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Implementation of Six Sigma for Improved Performance in Power Plants

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Abstract:
Six Sigma (SS) is an emerging powerful management framework tool increasingly utilized for process, quality, inventory control etc. in diverse industrial and business sectors across the globe. It can also be utilized to analyze and provide best possible solution for a complicated task in the process. It facilitates in identifying the causes for defects and errors in manufacturing and business processes by utilizing various input tools like engineering, management, statistical, infrastructural, manpower,marketing and quality to name a few.Six Sigma basically aims to deliver breakthrough performance improvement from the existing levels to enhance performance in user-defined tasks of organisation. In a power plant, lack-of-control in inventory severely affects the performance of power production that eventually may lead to various breakdowns and maintenance schedules. In the present study, it is proposed to collect all relevant data of input raw materials required for one-year continuous running period (as per plant shut-down schedule) and will be analyzed by applying SS to finally provide output solution accordingly. Another aspect that will be implemented for SS analysis is to provide significant measures for reducing DM (De-mineralize) water consumption in power plant
Keywords: *DMAIC, DM make up, Minitab 17.1, Process capability, Process industry.*

I. Introduction

Six Sigma DMAIC methodologies reduce cost and improve quality. Six Sigma works as a quality tool in manufacturing as well as in process industry. In process industry quality is measured by flow measurement, pressure, temperature. In manufacturing industry by applying Six Sigma DMAIC methodology sigma level improved upto 5-6 from 1-2 level. In process industry some of the sub-processes operate at negative sigma level because of being secondary in nature. So in process industry six sigma level can be improve maximum upto 2-3 six sigma levels. Present work is an initiative to implement Six Sigma DMAIC in thermal power plant.

II. Methodology Adopted

To apply Six Sigma DMAIC methodology in minitab 17.1 version software one year data from 1st Dec 2013 to 30th April 2014 data of all 5 units has been taken.DM cycle make up water converted in terms of percentages of MCR(maximum continuous rating)of feed water flow so that this methodology can be applied to other power plants. And cycle make up water cannot be reduce to zreo but it can make minimum hence LST (lower specification limit) cannot be fixed for water consumption. So only USL(upper specification limit) of 100 tonnes and target value of 50 tonnes has been taken based on water consumption.

Implementation Of Six Sigma Dmaic Methodology

A five step improvement cycle using Six Sigma organizations (Define, Measure, Analyse, Improve, and Control DMAIC) has been successfully implemented in Thermal Power Plant to reduce DM make up water reduction.

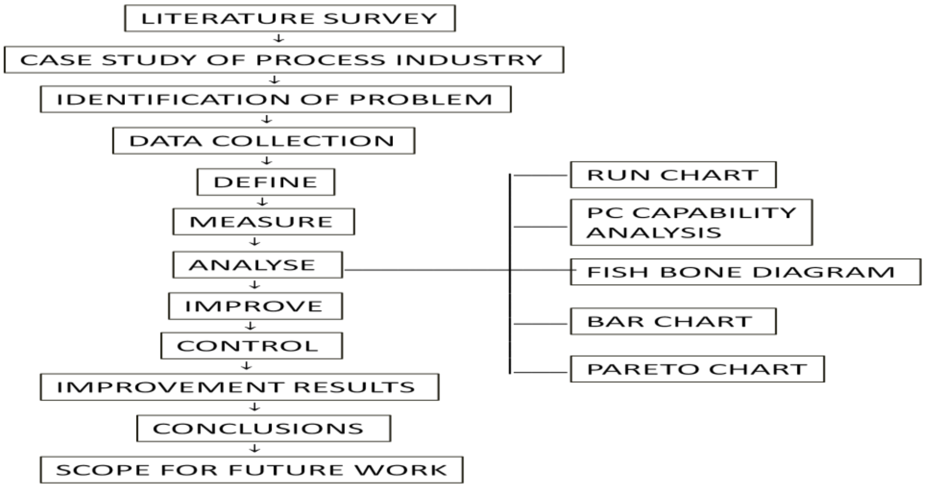

Fig.1 - Flow Diagram of Six Sigma DMAIC Methodology

III. Literature Survey

Literature review on implementation of SS for quality improvement and inventory control is well known and widely reported, however, its implementation and analysis in power plant engineering is very few, in particular critical inputs from like DM (de-mineralize) water management and raw material inventory. From the past experiences and statistical data, it has been found that even a 2% improvement in inventory control in a coal based thermal power plant, may lead to significant increase in profits and reduction in power generation costs. Previous investigated studies also indicated that even 1% increase in DM water consumption may lead to increase in power generation cost by ten-crores (0.1 billion dollers) per annum.

IV. Case Study Of Process Industry

In Thermal Power Plant optimisation of De-Mineralised (DM) water consumption process cost is high. DM cost is used for steam generation through gas based combined cycle power plant. DM water make up cycle is essential to compensate for the losses takes place in water steam cycle due to evaporation, blow down,start up and shut down venting, valve passing. DM make up water enters in a condeser at atmospheric temperature that is heated over

500^{0C} for raising steam. Flow meter is used to measure day cycle make up water as percentage of feed water flow. Each 0.1% increase in cycle make up water increases generation cost 1 crore per annum which includes cost of heat loss, extra water and consumption of chemicals. Hence implementation of Six Sigma is to conserve energy by reducing DM make up water requirement at Thermal Power plant.

V. Identification Of Problem

Steam is generated by DM water. So it is key element in generation cycle. DM water is of two types cyclic and non-cyclic DM. Cyclic DM water is that which is a part of steam cycle and non-DM water is used in various applications like Stator water, SG ECW/TG ECW etc. Here our focus is on cyclic DM water consumption only. Calculations based on four months DM water consumption of stage I of Rayalaseema Thermal Power Plant. DM make up water enters in a condenser at atmosphere pressure that is heated around 540^{0C} degrees for steam. Flow meter is used to measure daily cycle make up water as percentage of feed water flow.Presently make up water consumption of RTPP is around 0.5-0.55% of MCR (Maximum Continuous Rating).

VI. Data Collection

6.1 Define

In define phase, High level process map-a SIPOC (Supplier, Input, process, Output, Customer) diagram, was drawn for cycle make up water consumption (Fig. 2).

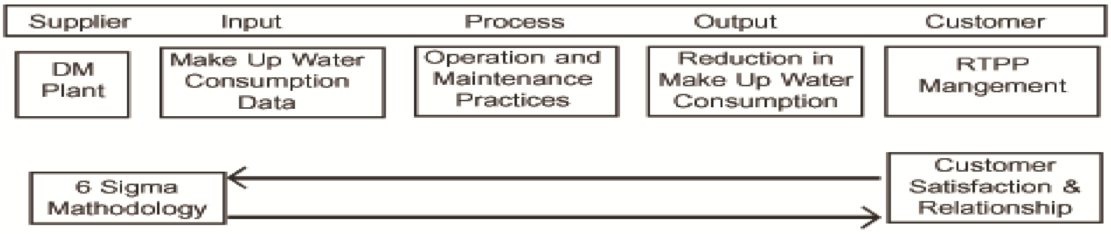

Fig. 2 - High-level process map for cycle make up water consumption

In this phase problem statement defined and also identifies the need of implementation of six sigma and minimise the variability in DM consumption. In this phase define Critical success factors, which are Reduction in DM make up and its inventories, Improvement in heat rate due to reduction in APC and Secondary benifits and periodically water audit for continuos improvement.

6.2 Measure

In cycle make up water consumption at TPP, make up water flow is measured by a flow meter. To perform Gauge R&R study on this process, another flow meter of tested accuracy and characteristics needs to put in series to the installed flow meter. This phase involves analysing CSFs determined in measure phase. Before going to six sigma tools a grapical summary of DM makeup.

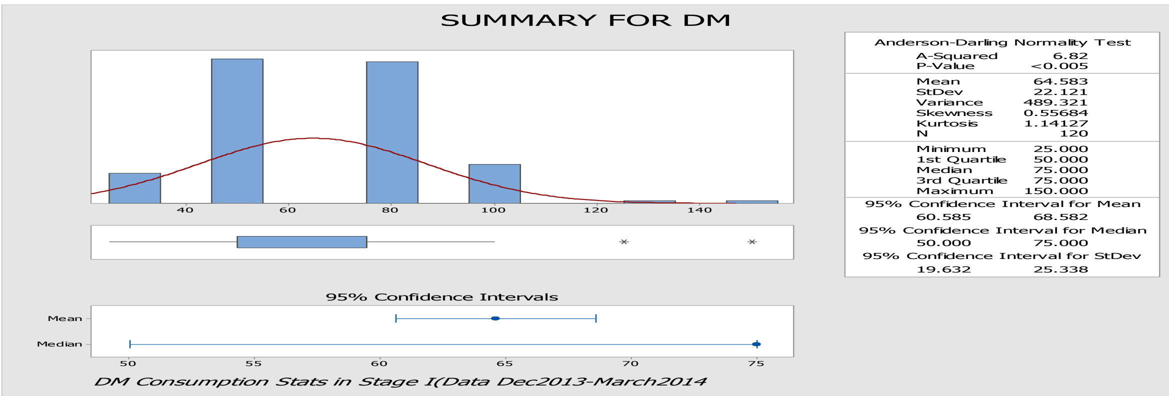

Fig. 3 - DM consumption stats in Stage I (Data :Dec-April 2014)

6.3 Analyse

Firstly when we take data of four months minitab 17.1firstly trims value of top 5% and bottom 5%data.We see a squared value is 6.82.Graph is skewed to higher side positively skewed. Data is analysed and causes of problem are discovered using following tools.

6.3.1 Run Chart

Run chart was drawn from Dec 1st to 1st April data collected for day cycle make up water from TPP measured through flow meter. From the results found using Minitab, P-values (Fig.4) for clustering (0.458), trend (0.695), oscillation (0.305) and mixtures (0.542) come out to be more than the significance level (0.05), indicating not any special cause of variation in data. If p value is more than 0.05 it means that disribution is normal.

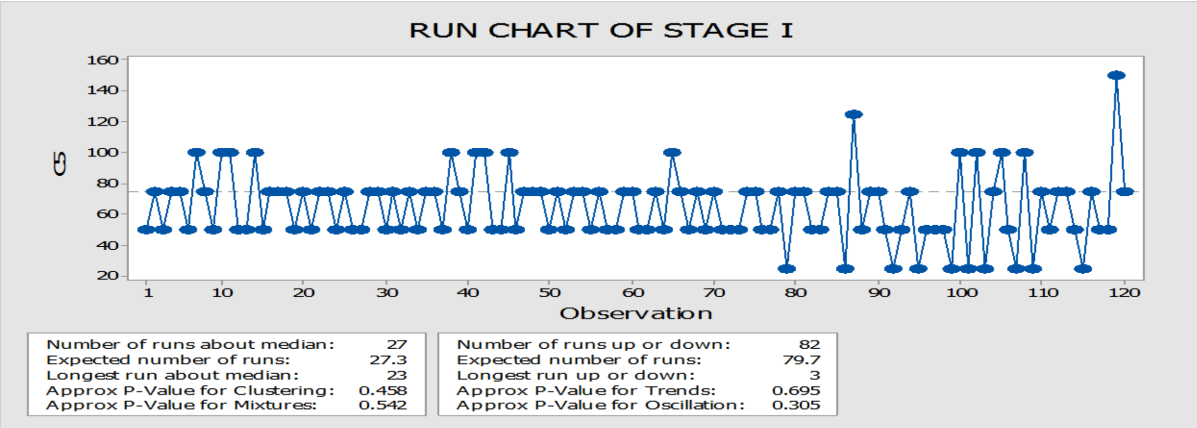

Fig.4-Run Chart of Stage I

6.3.2 Process Capability analysis

Process capability analysis was performed using Minitab to draw curve for cycle make up water from TPP measured through flow meter (Fig.4) Z-bench sigma value of process was found to be 1.45 and existing DPMO level of the process comes out be 122404.15, which is remarkably high and shows that there are a lot of opportunities for improvement in the process. If we limit upper specification limit 100tonnes and target value around 50 tonnes.

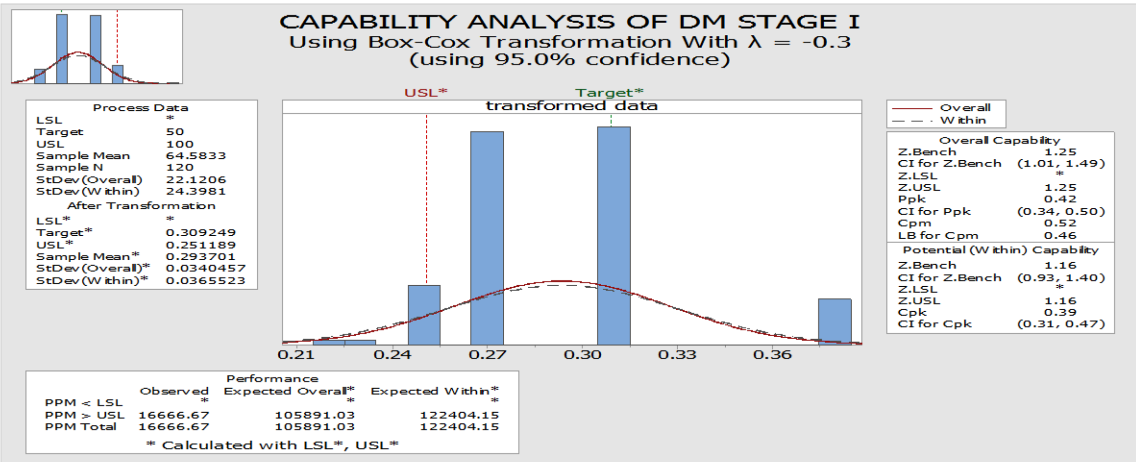

Fig.5 - Process Capability Analysis of DM for Stage I

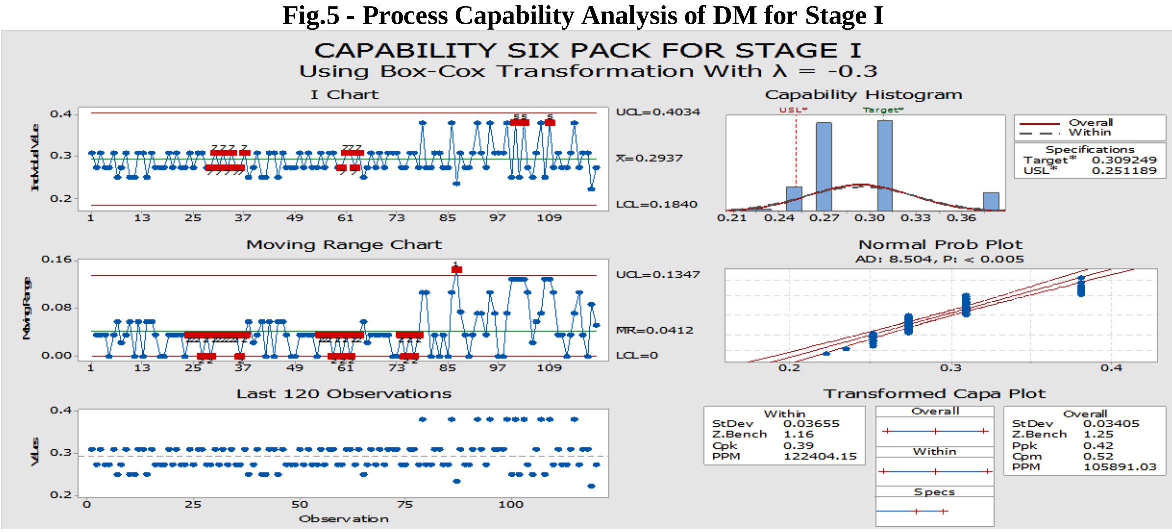

Fig.6 - Process Capability Six Pack Analysis for Stage I

Test Results for MR Chart of process capability six pack for stage I
TEST 1. One point more than 3.00 standard deviations from center line.
Test Failed at points: 87
TEST 2. 9 points in a row on same side of center line.Test Failed at points: 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 74, 75, 76, 77, 78.

6.3.3 Fish-bone Diagram

Using expert experience and critical analysis of actual combined cycle at site, a fish bone diagram drawn (Fig. 7) to find causes of more DM water consumption during combined cycle.

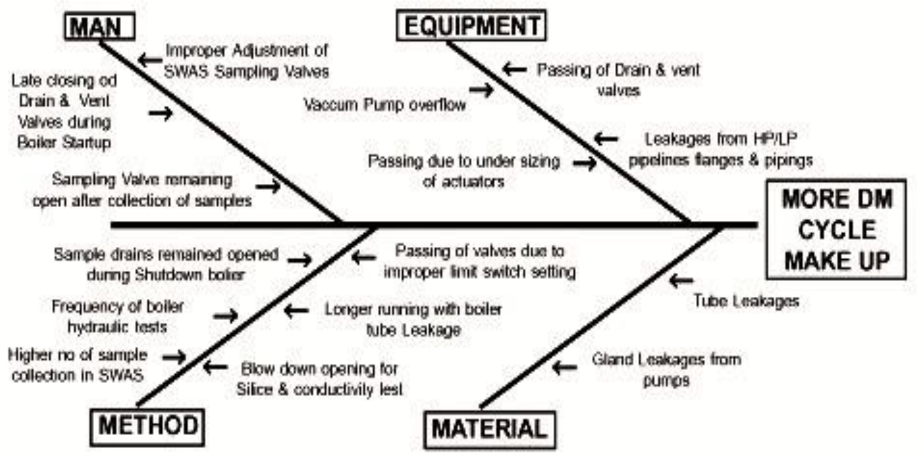

Fig.7-Fish Bone Diagram For cause - effect of Stage I

6.3.4 Bar Chart

Actual DM water wastage from different points was measured or approximated where no measurement was possible. Based upon measurement results, bar chart was drawn and resultant causes with their percentage contribution were found to have biggest impact on cycle make up water consumption (Fig.8).

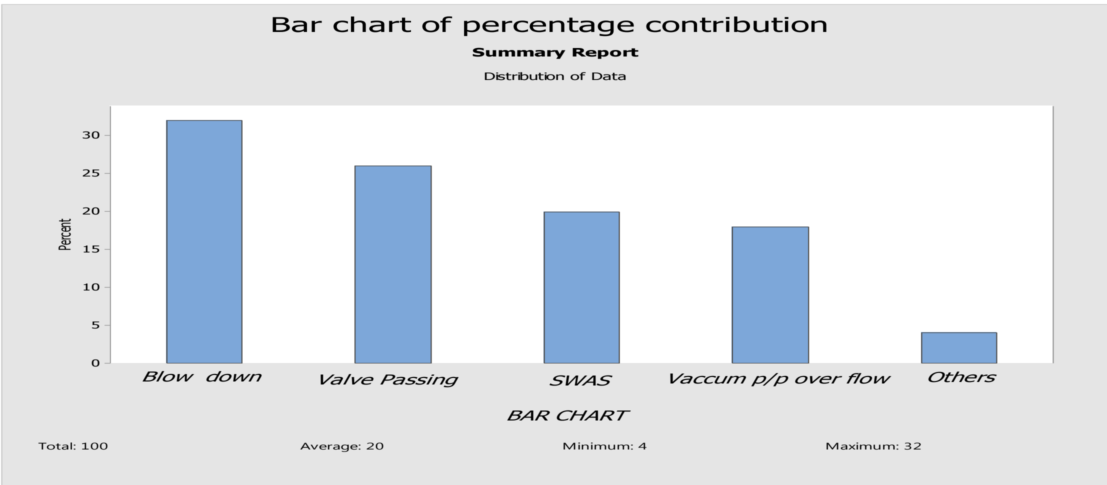

Fig.8 - Bar Chart of DM for Stage I

6.3.5 Pareto Chart

Display defects in order of decreasing frequency to prioritize improvement efforts.

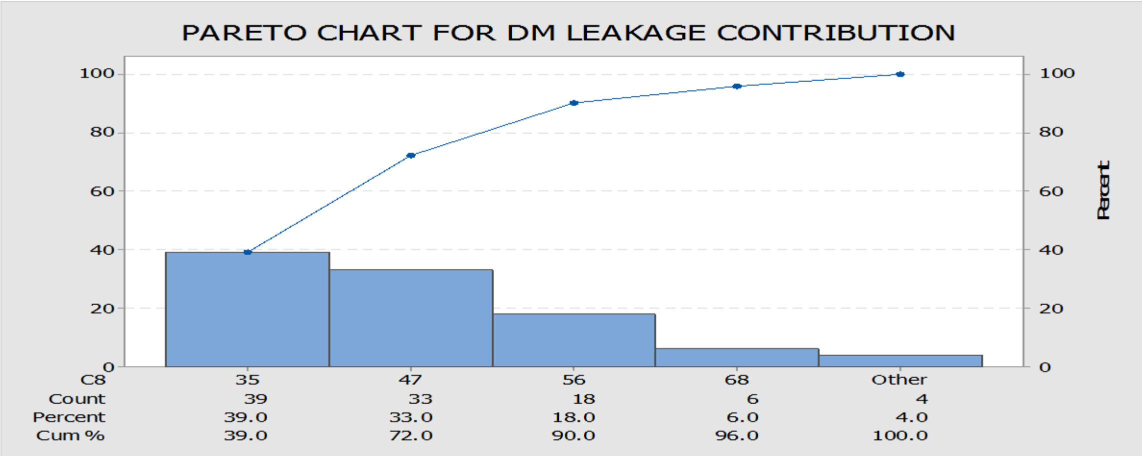

Fig.9 - Pareto Chart For Stage I

From the above analysis we find that Blow down , Valve passings like safety valve passing, drain valves passing ,SWAS are the main causes of the problem. DM leakages can reduces by regular chek up and training of lab analysts, and by reducing communication gap between chemical and operation staff casual approaches can be eliminated to find out solutions. For RTPP we consider following two things. First one is for any Stastical Quality Control we require UCL (upper critical level) and LCL(lower critical level) OEM gives us relaxation of 2% of BMCR (boiler maximum continuos rating) we know our LCL can't be zero as power generation does not work on isolated system concept.Process are practically open system. So our goal statement converges to a band of DM. Say like 0.3% to 0.5% BMCR. So for calculation LCL we have used stastics. Firstly we find the type of distribution which follows the DM consumption by using minitab 17.1.

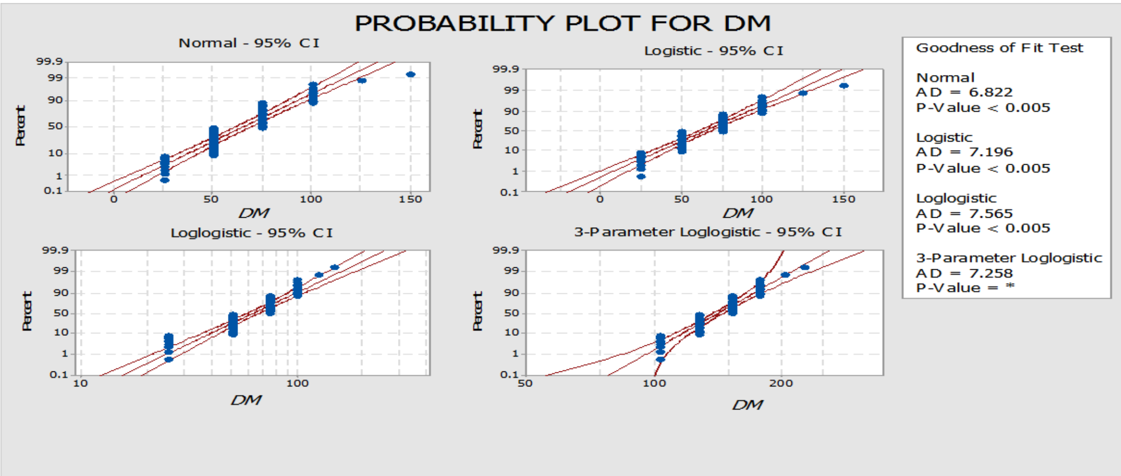

Fig.10-ProbabilisticDistribution

P value of DM pattern in lologistic normal distribution is more than 0.05(with 95%conformality). The greater the cpk value, the better. A Cpk value greater than 1 means that the 6 spread of the data falls completely within the specification limits. A Cpk of 1 means that one end of the 6 spread falls on a specification limits. Sigma level is 3 x cpk. A Cpk between 0 and 1 means that part of the 6 spread falls outside the specification limits.

Loglogistic	2	28.0975	1.93903	24.5	32.2
3-Parameter Loglogistic	2	22.4430	4.75035	13.1	31.8

Distribution	Percent	Percentiles	Standard Error	95.0% CI	
Normal	5	28.1982	3.10297	22.1	34.3
Logistic	5	27.4308	3.35086	20.9	34.0
Loglogistic	5	34.0734	1.92539	30.5	38.1
3-Parameter Loglogistic	5	31.1046	3.29947	24.6	37.6

VII. Control

In this stage, considerations of new process are documented and frozen into systems so that the gains are permanent. In anlysis phase all possible related causes of specific identified problem were solved.Regular inspection of all sources to be done on regular intervals.Frequency of Blow down can reduces because of more DM wastage in blow down . Due to regular DM leakages in flanges we can also go for some retrofitments in flanges.To determine the actual quantity of DM leakages Ultrasonic meter must be used. During overhauling, Deareator vent valve orifice can be checked for its erosion.Stream strap drains to be collected at one vessel. Flow measurement of CBD and LPD valves passing to be checked regularly.

Table 1 – Action Plan (Improve and Control Phase)

	Recommendation proposed	Status
1	Importance of closure of SWAS valves after sample collection must be intemated to all lab analysts.	Implemented Instruction pasted
2	Six month periodic training cum awareness program for lab analysts to be conducted to make them aware of the impor-tance of DM water loss.	First program already conducted
3	Instructions to pasted on SWAS panel for closure of sample valve's each time after sample collection.	Implemented Instructions pasted
4	Operation staff to cross check the position of SWAS sampling valves in their regular rounds.	Instructions being followed.
5	The frequency of blow down opening to be changed from weekly to fortnightly.	To be implemented
6	To avoid the loss of DM water due to vaccum pump overflow solenoid makeup vlaves of both the seal water tanks to be adjusted properly for both low and high level settings.	Implemented.
7	The leakages identified from HP/LP pipelines, valve passing to be attended during shutdown.	Not implemented
8	Quarterly checking of solenoid valves of both seal water tanks to be carried out.	Implemented
9	A schedule to be prepared to check / tighten the glands of all the pumps fortnightly	Implemented

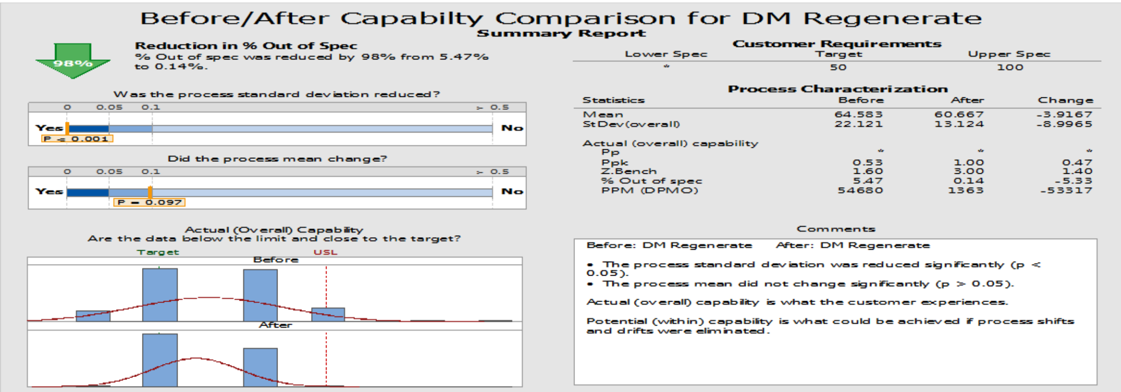

Fig.11- Capability Comparison for DM Generate summary report

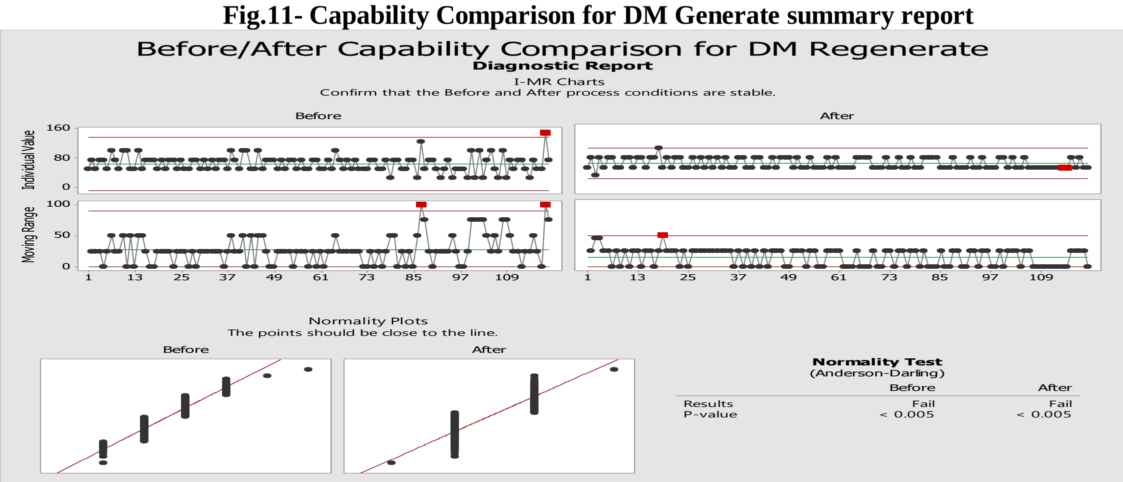

Fig.12 - Capability Comparison for DM Generate Diagnostic report

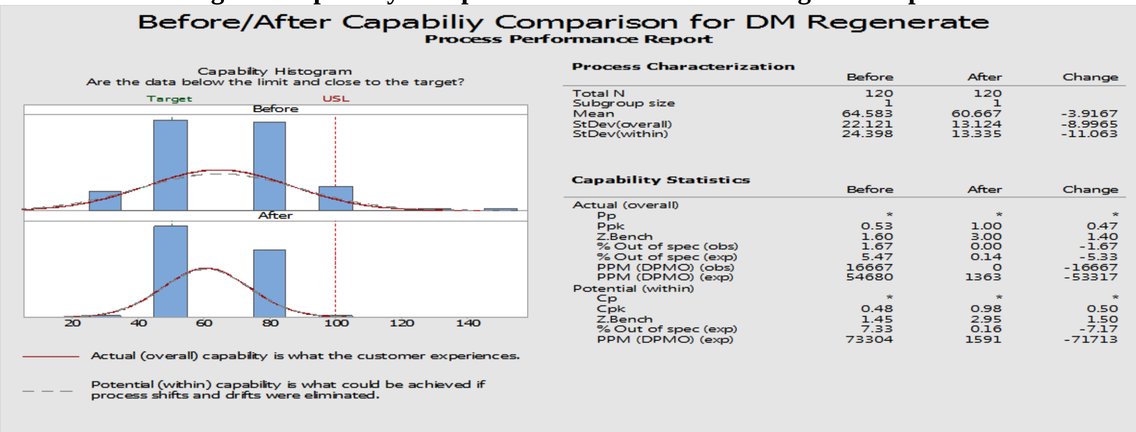

Fig. 13 - Capability Comparison for DM Generate Process performance report

Fig. 14 - Capability Comparison for DM Generate Process performance repor

VIII. Results

Cycle make up water consumption was 0.9% MCR. Application of project recommendation brought up the sigma level to 2.95 with DPMO level of 1363 (an improvement of 54680) and mean of the process reduced to 0.293701% (an improvement of 0.168% mean). A few more agreed recommendations are still to be implemented during plant shutdown.

IX. Conclusions

Study proves that firms successfully implement six sigma perform better in virtually every business category, including return on scales, return on investment, employment growth and stock value growth higher consumption of DM water is found to be a big problem in a thermal power plant. The causes for more DM water consumption are SWAS, problem of valve passing, vacuum pump overflow etc. SWAS makes a big impact having 33% contribution for DM water consumption. Further, some actions are recommended to reduce the consumption of DM water. Application of six sigma project recommendations brought up the sigma level to 2.95.

X. Scope For Research Work

Present process in DM cycle make up water and its analysis suggest that there is a lot of scope of improvement in reducing leakages and variability.Cost of every additional DM make up at any given plant depends on cost of raw water, chemical consumption, and heat energy loss.Our calculations suggest that every 0.1% reduction in DM make up at RTPP saves of 1crore per year. Today our plants do not have system to carryout regular flow audits to identify sources and quantify leakages and objective of our paper is to tell that importance of DM make up and its financial impact.

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