Improvement in Polarization Index of Transformer by using Six Sigma Methodology

Krishna R. Dachawar[1]
[1]Production Engineering Department
[1]V.J.T.I. ,Matunga,Mumbai-400019

Abstract— Transformer is an important electrical device in the power system which is used to step up and step down the voltage & Transfer electrical power according the need of customer. Oil filled Transformers get the insulation and heat transfer properties form the oil. But ironically the same oil causes one of the major defects of the transformer i.e. moisture. The transformer there is always mechanical, thermal or electrical stress generated during its operational period , it causes fault in transformer, the source of fault may lie in design, manufacturing, material used, handling & site , as this is the major pain area for all transformer industries , we introduced a latest quality tool to resolve this repetitive problem with target to reduce it at 0.01 DPU level ,In this paper we used six sigma methodology & approach, this is statistical tool which is based on past data, process parameter , results and analysis of the problem .
Keywords: six sigma,DMAIC,Methodology,PI.

I. Introduction

Above subjected project has been completed on Transformer manufacturing unit of a renowned name in power sector. Project has been selected by collecting customer compliant data was collected over a period of past 2 years. Six sigma methodologies are highly effective in finding the root cause of a problem. Six sigma method having five phases. On analysis of the data using the paretto chart, it was found that one of the highest compliant received was that of transformer with less polarization index. To find the solution of this problem, the six sigma (DMAIC) methodologies were used. This technique a second level peretto was of the customer compliant for the particular issue was made. Various reasons were found out during the same. Using the information we moved ahead. Next phase of this methodology is Measure, where using various tools such as process mapping, cause and effect diagram (CED) and FMEA (Failure mode and effect analysis) the probable reasons of the problem were identified.

The probable reasons identified through FMEA are then funneled using various tools of analysis phase such as capability analysis test or equal variance to get the critical reasons. These reasons were then worked or in Improve phase and continuously monitoring result when we got the satisfied results i.e. customer compliant is minimized then issue a control plan to concerned department of turns.

II. Literature review

Six Sigma has been the subject of interest to many researchers over the years. Many researchers have studied Six Sigma programs and identified many critical dimensions of six sigma programs. For example, Brue Greg; “Six Sigma For Managers, McAdam and Evans (2004) [2] for Challenge to Six Sigma in a high technology mass-manufacturing of transformers, Savolainen and Haikonen (2007) [3] for dynamics of organizational learning and continuous improvement in Six Sigma implementation. research of Antony and Banuelas (2002)[4] Key ingredients for the effective implementation of Six Sigma program., Coronado and Antony (2002)[5] for Critical success factors for the successful implementation of Six Sigma projects in organizations , Gitlow and Levine, 2005[6] for Six Sigma for Green Belts and Champions: Foundations, DMAIC, Tools, Cases, Keller (2005) [7] points out, Six Sigma programs have performance metrics and measurements based on cost, quality, and schedules ,Davison and Al-Shaghana (2007)[8] for the link between Six Sigma and quality culture—an empirical study, Minitab software [9] for various statistical tools.

III. Case study

This case study is undertaken at one of the leading transformer manufacturing in India. The unit produces distribution transformers ranging from 315 KVA to 40000 KVA and voltage class upto 145kV. Transformer manufacturing is an engineering industry with lot of assembly operations categorized in various sections such as winding, assembly & tanking. Our area of work is from design to dispatch section of transformer manufacturing. The company had a challenge to produce the transformer with less moisture i.e. with more polarization index. Any transformer with less polarization index whether at the shopfloor or at site would pose lot of rework and interruption to the production process or to the user.The company is also increasing its global footprint and needs to be cost competitive to lead the market. The increased application of six sigma can definitely help the company towards its goal.

A. Data Collection

Data is the backbone of all Six Sigma projects. We employed this concept in our study. Data of qualitative nature was collected through various documents available in form of minutes of meeting, letters, e mails, reports and studies etc. Quantitative data were collected in the form of customer complaint reports, manufacturing plans and schedules, archival records of financial data, quality performance reports, purchase orders, operational data (such as category of products produced), performance measurements (such as annual sales and responsiveness). Additional qualitative data were collected through interactions and open information exchange sessions with various interested parties such as managers, engineers, technicians and other employees. The free and fairness of our sessions enabled the capturing of the micro level details of the process and product issues related to our project. Further qualitative data were collected by observation and taking the data based decisions during the implementation. Also qualitative data were collected for the components, vendor source, process parameters, detection results, long rework hours, wastage of material, time etc. These indicated the need for further study of the process to reach to the vital few Xs affecting the Y of our project that is the issue of moisture in transformer. During the study the researcher kept a research log that documented each problem encountered during the implementation, in addition to the thoughts and insights gained during the process. Data collected is in Metric units i.e ppm (parts per million) with Base ppm of our case as 12987 and target as 5000 ppm after completion of the project.

B. Data Analysis

The researchers with their experience on the Six Sigma methodology maintained the rigour throughout the progress of their study. The preliminary data analysis in case study is the reflection by the researcher on their own experience. The researchers identified common threads by grouping and analyzing the experiences of themselves and other contributing participants. Data analysis however was the base for identifying probable root causes and prioritizing alternative solutions. In spirit, data analyses is the collection of all the relevant data in variable or attribute form, applying analysis tools and deriving meaningful information for decision making. In this study, the unit of analysis was the operational/department level where the data was generated.

To understand the process and examine the flow of information through the system; we employed process mapping. Each activity in the manufacturing process is represented on a two-dimensional scale. The process steps are then connected with arrows showing the direction of service flows. These maps helped identify where process stoppages occurred, major rework areas, decision/inspection points, defect levels at intermediate stages.

The researchers maintained the flavour of six sigma methodology on daily basis. They spent several hours on sharing the study objective methodology with the interested parties. They worked based on the project gantt chart and kept a close eye on the target completion of stages and milestones. All the information gathered from the experience of the experts and operational level personnel were verified against the data and only data supported ideas were taken further for implementation. Results of the ideas implemented during the current day were reviewed for performance. The results were taken through the further steps of six sigma methodology to reach the goal. The production process progressed in steps and the researchers were involved throughout the steps to capture the significant results and conclusions. Refer Process Map showing typical process mapping for production of process.

IV. IMPLIMENTAION OF SIX SIGMA METHODOLOGY

Our project is based on six sigma methodology which is often called as DMAIC process**.** This is advanced breakthrough method of identifying and resolving issues permanently and taking the processes to the next level. The improvements are not incremental in nature but are massive taking the performance levels to exponential rise. There are five phases of solving problem by DMAIC methodology as name suggests: Define phase, Measure Phase, Analysis Phase, Improve phase & control phase. We will discuss each phase in relevance to our project progress.

A. Define Phase

In this phase we define problem in measurable form i.e. less polarisation index in transformers manufactured with base data 12987 ppm and target ppm 5000 after completing the project. For defining the problem we have collected data form customer complaints, MOM, our and vendor in-process checks etc. As mentioned in Data collection method. We prepared Pareto charts using Mintab software to define our problem. As mentioned in graph below.

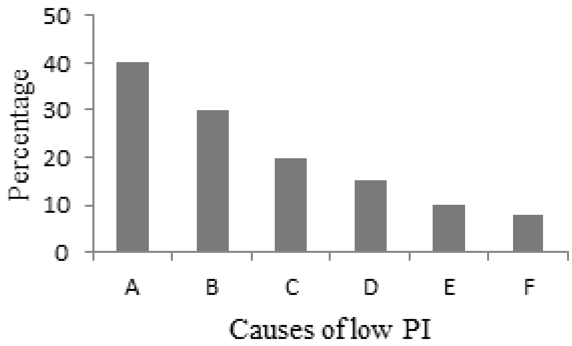

Fig. 1: Causes of low PI

Where,
A= High moisture content in insulation
B= Heavy water sprinkling while making cylinder
C= Use of high conductivity water
D= CCA in uncontrolled atmosphere
E= High particle count of oil
F= Dust on CCA
From the above the main factor that affects PI is moisture in insulation i.e. in oil.

B. Measure Phase

Under Measure phase, we establish the base levels of the probable many Xs contributing to the problem at the place of project. It is based on mathematical equation **Y=*f*(X).** It means 'Y' is the function of 'X'. i.e, Y is the desired result or may be the undesired result or problem as we see in our study in form of less polarisation index and is dependent on various Xs means causes for less polarisation index at various stages of the product.

The causes or Xs were gathered from the inputs of cross functional team. In our case study, team members form production, quality, material department heads, executives and technicians, under guidance of Guide. Thereafter we used various six sigma tools to find the vital few causes as follows:

1) Process Map

A process map is graphic representation of a process, showing the sequence of tasks using a modified version of standard flow charting symbols. The map of a work process is a picture of how people do their work .Work process maps are similar to road maps in that there are many alternative routes that will accomplish the objective. In any given circumstance, one route may be better than others. By creating a process map, the various alternatives are displayed and effective planning [to improve the process] is facilitated. Refer Process Map which shows typical process mapping of tanking area for production of transformers.

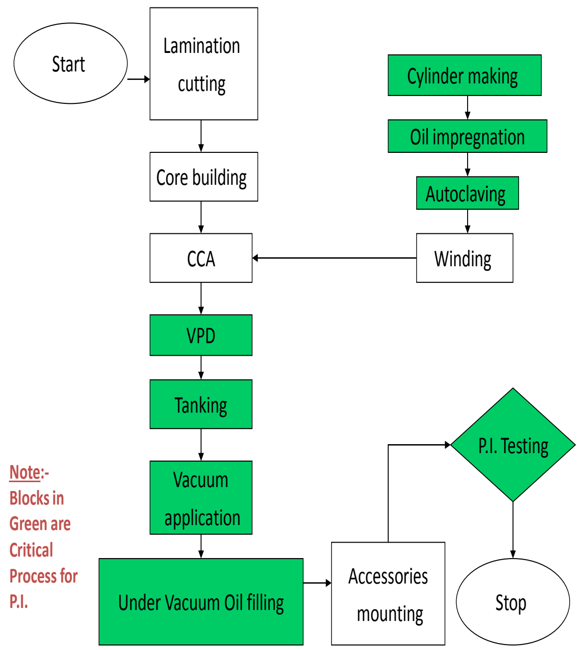

Fig. 2: Process Map

2) *Cause & Effect Diagram*

The Cause & Effect Diagram (CED), also sometimes called the 'fishbone' diagram, is a tool for discovering all the possible causes for a particular effect. The major purpose of the CE Diagram is to act as a first step in problem solving by generating a comprehensive list of possible causes. It can lead to immediate identification of major causes and point to the potential remedial actions or, failing this, it may indicate the best potential areas for further exploration and analysis. CE Diagrams are also often called Ishikawa Diagrams, after their inventor. By a brainstorming session various causes were gathered and placed into the relevant branch.

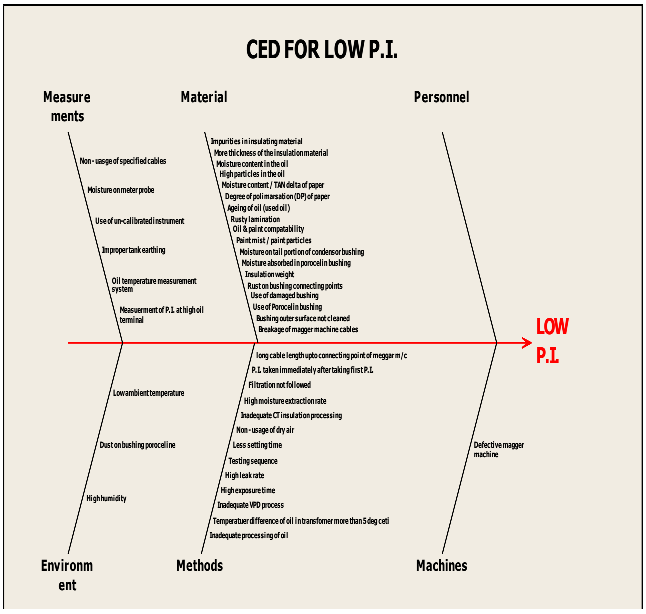

Fig. 3: CED for low PI

3) *FMEA*

FMEA is the short form of **F**ailure **M**ode **E**ffect & **A**nalysis. It is a very effective tool to reduce the number of Xs by evaluating them against the severity, occurrence and detection on a scale of 1-10. It is often done in a Excel sheet with columns for the process steps, effects, causes. By multiplying occurrence, detection & severity we get the RPN (Risk Priority Number). On the basis of RPN number the causes are prioritised for Analyse Phase. Refer FMEA in Table 1and Graph E for Pareto chart of FMEA.

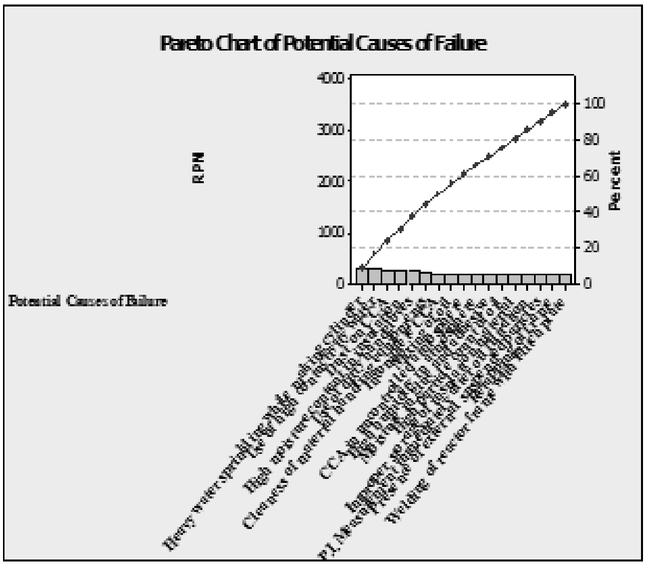

Fig. 4: Pareto of FMEA

C. *Analyse Phase*

This is the phase of six sigma methodology where using various tools the Xs obtained from the Measure Phase are reduced to vital few which then can be taken up for improvement. The effectiveness of this phase is very critical for carrying out the improvement experiments and the feasibility of such experiments. Therefore lot of time was spent on analysis activities in this phase to filter out the trivial many Xs from the probable Xs.For this project the vital Xs are,

1) High moisture content in insulation
2) Heavy water sprinkling while making cylinder
3) Use of high conductivity water

D. Improve Phase

With the preceding effective work in the Measure and Analyse phase the number of Xs in the Improve phase is limited and this phase can be completed in quick time. The objective of Improve Phase is to carryout the experiments to identify improvement breakthroughs, to improve the capability of the Xs and finding the right levels, attempting to make the Xs redundant , select preferred approach, determinethe new Sigma level, design dashboards/ scorecards, finalising the improved process and giving a complete solution.

In our project we worked on improving the vital Xs and found an important factor which affects moisture content is low quality of oil. All of these would have required huge effort to maintain the improved levels taking into account the manual involvement at various vendors, designs. We also introduced the new filter machineand found that quality of oil is increased resulting in higher polarisation index thus meeting our DOE criteria and the process became first time right providing the way towards going Lean.

Potential Causes of Low oil BDV(<85)

1) Moisture ingression/contamination through oil handling system (storage/ Tanks/Pipes/Flanges/Machines)
2) Repetitive usage & mixing of system oil with fresh oil.
3) Low BDV at storage end & inadequate filtration before oil filling in transformers
4) Poor efficiency of Filter machines

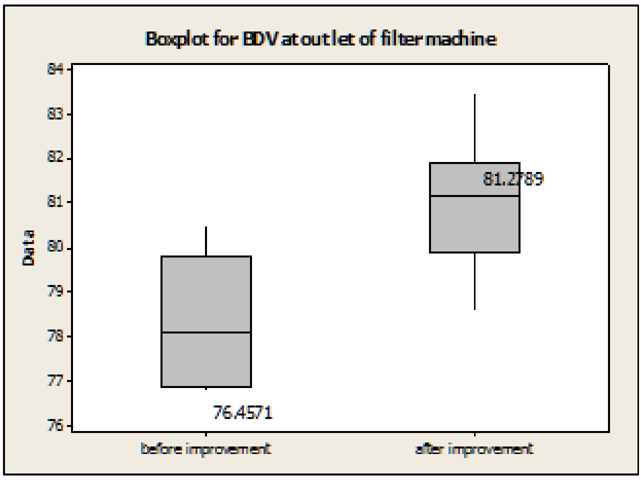

Fig. 5: Oil BDV before & after Improvement on Filter m/c

Basically there is a issue with the repetitive usage & frequent mixing of system oil with fresh oil due to inadequate capacity of storage oil which results into Low BDV.

Action taken

1) New tanker installed with capacity 80KL.
2) New filter machine with capacity 6 kl/hr.
3) No of passes through filter machine is increased

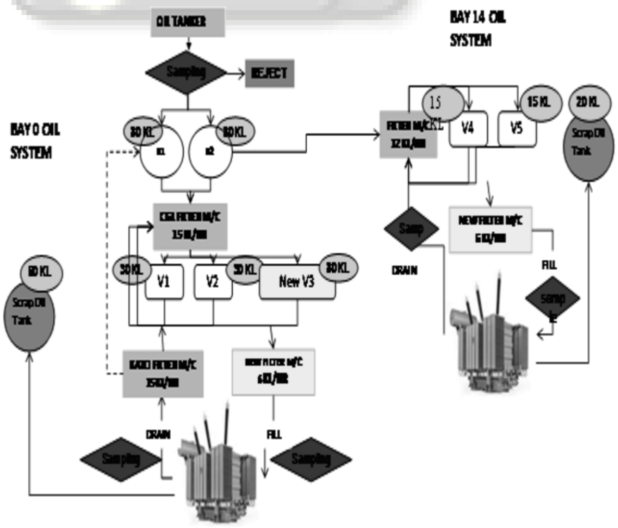

Fig. 6: New oil management systemfor oil > 85Kv BDV

E. Control Phase

The control phase as mentioned earlier is very important for the sustenance of the improvements recommended and gives permanence to the solutions discovered. This also completes the handover of the project to the regular process owners who would implement the solutions and ripe the benefits, reconfirm the effectiveness of the project undertaken and establish credibility of the company's Six Sigma program. New filter machine and number of passes through filter machine is increased on the recommendations of this project to ensure continued implementation for future.

V. CONCLUSION

The motive of this research was establishing Six Sigma, the powerful pillar of the modern industrial revolution. The major hurdle in achieving a flawless production cycle is the presence of defects in the processes being carried out, defects in the inputs to the process in form of material, components, information, sub assemblies. The research identifies Six Sigma methodology as a strong enabler of Lean Manufacturing. Using a successful Six Sigma program in a Transformer manufacturing unit this research developed an implementation model consisting of the DMAIC rigour. The steps of DMA enable establishing the problem in measurable form, finding out the existing current levels of the result as well as contributing inputs or causes and all this in real time. The strong data based approach ensures the objectivity of the whole process and eliminates the traditional mistakes of experience based or gutt feeling based decision making. The steps of IC are then carried out with concentrated limited effort to find exhaustive solutions using different level of the Xs and providing the breakthrough for taking the process to the level of virtual zero defects. In addition, important for both practitioners and academicians, several areas of future research are also discussed regarding the implementation model. Lastly, this research provides a framework, to use the six sigma methodology for effectively guiding the journey towards Lean manufacturing. Implementation of Six Sigma programs to reduce variation or waste from the operations. It provides the newer view for organisations to decide the direction or objective of their Six Sigma programs. More research in this area is necessary to contribute to the science and practice of implementation of Six Sigma or any other process improvement model, to reduce waste and create value. The solutions recommended in this case study support radical thinking, de-bottlenecking and eliminating defects making the process smooth and supportive for Lean and also increased the PI value.

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