Improvement of Motor Performance By Applying 6-Sigma (Dmadv)

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ABSTRACT

Highly competitive markets are justifies the use of advanced technologies and methods to improve product's quality and sales, which is the survival of any organization involved in business to be adaptive, proactive, and responsive to changes and has the capability to provide customer expectations. The success of products depends on how well they meet customer requirements. In order to achieve competition in Iraqi market, and to get high quality performance, Six Sigma has been applied in the "State Company for Electrical Industries" on motor of (1/4) HP. It is important to evaluate product strengths and weaknesses among competitive products available in Iraqi market to get the needed specifications to implement it in QFD (HOQ). The calculations were carried out by using "sigma xl version 6.2" program. Six sigma methodology: DMADV was adopted. Quality Function Deployment (QFD) was applied to improve motor performance. Thirty questionnaires were distributed and collected back to build QFD Matrix which determines four problematic issues with high scores: starting current, losses, coil winding, and rotor dimensions which indicates the need to resolve. Referring to QFD results which indicate the starting current is one of the main problems of motor performance, the researchers suggest motor redesign by adding "Soft Starting Circuit" to resolve this problem. Starting current for motor was measured and found to be 5.2 amp, while it decreased to 3.2 amp after redesign. Motor performance will be improved, cause the reduction of losses from 312 to 128 watt.

Key words: 6-Sigma , DMADV , QFD ,HOQ.

تحسين اداء محرك بتطبيق 6-sigma (DMADV)

الخلاصة

تبررالمنافسة العالية في الاسواق ضرورة أستخدام تكنولوجيا متقدمة وطرائق لتحسين جودة المنتوج والمبيعات. لتستمر أي شركة ضمن مجال الاعمال لابد ان تكون متكيفة , استباقية , مستجيبة للتغيرات ولها القدرة على توفير توقعات الزبون. نجاح المنتجات يعتمد على امكانيتها لتلبية متطلبات الزبون.لأجل تحقيق المنافسة في الاسواق العراقية

ولتحسين جودة الاداء, طبقت منهجية "sigma 6" في الشركة العامة للصناعات الكهربائية على المحرك ربع حصان.
لغرض تقييم نقاط قوة المنتوج وضعفه بالنسبة للمنتجات الاجنبية المنافسة الموجودة في السوق العراقية للحصول على
المواصفات المطلوبة تم تطبيق QFD (بيت الجودة). واجريت الحسابات باستخدام برنامج sigma xl version "
6.2". تم تبني منهجية "sigma 6" DMADV وطبقت وظيفة نشر الجودة لتحسين اداء المحرك.وزعت واسترجعت
ثلاثين استمارة استبيان لبناء مصفوفة QFD منها تم تحديد اربع مشاكل لها قيم عالية : تيار البدء , المفاقيد, الملفات , و
ابعاد المحور الدوار.وبالعودة الى نتائج QFD والتي اشارت الى ان تيار البدء هو احد اهم المشاكل اداء المحرك الذي
تتطلب اعاده تصميمه وتم اقتراح اعادة تصميم المحرك واضافة دائرة التشغيل الناعم "Soft Starting Circuit" لحل
المشكلة. قيس تيار البدء ووجد أنه 5.2 امبير بينما انخفض الى 3.2 بعد اعادةالتصميم. تحسن اداء المحرك بسبب تقليل
المفاقيد في التيار من 312 واط الى 128 واط.

INTRODUCTION

Today the competition between organizations plays major role in market, this leads
organization to improve their products quality and performance so each competitor
hopes to influence as many customers as possible to choose his products over
alternative products, hence every marketing decision maker focuses on customers and their
needs to get the customers confidence. The voice of the customer serves as significant
source of information for marketing improvement to company's products and services [1,
2].
Six Sigma and DFSS (Design for Six Sigma) in both manufacturing and service industries
are used since 80s. Six Sigma focused heavily on variation reduction through statistical
analysis for factory related issues [3]. DFSS is a systematic methodology consisting of
engineering design methods integrated with statistical methods to allow prediction and
improvement in quality prior to building prototypes. Companies that adopted Six Sigma
have learned that quality saves money through increased sales and win the competition
[4,5].

Literature Survey:
Khalil I. Mahmoud, et.al (2010)[6]:

The researchers were applied for new techniques to   representing and established the
House of Quality matrix using Auto Cad program. Taken an electrical motor (1/4 HP) as
case study and the needed data from survey among specialists as engineers and technicians.
The researchers conclusions were on the important of QFD and they point out some
important variables to overcome regarding the ease of fix and maintains, low noise and
vibration.

Chee-Cheng (2010)[7]:   Uses Six Sigma to integrate product and process development
model by product type to enhance the effectiveness of QFD; the researcher combined this
model with a company's customer satisfaction strategy and QFD techniques and presented
a case study from the semiconductor industry to demonstrate the model's applicability and
suitability .

P.N. Koch, et. al (2004)[8]: Define Six Sigma in an engineering design context and present
an implementation of design for Six Sigma. The results presented illustrate the tradeoff
between performance and quality when optimizing for Six Sigma reliability and robustness.

Sebastian Koziołek and Damian Derlukiewicz (2011)[9]: Present the methodology for assessing the process of designing and constructing vehicles and machines, which implements Design For Six Sigma. The purpose was to determine how defects affect the quality of the structure, based on the criteria of its conformance.

Methodologies of Six Sigma: Well known methodologies that used for Six Sigma are [10, 11]:
1-The first methodology of Six Sigma typically involves implementing a five-phase called the DMAIC (Define, Measure, Analyze, Improve, and Control) process. This process is used to guide implementation of Six Sigma statistical tools and to identify process wastes and variation. The DMAIC is the result of a process that involves covering the following stages, namely:
i. defining the process improvement objectives
ii. measuring the current performance level
iii. analyzing the data in order to observe the cause-effect relation within the process
iv. Improving the project, team evaluates the information from the analyze phase about the major causes of the problem and puts forth various solutions to eliminate or reduce those causes.
v. The control is vital because it must verify and correct any variation in order to prevent the loss of the process quality.
2-The second methodology is Design For Six Sigma **(DFSS)** used for assessing a new product or designing a new process or redesign, and its procedure implies covering the following stages [5]:
i. Define
ii. Measure
iii. Analyze
iv. Design
v. Verifying.
The DFSS strategy can also be applied to processes, because in many cases the original design of the process is fundamentally flawed; merely patching the holes in the process will not yield satisfactory performances. DFSS for Process is needed when:-
• A business chooses to replace, rather than repair, one or more core processes.
• A leadership or Six Sigma team discovers that simply improving an existing process will never deliver the level of quality customers are demanding. Researchers will adopt this methodology to improve motor performance.
• The business identifies an opportunity to offer an entirely new product or service.
Many companies use DFSS as methodology to make the introduction of new products and Services more efficient, reliable, and capable of meeting customer expectations or requirements [12, 13].

DFSS Procedures:
There are two most popular procedures in DFSS [14]:
i. IDOV**:** (Identify, Design, Optimize and Verify): The IDOV project procedure is usually used for new designs.

ii.   DMADV: DMADV (Define, Measure ,Analysis, Design ,Verify) used during the design/redesign of processes or products in order to transformation of what is wanted and perceived in the customer domain to what can be produced in the engineering and operations domain. [4, 12].

DFSS is a systematic methodology to product or process design including all organization functions from the early beginning, with the objective to design things right from the first time[56]. These phases of DMADV as following:- and as shown in figure (1):

DEFINE - This phase encompasses the definition of the goals of the design activity.

MEASURE –This phase research is planned to determine customer needs and competitive performance as well as to identify those features and options that are differentiators of the product.

  ANALYZE - The Analyze phase completes characterization of the product and includes the following key activities: Functional analysis of the features and their capability to address the identified customer requirements, and a design requirement specification.

DESIGN - The Design phase involves the design of the product, process or service.

VERIFY- The final phase involves piloting the new product or service, gathering data and evaluating performance, satisfaction, or results [12, 15, 16].

Quality Function Deployment (QFD):

  Quality Function Deployment (QFD) is a structured technique to ensure that customer requirements are built into the design of products and processes. In Six Sigma, QFD is mainly applied in improvement projects on the (design of products and processes). Hence, QFD is perhaps the most important tool for DFSS. QFD enables the translation of customer requirements into product and process characteristics including target value. The tool is also applied in Six Sigma to identify the critical-to-customer characteristics which should be monitored and included in the measurement system [17].

Stages of QFD (HOQ):

  There are six stages to develop in House Of Quality [13, 17, 18] these stage are shown in figure (2) and explained below:

Stage 1: Customer Requirements (Voice of Customers, Whats): One of the objectives of QFD is to make sure that all customer requirements are met; therefore it is crucial to identify the customer requirements/needs. A good practice is to rate each customer expectation against a scale from (1 to 5) with 1 being the least important and 5 being the most.

  Stage 2: Technical Requirements (Hows): Hows are design features derived by the DFSS team to answer the What's. Each of the initial What's needs operational definitions. The answering activity translates customer expectations into design criteria such as speed, torque, and time to delivery. For each What, there should be one or more Hows that describe a means of attaining customer satisfaction.

  Stage 3: Relationship Matrix: As the Whats and Hows might not be independent, and a How might affect more than one What, it is necessary to evaluate the relationship among the Whats and Hows. The key question is: "To what extent does the How fulfill the What" Relationships are typically defined as Strong=5, Moderate=3, Weak=1, and No relationship=0 (or blank).

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   Stage 4: Competitive Analysis: Comparison with competitors for each characteristic of the "what" can be made to determine how they are performing.

   Stage 5: Correlation Matrix: In the correlation matrix, the correlations among the "Hows" characteristics are identified. Two characteristics at a time are compared with each other until all possible combinations have been compared. Positive correlation is commonly denoted by "+," and negative correlation by "–." There does not need to exist correlation among all the characteristics.

   Stage 6: Process Targets: For every How shown on the relationship matrix, a How Much should be determined. The goal here is to quantify the customers' needs and expectations and create a target for the design team. The How Muchs also create a basis for assessing success. For this reason, Hows should be measurable.

Practical Work:

   In the formalizing and constructing the proposed methodology shown in Figure (3),the framework will consist of DMADV.

Define Phase:

   The objective of this study is to improve the performance of air cooler motor (1/4) HP due of product multiple problems. Intending to improve the quality of performance of motor to make it better and with longer life. DMADV was used to explore opportunities to improve motor performance.

Measure Phase:

   Voice of customer used to indicated customer needs and determine the CTQ by QFD. In measure phase QFD is used to get the high rate to check the best solution, questionnaire were distributed to customers with discipline back ground (mechanical, electrical, technical, maintenance workers), to detect important requirements.

*Step 1***:** Form market research, new study determines the customer requirement and Use scale to detect the importance.

Step 2: The results of Voted (30) customers is detected.

Step 3: The engineering specifications of product are identified in QFD that is related with each requirement.

Step4: Build a house of quality to compare customer requirements and technical descriptors and determine their respective.

Step 5: Derermine the relationship between two technical requirements and the direction of improvement

Step 6: Make comparison of the motor that available in Iraqi market with other competitors.Regarding motor re-design to improve the quality of performance depending on high score results from matrix shown in figure (4).\

Analyze Phase:

   To discuss the results from QFD matrix, the following high score were obtained and listed below:

1-Starting Current 2-losses 3-Coil Winding 4-Rotor Dimensions. Which yield a first three high score from matrix, that leading to propose a new design/redesign: an electrical circuit to improve quality of performance for induction motor. This problem related to electrical design shown in figure (4).

Experimental work:

The Staring Current is one of the mean problem of motor performance which required to redesign, that can be achieved by adding soft starting circuit, where starting current for a single induction motor is considered as a problem because it is relatively high as it found from QFD analysis.

The Soft Starting is a technique used to control the applied voltage during the starting period reducing the starting voltage to a pre-determined value and then increased it to its rated value at its end.

Motor starting current can be controlled by many ways, one of them varying the frequency ,since current is proportional to frequency, but this type of control is expensive and needs more electric parts, so the researchers choose the control circuit with fixed frequency and variable voltage in order to save money.

A triac controls the average A.C power to the motor by passing a portion of positive and negative half cycles of A.C input. This is achieved by changing the firing angle and that controlled by Rc circuit, by change variable resistor which is controlled by analyze circuit and this circuit is driven by microprocessor to change the variable resistor automatically as shown in figure (5).

The Results and Conclusions:

An electrical circuit prototype used to enhance motor performance the final designed circuit with (pic 16f84a: a micro controller), and form QFD and experiments:

1-   QFD indicate that the first issues: Starting Current, Losses, Coil Winding, Rotor dimensions gets high scores and detect what the problems are, and necessitate a need to solve and to find a suitable solution. To improve motor performance a designed part called "Soft Starting Circuit"   to be added to the existing motor.

2-   The Starting Surrent is reduced to (3.2) amp. That means losses equal (square current * resistance)   are $(5.2)^2 * 12.5 = 312$ watt. In the new designed motor ,the loss reduced to128 watt .

3-   The suggested design reduced the Starting Current from 5.2 amp to 3.2 amp

4-   The cost of Soft Starting Circuit is less than 10% of the cost of motor.

5-   The new design has high efficiency of control by using micro controller.

6-   The new design will prevents sudden vibration of motor and the sudden rise heat which breaks insulators between the wires and therefore the soft starting increases the life of motor. The results are shown in Table(1).
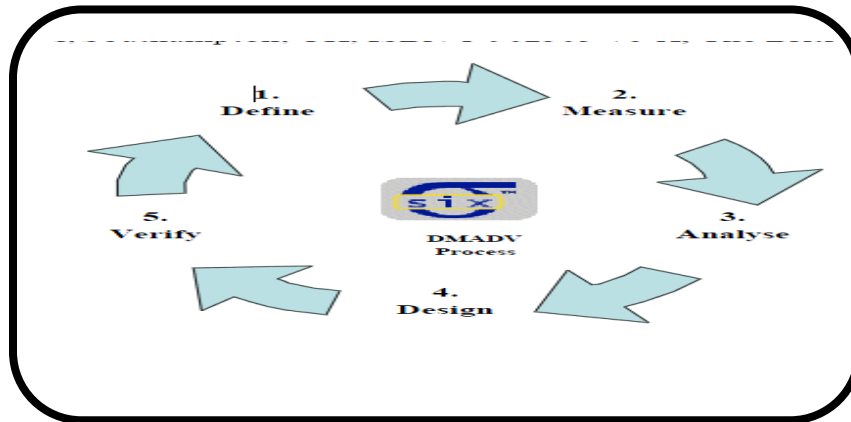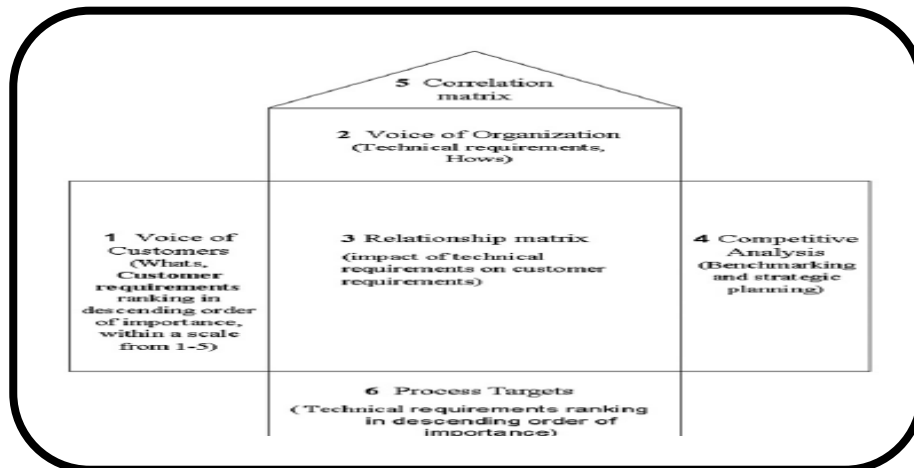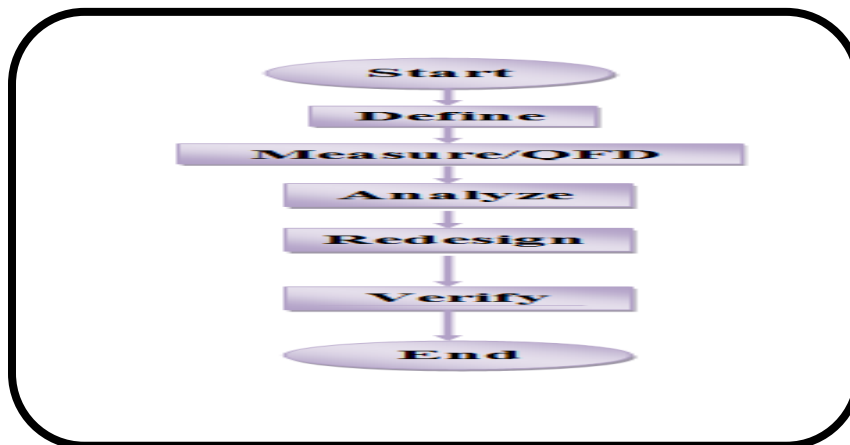
Figure (1) DMADV procedure [11]

Figure (2) QFD

Figure (3) the research approach

Customer Requirements (What):	Customer Importance Rating	Starting Current	Cost	Isolation	Losses	Stator Dimension	Rotor Dimension	Wire Type	Screw Feature and Be	Cover Dimension	Coil Winding	Dimension of Wire	Our Customer Satisfaction (CS) Rating	Competitor 1 Rating Chinese	Competitor 2 Rating syrian	CS - Max(Competitor Rating)
Desired Direction of Improvement:		↓	↓	↑	↓				↑	↑		↑	↑			
Less Vibration	4	7				9	9		5	5	1		3	4	4	-1
Less Noise	4	7				7	7		5	5	3		3	4	4	-1
Good Price	5	1	9					5			5	3	4	3	2	1
Long Life	5	7	3	7	7	5	5	7	5	5	3	3	4	3	4	0
Low Maintance Cost	2	5	3	3	3	3	3	7	5	3	3	3	2	2	2	0
Electric Saftey	4	1	5	9	3	1	1	3		1		1	3	3	3	0
Stable System Voltage	4	9	3		5	5	5	3		5	5	3	2	3	3	-1
Low Tempture	4	7	3		9	3	5	7	1	3	7	3	3	3	4	-1
Efficiency	5	5	7	1	9	1	1	1	1	1	9	5	3	3	3	0
Finishing	2	2		7									3	3	3	0
Low Electric Consuming	5	3	1	1	9	5	5	5		5	7	7	3	3	4	-1
Maintainable	3		1	5	1	1	1	3	5				3	3	3	0
Customer Requirement 13																0
Customer Requirement 14																0
Customer Requirement 15																0
Customer Requirement 16																0
Customer Requirement 17																0
Customer Requirement 18																0
Customer Requirement 19																0
Customer Requirement 20																0
Raw Score:		218	153	116	202	164	172	165	99	137	190	124				
Rank:		1	7	10	2	6	4	5	11	8	3	9				

Figure (4) QFD matrix

Figure (5) Designed circuit diagram

Table(1) Results of experiments

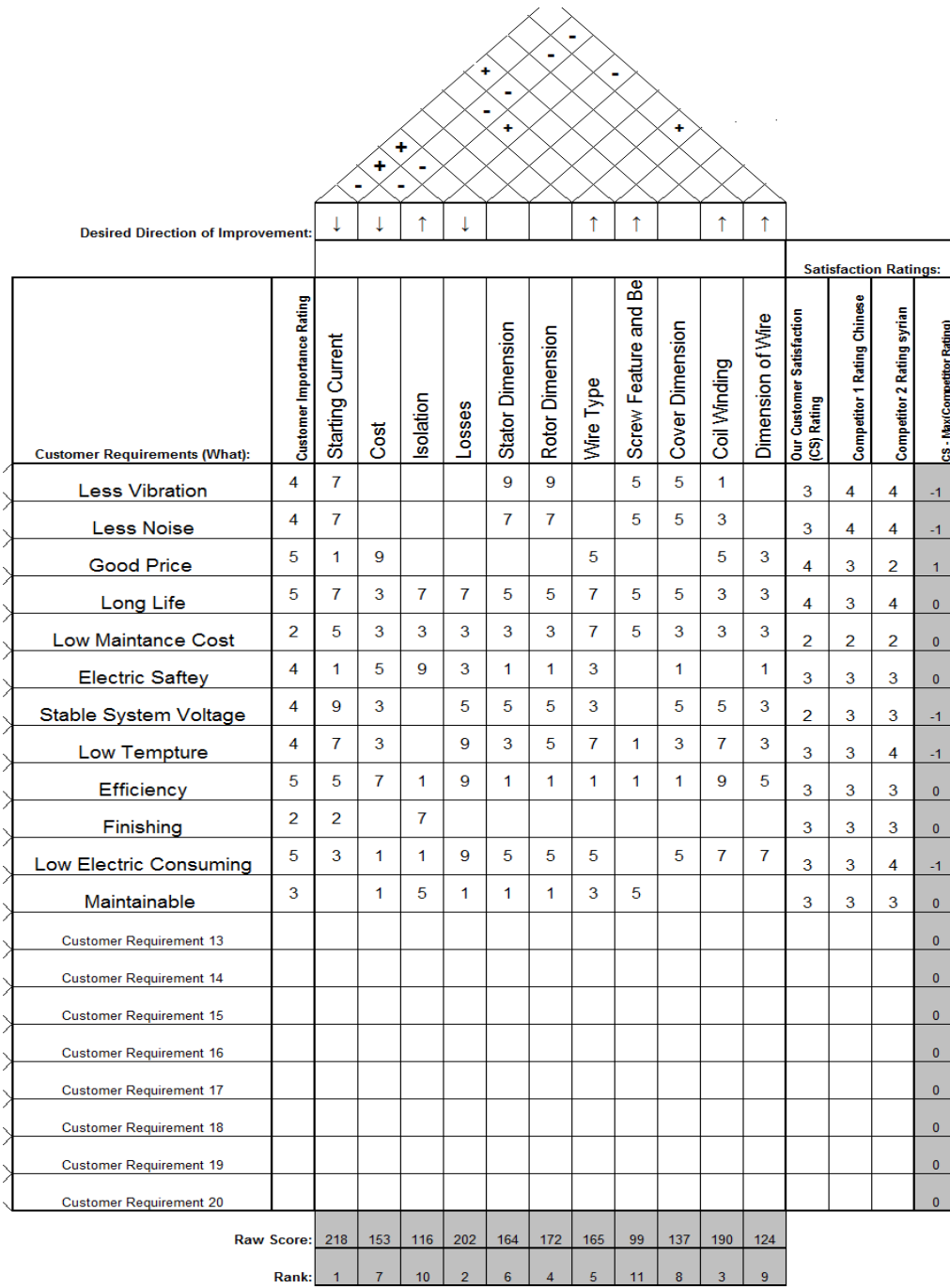| Current	Before	after
Start current	5.2 amp	3.2 amp

Questionnaire

Ministry of higher education and scientific research

University of technology

Department of production and metallurgy engineering

Branch of Industrial engineering

Questionnaire related with the users of the electric motor for air coolers with power (1/4 HP)

Dear customer…

Thank you for participation my questionnaire, I would like to get some information from you when answering some questions, which relate to motor (1/4 HP) used for evaporative air coolers. The aim of my research is for developing this product. the results will be used for scientific research only

Thanks for your cooperation.

Researcher

Shatha Mouayad

Please, mark with (√) the answers

that you think they fit more to related questions.

Questionnaire form

Q1: In your opinion, what the importance of each attribute of the following characteristics in the electric motor (1/4 HP), for you?

w	CR	No important (1)	No so important (2)	Less important (3)	Important (4)	Very important (5)
1	Low Vibration of motor					
2	good price					
3	Low noise					
4	Long life					
5	Low cost maintenance					
6	Electric safety					
7	Stable system voltage					
8	Low temperature					
9	finishing					
10	Efficiency					
11	Low electric consuming					

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