Article # 27

Quick analysis of financial attractiveness of system efficiency gains

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Interestingly enough the only technical subject in energy efficiency where the qualifier "most economical" has entered the literature is the topic of "most economical insulation thickness of a pipe". Intuitively it is understood that one may initially save more energy by putting more insulation on a pipe, but there is one and only one insulation thickness that is the most financially attractive. The same principle of the "most economical efficiency" may be applied to any energy conversion system.

As an example take a power plant and in a quick first level assessment answer the question:

"How much rupees could we invest per MW installed power to improve the system efficiency of a thermal power plant from $\eta_{as\ is}$ to η_{new}:" The answer is:

$$I_{max} = \frac{(q^n - 1) \bullet 8760 \bullet PLF \bullet C_{MWh} \bullet (\eta_{new} - \eta_{as\ is})}{q^n (q - 1) \bullet \eta_{new} \bullet \eta_{as\ is}}$$

I_{max} = the maximum acceptable investment per MW installed capacity

$q = 1 + \frac{i}{100}$ with i = expected return in %

PLF = plant load factor as a fraction $= \frac{MWh_{generated}}{MW_{installed} * 8760}$

$\eta_{as\ is}$ = the actual system efficiency
η_{new} = the envisioned improved system efficiency

C_{MWh} = Fuel costs in Rs/MWh where MWh[1] refers to energy in the fuel.

The equation has been derived as follows:

1. Whenever an energy conversion technology (i.e. coal to electricity) is modified to improve the efficiency from $\eta_{as\ is}$ to η_{new}, the fuel savings, $S_{\%}$, in % will be.

$$S_{\%} = \frac{\eta_{new} - \eta_{as\ is}}{\eta_{new}} \times 100$$

2. Furthermore the annual energy and cost savings, S_e and S_{Rs} in a power plant efficiency improvement are

$$S_e = \frac{MW_{installed} \bullet 8760 \bullet PLF \bullet (\eta_{new} - \eta_{as\ is})}{\eta_{as\ is} \bullet \eta_{new}} \quad \text{MWh/ year}$$

$$S_{Rs} = \frac{MW_{installed} \bullet 8760 \bullet PLF \bullet (\eta_{new} - \eta_{as\ is}) \bullet C_{MWh}}{\eta_{as\ is} \bullet \eta_{new}} \quad \text{Rs/ year}$$

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[1] It is more convenient to express the energy content of coal, gas, oil or any fuel for that matter in MWh and not in kCal or MJ. Consequently a coal with a GCV of 4000 kCal/ kg has as well a GCV of 4000 kCal/ 860 = 4.65 kWh per kg, or 4.65 MWh per ton. In case one ton of this coal is fired in a power plant with a system efficiency of 33%, we would generate 4.65 x 0.33 = 1.53 MWh of electricity.

3. A financially attractive energy efficiency measure should at least be able to recover the annual annuity, A, of the measure, i.e. annual payments of the project to a bank or the company, to pay back the investment with interest over a agreed or desired period. In other words:

$$A = \frac{q^n (q - 1)}{q^n - 1} \bullet \text{Investment}$$

Where
A = Annual payment in Rs.

$q = 1 + \frac{i}{100}$, with i = expected return in %

n = the desired investment recovery period in years.

It is noted that selection of i and n is the choice of the owner of the project and not necessarily based on the terms and conditions of a bank loan. The desired pay pack period may be the technical life time of the modification or simply a company rule such as "we do only investments that pay back in 2 years". The return i may not be the bank interest rate but the return the firm expects from the total investment.

Next we equate S_{Rs} = A, meaning the annual fuel cost savings, S_{Rs}, are used to pay for the annuity, A and solve for I_{max}.

Practioners know and fix C_{MWh}, $\eta_{as\ is}$, PLF, n, and i. The maximum investment I_{max} is then calculated as the borderline investment acceptable to increase system efficiency from, $\eta_{as\ is}$, to a new and higher efficiency η_{new}.

A few examples may illustrate the usefulness of the equation for many standard quick calculations energy auditors need to perform. Once I_{max} is calculated it is then a matter of judgment and experience to either declare it a mission impossible or an interesting option to explore further by doing a detailed project report.

<u>Example 1</u>:

Take as an interesting first example a 3 x 210 power plant that operates at $\eta_{as\ is}$ = 33%, PLF = 0.85 and uses coal costing[2] Rs. 473/ MWh. Furthermore assume this power plant unit should be replaced by a supercritical one with η_{new} = 42%. Assume a life time of 20 years and q = 1.16.

$$I_{max} = \frac{(1.16^{20} - 1) \bullet 8760 \bullet 0.85 \bullet 473\ (0.42 - 0.33)}{1.16^{20} \bullet 0.16 \bullet 0.42 \bullet 0.33} = 13.5 \text{ Million Rs./ MW}$$

[2] Assume 4000 kCal/ kg and Rs. 2.2 per kg of grade F coal, i.e. 473 Rs./ MWh. At this coal price it is not economical to shut down and replace the old one. But considering initially a price of 1500 Rs./ MWh, will result in I_{max} of 5 Crore Rs. per MW.

Example 2:

Assume a power plant operator has the objective to improve the “as is” efficiency by 1 percentage point from 0.32 to 0.33. Calculate the investment limit I_{max} per MW if coal cost are 350 Rs/ MWh, q = 1.16 and 10 years pay back is desired.

$$I_{max} = \frac{(1.16^{10} - 1) \bullet 8760 \bullet 0.85 \bullet 350 \bullet (0.33 - 0.32)}{1.16^{10} \bullet 0.16 \bullet 0.33 \bullet 0.32} = 1.2 \text{ Million Rs./ MW}$$

This means for a 210 MW block 252 Million Rs could be invested. Those not so familiar with financial discounting procedures would try to “fix” a low I_{max} figure by arguing that technical life of the measure could be 20 years. Recalculate at n = 20 to realize that I_{max} slightly increases to 1.46 Million Rs/ MW.

It is quite feasible to improve from 32% to 33% for this I_{max} by better housekeeping measures, and more advanced instrumentation control as well as analysis of performance, without replacing major hardware components. Consequently the example describes a realistic scenario. Payback may be more likely less than 2 years.

Example 3:

How large could be the investment cost difference between a 500 MW supercritical and 500 MW subcritical if system efficiency improves from 0.38% to 0.42%. Assume coal cost of 600 Rs./ MWh, n = 25 years and q = 1.16.

$$I_{max} = \frac{(1.16^{25} - 1) \bullet 8760 \bullet 0.85 \bullet 600 \bullet (0.42 - 0.38)}{1.16^{25} \bullet 0.16 \bullet 0.42 \bullet 0.38} = 6.83 \text{ Million Rs./ MW}$$

It is up to the experts to decide whether the investment cost difference of 0.68 Crore Rs/ MW between subcritical and supercritical is a reasonable figure.

Example 4:

The equation may be used as well to answer completely different questions such as:

Calculate I_{max} to replace a 25 kW electric motor with $\eta_{as\ is}$ = 88% at PLF of 0.60 with a new motor of η_{new} = 91%. Assume C_{kWh} = 6 Rs/ kWh, n = 20 years, q = 1.20

$$I_{max} = \frac{(1.20^{20} - 1) \bullet 8760 \bullet 0.60 \bullet 6 \bullet (0.91 - 0.88)}{1.20^{20} \bullet 0.2 \bullet 0.88 \bullet 0.91} = 5{,}753 \text{ Rs/ kW}$$

In other words one could spend 5,753 Rs x 25 kW = 143,825 Rs on a new 25 kW motor and still break even. Recalculation with n = 3 years yields I_{max} = 2,488 Rs/kW

This example shows that it would in any case make sense to junk inefficient electric motors and replace them by new efficient ones even if $\eta_{new} - \eta_{as\ is}$ = 2%.