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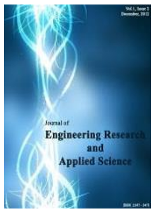

Choosing of single phase to three phase converter with fuzzy topsis method

U. Kurt

Amasya University, Technology Faculty, Electrical and Electronics Engineering, Amasya, Turkey

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Abstract

In this study comparative analysis of the different converter models were conducted. Different switching elements such as triac, IGBT, thyristor, the transistor was used in the examined converters. Properties of switching elements affect parameters of the converters such as efficiency, stability, harmonic characteristics, sinusoidal structure, torque vibration, cost and power factor. As well in the detailed literature review, it was drawn attention that there are differences between mentioned parameters in the models where different switching elements are connected with different connection forms. The requirements of the converters vary according to where it will be used and to the purpose of usage. In this case importance of mentioned parameters varies at the converter selection. For the applications, which require precision select having also judgements of people in, Fuzzy TOPSIS is often used. In this study, Fuzzy TOPSIS method was also used for the selection of most appropriate converter. By comparing acquired results converters were ranked according to the appropriateness level.

Keywords: Single phase to three phase converter; TOPSIS method; unbalanced supply; induction machines.

1. Introduction

From the past to present along with ever growing consumption the importance of production rate and quality has increased. Automatic control systems were introduced to meet growing demands of production quickly. Mentioned automatic control system performs its function with the electric motors. Initially, single-phase motors have been widely used. However, the disadvantages of electric motors caused to the research of other electric motors that can supersede single phase electric motors. Because of the systems consisting of single phase electric motor have inadequate performance and too complicated structure, demand to these motors decreased at the industry. Also, noise level during the operation, low initial torque and unsatisfactory level of efficiency of single phase electric motors led to use of three phase electric motors. Three phase systems;

1) Because of less conductive material needed they are more economical.
2) From the three phase machines, the more output power can be acquired compared to single phase machines at the same sizes.
3) Torque fluctuations of three phase motors are less than single phase motors and more torque can be obtained from the three phase motors.
4) The regular voltage signals are getting by using three phase systems.
5) Unlike single phase systems, three phase systems are self-excited.
6) Both domestic and industrial systems can be operated by using three phase motors with the same feeding.

Since three phase electric motors are able to supply high power needs, it is considered that they requisite more power in their first starting condition with respect to single phases. However, due to fact that coils of three phases motors create rotating magnetic fields, their activation become easier. Therefore, it prevents generation of network fluctuation. Since single phase motors do not have three coils they cannot create such magnetic fields so that they require more power from the system.

Along with progressing of semiconductor technology, electrical control methods and speed control of AC motors have been improved correspondingly. Typically, fans, compressors, home electronic systems, and many electrical applications are developed with three phase systems has been useful in terms of energy saving.

In generally, to obtain three phases from single phase a switching section are used. In addition, in some applications, electrical devices used to suppress harmonics such as coil and condenser are added. Diodes are used for the converter. In the switching section switching devices are used such as a thyristor, triac,

Corresponding author; unalkurt@amasya.edu.tr

IGBT, and transistor. Maximum power need of the system and system switching frequency have a significant effect on to choose suitable switching devices.

2. Investigation of transformation of mono phase to three phases

In the literature, there are many examples of systems, transfer mono phase into three phases, with using varied circuit connections and varied switching devices. The differences between methods used for transformation arise from some reasons such as desired output power differences, the differences switching devices which requested operation, desired more stability with power factor which is approaching to one, desired output curve which approaches sinusoidal curve as far as possible, and increasing efficiency.

In the reference [1], to transfer mono phase to three phases, 4 IGBT has been used, and system does not include any reactive components such as L and C. Due to fact that system does not have any reactive element, stability of system is high and its dimension is slightly small. In the reference study, by using 4 steps switching strategy, smoother load – current transition has been provided. Obtained yield has been limited as a 63%. However, since recommended system does not have inter-stage to constrain harmonic currents, it causes overheat in motor and fluctuation in output torque.

In the reference [2], three phases induction motors which are drived with 6 triac and 1 digital control circuit being in communication with each other has been mentioned. The mentioned method's cost is low and it can be suitable to use local implementations which are required low power. By using double integral technique, sinusoidal phase flux has been obtained. Due to its low efficiency and low power factor, a torque-velocity graphic of the motor has been quite approximate wave shape of a sinusoidal source. Since the system does not have element to store energy, it is small and long-lived

The most important feature of the study, mentioned in the reference [3], is that it suppresses system harmonics effectively. The system has L and C components, and one switching stage. Switching stage is beneficial to obtain good output signal through by being controlled of 6 IGBT. The system has been limited to 2kW and 5 kW. In the recommended method, power factor (PF) is independent of fluctuations which arise from input voltages.

Smith coupling method has been mentioned in the reference [4]. In the reference study, symmetrical component method has been used for smith coupling. Indeed, that coupling method is asymmetric. But by choosing convenient terminal capacity, balanced current values can be provided for induction machine to given load and speed values. In this case, to get balanced phase voltages, capacitive components are only needed. When motor draws full current, inlet power factor gets close one. It gets economic method for high efficiency due to used connection shape.

In the reference [5], 7 thyristors and 1 capacitor which are communicated each other are located. As a result of that, it becomes more cheap and compact. When the system starts working, it reaches high initial torque immediately. Due to fact that it does not have any component which stores energy, it can produce small dimensions and it can be long-lasting devices. In this case, it reaches high values around the 50 Hz. If this situation is used other frequencies value, it will become a disadvantage.

In the reference [6], it is mentioned a strategy whose one of the fundamental aim is that increases power factor's quality. The cost of the system has decreased by keeping a minimum number of the switching devices. Power factor unit has been improved to get high sinusoidal wave which is reached load and to obtain maximum active power. Harmonic currents observed load flow arise from mono phase sinusoidal sources. Wide voltage interval, good for power factor, provides high efficiency for low power applications.

In the reference [7], circuit cycle, which used in this reference, comprise of the motor control unit, two half wave converters, and 1 DC separator converter. Inverter unit of the system consists of 2 active switching devices and 1 triac whose control motor current. In this method, it is impossible to eliminate torque fluctuations. Another problem is that system cause sub harmonics during the working. In the output of the system with nominal frequency, balanced output voltages which have high input power factor can be produced almost without any disturbance.

In the reference [8], it has been focused that obtaining output voltages for different motors which are under high initial torque and minimum unbalance. The system does not have a complex control unit and it only consists of simple switching unit. The main purpose for a used control unit in the system is that designing simple and cheap control unit.

The system, which is used in the study mentioned by the reference number [9], has strong capabilities in practical applications of motor driving. In this application, a new and simple approach, called disjoint and connect, was suggested. By arranging semiconductor switches in a matrix the output load is connected directly. In this process, different switching elements play an active role at the positive and negative alternans of source voltage. The input voltage of system is affected by the slightest fluctuation of the source voltage. Electromagnetic torque reaches to the desired positive speed value and remains steady. Therefore, effective methods are suggested to dampen the vibration. The fluctuations in the source voltage affect adversely the system operation. The system, which is used in the study mentioned by the reference number [10], consists of full wave rectifier and 3 phase inverters. By utilizing the elements in the filter circuit efficiently, 25 % saving of using material and 50 % saving of size is provided. Primarily a 3 phase balanced exit voltage was tried to obtain. Then, the inverter exit voltage was controlled and lastly, harmonics were suppressed. The basic risk of this method is its low harmonics at the high voltages. These harmonics can be suppressed by using convenient adjustable line filters. In this study, harmonic suppression method is utilized with switched wave form optimization. This process occurs thank to switching time.

The system which is mentioned by the reference number [11], consists of six switching elements. Thus, it is low cost. Convenient applicable this system has a power factor that is close to 1. Owing to being quite successful against input voltage fluctuations and remaining within the standards, exit voltage is close to the sinusoidal signal. However, being narrow frequency range where the system can operate, the lack of the ability to pass bidirectional current and also requiring additional power devices to conserve the quality of current increases the cost of system.

3. Fuzzy topsis method

In cases where there are more than one evaluation criteria is used Fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) Method, which is one of decision methods, was developed by Hwang and Yoon in 1981. The main idea in the discussed method is the determining the closest alternatives to the solution and thus maximization of the beneficial criteria achieved in the solution and also minimization of undesirable criteria like cost. On the other hand, by determining the furthest criteria to negative ideal solution undesirable criteria like cost is maximized and benefit criteria are minimized. The reason of analyzing at the same time both ideal positive and negative solution is to get the most appropriate alternative by considering the conditions to be minimized along with the conditions to be maximized during the solution. Because it is not possible to reach the ideal solution exactly, by determining the closest ideal solution, namely most desirable and the furthest ideal solution, namely most undesirable, it is decided according to the distance of the chosen alternative to these. These distances are the given priorities and grades initially [12].

Nowadays by growing demand, the competition has been increasing as in the manufacturing and marketing areas. Considering the whole sizes of manufacturing it is a matter to determine the most appropriate product. At the industry, many parameters like cost, quality, elasticity, timing play an active role in the production chain. So while purchasing row material or getting service, manufactures consider such type parameters. Conventional decision making methods are inadequate of tackling with ambiguous or not certain conditions. Fuzzy TOPSIS Method in such cases is the used methods to find the best service provider or the best product.

The first study using TOPSIS Method began by doctorate thesis written by Negi in 1989. Another startup resource is the book written by Chen and Hwang in 1992. In 2000, by evaluating all alternatives, Chen suggested the TOPSIS Method which all criteria weights are expressed by triangular fuzzy numbers and are defined by verbal variables. Chu in 2002 for a selection of plant location suggested the TOPSIS Method where several alternative evaluations can be done under various subjective criteria and criteria weights can be expressed verbally. In 2005, Abo-Sinna and Amer suggested the fuzzy TOPSIS Method discuss versatile large-scale nonlinear programming problems. By the year 2006, the TOPSIS Method has been widely used and many problems solving techniques has been proposed. Some of these; done by Bottani and Rizzi, determining the most suitable third party logistic (3PL) service providers, Wang and Elhag suggested the fuzzy TOPSIS Method that is based on α level set and linear programming. TOPSIS approach which is done by Yong is for the plant location choice. In 2007 Wang and Chang used TOPSIS Method for evaluation training planes in the fuzzy medium. Dundar and others have made the choice to be offered to the customer appreciation of the websites of virtual stores using fuzzy TOPSIS method in 2007. In 2008 Wang evaluated the financial condition of three airline operators that showed the activities of local airlines in Taiwan.

While applying the TOPSIS Method, decision makers, decision criteria, and alternatives are required. Evaluation of decision criteria and available alternatives can be done linguistic variables in the fuzzy TOPSIS Method. The evaluations by converting into the fuzzy numbers are digitized, then fuzzy weights matrix, fuzzy decision matrix, normalized fuzzy decision matrix and weighted normalized fuzzy decision matrix are found. After determination of fuzzy positive and negative ideal solution, closeness coefficient of alternatives is found by vertex method then according to the closeness coefficients the available alternatives are ranked from the best to worst [13,14].The algorithm of fuzzy TOPSIS Method is as follows [14]. At the first step of fuzzy TOPSIS Method suggested by Chen in 2000, a group is created by decision makers. The group consisting of N number decision makers;

$$E = \{KV_1, KV_2 \dots KV_3\} \quad (1)$$

is expressed as. The available alternatives then the group were created by decision makers;

$$E = \{A_1, A_2 \dots A_n\} \quad (2)$$

and the criteria to be used for evaluation of these alternatives;

$$E = \{K_1, K_2 \dots K_n\} \quad (3)$$

are identified.

After the groups given in equation (1), (2) and (3) were created, verbal variables are determined to be used in the evaluation of the alternatives and determination of weights of criterion importance. By using specified verbal variables, alternatives and criteria are evaluated. And the evaluations made by decision makers with verbal variables are expressed in the form of fuzzy numbers. This evaluation in the form of fuzzy numbers is as in Table 1 and Table 2.

Table 1. The verbal variables used for determination of weights of criterion importance [14]

Linguistic variable	Triangular Fuzzy Numbers (TFNs)
Very low (VL)	(0,0,0.1)
Low (L)	(0,0.1,0.3)
Medium low (ML)	(0.1,0.3,0.5)
Medium (M)	(0.3,0.5,0.7)
Medium high (MH)	(0.5,0.7,0.9)
High (H)	(0.7,0.9,1)
Very high (VH)	(0.9,1,1)

Table 2. The verbal variables used for evaluation of alternatives [14]

Linguistic variable	Triangular Fuzzy Numbers (TFNs)
Very poor (VP)	(0,0,1)
Poor (P)	(0,1,3)
Medium poor	(1,3,5)
Fair (F)	(3,5,7)
Medium good	(5,7,9)
Good (G)	(7,9,10)
Very good (VG)	(9,10,10

To reduce evaluations to one value for the alternatives and criteria, which is made by N number decision makers, is possible with following formula;

$$\tilde{x}_{ij} = \frac{1}{N}\left[\tilde{x}_{ij}{}^{1} \oplus \tilde{x}_{ij}{}^{2} \oplus, \dots, \oplus \tilde{x}_{ij}{}^{N}\right] \quad (4)$$

Here, $\tilde{x}_{ij}^{N}$ shows N number of decision maker's evaluation. For every alternative condition, the weights determined by N numbered of decision makers are reduced to one value by using Equation 5.

$$\tilde{w}_i = \frac{1}{N}\left[\tilde{w}_i{}^{1} \oplus \tilde{w}_i{}^{2} \oplus, \dots, \oplus \tilde{w}_i{}^{N}\right] \quad (5)$$

$\tilde{W}_j^{N}$ in the equation shows the weight of N number of decision makers. After one value is get for all criteria and alternatives, decision problem is expressed as follows in the form of matrix.

$$\tilde{D} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \cdots & \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix} \quad (6)$$

After the creation of decision matrix, the next step is to normalize of the decision matrix. The fuzzy decision matrix is normalized by the help of equation (8) and (9) and then normalized fuzzy matrix $\tilde{R}$ is acquired.

$$\tilde{x}_{ij} = \frac{1}{N}\left[\tilde{x}_{ij}{}^{1} \oplus \tilde{x}_{ij}{}^{2} \oplus, \ldots, \oplus\, \tilde{x}_{ij}{}^{N}\right] \quad (7)$$

$$\tilde{x}_{ij} = \frac{1}{N}\left[\tilde{x}_{ij}{}^{1} \oplus \tilde{x}_{ij}{}^{2} \oplus, \ldots, \oplus\, \tilde{x}_{ij}{}^{N}\right] \quad (8)$$

$$\tilde{x}_{ij} = \frac{1}{N}\left[\tilde{x}_{ij}{}^{1} \oplus \tilde{x}_{ij}{}^{2} \oplus, \ldots, \oplus\, \tilde{x}_{ij}{}^{N}\right] \quad (9)$$

calculated as $r_{ij}, (\forall i, j)$ are the normalized triangular fuzzy numbers. First of all normalized fuzzy decision matrix is created. The importance that every decision criteria possess is different from each other. Considering this situation fuzzy decision matrix is calculated as follows.

$$\tilde{V} = \left[\tilde{v}_{ij}\right]_{mxn}, i = 1,2, \ldots; mj = 1,2, \ldots, n \quad (10)$$

Here $\tilde{v}_{ij} = \tilde{r}_{ij}(.)\tilde{w}_j$ (11)

After calculation of fuzzy decision matrix, fuzzy positive ideal solution (FPIS, A^+) and fuzzy negative ideal solution (FNIS, A^-) are identified as follows:

$$A^+ = (\tilde{v}_1^+, \tilde{v}_2^+, \ldots, \tilde{v}_n^+) \quad (12)$$

$$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, \ldots, \tilde{v}_n^-) \quad (13)$$

Here $\tilde{v}_{ij}^+ = (1,1,1)$ and $\tilde{v}_{ij}^- = (0,0,0)$ (14)
j=1,2,…,n.

Then the distances of all alternatives to fuzzy positive ideal solution (A^+) and fuzzy negative ideal solution (A^-) are calculated separately.

$$d_i^+ = \sum_{j=1}^{n} d_v(\tilde{v}_{ij}, \tilde{v}_j^+), \quad i=1,2,\ldots,m; j=1,2,\ldots,n \quad (14)$$

$$d_i^- = \sum_{j=1}^{n} d_v(\tilde{v}_{ij}, \tilde{v}_j^-), \quad i=1,2,\ldots,m; j=1,2,\ldots,n \quad (15)$$

dv(a,b) represents the distance between two fuzzy number. This distance can be calculated by the vertex method given equation (16). After determination of the distances, closeness coefficient (CC_i) relating to every alternative is calculated. Closeness coefficient considers the distance to fuzzy positive ideal solution (A+) and to fuzzy negative ideal solution (A-) at the same time.

$$d(a,b) = \sqrt{\frac{1}{3}\left[\left(l_q - l_b\right)^2 + (m_a - m_b)^2 + (u_a - u_b)\right.} \quad (16)$$

$$d(a,b) \in R^+$$

Closeness coefficient of each of the alternatives:

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-}, j = 1,2 \ldots m; \quad (17)$$

is calculated by using the equation. As closeness coefficient closes to 1, the possibility of preferring the alternative increases. When analyzed according to the closeness coefficients, the acceptance conditions of alternatives are given in Table 1.3.

As a result, fuzzy TOPSIS Method can be summarized by the given information:

- Step 1: A group which consists of decision makers are created and decision criteria are chosen.
- Step 2: The decision makers evaluate the decision criteria and the candidates with linguistic variables.
- Step 3: After the evaluation, weights of importance of decision criteria and criteria values of candidates are found by converting linguistic variables into triangular fuzzy numbers.
- Step 4: Fuzzy decision matrix and fuzzy weights matrix are created.
- Step 5: Normalized fuzzy decision matrix is

created.

- Step 6: Weighted normalized fuzzy decision matrix is created.
- Step 7: Fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS) is determined.
- Step 8: The distances of each alternative to the FPIS and FNIS are calculated.
- Step 9: Closeness coefficients of each alternative are found and are arrayed.

Table 3. Acceptance conditions of alternatives [15]

Closeness coefficient CC_i	**Evaluation**
$CC_i \in [0, 0.2)$	İnadvisable
$CC_i \in [0.2, 0.4)$	Advice with high risk
$CC_i \in [0.4, 0.6)$	Advice with low risk
$CC_i \in [0.6, 0.8)$	Acceptable
$CC_i \in [0.8, 1.0)$	Acceptable and preferable

5. Converter selection by TOPSIS method

In this study, during the selection process to select the most appropriate converter, Fuzzy TOPSIS Method, which is one of multi-criteria decision methods, is used. For this process, 7 criteria are selected. And according to these criteria, 10 studies were examined.

5.1. Fuzzy converter selection by TOPSIS method

After determination of the criteria and arrangement, in the process of selection of alternative converter, the converted verbal values of the numerical values specified in Table 1 are used. In Table 4, the importance weights of the desired criteria are given. Then Table 5 is created by the help of data given in Table 2.

Table 4. İmportance Weights of the Criteria

Criteria	**Decision**	**Fuzzy**
Total Efficiency	VH	(0.9,1,1)
Stability	VH	(0.9,1,1)
İnput Power	MH	(0.5,0.7,0.9)
Harmonic	MH	(0.5,0.7,0.9)
Torque Vibration	M	(0.3,0.5,0.7)
Cost	L	(0,0.1,0.3)
Sinusoidal Output	H	(0.7,0.9,1)

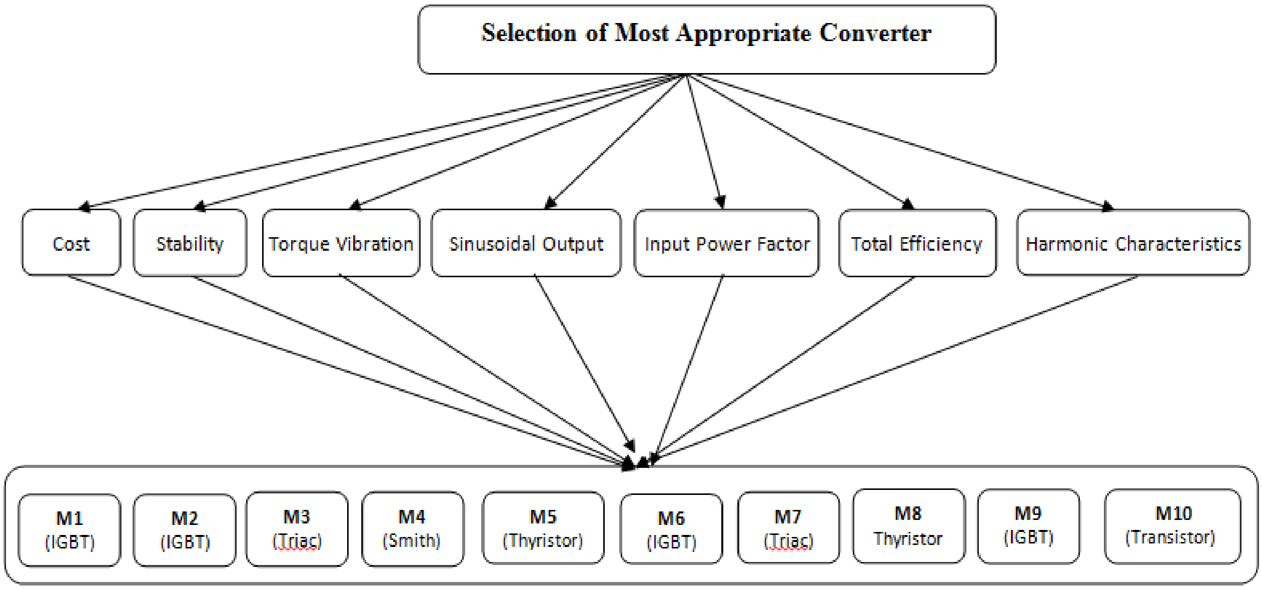

Figure.1 Hierarchical Structure of Converter Selection

Table 5. Evaluation Data According to the Specified Criteria

Criteria	Alternatives									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Total Efficiency	G	MP	G	P	F	VG	MG	F	MG	G
Stability	G	G	F	MP	MG	G	F	F	G	MG
İnput Power Factor	VG	MP	VG	MG	G	VG	VG	MG	G	VG
Harmonic Characteristics	F	MG	G	MP	F	G	F	MG	MG	G
Torque Vibration	MP	G	G	VG	VG	MG	F	F	MG	G
Cost	MP	G	F	G	VG	MG	MG	G	P	VG
Sinusoidal Output	F	F	MG	F	P	VG	F	MP	G	G

Table 6 is created by converting verbal evaluations and fuzzy values in Table 5 into each other.Fuzzy decision matrix in Table 6 is normalized and then converted to in the form of Table 7. Every value in the matrix is multiplied by weight values and converted to in the form of Table 8.

Table 6. Fuzzy Decision Matrix and Fuzzy Weights

Criteria	Alternatives									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Total Efficiency	(7,9,	(1,3,5)	(7,9,10	(0,1,3)	(3,5,7)	(9,10,1	(5,7,9)	(3,5,7)	(5,7,9)	(7,9,10
Stability	(7,9,	(7,9,10	(3,5,7)	(1,3,5)	(5,7,9)	(7,9,10	(3,5,7)	(3,5,7)	(7,9,10	(5,7,9)
İnput Power	(9,1	(1,3,5)	(9,10,1	(5,7,9)	(7,9,10	(9,10,1	(9,10,1	(5,7,9)	(7,9,10	(9,10,1
Harmonic	(3,5,	(5,7,9)	(7,9,10	(1,3,5)	(3,5,7)	(7,9,10	(3,5,7)	(5,7,9)	(5,7,9)	(7,9,10
Torque Vibration	(1,3,	(7,9,10	(7,9,10	(9,10,1	(9,10,1	(5,7,9)	(3,5,7)	(3,5,7)	(5,7,9)	(7,9,10
Cost	(1,3,	(7,9,10	(3,5,7)	(7,9,10	(9,10,1	(5,7,9)	(5,7,9)	(7,9,10	(0,1,3)	(9,10,1
Sinusoidal Output	(3,5,	(3,5,7)	(5,7,9)	(3,5,7)	(0,1,3)	(9,10,1	(3,5,7)	(1,3,5)	(7,9,10	(7,9,10

Table 7. Normalized Fuzzy Decision Matrix

Criteria	Alternatives									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Total Efficiency	(0.7,0.9,1)	(0.1,0.3,0.	(0.7,0.9,1)	(0,0.1,0.3)	(0.3,0.5,0.	(0.9,1,1)	(0.5,0.7,0.	(0.3,0.5,0.	(0.5,0.7,0.	(0.7,0.9,1)
Stability	(0.7,0.9,1)	(0.7,0.9,1)	(0.3,0.5,0.	(0.1,0.3,0.	(0.5,0.7,0.	(0.7,0.9,1)	(0.3,0.5,0.	(0.3,0.5,0.	(0.7,0.9,1)	(0.5,0.7,0.9
İnput Power Factor	(0.9,1,1)	(0.1,0.3,0.	(0.9,1,1)	(0.5,0.7,0.	(0.7,0.9,1)	(0.9,1,1)	(0.9,1,1)	(0.5,0.7,0.	(0.7,0.9,1)	(0.9,1,1)
Harmonic	(0.3,0.5,0.	(0.5,0.7,0.	(0.7,0.9,1)	(0.1,0.3,0.	(0.3,0.5,0.	(0.7,0.9,1)	(0.3,0.5,0.	(0.5,0.7,0.	(0.5,0.7,0.	(0.7,0.9,1)
Torque Vibration	(0.1,0.3,0.	(0.7,0.9,1)	(0.7,0.9,1)	(0.9,1,1)	(0.9,1,1)	(0.5,0.7,0.	(0.3,0.5,0.	(0.3,0.5,0.	(0.5,0.7,0.	(0.7,0.9,1)
Cost	(0.1,0.3,0.	(0.7,0.9,1)	(0.3,0.5,0.	(0.7,0.9,1)	(0.9,1,1)	(0.5,0.7,0.	(0.5,0.7,0.	(0.7,0.9,1)	(0,0.1,0.3)	(0.9,1,1)
Sinusoidal Output	(0.3,0.5,0.	(0.3,0.5,0.	(0.5,0.7,0.	(0.3,0.5,0.	(0,0.1,0.3)	(0.9,1,1)	(0.3,0.5,0.	(0.1,0.3,0.	(0.7,0.9,1)	(0.7,0.9,1)

Table 8. The Weights of Normalized Fuzzy Decision Matrix

Criteria	Alternatives									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Total Efficiency	(0.63,0.9,1)	(0.09,0.3,0.	(0.63,0.9,1)	(0,0.1,0.3)	(0.27,0.5,0.	(0.81,1,1)	(0.45,0.7,0.	(0.27,0.5,0.	(0.45,0.7,0.	(0.63,0.9,1)
Stability	(0.63,0.9,1)	(0.63,0.9,1)	(0.27,0.5,0.	(0.09,0.3,0.	(0.45,0.7,0.	(0.63,0.9,1)	(0.27,0.5,0.	(0.27,0.5,0.	(0.63,0.9,1)	(0.45,0.7,0.
İnput Power Factor	(0.45,0.7,0.	(0.05,0.21,0	(0.45,0.7,0.	(0.25,0.49,0	(0.35,0.63,0	(0.45,0.7,0.	(0.45,0.7,0.	(0.25,0.49,0	(0.35,0.63,0	(0.45,0.7,0.
Harmonic	(0.15,0.35,0	(0.25,0.49,0	(0.35,0.63,0	(0.05,0.21,0	(0.15,0.35,0	(0.35,0.63,0	(0.15,0.35,0	(0.25,0.49,0	(0.25,0.49,0	(0.35,0.63,0
Torque Vibration	(0.03,0.15,0	(0.21,0.45,0	(0.21,0.45,0	(0.27,0.5,0.	(0.27,0.5,0.	(0.15,0.35,0	(0.09,0.25,0	(0.09,0.25,0	(0.15,0.35,0	(0.21,0.45,0
Cost	(0,0.03,0.15	(0,0.09,0.3)	(0,0.05,0.21	(0,0.09,0.3)	(0,0.1,0.3)	(0,0.07,0.27	(0,0.07,0.27	(0,0.09,0.3)	(0,0.01,0.09	(0,0.1,0.3)
Sinusoidal Output	(0.21,0.45,0	(0.21,0.45,0	(0.35,0.63,0	(0.21,0.45,0	(0,0.09,0.3)	(0.63,0.9,1)	(0.21,0.45,0	(0.07,0.27,0	(0.49,0.81,1	(0.49,0.81,1

The closest positive solution to ideal solution as d_i^+, the furthest negative solution to ideal solution as d_i^- are named.

Table 9. d_i^+, d_i^- and C_i values

	1	2	3	4	5	6	7	8	9	10
d_i^+	3,821	4,303	3,498	4,915	4,289	2,902	4,144	4,511	3,494	3,161
d_i^-	3,652	3,224	4,037	2,574	3,203	4,616	3,339	3,005	4,069	4,412
C_i	0,489	0,428	0,536	0,344	0,428	**0,614**	0,446	0,400	0,538	**0,583**

In Table 9, as is seen from the results the most appropriate converter design is the study 6. Study 10 is second best design and study 4 is the least appropriate solution. If we arrange these studies in terms of appropriateness degrees, it is sorted as 6>10>9>3>1>7>2>5>8>4.

6. Results

In this study, single phase to three phase converter system's important parameters such as efficiency, power factor, cost, harmonic, torque fluctuation and sinusoidal were analyzed comparatively. These parameters have different importance according to where and for what the systems are utilized. During the study, total efficiency and stability are the greatest importance in order of our priorities. Afterwards sinusoidal output, input power factor and harmonic, torque vibration, lastly cost follow these parameters. In other words, according to the evaluation criteria, the converters having high efficiency and stability are mostly preferable. Moreover, switching elements which are used in 3 phase converter systems affect the evaluation criteria of the system. Therefore the systems that are designed by different switching element were analyzed. It was observed that in general switching elements such as IGBT, triac, tyristor and transistor had been used in the studied converters systems. As the type of the utilized switching element affects the system, connection form of these elements also affect the system parameters. Therefore even though the same switching element was used, the studies, which had been made by different connection forms, were analyzed and it was observed that the results of these studies were different.

Various switching elements and several connection forms made with these elements were evaluated by TOPSIS Method. Because these examined studies exhibited very close performance to each other, precision select is required. Since generally there are judgments of people inside such type problems, intended precision selects can be done easily by using fuzzy TOPSIS Method. In TOPSIS Method specified criteria cannot be compared with each other. The comparative value is the effects of the discussed importance weights of the criteria on the results.

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