Using Six Sigma to Enhance Al Ain Distribution Network Performance

Maha AlDahmi and Omar Al-Ahmad

***Abstract*—Enhancing the performance of Al Ain Distribution Company (AADC) network by reducing the interruption can be improved and well-illustrated using Six Sigma method. The aim of this study is to apply Six Sigma approach with DMAIC framework to improve the overall service, to reduce operating costs, and to increase the customer satisfaction.**

Analyzing the AADC network performance using Six Segma application may help the management to illustrate the network and take better decisions. AADC network has been experiencing many power interruptions in terms of their frequency/repetition and duration. The Six Sigma DMAIC process is used to investigate a problem, analyze its various variables, and recommend specific action plan for improvement. The paper also presents the tools and techniques used in the DMAIC process to reduce power interruptions and improve the overall service level.

***Index Terms*—AADC-Al Ain distribution company, six sigma, KPI- key performance indicators, DMAIC.**

I. Introduction

Al Ain Distribution Company (AADC) is one of the two distribution companies under Department of Energy in the United Arab Emirates (UAE). AADC is the sole supplier of Electricity and Water in Al Ain City with an area of 13,100 sq.km. The company is responsible for operating and maintaining the power distribution network of voltage levels 0.4kV up to/including 33kV in eastern region of Abu Dhabi emirate. The power network covers about 170 nos. 33/11kV primary / package units substations and about 16,000 nos. of 11/0.4kV distribution substations. AADC always strive to meet its prime objective of providing continuous safe and secured power supply to all customers, with recorded peak load of 2.3GW in 2018 and expected demand of 2.45GW in 2019.

Network Key Performance Indicators (KPI's) such as System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) are the salient indicators that AADC uses to measure the customer's satisfaction in terms of continuity of power supply, in addition to customer connection times and feedback surveys [1]. In other words, every lost minute of operation often translates into significant cost to AADC, in addition to the negative impact on customer care and service. As the temperature of Al Ain in summer reaches 50º in the shade, the cooling loads (air conditioners) are an essential life requirement for AADC customers where power supply shall not be interrupted and should be kept continuous. Therefore, such performance aspects are increasingly becoming the focus of Six Sigma studies and applications [2].

The rapid development of many administrative and technical concepts has prompted service and industrial enterprises to search for appropriate methods, strategies and strategies to achieve their objectives and to enhance their services and products with their resources and potentials [3]. Six Sigma is one of the best methods of improving the quality of services, products and processes. Motorola is the first to use this method to express its quality program. Many international companies such as GE, Sony, Ford and others have proven successful in saving millions of dollars for the correct application of the Six Sigma strategy [4].

Six Sigma improves quality and performance using the structured approach of DMAIC (Define-Measure-Analyze-Improve-Control). DMAIC is a problem-solving approach that ensures complete understanding of process steps, measures process capability at the process Critical-to-Quality metrics (CTQs), applies Six Sigma tools and analysis to improve process performance, and implements methods to control the achieved improvement [5].

This section of the paper provides an overview of AADC network and six sigma DMAIC process. The following section presents the DMAIC methodology where each process will be explained. The Third section presents the application of the six sigma DMAIC process on AADC network to enhance the power network performance by enhancing the indices and reducing the interruptions as well as their impacts then improving the overall service level of supplying electricity. The last section covers the conclusions and findings with the expected network performance improvements.

II. DMAIC Metodology

The "Define" phase is the first phase of DMAIC which specifies the set of CTQs that characterize the quality attributes of interest to the improvement study. Measurement phase is used to estimate the quality attributes of the underlying system. The measured values are also utilized in the "Analyze" and "Improve" phases to identify causes of variability and to set effective improvement actions that serves the target. Finally, "Control" actions are prescribed to maintain the achieved process improvement and assure that "Improve" phase is implemented well. Fig. 1 shows the DMAIC process [6].

It is important that the DMAIC process is considered as a roadmap for stakeholders. Based on this, a systematic plan was developed to collect all the operational data, measure

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the performance of the various operations and provide a full explanation of the opportunities and defects. Thus, a data-based and well-structured approach is used to verify and analyze the sources of variation, to solve problems that hinder the process and to improve performance to achieve the target of Six Sigma. Table I summarize the commonly used tools and expected deliverables at each DMAIC tollgate.

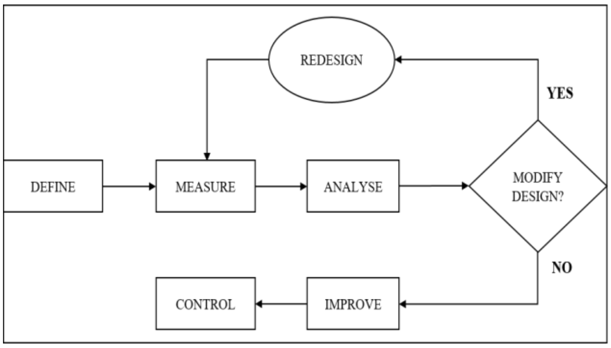

Fig. 1. The six sigma DMAIC process.

TABLE I: TOOLS OF DMAIC TOLLGATES [6]

	DMAIC Phase				
	Define (D)	Measure (M)	Analyze (A)	Improve (I)	Control (C)
Tools	Brainstorming, Project Charter,CTQ ,QFD, etc.	Data collection, sampling, Flowcharts, Check Sheets	5 – Why's, Cause and Effect Diagram, Scatter Diagram	Design optimization, robustness, brainstorming	Error proofing, FMEA, SPC, Standards, PUGH analysis
Deliverables	Project objectives, CYQs, design variables, resources, project plan, etc.	Measured performance, Process variation (Sigma value), process capability measures	Defined improvement opportunity, sources of variation, action plan.	Select the best solutions, changes deployment, adjustments to process variables.	Monitoring plan, maintained performance, documentation, transfer of ownership.

III. LICATION OF SIX SIGMA DMAIC PROCESS IN AADC NETWORK

The Six Sigma DMAIC process was applied to enhance the AADC network by reducing the interruptions. The Six Sigma quality tools were used to improve the Network Key Performance Indicators (KPI's) such as System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) which is considered an important indicator in AADC used to measure the service quality, reliability, and customer satisfaction in terms of continuity of power supply, in addition to customer connection times and feedback surveys. Also, the regulation in Department of Energy (DOE) requirements always challenge AADC to improve KPIs, which aims to be ranked in the top quartile performers amongst worldwide utility companies based on governmental targets.

AADC has set specific and focused targets to improve KPIs each year. For the Six Sigma methodology to be implemented efficiently and achieve the benefits, it is necessary to collect all data related to direct and indirect processes that affect the power interruptions from all different voltage level (low voltage (LV) and Medium voltage (M.V) 33kV&11kV). The next steps were for re-engineering the processes of power interruptions to improve service and increase efficiency, which is expected to provide better service at a lowest cost.

The challenge was to ensure that despite the rise in the number of customers, results will not mislead the measure as they would essentially show an improvement on both SAIDI and SAIFI, without an actual reduction in interruptions duration and frequency. Thus, a Six Sigma study is initiated to analyze the various elements of power distribution process and to reduce the overall interruptions of the process based on the two selected KPIs. The following sections present the application of DMAIC tollgates for power interruption reduction. Full details are not shown for confidentiality.

A. Define

At this phase the problem is defined to start using Six Sigma project and develop a project charter. The application of this phase is related to certain quality factors that have been linked to the energy distribution process (e.g., time, reliability and cost, etc.). It is important that this effectiveness maintains acceptable targeted ranges of SAIDI and SAIFI. In addition, this phase includes a clear understanding of the customer service process and a brief clarification of its Critical-to- Quality measures (CTQs).

Typically, the public in Al Ain area do not feel all kinds of M.V power interruptions when they occur because the grid network is well interconnected and designed based on ring system. However, when a massive interruption occurs, many customers might be affected based on the fault location. The duration to recover from the interruption and get back to normal mode is crucial. Thus, both frequency and duration of interruptions affect the reliability of the provided distribution services. Therefore, both SAIDI and SAIFI were defined as CTQs in the project charter.

The project charter also specifies the scope of the project for the processes being studied and analyzed by Six Sigma team. In order to obtain clear information and good knowledge, the relevant AADC team studied all the details of the power distribution process and developed flowcharts of power interruption incidents as shown in Fig. 2.

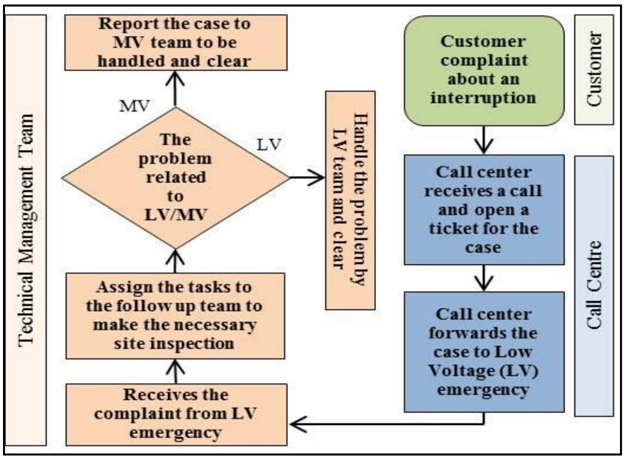

Fig. 2. AADC customer interruption flow chart.

B. Measure

This phase focused on collecting data collection and measuring the performance of the current state to determine the process capability and Sigma level. AADC uses the Distribution Management System (DMS) to measure the SAIDI and SAIFI, the system has facility to control and monitor most of the stations in AADC network. The following formulas are using to calculate SAIFI and SAIDI [1].

$$\text{SAIFI} = \frac{\sum \text{No. of customers interrupted}}{\text{Total Number of Customers Served}} \quad (1)$$

$$\text{CML (Customer Minutes Lost)} = \text{No. of Affected customers} \times \text{Interruption duration (hours)} \times 60 \quad (2)$$

$$\text{SAIDI} = \frac{\sum \text{Customer Interruption Durations}}{\text{Total Number of Customers Served}} \quad (3)$$

Table II illustrates a sample of data collected and the calculations of SAIDI and SAIFI in AADC network for year 2018. It's obviously shows that the SAIDI has reached 80.77 and SAIFI has reached 0.85.

TABLE II: AADC SAIDI&SAIFI CALCULATION

SAIDI-Measure	***Total number of customers***	157960
	Total customers minutes lost in interruptions	12,758,425
	KPI calculation	80.77
SAIFI-Measure	***Total number of customers***	157960
	Total number of customers interruptions	134,825
	KPI calculation	0.85
Overall Distribution Service Level (Sigma Level)		4.46

The distribution service level is then converted to a Sigma Rating. Table II, shows, the short-term Sigma Rating is set to 4.46. In most cases, the level of quality is high in manufacturing, but not so with critical processes such as the distribution process. An average of one interruption per customer in 2018 reaching approximately 81 minutes of lost power is not typically an indication of operational excellence given the enormous operational and business impacts of power interruptions. So, Six Sigma will be used to investigate the root causes of interruptions and to set a process improvement plan to reduce them.

C. Analyze

The role of the analysis phase is to identify the root causes for power interruptions and the variability in power distribution process. Advanced statistical methods are used to investigate AADC network process variability. Other quality tools are used in the analysis include fishbone diagram, process Mapping, and bar chart.

To start analysis, the interruptions raw data is firstly imported from spreadsheets, then filtered and categorized according to different regions and areas in AADC network. Afterwards, all the data were analyzed for one year to find out it's contribution on AADC KPI's. It's worth to highlight that the SAIDI and SAIFI in AADC network has been affected by planned/unplanned interruptions, where each type of interruptions categorized into three types based on different voltage levels. Then the contribution of each type of interruption was specified on SAIDI and SAIFI as shown in Table III.

TABLE III: CATEGORIZATION OF AADC INTERRUPTIONS

Voltage	**Incident Type**	**Interruptions**	**SAIDI**	**SAIFI**
33kV	***U***	0.7%	8.6%	5.3%
	P	0%	0%	0%
11kV	***U***	35.5%	66.9%	68%
	P	9.7%	13.5%	17.4%
LV	***U***	38.6%	3.4%	3.9%
	P	15.5%	7.6%	5.4%
U: unplanned		P: Planned		

A thorough study of the results followed by several brainstorming sessions were able to form a clear insight on the nature of the problem and its potential causes based on incident type and voltage level.

From Table III, it is noted that the unplanned interruptions in 11kv network has the highest contribution in SAIDI and SAIFI by 66.89% and 68.04% respectively. Accordingly, this part will focus on explaining the 11kV unplanned interruptions and their contribution on the mentioned KPI's as an example. Fig. 3 shows a bar chart of the key identified power interruption causes in 11kV network and their contribution on SAIDI and SAIFI.

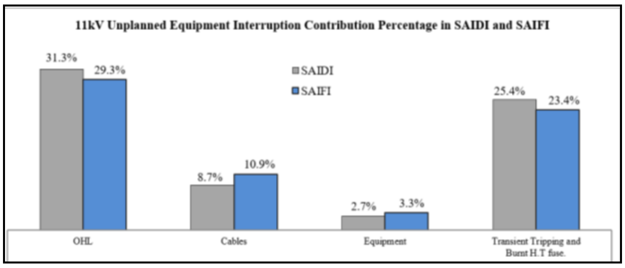

Fig. 3. 11kV unplanned interruption.

From the above figure it's clearly shown that the overhead line (OHL) has the major contribution in 11kv network in particular and the whole AADC network in general; where the unplanned 11kV interruptions lead the raise of both SAIDI and SAIFI by 31.3% & 29.3% respectively. It's worth to know that around 43% of Al Ain distribution network area is covered by OHL, where the 11kV OHL's network are extending in rural areas and the weather is considered the main cause for the OHL component failure, in addition to transient tripping and burnt H.T fuse.

This finding has focused the efforts spent to address the faults (sub causes) in OHL and to give them most priority. To this end, a separate cause and effect study and bar analysis were directed to OHL faults to identify, categorize, and address their root causes.

D. Improve

This phase is considered one of the most important stages in DMAIC. Where it verifies and implements the optimization plan that was derived from the analysis. An experimental design is used to determine the levels of the control factors and is designed to reduce the interruptions in AADC (based on frequency and duration). The outcomes of the analyses were formalized into an improvement action plan. The plan includes specific improvement measures at each factor that contribute to interruption in AADC network. Statistical analysis and data are then used to set specific action plan to enhance the network performance in terms of SAIDI and SAIFI. After that the resulting process translated into Sigma level after several brainstorming sessions. The example of an improvement actions is shown in control section.

The following Table IV shows the targeted SAIDI and SAIFI in AADC network based on benchmarking with the best practice along with the improvement plan.

TABLE IV: AADC KPIS 5-YEARS IMPROVEMENT TARGET

	2017	2018	2019	2020	2021
SAIDI	94.76	74.48	71.58	69.06	66.84
SAIFI	1.0013	0.85	0.827	0.806	0.788

To check the viability of the improvement plan, the performance of the distribution network in terms of SAIDI and SAIFI is compared to these targets quarterly and yearly. Along with the yearly reduction in both SAIDI and SAIFI, the overall process Sigma level is expected to be improved leading to higher service quality, reduced costs, and increased customer satisfaction. The team has also recommended to utilize Quality Function Deployment (QFD) to accommodate other customer needs and translate them into service features and functions. Full details are not shown for confidentiality.

E. Control

The control phase ensures that all efforts and plans developed to improve the performance of AADC network are maintained. This has been investigated by monitoring key performance indicators (KPIs) and controlling the factors of AADC network process. There are set of practical Six Sigma tools used in this phase such as:

1)Standard operating procedures.

2)Statistical Process Control.

3)Failure Mode and Effects Analysis.

The following are the list of recommended improve and control action plan for AADC network.

TABLE V: AADC RECOMMENDATIONS ACTION PLAN

	Proposed Recommendations	Status
1	Maintain all the equipment by developing a better maintenance plan.	Continuous
2	Undergrounding of OHL portions based on criticality.	In progress
3	Live line maintenance in OHL.	Contract awarded
4	Installation of more isolation point on OHL's (MHS-Master Head Switch & VMS-Vertical Mounted Switch).	In progress
5	Increase the number of monitored substations by accelerating the DMS-stage 4 contract	In progress
6	Increase the parallel mode of transformers and 33kV incomers	Continuous
7	Using infrared camera (Thermal camera) for OHL inspection	Continuous
8	Efficient applying of HSE rules would help to mitigate the outages.	Continuous
9	Initiate investigation team to evaluate and identify the root cause analysis for each incident happened in the network to come up with permanent solutions to the problem	Implemented

IV. CONCLUSION

The performance of AADC network in terms of SAIDI and SAIFI can be enhanced by the use of Six Sigma. The structured methodology of DMAIC process which is abbreviated from Define, Measure, Analyze, Improve and Control was used and illustrated on AADC network KPIs. The different types of failures are analyzed based on the said model and results are classified.

For confidentiality purpose this paper doesn't presented full details of the analysis. Implementing the recommendations and action plan in this study will contribute in improving the AADC KPI's and increase process Sigma level. Such improvement is expected to reduce the operating and maintenance costs for the company along with higher service level and customer satisfaction.

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Maha Al Dahmi was born in Al Ain city, United Arab Emirates. She finished her bachelor degree in electrical engineering from United Arab Emirates University in 2010, and master degree in business administration (MBA) from Abu Dhabi University in 2013. She graduated from alNokhba summer internship program to study the semiconductor in Dresden Germany in 2010 and in 2013. She graduated from young future energy leadership program (YFEL) from MASDER institute. Also, she is a certified energy manager (CEM) since 2018.

Maha joined Al Ain Distribution Company (AADC) in 2010 as a study engineer, the job includes maintaining the power quality and the security of the electricity network by preparing the required studies and analysis together with the continuous evaluation of the load in the network, as well as the re-distribution process depending on the general electricity standards in the distribution network.

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Eng. Omar is a member in the Jordan Engineers Association and a member in the technical team of evaluating power projects related to power network enhancement and security of supply compliance. His main areas of research interest are power system analysis, PV & renewable energy studies and power assets performance and system indices enhancements, and electricity markets.