The Facility Performance Index (FPI)

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ABSTRACT

A 2-number metric, the Facility Performance Index (FPI) has the potential to revolutionize the industrial and manufacturing sectors. A productivity metric derived from a machine learning algorithm using energy and production inputs, it provides a systematic and pragmatic path for the intelligent allocation of scarce and limited resources. The FPI is a derivative of the performance metric in the ISO 50001 energy management program.

Areas of application include providing systematic and pragmatic direction to the digitization of industrial and manufacturing plants.

Ability to quickly determine net effect of plant modification / maintenance interventions.

Indication of maintenance scheduling with pre- and post-intervention analysis quantifying relative improvement attained as well as comparison with new conditions showing relative performance.

Better performance indicator of equipment, process, system, plant / facility performance.

More accurate financial cost of equipment, process, system, and plant / facility operations with respective component breakdowns.

Future potentials include revamping of plant / equipment specifications with the FPI rating being attributed to both equipment (facility) and raw material categories.

Concurrent with the ISO 50001 goals this will increase the sustainability of plant operations and result in the reduction of greenhouse gas emissions.

Introduction

In 2011 the International Organization of Standardization (ISO) produced the ISO 50001 Energy Management International Standard – Energy management systems – Requirements with guidance for use. It brought to the world a concise document of methodologies and systems on which to build an efficient and effective program to reduce energy consumption in industrial and commercial enterprises and concurrently reduce greenhouse gas emissions. A product of this standard was the correct KPI (key performance indicator) for energy management which was termed the EnPI (Energy Performance Indicator). It was demonstrated that for the correct measurement and reporting of energy performance for any enterprise there needed to be the reporting of two variables viz. the baseload of the facility and concurrent with its generation, through linear regression, the performance efficiency metric. This took the basis from the linear equation of a line $y = mx + c$ where y would correspond to the energy output, the “m” the efficiency metric and the “+ c” the baseload. The independent variable “x” would be dependent upon the process or facility in question. For production enterprises it could be number of cars, kg of product manufactured etc., and for commercial enterprises occupancy, number of degree days etc. With this, correct comparisons, and analyses of the performance of organizations and their systems can be performed.

This paper is founded upon the application of the above in a machine learning linear regression algorithm to provide these metrics on a continuous cycle (30-day continuum). The FPI consists of values of the "m's" and "+c's" above. With this the applications have been

- To provide a systematic method of delivery of industry 4.0 digitization,
- A quick method of determining plant, process, and equipment process performance,
- Abilities to document empirically the status of equipment and their relative performance along with the result of maintenance activities (pre and post maintenance, renovations etc.), alongside overall indicators of plant, process, and equipment performance with the future application to more accurate reporting of plant performance and financial appropriation.

Background

Industrial plants have historically operated in siloes with information being handled in separate domains. Plant equipment and their status have usually been the responsibility of the maintenance department and equipment purchases largely determined through capital expenditures (capex) typically on an annual planning cycle with new projects being introduced and the merits voted on for inclusion in the company's short- or long-term objectives. Once approved the associate metrics of operations invariably gets lost in an overhead bucket where the expenditures may be combined with other equipment in the respective facility with costs appropriated to respective cost centers. Maintenance activities are monitored and executed along the lines of the recommendations given by the manufacturer with any pre, and post diagnostics being based materially on ensuring that the physical operations are in line with design specifications. The finer associated dynamics associated with the equipment is many times difficult to catch unless the equipment is in industries as power plants where vibrational monitoring equipment may give an indication of underlying conditions. When brought back into operation (from maintenance, renovation etc.) the relative production performance unless within an order of magnitude departure invariably goes undetected. The personnel who may realize that "something is just not as before" might be the production or operating personnel who not being able to give empirical evidence will offset through faster speeds etc. or the "system" might compensate. The point is, however, that the foundational analysis of whether the equipment is operating at prime, sub or even is not given a grade or overtly measured. The financial data is lost in overhead, the production numbers are reported based on sales and production forecasts with corrections made through greater or lesser hours of operations or increased line speeds etc. and the finer details missing in the multiplicity of functions with each having their own data requirements and the cross assimilation almost never occurs as there is no real reason for such activity.

The Facility Performance Index is a metric that lends significance to each of the operating areas with the ability to communicate across the respective platforms bringing great benefits to the firms who appreciate its application and the consequences.

For starters you now have a metric that can scale from the organization / plant / facility level to the process and finally to the individual equipment level, all with the exact representation maintained. This is extremely beneficial when there is a need to have a cross platform, cross functional ability. It is statistically generated meaning that functions as the R-squared can be applied to ensure that garbage in, garbage out is not the case.

The critical aspect to its benefit is that it combines variables that when linked generate an unbiased relationship that while with the ISO 50001 was made to designate energy performance has far reaching effects to all the associated areas that are affected by the energy consumption. Equipment, process, and plant efficiencies are intricately linked to energy performance. The same trail of energy can identify promising areas for the introduction of industrial 4.0 technology as the level of energy consumed can be an indicator of the level of activities or need for further insight, areas that 4.0 technology can bring greater understanding. Finally, because there is now the accurate determination of performance, coupled with the concurrent rise in digital technology making data and information availability almost ubiquitous, and the nature of the metric being one that brings formerly incommunicable areas directly in sync through a common language, readily understood between all parties, the advantages that this platform generates is widespread. The following are but only some of the areas, their application, and benefits.

Application & Benefits

Digitization of Industrial and Manufacturing Plants

The digitization of industrial and manufacturing plants has lagged other commercial areas and institutions primarily due to the multifaceted operational structure of these enterprises and the disparate associated functions. In turn the introduction of Industrial 4.0 initiatives has many times been introduced to companies by organizations with limited manufacturing or plant experience who approach them from the standpoint of the vendor rather than the company's operations with limited knowledge of how to bridge the gap. Faced with an opportunity with several areas of intervention it is daunting if not seemingly impossible to determine how best to identify the most effective action plan of implementation for the client. This is not an arbitrary or insignificant decision as profit margins of the company might be thin and the capital outlay along with the resources dedicated to the venture while even if facing a respectable payback if implemented in other more significant areas may have yielded several returns over making the enterprise significantly more competitive. Even more dangerous is the association that the company has advanced into the digital arena with subsequent interventions being told "been there done that" without realizing the significant savings and operational changes that still are waiting to be capitalized upon.

Following the trail of the FPI allows a systematic and pragmatic approach to be realized. Focus can automatically be directed towards the areas of the plant that are having the most potential for impact. The vendor might not have realized that the respective operations existed. The technology when implemented delivers outputs that are not easily replicated by their competitors, the bottom line is impacted, with quantum results, and margins being similarly affected.

Plant modification & maintenance interventions

The FPI provides an easy way of keeping track of plant overall function as well as the subsidiary elements right down to the operating equipment. It has been demonstrated that its continual tracking has given prior indication of major downtime events as the complete shutdown of a manufacturing plants air compressor as well as unique insight to plants purchases of "efficient" equipment. The plant FPI allows senior management a quick gage of the relative performance of plant divisions. This is of value when comparing performances against labour arbitrage and other unique geographic, political, economic interests. It provides a more accurate weighting analysis performance to take place. With it also can be more accurate distribution of product assignment and production scheduling due to the unique attributes presented at facilities producing equitable product ranges. This also leads to other worthwhile initiatives as the discovery of benchmark practices that hitherto were unknown being discovered and replicated in other areas so as making the entire organization more profitable.

With regards to direct equipment procurement, it was discovered at a grain producing plant that equipment efficiencies were not as expected with new purchases rivaling old. Further, significant savings US $,000's was saved annually when a slight tweak to batching cycles was done through comparing plant baseloads. Furthermore, for any plant it is desired that a piece of equipment after undergoing major repair or renovation is returned fully functional and allowing operation that hopefully exceeds but at least meets prior performance. While previous checks as amperage, temperature and vibration would have been used as determining factors, what the FPI now allows is an easy manner of assessment that demonstrates the effect of the repairs. When applied to new purchases the FPI when documented will provide a long-term frame of reference to compare gradual inherent equipment degradation and this could determine optimum times when a change is needed. When compared with the levels attained by other equipment it might then initiate a plant wide modification or even the mothballing or complete replacement. This will allow greater levels of insight into a plant and its processes that will only lend to greater efficiencies, more competitive operations, and greater profits.

Production

The FPI will allow comparative performance with raw materials and their direct impact to the bottom line to be measured and reported. As an example, in the extraction ore industries associated ores from pits when ground / milled can be reported based on the performance of the associated equipment. This will have far reaching implications. When pits were mined to depletion and new ones then started could be substituted for joint pit mining configurations where the associated dynamics suit the extra configurations. Further the price paid for cheaper raw materials might be offset by the process dynamics making the overall purchase more expensive. Such information can be easily measured and reported to purchasing and finance for more intelligent purchasing decisions being made.

Accurate Financial Decision making

ISO 50001 corrected a major error in reporting plant equipment and facility performance through the use of linear regression in separating the baseload from the component efficiency as stated earlier. In the previous method which was the simple quotient of energy / production (or relevant independent variable) the "economies of scale" of processes was not captured and thus grave mistakes could have been made in plant procurement practices which would otherwise have gone undetected. As an example, a mill when used in a facility in a developed country may have an associated production quantity that more than offsets the significant baseload accompanying the unit and therefore is able to maximize on the lower operating efficiency. When the similar piece of equipment is deployed in a facility with a much lower production capacity the touted efficiencies of the unit may never be experienced as the production quantities may never offset the much higher baseload. This may therefore bury the purchasing company in debt with the reason never fully appreciated. With the advent of the FPI the company is now able at a minimum to appreciate the possibilities of this occurrence and employ adequate due diligence to prevent same. Better yet the company can investigate the application of the equipment in other organizations, compare production quantities, perform the necessary analyses to derive the respective metrics and determine if similar deployment would be beneficial under the prevailing conditions.

Future application(s)

Like with the pump curves, the FPI forms a basis for the specification of equipment and raw materials that will bring great benefits to the procurement process. Manufacturers will be able to provide information based on production quantities and material for both baseload quantities and efficiencies that buyers will use in determining applicability and suitability to their plant / facility conditions. A similar condition could be applied for raw materials. This might be more however of an internal marker giving a specification or grade to vendor supplied materials as per batch and over time if consistent per vendor. This then would be applied to the purchasing decisions made when costs and other associated variables are considered.

Implementation

The implementation of the FPI includes determining a causal relationship between the energy consumed and facility independent variables (e.g., production quantity, occupancy, degree days, etc.). First, it is necessary to define the scoped area(s) of investigation. Second is to determine a point of access for the measurement of both the energy expended and the respective quantity of product produced. If not accessible the scope may need to be expanded until a direct correlation is arrived at or (based on resources and economics) adequate submetering installed. Third the energy is then compared with the respective production quantities using a linear regression machine learning algorithm. In our experience a 30-day continual regression cycle for the Machine Learning algorithm was implemented and R^2 values of 0.72 – 0.85 were realized.

Finally, it is necessary to map the readings to the manufacturing cycle. This is where the great advantages of this method are obtained. With accurate information now available (as in the baseload and correct efficiency values) even without prior comparisons, objective reasoning can be applied. For example, if in manufacturing a certain line of product it is seen that the baseload is disproportionately high then whenever the particular product or equipment is used a minimum quantity must be manufactured. This may then dictate changes in inventory of the respective item allowing more accurate cost analyses to be performed. Previously this energy cost would have been simply summed or allocated to overhead resulting in relative inefficiencies not being accounted for and remedial actions not taken. Now with accurate accounting and benchmarking through the FPI the specific processes can be identified and corrected. Several other analyses can also be conducted. Does a particular shift produce a production line better than others? Closer examination may reveal minor adjustments which can then be replicated throughout the plant.

The application of the FPI throughout the manufacturing cycle brings the “personal trainer” benefits to the organization. Insights into the plant’s operations are obtained which result in greater understanding of the operations, ultimately resulting in increased savings and better care of the environment.

The following provides real life examples of a Dashboard (Figure 1) from which the basic information is derived for the Facility Performance Index (Figure 2). In Figure 2 you will see the components of the FPI diagrammatically with production information included.

Figure 1 – Example Energy Dashboard depicting essential data for the production of the Facility Performance Indicator (FPI)

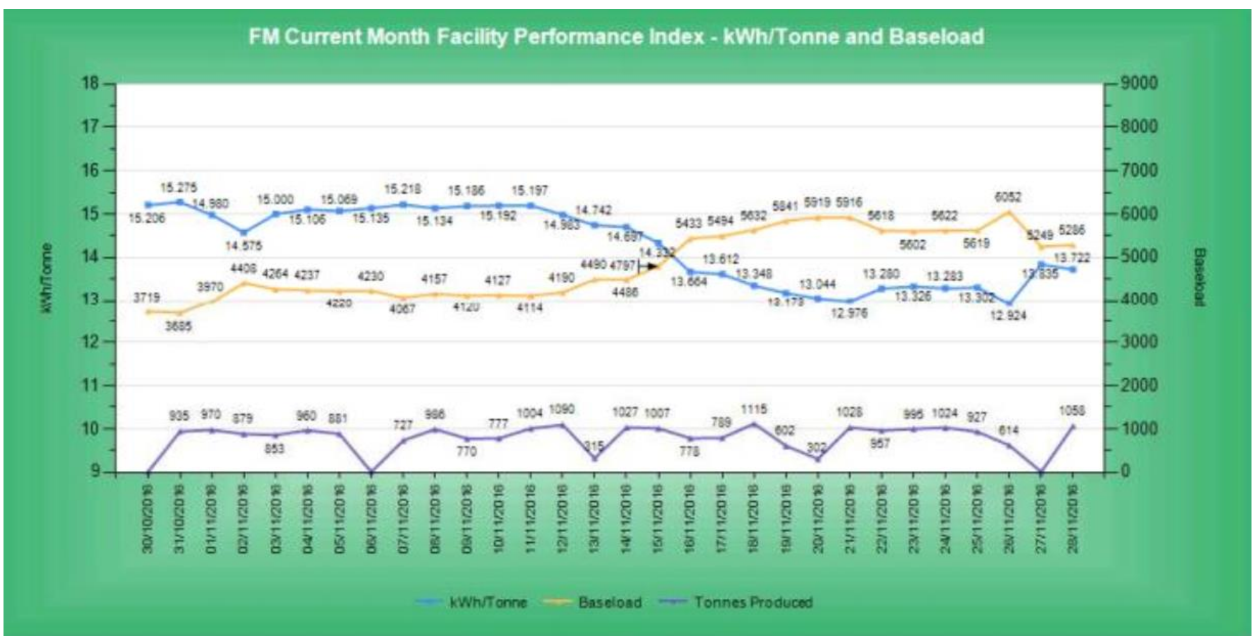

Figure 2. The Facility Performance Index showing the Baseload, efficiency (kWh/Ton) and Tons produced.

Conclusion

The ISO 50001 has given an underutilized metric that for its purpose is solely used regarding energy conservation but whose wider applicability can form the foundation for an elaborate scheme of utilization that greatly enhances manufacturing and industrial plants profitability through the correct streamlining of their operations.

This paper demonstrates some practical applications of the Facility Performance Index along with future roles that will further the impact and acceptance of its use internationally. It will minimize waste, enhance proper decision making, save energy costs and minimize greenhouse gas emissions. Altogether it will add a significant dimension to the continuing Industry 4.0 revolution.

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