimation is very important in the distribution systems. Because of the harmonic distortion the losses and the various defects occur. Harmonics is adversely affects power quality because of this type of effect. □□□□ values were estimated with Fuzzy estimation method. The values measured from the energy distribution system have been used by for training and testing purposes. □□□□ estimation by Fuzzy estimation method was determined close to real □□□□ value especially the residential areas. This indicates that proposed method can be used to estimate □□□□ values. According to this estimated □□□□ value, the required filter parameters are determined and applied to a power distribution system. In this way, by reducing the harmonic values, a considerable increase in power quality can be provided. With the proposed Fuzzy estimation method , power quality equipment can be preselected while the energy distribution systems planning. Fuzzy □□□□ estimation method, also can be used in other systems with the purpose of □□□▫ estimation.

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