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Integration and Resources Management of Small and Medium Enterprises

Toshko Zhelev, Bernadette O'Regan, Richard Moles

Charles Parsons Initiative, University of Limerick,Limerick, Ireland,toshko.zhelev@ul.ie

Abstract

Presented paper focuses on the selection of appropriate process integration methodologies and their tuning for integrated management of resources in a cluster of small and medium enterprises (SME) located in close proximity. Proposed integration aims the improvement of industrial efficiency with strong emphasis on the environmental impact. The resources in question include in the first instance utilities, such as energy and water, but do not exclude transport, waste, services, IT, inventories, etc. Three major methodologies are proposed for direct implementation: The first one explores the concept of *integration between areas of integrity*, the second utilises the *marginal value* concept and the third one attempts to amalgamate two successful systems integration tools such as *Pinch analysis (thermal, water and oxygen Pinch)* and *eMergy analysis* entering the domain of multiple resources management, including environment consideration and elements of the life-cycle analysis.

Keywords: Integration, Pinch, SME, resources management

1. Introduction

Currently, process integration can be seen as a holistic approach to process design, retrofitting, and operation, which emphasizes the unity of the process. It can be seen as a common term for the application of methodologies developed for system-oriented process plant design. The three major features of process integration methods are: The use of heuristics; the use of thermodynamics (e.g.

pinch analysis, exergy analysis) and the use of optimisation techniques. The core element of such integration remains at the system approach to energy and material flows, where the effluent's flows and waste management becomes a whole new dimension of it.

2. Background

The focus of this study is on the local small and medium enterprises (SMEs) allocated within the Mid-West region of Ireland. It includes approximately 10% of the national land area and population of Ireland. It is estimated that there are approximately 400 SMEs in the Mid West region.

While SMEs contribute to growth, employment and rural development they also exert quite significant impacts on the environment. It is estimated that in total SMEs are responsible for 70% of all industrial pollution across the EU [1].

The announcement of our research in the area of industrial integration has attracted significant interest in the region, but only 22 SMEs formally expressed commitment to this project. Many of these companies already work together in other areas of mutual trust, but there is still to be done in terms of methodology development that can place the beneficial integration at a firm scientific ground.

3. The system approach

System oriented methods provide practical way to find required minimums for energy, raw material and water based on process integration.

3.1. Heat recovery between areas of integrity

The energy integration concept introduced in [2] may very well match the undertaken task of beneficial integration within the Eco-Industrial Network. The concept utilises the natural division of process plants in logically identifiable regions (areas of integrity) and the potential for heat (energy) recovery between these areas. The optimisation task in the case is formulated as identification of schemes of energy recovery between areas of integrity, which offer maximum heat flow exchange with least number of interconnections between the regions. This concept can be adapted without changes for the purposes of energy conservation within an Eco-Industrial Network. The areas of integrity in this case are the SMEs themselves and the integration of energy will be done with minimum re-piping or other type of interconnections between them.

3.2. Marginal value analysis

As shown in [3], this method evaluates the real value of utilities, such as steam, water, etc., which in the general case have different value when different production sites are concerned. It allows more transparent and convincing ground for decision-making when the integration of energy and other resources between industrial partners is an option.

To define the marginal value of any stream or utility, the evaluation of three marginal values is proposed. Those are the marginal profit, the production cost and the production value. The calculation of these three values can be done using so-called site model, which consists from material and energy balances and topology (structure) of the system in question.

We propose a new application of marginal values for integration decision-making and multi-site application. An important side of this analysis is the creation of an integrated site model. The proposed analysis in general case will include marginal values of utilities, services, inventories, transport, IT, treatment, etc. The final purpose of the analysis is the evaluation of eventual changes of marginal values as a result of proposed integration.

3.3. Emergy-Pinch analysis

The available solar energy used up directly or indirectly to make a service or product available, defined as emergy [4], was applied by number of authors to compare inputs of different origin, such as human labour, transportation, energy, fuels, chemicals, utilities, plant cost, etc. Solar emergy is the solar energy directly or indirectly necessary to obtain a product or a flux of energy in a process; it is an extensive quantity and its unit is the solar emergy joule [sej]. To convert inputs and other kind of flows into the solar equivalent, it is necessary to know the solar transformity, which is the emergy necessary to obtain one unit of product. Unlike the emergy, transformity is an intensive quantity and usually measured in [sej/J]. Transformity calculation is a difficult task stimulating researchers to exchange data and build databases establishing common ground for analysis. An interesting feature of Emergy analysis is the historical information about the resource or activity in question. The emergy value associated with a product is the memory (the sum) of the all energies that were used to produce it. Another great feature of emergy analysis is its ability of identify critical processes/stages/units. This makes it quite suitable for the purposes of environmental consideration in the Eco-Industrial Network.

In [5] it was promoted the interesting idea of combining emergy analysis with Pinch analysis [6] – a well-known tool for resources management in industry. These two methods give the missing link between the industrial resources management for economic benefits and the environmental impact assessment comparing alternative solutions.

The treatment and reuse of wastes is the key to the evaluation of systems sustainability. The emergy loss is considered through the investment of waste treatment, but in the same time, this treatment may not only recover ecological acceptable level of the resource, but raise its potential for regenerated usage.

3.4. Bottlenecks identification

Combining Emergy and Pinch concepts makes possible to identify more precisely the combined influence of critical processes or phases through allocation of constrained processes (these touching the total emergy investment supply line and preventing its further lift up). The Pinch-type of targeting gives several important evaluation parameters: (1) The ultimate minimum emergy supply to run the entire process at any time (the slope). This is the flow of resources, services and work required to run the entire system; (2) The total emergy investment for the entire process for the entire period; (3) The maximum transformity (the "amplitude" of transformity, giving the total "power" of resources to run the process – another criteria to compare alternatives, identifying what process needs resources of highest quality) – the horizontal projection of the right end point of the emergy investment supply line; (4) Limiting stages/resources (restricting the emergy investment supply line to increase its slope). This one gives indication about processes and resources which utilisation is to be intensified in order to improve the efficiency of the entire process; (5) Pinch point – limiting point allocation. Details of these cases can be found in [5].

3.5. Oxygen-water-Pinch

The intent to design more cost attractive wastewater treatment systems was approached by extending Pinch principles towards so-called Oxygen Pinch analysis [7]. The idea is to target prior to design the idealistic minimum oxygen required by the micro-organisms to degrade organic waste and to suggest treatment flowsheet and design changes ensuring efficiency of operation close to the earlier stated target. In most of the cases the oxygen is supplied to the micro-organisms through agitation. Agitation and other forms of aeration require energy, so finally the analysis based on Oxygen Pinch principles leads again to their original application associated with energy conservation. Apart from this, Oxygen-Pinch concept allows for the first time targeting a quality characteristic – the growth (the reproduction rate, or heath) of micro-organisms.

- *Combined Water-Oxygen Pinch Analysis*

The aim of this methodology is to help decision making about the strategy and the organisation of wastewater treatment within an Eco-Industrial Network. Major factors contributing to the cost of wastewater treatment and pollution levels are the wastewater quantity and the wastewater quality. The wastewater quantity is directly linked to the amount of energy required for the wastewater treatment. The objective to minimise the wastewater quantity can be achieved using the Water-pinch analysis. Water Pinch helps to increase concentration levels of wastewater and decrease its quantity. In contrary, wastewater quality is inversely proportional to the energy required for wastewater treatment as well as pollution levels. There is no integration technique that would facilitate wastewater quality improvement. A mechanism to negate this effect is required. This objective can be achieved by the application of Oxygen Pinch Analysis. Thus the overall effect of increasing the cost effectiveness of wastewater treatment can be addressed through combination of Water and Oxygen Pinch Analysis. The expected result is a decision-making procedure suggesting within particular market circumstances what amount of wastewater to be taken for treatment within particular member factory of the Eco-Industrial network and what part of it to be sent to the servicing wastewater treatment plant.

The above methodology may very well serve particular Eco-Industrial network as a convincing argument for or against the idea for commissioning of a centralised wastewater treatment plant, its allocation, etc. It can serve as a firm ground for targeting the minimum electrical energy (respective cost) for treatment of different quantities and qualities wastewater – a tool for determination of servicing charges.

3.6. Emergy-Water-Pinch

An important feature of Water Pinch, inherited from the classical Pinch analysis is that it gives design guidelines - an important advantage to Emergy analysis. Water Pinch considers mainly streams' contamination level, what in the general case is not enough. It is more than obvious that different contaminations and concentration levels would need different effort of water treatment depending on the nature of contamination, composition, chemical bounds, etc., not only concentration levels and limits. Here comes the help of Emergy analysis. The ability to assess the history and the effort associated with making water resource available (boring dept, pumping, pre-treatment (softening, filtration, chlorinating, etc.)) provides good ground to compare resource of equal quality.

Therefore, the Water-Emergy Pinch analysis can be used for decision making in the constrained cases of plant expansion, when the water resources are limiting the expansion decision.

4. Case study - Integration in Eco-industrial park

We constrained the possible integration into four different vertical levels: (a) energy; (b) water; (c) waste treatment; (d) transportation. With the help of geographic data management system we first considered the possibility of horizontal integration between areas of integrity. First, decomposition in clusters of member SMS was proposed accounting for their geographic allocation. Second level of decomposition was based on common landfill waste-disposal sites. The third level of decomposition accounted for potentials of inter-factories waste-reuse/waste and utilities utilisation options. The optimisation problem of maximum cost benefit can be formulated as a problem of finding the maximum of the "vertical sum" of "horizontal integration benefits". The proposed principle for redistribution of the achieved savings amongst the member enterprises was proportionality to the integration investments.

5. Conclusions

This paper builds a set of appropriate methodologies and develops procedure suitable to identify synergies between collaborating SMEs targeting opportunities for socio-economic benefits. The idea behind the integration of these methodologies is the merge between sustainability concerns at regional level with environmental concerns first at process level and second at SME level. The effort of such a project can demonstrate the practicality of the proposed framework providing a platform for the eventual set up of an Industrial Ecology Park.

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