Statistical Process Control

Method of Monitor and Quality Control

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***Abstract*— Statistical process control (SPC) is a method of quality control which employs statistical methods to monitor and control a process. This paper helps us to ensure that the process operates efficiently, producing more specification-conforming products with less waste (rework or scrap).SPC can be applied to any process where the "conforming product" output can be measured. Key tools used in SPC include run charts, control charts, a focus on continuous improvement, and the design of experiments. An example of a process where SPC is applied is in manufacturing lines.**

Keywords—Statistical process control, control charts, Methodology, rules.

I. INTRODUCTION

Statistical process control (SPC) is a method of quality control which employs statistical methods to monitor and control a process. This helps to ensure that the process operates efficiently, producing more specification-conforming products with less waste (rework or scrap). SPC can be applied to any process where the "conforming product" (product meeting specifications) output can be measured.

II. EASE OF USE

A. Control charts

Control charts, also known as process behaviour charts, this are statistical process control tools used to determine if a manufacturing or business process is in a state of control. It is more appropriate to say that the control charts are the graphical device for Statistical Process Monitoring (SPM). Traditional control charts are mostly designed to monitor process parameters when underlying form of the process distributions is known.

B. Interpreting Control Chart

The interpreting an SPC chart has an average line (i.e mean or median – the mean is most often used in SPC charts) and two control lines above and below the average line, both of which allow more statistical interpretation There are 8 signs of interpreting an SPC chart or we can call them as 8 rules of an SPC. The data itself, usually shown as distinct data points with lines between.

The mean of the data. The upper and lower control limits (UCL and LCL), which are set depending on the type of SPC chart. Usually these are 3 standard deviations from the mean. Sometimes the chart will show thirds between the mean and the control limits as shown in fig no 1.

A control chart consists of:

Points representing a statistic (ex., a mean, range, proportion) of measurements of a quality characteristic in samples taken from the process at different times (i.e., the data).

The mean of this statistic using all the samples is calculated (e.g., the mean of the means, mean of the ranges, mean of the proportions)

A centre line is drawn at the value of the mean of the statistic

The standard deviation (square root variance of the mean) of the statistic is also calculated using all the samples.

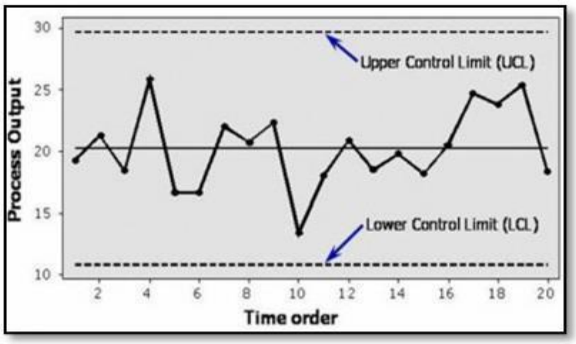

Fig No 1: - Control Chart

C. Abbreviations and Acronyms

SPC Statistical Process Control ,CMMs Co-ordinate Measuring Machine, 5M&M Man, Machine, Material, Method, Movement, Environment, SPM Statistical Process Monitoring, LCL Lower Control Limits, UCL Upper Control Limits, CMM Capability Maturity Model, CMMI Capability Maturity Model Integration, HML Hypertext Mark-up Language, HCM Hardware Compatibility List, BSD Berkeley Software Distribution.

III. PROBLEM DEFINITION

The potential of machine learning tools in statistical process control identification and quantification. While the initial resource cost of statistical process control can be substantial the return on investment gained from the information and knowledge the tool creates proves to be a successful activity

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time and time again. This tool requires a great deal of coordination and if done successfully can greatly improve ability of a process to be controlled and analysed during process improvement projects.

A. Scope

Statistical process control (SPC) is defined as the use of statistical techniques to control a process or production method. SPC tools and procedures help to monitor process behaviour, discover issues in internal systems, and find solutions for production issues.

B. Limitations

SPC emphasizes early detection and prevention of problems, but it takes time to apply rigorously in a manufacturing setting, as it requires more observations.

C. Rules to be followed

Rule 1: One point is more than 3 standard deviations from the mean. One point is outside the control limits as shown in fig 2(a).

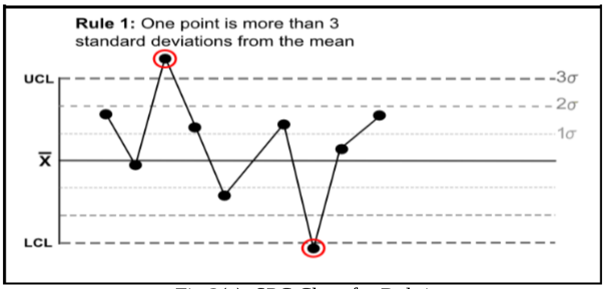

Fig 2(a): SPC Chart for Rule1

Problem Indicated: One sample (two shown in this case) is grossly out of control.
Rule 2: Nine (or more) points in a row are on the same side of the mean. This represents sudden, large shifts from the average. These are often fleeting – a one-time occurrence of a special cause – like the flat tire when driving to work as shown in fig 2(b).

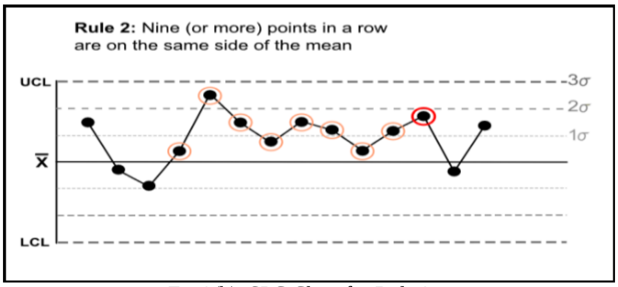

Fig 2(b): SPC Chart for Rule 2

Problem Indicated: Some prolonged bias exists.
Rule 3: Six (or more) points in a row are continually increasing (or decreasing) trend exist either moving to upper limit or lower limit as shown in fig 2(c).

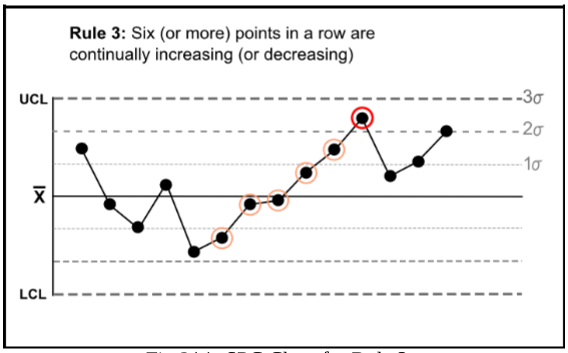

Fig 2(c): SPC Chart for Rule 3

Problem Indicated: A trend exists.
Rule 4: Fourteen (or more) points in a row alternate in direction, increasing then decreasing. They represent smaller shifts that are maintained over time. A change in raw material could cause these smaller shifts as shown in fig 2(d).

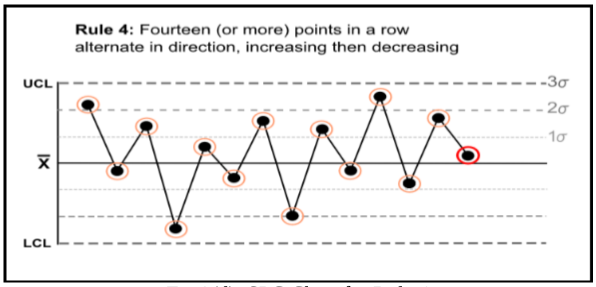

Fig 2(d): SPC Chart for Rule 4

Problem Indicated: This much oscillation is beyond noise. This is directional and the position of the mean and size of the standard deviation do not affect this rule.
Rule 5: Two (or three) out of three points in a row are more than 2 standard deviations from the mean in the same direction. This represents a process that is trending in one direction. For example, tool wearing could cause this type of trend. This is shown in fig 2(e)

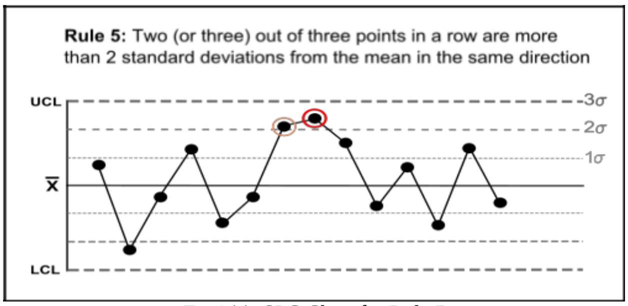

Fig 2(e): SPC Chart for Rule 5

Problem Indicated: There is a medium tendency for samples to be medium out of control. The side of the mean for the third point is unspecified.
Rule 6: Four (or five) out of five points in a row are more than 1 standard deviation from the mean in the same direction. It occurs when you have more than one process present and are sampling each process by itself. This is shown in fig 2(f)

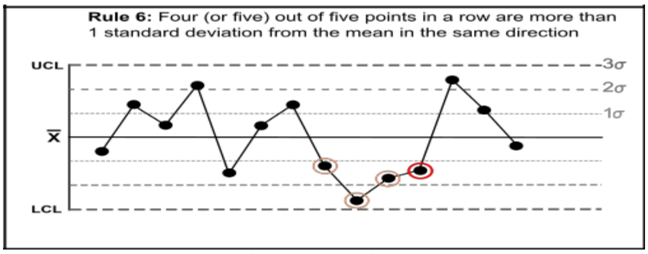

Fig 2(f): SPC Chart for Rule 6

Problem Indicated: There is a strong tendency for samples to be slightly out of control. The side of the mean for the fifth point is unspecified.

Rule 7: Fifteen points in a row are all within 1 standard deviation of the mean on either side of the mean. Rule 7 (stratification) also occurs when you have multiple processes, but you are including all the processes in a subgroup. This can lead to the data "hugging" the average. This is shown in fig 2(g).

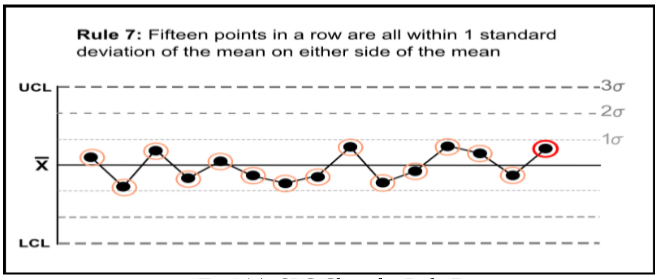

Fig 2(g): SPC Chart for Rule 7

Problem Indicated: With 1 standard deviation, greater variation would be expected. With 1 standard deviation, greater variation would be expected.

Rule 8: Eight points in a row exist with none within 1 standard deviation of the mean and the points are in both directions from the mean. Rule 8 (over-control) is often due to over adjustment as shown in fig 2(h).

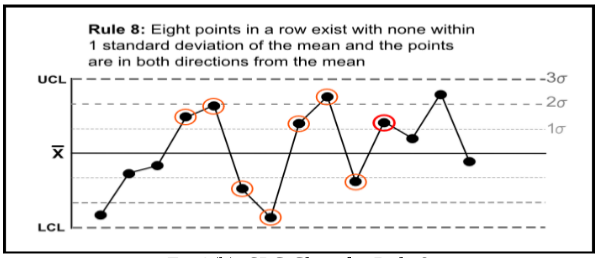

Fig 2(h): SPC Chart for Rule 8

Problem Indicated: Jumping from above to below whilst missing the first standard deviation band is rarely random.

D. Application

SPC is used in manufacturing industries or units that measure quality using CMMs (Co-ordinate measuring machine) understanding the process and the specification limits. Eliminate assignable (special) sources of variation, so that the process is stable. Monitor the on-going production process, assisted using control charts, to detect significant changes of mean or variation.

IV. METHODOLOGY

The methodology is a general framework used in research work and addresses a more practical perspective, referring to tangible paths used to better understand the involved certainties. A case study can make an important contribution to scientific development and such research is not simplistic at all since requires adequate theoretical basis, expertise, dexterity and time availability. On the other hand, certain situations and processes run the risk of going undetected in studies of larger proportions while analyzing cases, even unusual cases, can be illustrative of critical conditions for systems and organizations. In project management, methodologies are specific, strict, and usually contain a series of steps and activities for each phase of the project's life cycle. They're defined approaches that show us exactly what steps to take next, the motivation behind each step, and how a project stage should be performed.

A. Steps in SPC.

The proposed system is a web application. The user will login using login id and its related password on the dashboard that shows control charts and other relevant information. The steps used in Statistical Process Control are, identifying defined processes, Identifying Measurable attribute of processes, characterizing natural variation of attributes and Track the variations as shown in fig no 3.

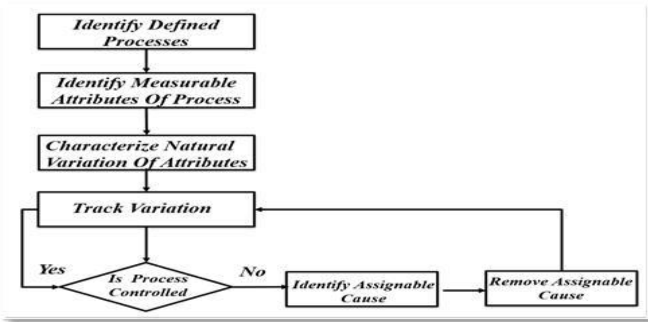

Fig No 3: -Steps In Statistical Process Control

Identify defined process: This step includes considering the process that process control will be done on. Usually it is a manufacturing process as Statistical process control works best with manufacturing process and quality control in them.

Identify measurable attributes of process: To control the process and give an analysis, it is important to identify the attributes of the process that affect the quality.

Further control: How these attributes vary is monitored in further steps of SPC. The variation is tracked, and the process is monitored to be controlled. In this application, the tracking of variation and checking to see if the process is controlled is assisted.

B. Block Schematic for Implementation

The steps used to provide a tool for quality control that can be accessed from anywhere on any device on all the datasets as shown in fig no 4.

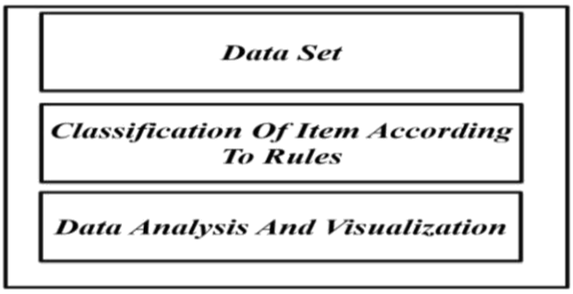

Fig No 4: -Steps Used To Provide A Tool For Quality Control

The collected datasets are converted into SQL files so that it is easy to access. The database is categorized into Nominal and Actual data to generate the graphs. Python program are saved with. py extension and the data is saved with. SQL extension. The main dataset obtained with .xsl extension are classified according to the rules. The results are shown in the form of graphs on HTML pages so that the user can easily extract the required data.

The report is generated as it needs to give title for its page followed by graph and by its rules. The visual representation of classification is done with its explanation in text as shown in fig no 5.

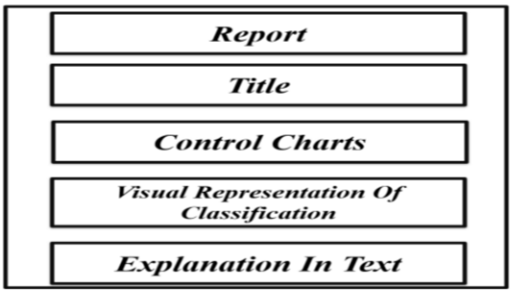

Fig No 5: -Structure of Report On Manufactured items

V. IMPLEMENTATION DETAILS

- Data is stored in databases.
- Pymysql is used for connecting to databases.
- Python language is used for coding the web application.
- Flask framework used for development of web application page.
- Jinja is used to display variables on html pages.

A. Requirements Usability

- The system is user friendly and self-explanatory.
- User interface is easy to use.
- Whenever user commits any mistake, the system will pop up an appropriate message.

B. Availability

The system is available 100% for the user and can be used 24 hours a day.

SPC is used in manufacturing industries or units that measure quality using CMMs (Co-ordinate measuring machine) understanding the process and the specification limits. Monitoring the on-going production process is assisted by the use of control charts, to detect significant changes of mean or variation.

The application of SPC involves three main phases of activity:
Understanding the process and the specification limits.
Eliminating assignable (special) sources of variation, so that the process is stable.
Monitoring the ongoing production process, assisted using control charts, to detect significant changes of mean or variation.

C. Common causes

'Common' causes are sometimes referred to as 'non-assignable', or 'normal' sources of variation. It refers to any source of variation that consistently acts on process, of which there are typically many. This type of causes collectively produces a statistically stable and repeatable distribution over time [4].

D. Special causes

'Special' causes are sometimes referred to as 'assignable' sources of variation. The term refers to any factor causing variation that affects only some of the process output. They are often intermittent and unpredictable. Most processes have many sources of variation; most of them are minor and may be ignored. If the dominant assignable sources of variation are detected, potentially they can be identified and removed. When they are removed, the process is said to be 'stable'. When a process is stable, its variation should remain within a known set of limits. That is, at least, until another assignable source of variation occurs. For example, a breakfast cereal packaging line may be designed to fill each cereal box with 500 grams of cereal. Some boxes will have slightly more than 500 grams, and some will have slightly less. When the package weights are measured, the data will demonstrate a distribution of net weights.[4][5]

If the production process, its inputs, or its environment (for example, the machine on the line) change, the distribution of the data will change. For example, as the cams and pulleys of the machinery wear, the cereal filling machine may put more than the specified amount of cereal into each box. Although this might benefit the customer, from the manufacturer's point of view it is wasteful, and increases the cost of production. If the manufacturer finds the change and its source in a timely manner, the change can be corrected (for example, the cams and pulleys replaced).

Stable process: when the process does not trigger any of the control chart "detection rules" for the control chart, it is said to be "stable". A process capability analysis may be performed on a stable process to predict the ability of the process to produce "conforming product" in the future.

a stable process can be demonstrated by a process signature that is free of variances outside of the capability index. A process signature is the plotted points compared with the capability index [6].

Excessive variations: When the process triggers any of the control chart "detection rules", (or alternatively, the process capability is low), other activities may be performed to identify the source of the excessive variation. The tools used in these extra activities include: Ishikawa diagram, designed experiments, and Pareto charts. Designed experiments are a means of objectively quantifying the relative importance (strength) of sources of variation. Once the sources of (special cause) variation are identified, they can be minimized or eliminated. Steps to eliminating a source of variation might include: development of standards, staff training, error-proofing, and changes to the process itself or its inputs.

VI. RELEVANCE AND TYPE

This paper is specially to aimed as General purpose in industries and plants that record the data about quality of production and are able to save it in digital form. The type of measure can be of quantity, weight, length any type of flexible. The system needs one measure of quality.

This is the product-based web application. The main aim is to give the quality control team a dashboard to monitor and control relevant processes. It helps to ensure that the process operates efficiently, producing more specification-conforming products with less waste. It can be applied to any process where the product meeting its specifications output can be measured. Key tools used in SPC include run charts, control charts, a focus on continuous improvement, and the design of experiments. An example of a process where SPC is applied is manufacturing lines (Industry).

A. Use Case Diagram

It is a behavioural diagram that shows a set of objects and their relationships. The user can create an account, can login to his id, can upload a file, can view his/her own dashboard after logging in, can view graphs for individual items, can generate reports and view which item falls under which rules item as shown in fig no 6.

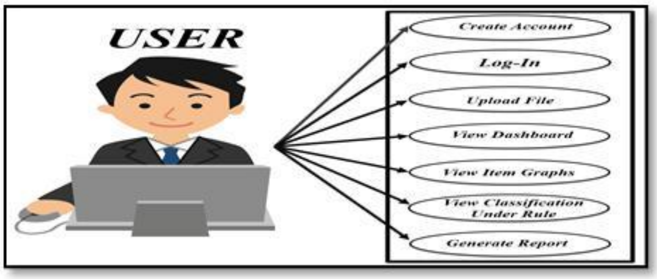

Fig No 6: -Use Case Diagram

B. Sequence Diagram

A sequence diagram is UML representations which interpret an object interaction arranged in time sequence. It depicts the objects and classes involved in scenario and the sequence of messages exchanged between objects needed to carry out the functionality of the scenario as shown in fig no 7.

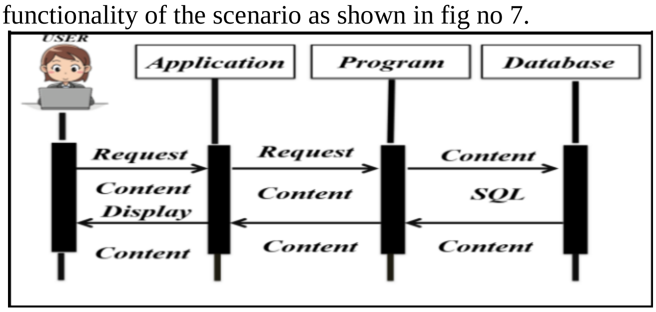

Fig No 7: -Sequence Diagram

C. Steps Carried Out In SPC

Steps carried out in the Statistical Process Control study are as follows:
Step 1: Collection of Dataset.Step 2: Programming to maintain database.
Step 3: Programming to make calculation
Step 4: Showing Result on HTML pages.

D. Functionality In SPC

Representation of functionality in SPC the steps carried out in SPC. The collection of data is done on google.com. Also, one of the datasets found was gotten from an internship of a team member. The datasets were found on kaggle.com, on searching for manufacturing datasets. Then, programming to maintain database is carries out. The datasets found are xlsx files. These must be converted to sql databases as it is easy to handle in a web application. It should have Nominal and Actual values in data to show a control chart. Next step is to programming to code the program to make calculations. In the python program, calculation is made to perform classification under rules. The result is shown on HTML pages. The result is shown in the form of graphs so the user can comprehend it easily as shown in fig no 8.

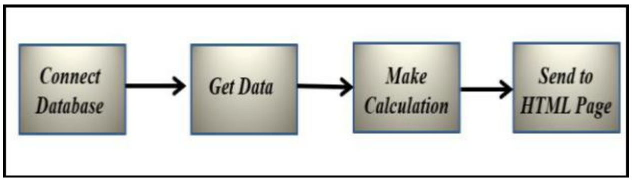

Fig No 8: - Representation Of Basic Functionality

VII. RESULTS

In this chapter, results observed with the implementation of the statistical process control using the web application tools mentioned in previous chapters are discussed. The results of the web application are presented. User interface of the application test scenarios and functionality tests are discussed.

A. Selection of Dataset

The start of the application takes us to a page with the name of the application at the top of the page and a box division with three selections of datasets. The titles of these datasets are given in this box division. The datasets are of dynamic technologies, a pharmaceutical manufacturing company and candy production as shown in fig 8.

Fig 8: Dataset Selection

B. Login

The initial page is a login page as shown in fig 9. This page asks for username along with a user id and password. There is an option to login with google which only works with websites that are .coms. There is also a signup option for new users.

Fig 9: Login

C. Sign Up

The signup page requests the user information necessary to sign up as shown in fig 10. These include username, an id, email, password, and confirmation. Along this there is also google re-captcha completing which the Sign-Up button is enabled.

Fig 10: Sign-Up

D. Classification According to Rules

The classification of items is shown on the sidebar. These listed items are links. The name of each rule is shown with the number of items falling under the rule and the number of occurrences in brackets as shown in fig 11(a).

Fig 11: Classification According To Rule

When this link is clicked, items falling under that rule are shown as shown in fig 12.

Fig 12: Classification of Items under One Rule

E. Individual Item Page

The individual item page shown in Fig 13 has the control chart for the item with title. There is a series of boxes for rules. The rules that the item falls under are shown in red. There are points/sentences for the rules' implication. These points depict the problem with manufacturing.

Fig 13: Individual Item Page

F. Reports

The report shown as in Fig 14 contains the control chart with the visual representation of what rules the item falls under and points that convey what is going wrong according to the rules.

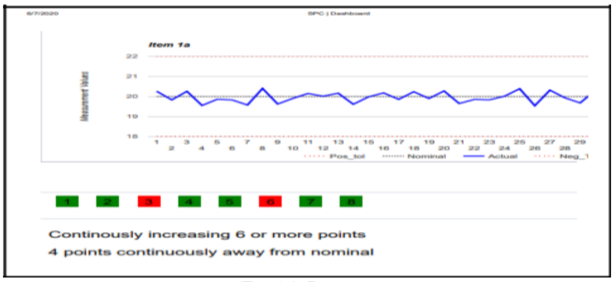

Fig 14: Report

G. Rules Description

For user's ease, a page with description of each rule is given as shown in Fig 15. This page contains charts showing occurrences that fall under those rules. The page also has text explaining how an occurrence is considered to be under the rules.

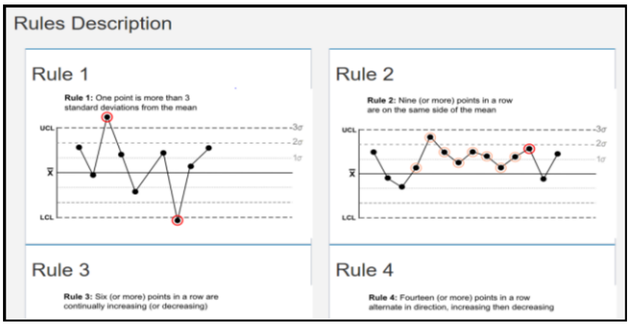

Fig 15: Rules Description

H. Figs and Tables

Table Head	**Table Column Head**		
	Table column subhead		***Figs no***
EASE OF USE	Control charts	Interpreting control chart	Fig 1
Problem Definition	SPC Chart for Rule 1	Rules to be followed	Fig 2(a)
Problem Definition	SPC Chart for Rule 2	Rules to be followed	Fig 2(b)
Problem Definition	SPC Chart for Rule 3	Rules to be followed	Fig 2(c)
Problem Definition	SPC Chart for Rule 4	Rules to be followed	Fig 2(d)
Problem Definition	SPC Chart for Rule 5	Rules to be followed	Fig 2(e)
Problem Definition	SPC Chart for Rule 6	Rules to be followed	Fig 2(f)
Problem Definition	SPC Chart for Rule 7	Rules to be followed	Fig 2(g)
Problem Definition	SPC Chart for Rule 8	Rules to be followed	Fig 2(h)
Methodology	Steps In Statistical Process Control	Steps in SPC	Fig 3
Methodology	Steps Used To Provide A Tool For Quality Control	Block schematic of SPC	Fig 4
Methodology	Structure of Report On Manufactured items	Block schematic of SPC	Fig 5
Relavance and type	Use Case Diagram	Use Case Diagram	Fig 6
Relavance and type	Sequence Diagram	Sequence digram	Fig 7
Relavance and type	Representation Of Basic Functionality	Representation Of Basic Functionality	Fig 8
Results	Dataset Selection	Selection of data	Fig 9
Results	Log in	Log in	Fig 10
Results	Sign up	Sign up	Fig 11
Results	Classification According To Rule	Classification according to rule	Fig 12
Results	Individual to item page	Individual to item page	Fig 13
Results	Report	Report	Fig 14
Results	Rules Description	Rule description	Fig 15

VIII. CONCLUSION

With verification of Statistical Process Control, following points are observed.

The data for statistical process control is more accurately measured by machines which give data digitally which is better for a system for Statistical Process Control.

Control Charts that help monitor manufacturing processes can be more helpful digitally as they can be presented by a well-designed system.

Data for monitoring and visualization is better through applications as all data and visualization for it is accessible easily.

Customization to system and any addition to Statistical Process Control is easier as systems can be reprogrammed to add functionalities necessary, without excessive usage and analysis training.

Provision of other charts that could be useful such as normality charts and mean charts.

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