

# INTERNATIONAL JOURNAL FOR ADVANCE RESEARCH IN ENGINEERING AND TECHNOLOGY

WINGS TO YOUR THOUGHTS.....

## OPTIMIZATION OF MACHINE EFFICIENCY USING CUSUM METHODOLOGY

Vinay K.S<sup>1</sup>, H. Ramakrishna<sup>2</sup>

<sup>1</sup> M.Tech in Master of Engineering Management, <sup>2</sup> Prof and Head of industrial engineering and management

<sup>1</sup>Dayananda Sagar College of Engineering, <sup>2</sup> Dayananda Sagar College of Engineering  
Kumaraswamy Layout, Bangalore-560078

<sup>1</sup>vinaysgv2008@gmail.com, <sup>2</sup> hrkrishna1963@gmail.com

**Abstract:** Energy is a prerequisite for industrial development and activity; without an effective energy supply neither is possible. While there is at present little real constriction on the overall supply of energy to industry, there are a number of serious issues when considering industrial energy use and the sustainable growth of industries particularly in developing countries like India. Such issues range from the additional cost of energy processes due to inefficient utilization, vulnerability to price shocks of imported fuels etc., hence continuous improvement in energy management for industrial organizations is essential. Monitoring and Targeting is a proven method for measuring and maintaining energy performance, and for identifying opportunities to improve energy efficiency. Key elements of an M&T Technique include: Measurement of utility (steam, fuel, power) consumption levels, The establishment of consumption targets that take variations in key variables into account, Comparison of actual vs. target energy usage, "Exception reports" to highlight areas experiencing unusually good or unusually poor performance, An established protocol, involving both management and operating personnel, for reviewing and acting upon the energy information available. Tracking and reporting of the savings achieved

**Keywords:** Energy Savings, Monitor, Target, Error Report, Regression, CUSUM Analysis.

### 1. INTRODUCTION

The Energy used by any business varies as production process. Energy efficiency is a measure of energy used for delivering a given service. Improving energy efficiency means getting more from the energy that we use [1]. Operating costs related to heating, cooling, and electricity can be controlled only through the proper management of the overall utility infrastructure and effective energy conservation practices. Among several low/no cost energy savings, Monitoring Targeting is a proven method for measuring and maintaining energy performance, and for identifying opportunities to improve energy efficiency.

### 2. LITERATURE REVIEW

P.Veeranjaneyulu and Dr Purna Chandra Rao They had discussed about Regression Analysis and stated that to solve real world applications; we apply precise models like problem domain knowledge of the system and proper functioning of the system. Generally a model can be defined as a combination of structure and parameters.

Model = Structure + Parameter.

Models can be broadly classified as linear and nonlinear. The main focus of this paper is on linear regression model. A linear model is linear regarding its parameters. [2]

Harini H N and Surekha Naagesh successfully Regression method for predicting CBR of Fine

Grained Soils and Stated Multiple linear regressions (MLR) determine the relationship between two or more independent variables and a dependent variable by fitting a linear equation to observed data. Every value of the independent variable is associated with a value of the dependent variable. [3]

### 3. M&T CONCEPT

M&T proceeds from the idea that if you can measure a particular variable, you can, over time, develop the information and insights needed to influence that variable in a beneficial way. More specifically, by tracking energy use and relating that use to key production variables, plant management, technical staff, and operators can establish a meaningful baseline characterization of energy use patterns and respond to deviations from that baseline [4].

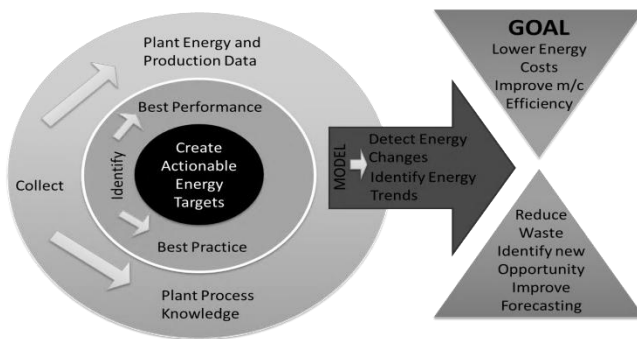


Figure 1.1 Monitoring and Targeting Concept

# INTERNATIONAL JOURNAL FOR ADVANCE RESEARCH IN ENGINEERING AND TECHNOLOGY

*WINGS TO YOUR THOUGHTS.....*

The implementation of an Monitoring and Targeting system ensures that a company continually passes through the cycle (as shown in fig 1.2) of making energy policy, planning energy efficiency actions, implementing those and checking the results, on the basis of which new policy is made.



**Figure 1.2** Monitoring and Targeting Methodology

## 4. WORKING OF M&T

M&T is based on principles of statistical process control and energy accounting. It involves four key information management techniques [5]:

- Data and Information
- Energy Performance Model
- CUMulative SUM [CUSUM] Analysis
- Energy Performance control charts

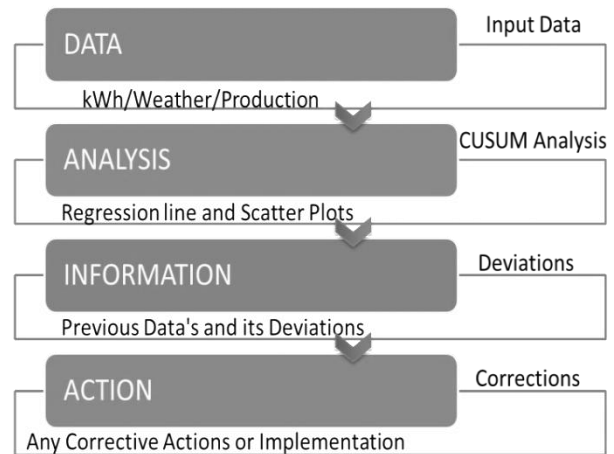
Monitoring and Targeting can be focused on invoice checking, financial budgeting, or assessing the performance of buildings, process. And often Targets are set without consideration of practical application.

An operational target should be

- Calculated rationally to reflect the known achievable performance
- Reviewed monthly or daily or even shift wise
- Is beneficial for day-day cost and environmental management

The activity of Monitoring encompasses both measurement and analysis. Data gathered initially are raw numbers for measurement and Information is the result of Measurement.

Below figure illustrates the distinction between Data and Information



**Figure 2.1** Data and Information for Production plan

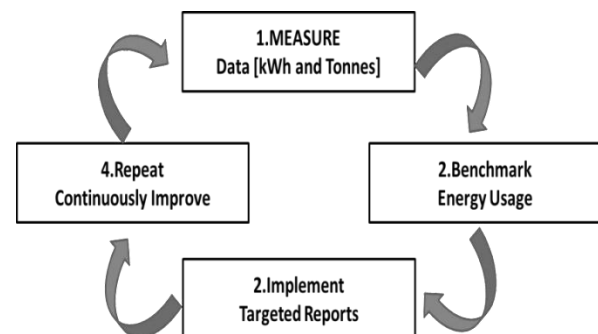
Figure 2.1 shows that the process is linear however, we prefer to think in terms of a continuous improvement cycle.

Thus performing energy Monitoring and Targeting is similar to Energy Auditing. Performing an energy audit is a crucial step to assessing and improving energy efficiency.

Data collection may be manual, automated, or a mixture of the two. Once an M&T scheme has been set up, its routine operation should be neither time-consuming nor complex.

Once the M&T scheme has operational targets are set for at least some of the consumption streams, routine operation is very easy. At the chosen assessment interval:

- Acquire the necessary data.
- Display the energy data table [in this case kWh].
- Check the data behind any significant overspends.
- Ask for explanations.



**Figure 2.2** Measure and Implement cycle

# INTERNATIONAL JOURNAL FOR ADVANCE RESEARCH IN ENGINEERING AND TECHNOLOGY

WINGS TO YOUR THOUGHTS.....

## 5. EVALUATION OF DATA

Energy Consumption Data can be evaluated in two ways

1. Precedent based Forecasting
2. Activity Based Targeting

In Precedent based Forecasting data can be expressed with the help of electrical power kWh or Electric Power consumption to amount of units produced i.e. kWh/kg.

In Activity based forecasting, calculate the expected power or energy consumption by reference to its driving factors as shown in table 2.1.

**Table 2.1:** Possible Driving Factors

Power Consumption in m/c	Products Produced
Space Heating	Outside Temperature
Air Conditioning	Outside Temperature and Humidity levels
Lights	Hours of Darkness
Drying	Quantity of water removed from process

### 5.1 M&T Tasks and Elements

The energy used by any business varies with production processes, volumes and input. In the M&T system the level of energy use is compared to key performance indicators, which enables the company to evaluate the energy efficiency of their own processes, compared to standard values. The M&T Typical tasks are:

- Measuring energy consumption over time
- Relating energy consumption to drivers
- Setting targets for reduced consumption
- Frequent comparison of consumption with Targets
- Reporting variances
- Taking action to correct Variances

To sum up, monitoring and targeting system allows a company to control the following criteria: Checking the accuracy of energy invoices, allocating energy cost to specific departments, determining energy performance, recording energy use in order to improve the energy efficiency and finally detect performance problems in equipment or systems.

## 6. INTERPRETING THE DATA

The energy used by any business varies with production processes, volumes and input.

Energy used in production processes typically heats, cools, changes the state of, or moves material. Electricity bills and other fuel bills should be collected periodically and determine the functional relationship between energy consumption and the key determining parameters are analyzed as below.

**Table 3.1:** Monthly Energy Cost Sheet sample

Month	Production in Tons	Energy Consumption kWh
Jan-14	500	17500
Feb-14	528	16000

### 6.1 M&T Plot Analysis

Scatter Plot are used to derive "standard" for the upcoming years or months consumption. Scatter plot shows a low degree of scatter indicative of a good fit. If data fit is poor, there should be a relationship, it indicates a poor level of control and hence a potential for energy savings.

However, a theoretical valuation leads to the conclusion that energy [kWh] plotted against production [Ton] will produce a straight line of the general form [6]:

$$y=mx + c$$

Eq: 3.1

Where:

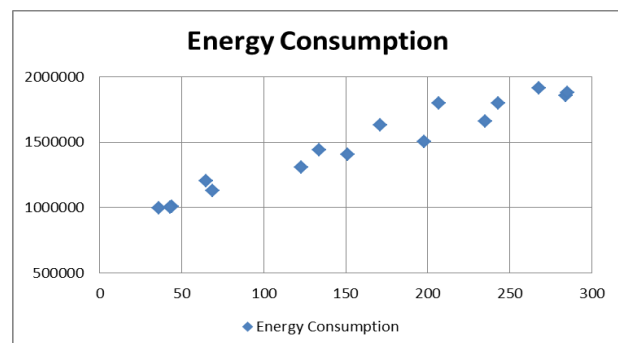
y= Energy consumed for the period

m=Slope

x=Production for the period

c=Intercept

Preliminary examination of Fig 3.1 suggests that the energy/production points do fall into a roughly linear pattern, energy increasing with production.



**Figure 3.1:** Energy vs. Production Scatter Plot

# INTERNATIONAL JOURNAL FOR ADVANCE RESEARCH IN ENGINEERING AND TECHNOLOGY

WINGS TO YOUR THOUGHTS.....

As in figure 3.1 for the same production quantity of ~60 Ton the energy consumption is different shown. In order to sort this we need to analyze the above plot with the help of Cumulative Sum Analysis or in short CUSUM analysis

## 7. CUSUM ANALYSIS

CUSUM is a powerful technique for developing management information regarding the energy performance of a plant, or an energy-consuming system such as an oven or furnace, for example. It distinguishes between significant events affecting performance faults or improvements and noise [7].

### 7.1 Calculation

The baseline relationship is used to calculate the expected energy consumption for any given production level. It is the difference between the given productions level and actual value.

The determination of a suitable baseline often is an iterative process in which the baseline regression and CUSUM sequence is repeated until a useful analysis emerges.

### 7.2 To determine Baseline

In order to determine baseline first construct linear regression line

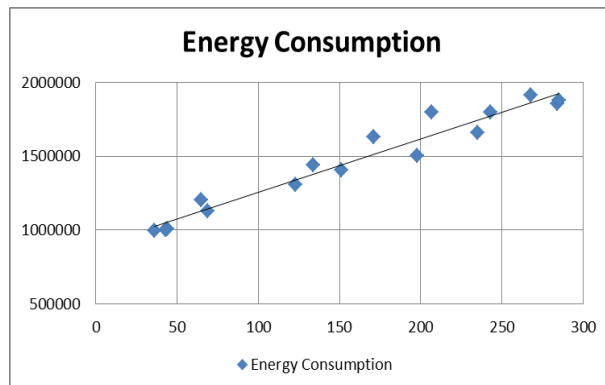


Figure 4.1 Linear Regression line

Now the straight line will produce an equation as below

$$\text{Energy consumed} = 3580.5 * \text{Production} + 945936$$

Eq: 4.1

This technique can generate several baselines. In order to generate a baseline consider first half readings in the data set. Here half of the data set is considered (Either before or after the maintenance) carried out on machine. For machine efficient sustainability the Base line data should be more than total data.

Table 4.1 Comparison of Performance Models

Performance Model	Incremental Load kWh/Ton	Base Load kWh
Total Data	3580.5	945936
Base line Data	3676.6	860739

From the table 4.1 Incremental Load and Base Load for Total data is less than Base line. It states that the machine performance in initial days was not satisfactory. After machine maintenance the Performance has been optimized.

$$\text{Energy Consumed} = 3676.6 * \text{Production} + 860739$$

Eq: 4.2

Now the KPI for the machine is set to 3676.6 and 860739 as a target till next analysis.

CUSUM analysis will shed more light on this. The CUSUM chart shows what is really happening to the energy performance.

Once a change in pattern occurs due to the presence of a fault or to some improvement in the process being monitored, the distribution of the differences about zero becomes less symmetrical and their cumulative sum, CUSUM, increases or decreases with time. It distinguishes between significant events affecting performance faults or improvements and noise.

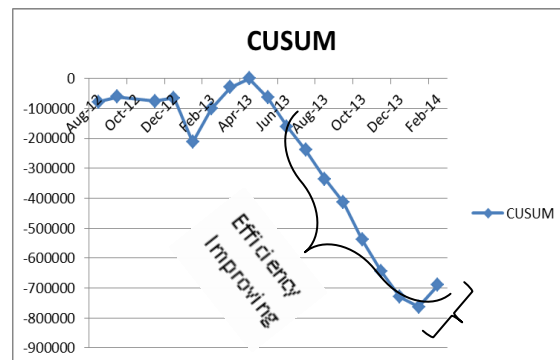


Figure 4.2 CUSUM Analysis

Thus it can be seen that the CUSUM has both upward and downward sloping sections. Downward gradients signify a persistent tendency to use more energy than expected and upward gradients show sustained better than expected performance.

## 8. BENEFITS AND BARRIERS

M&T can provide the following benefits to organizations: M&T is a useful tool to not only track energy use but to control it. Industry may gain improved insight into their operation through M&T [8].

# INTERNATIONAL JOURNAL FOR ADVANCE RESEARCH IN ENGINEERING AND TECHNOLOGY

*WINGS TO YOUR THOUGHTS.....*

M&T is a useful way of turning data on energy use into useful information that can lead to significant energy and cost savings. A reasonable savings range is between 1 and 5% achieved through M&T. It showed that if the best performance periods could be replicated, savings of 4% would be achievable.

## **8.1 To Design M&T Successfully**

Too much metering can be detrimental less data may be better if it is the right data. One should establish what data needs must be collected first. There is a need to balance between metering every possible point and just to have one summary meter that does not “DRIVE” energy. There is no “one size fits all” report. Reports need to be designed for operators, supervisors, energy managers (weekly to monthly) and senior managers (monthly or quarterly). In many cases, hourly is too frequent, daily may or may not work, and weekly or monthly typically better. Storage is handled well with CUSUM as it “never forgets”. Ensure that IT programmers have a strong sense of energy relationships and requirements [9]. Thus the M&T is a basis for integrating energy efficiency into the management structure of any organization.

## **8.2 Barriers of this Technique**

M&T is a new approach to analyzing energy data so the knowledge and understanding of its benefits is limited.

Companies struggle with How to do the Analysis hence proper skill set is essential.

As Extensive data is required to plot the Energy consumption Regression and CUSUM charts hence metering is essential where the efficiency is to be optimized.

M&T is a continuous improvement process tool, and savings can be obtained only by proper follow up of the process.

## **9. COST SAVINGS**

The costs and benefits presented in the tables in this section were derived in the following manner.

There are five categories of cost: (i) measure, (ii) customer, (iii) incentive, (iv) marketing and (v) administrative costs. In programme modelling, the model splits the costs into customer costs (cost paid by the customer) and the incentives paid to the customer. The sum of the customer costs and the incentives costs for any given measure is the measure cost. The majority of the costs presented here are the incremental costs between the efficient measure and the alternative. In a few cases, full costs were used. The administrative and marketing costs are estimates developed to support these programmes. [10]

## **10. CONCLUSION**

Monitoring and Targeting can significantly reduce energy bill and increase productivity through identification of best practice opportunities in site utilities and processes, assessment of behaviors & practices and monitoring & targeting strategies.

- Lower balancing power and cost.
- Lower demand charges and penalty fees
- Higher energy efficiency and reduced carbon footprint
- Detect waste early to minimize losses
- Identify best performance for target setting
- Identify bad performance for corrective action .

## **REFERENCES**

- [1] **Energy Efficiency Strategy: The Energy Efficiency Opportunity in the UK.**
- [2] **P Veeranjeyulu, Dr. T Purna Chandra Rao: “Voltage Stability of Power Systems Using Regression Models and K Means Clustering” IJEET 2013, ISSN 0976 – 6553**
- [3] **Harini H N, Surekha Naagesh: “Predicting CBR of Fine Grained Soils by Artificial Neural Network and Multiple Linear Regressions” IJCIET 2014, ISSN 0976 – 6316**
- [4] **Andrew McMullan Mike Rutkowski Alan Karp: “Monitoring and Targeting (M&T): A Low Investment, Low Risk Approach to Energy Cost Savings“**
- [5] **Kevin Wallace, BC Hydro Power Smart “Monitoring, Targeting and Reporting: A Pathway to Continuous Improvement in Energy Management”. 2007 ACEEE Summer Edition**
- [6] **Cleaner Production – Energy Efficiency Manual prepared for GERIAP, UNEP, BANGKOK by National Productivity Council**
- [7] **Industrial Energy Management Training Course: IEMTC Malaysia Module 7**
- [8] **Kevin Wallace, BC Hydro Power Smart “Monitoring, Targeting and Reporting: A Pathway to Continuous Improvement in Energy Management”. 2008**
- [9] **Dale R. Patrick Stephen W. Fardo Ray E. Richardson Steven R. Patrick “Energy Conservation Guidebook”, Second Edition, CRC Press**
- [10] **A Study by Kema for Sustainable Energy Ireland “Demand Side Management in Ireland: Evaluating the Energy Efficiency Opportunities”, SEI 2008**