Using the IMV's standard ECO system to improve shock capability

Optimising Vibration Test Systems for Battery Testing using ECO Technology

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Overview

- Emerging Vibration Test Requirements
- Vibration Test System Requirements
- Integrated Shaker Manager
  - High Shock Velocity control
  - Energy Management control
- User Benefits
- Questions

Emerging Vibration Test Requirements

- Increasing use of electronics and battery systems in vehicles has seen rapidly changing test specifications from the Automotive Industry
- Test specifications cover very broad range of requirements
  - High acceleration shock tests
    - At least 100g 11ms is frequently requested
    - Equivalent velocity of 3.5m/s (e.g. IEC 60068-2-27)
    - Working displacement of at least 50mm peak-to-peak
    - Force requirement > 100kN
  - Long durability tests in sine and random
    - 5g - 10g rms acceleration levels
    - Significantly lower force levels than shock requirement
    - Force requirement > 30kN peak (at three sigma random)

Vibration Test System Requirements

- The development of the required test specifications has a consequent increasing demand on the vibration test system
- High levels for Force, Acceleration, Velocity and Displacement
  - Option to move to a larger (often water-cooled) test system
    - High cost solution, with capital investment for cooling systems and high maintenance costs
    - High moving mass
  - Transformer-coupled system to achieve high velocity
    - No active DC control of the armature is possible, which requires larger displacement specification and harder to control shock tests
    - Transformer is large and expensive for ‘low frequency’ shock (100ms = 5Hz)
  - Possibly two test systems to cover the wide test requirements

Key factors

- Key factors in a vibration test system
  - Armature voltage (e) = field density (b) x armature coil length (l) x velocity (v) (e = blv)
  - Armature force (F) = field density (b) x armature current (i) armature coil length (l) (F = bil)

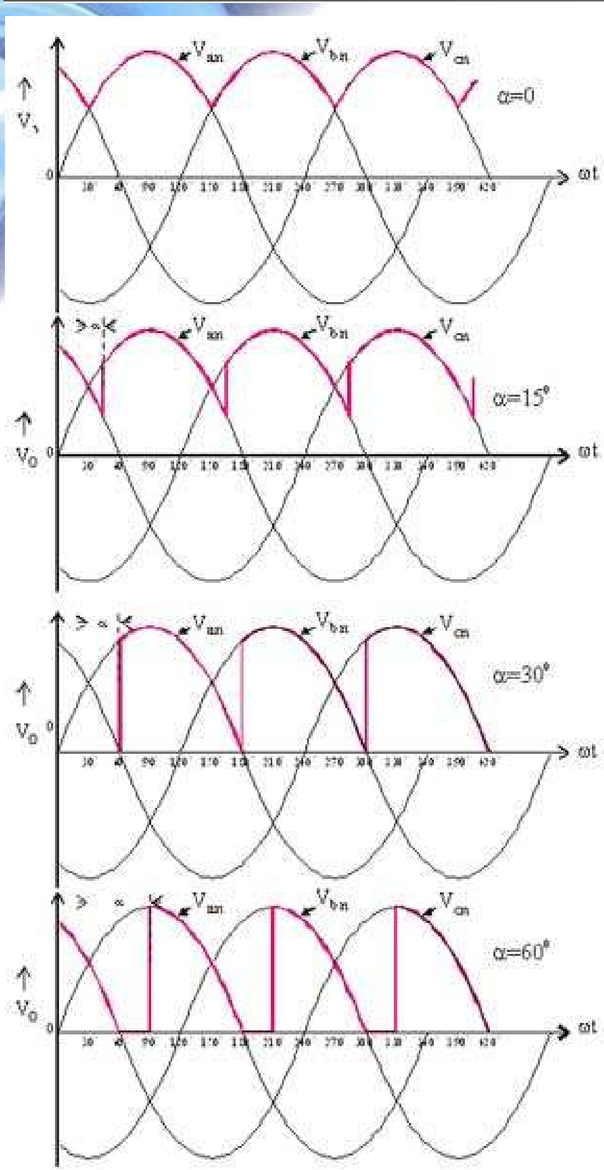
  - The maximum amplifier armature voltage (e) normally determines the maximum velocity for a shaker
  - The maximum amplifier armature current (i) normally determines the maximum force for a shaker

  - Force x velocity $\propto$ e x i = constant (for a given amplifier)
  - Therefore within a given ‘e’ and ‘i’ (amplifier rating) we can ‘trade’ force and velocity to suit a varying test requirement
  - The parameter to achieve this variation is ‘b’, the field density

  - The field density ‘b’ is proportional to the field supply voltage. By varying the field supply voltage it is possible to vary the field density.

  - The vibration controller calculates each parameter of a test (force, acceleration, velocity, displacement) and therefore has the ability to optimise the performance of the vibration test system through setting of ‘b’ to meet the test requirements

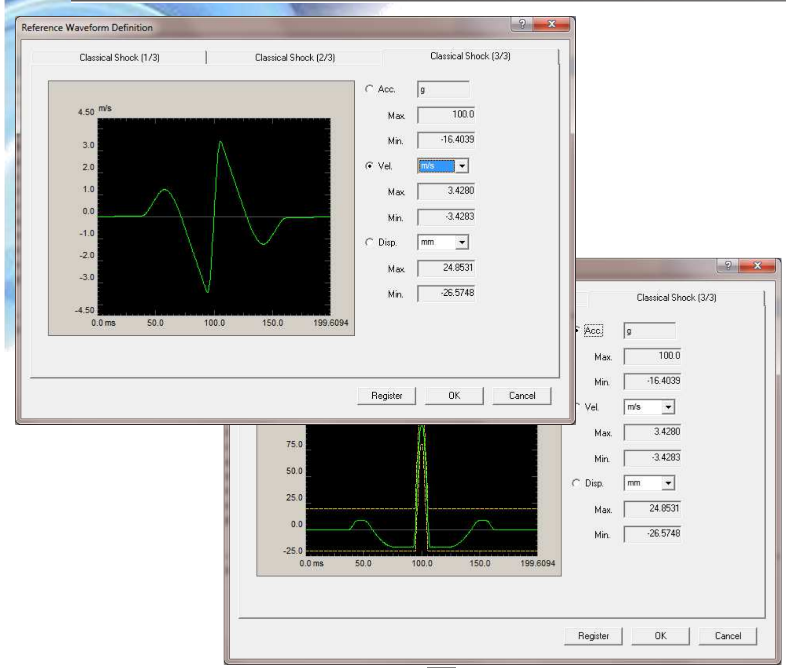
Field Control



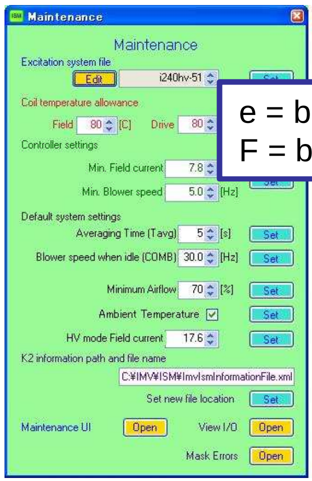
- Standard field supply voltage waveform is shown left – 3-phase half-controlled rectifier giving 300Hz ripple
- 300Hz ripple is within the test frequency bandwidth of most tests
- It is clear that as the field voltage is reduced (to control 'b'), the 'ripple' or disturbance on the field supply voltage increases
- This ripple limits the ability to vary 'b' by no more than 100% - 60% without distortion in the vibration waveform
- A better solution is required……

Reducing the field supply voltage

Shock Optimisation



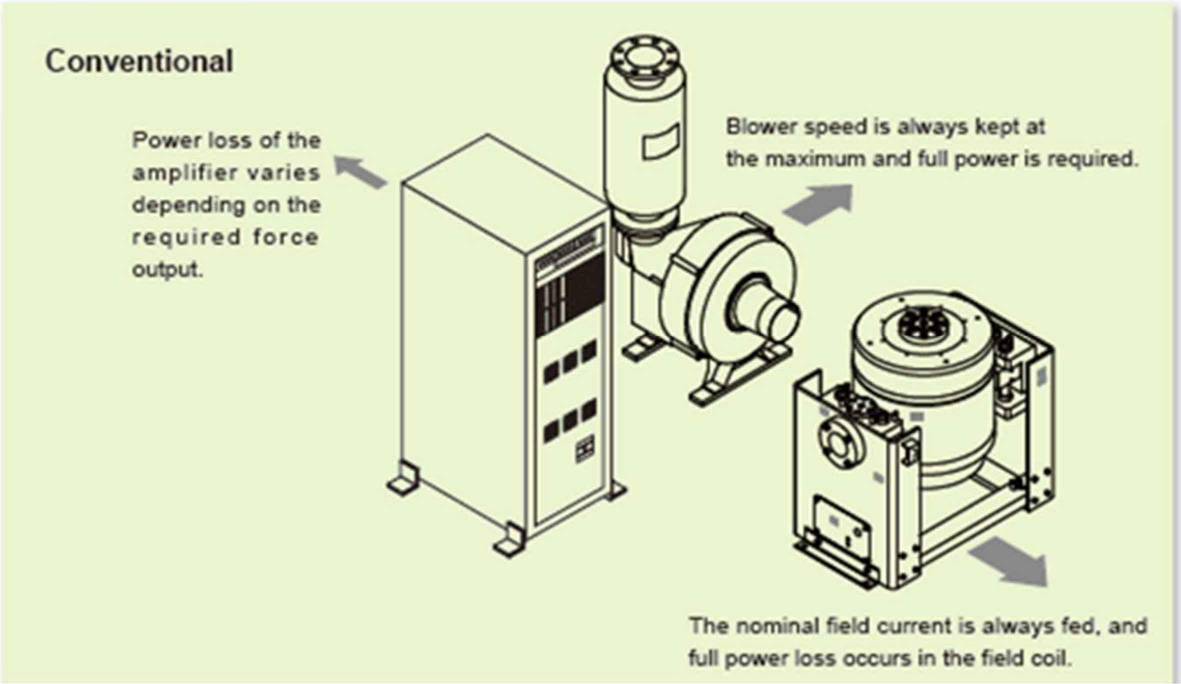
- Vibration test system data is entered in to the controller, including the low-field:high-shock capability
- Shock test specification is entered in to the K2 controller
- K2 controller compares shock specification against system specification and optimises field setting



$e = blv$
$F = bil$

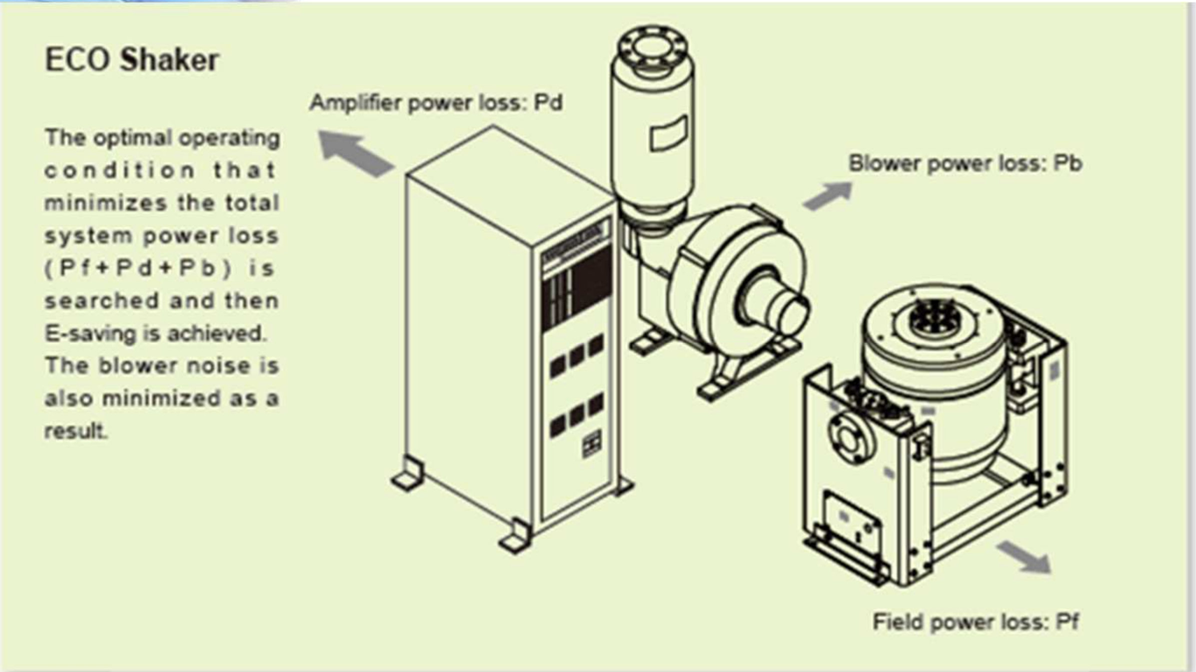
- Optimisation is performed against the two equations
- The optimised field current setting is automatically passed to the vibration test system

Power Loss



- Conventional Vibration system
  - Field current and blower speed are always set to nominal values
  - This always gives maximum power loss in the field and blower
  - Only the armature power loss varies in proportion to the output force
    - F = bil and the power loss is proportional to the armature current
  - But, from the previous discussion, we want to vary ‘b’……

Optimised Power Consumption



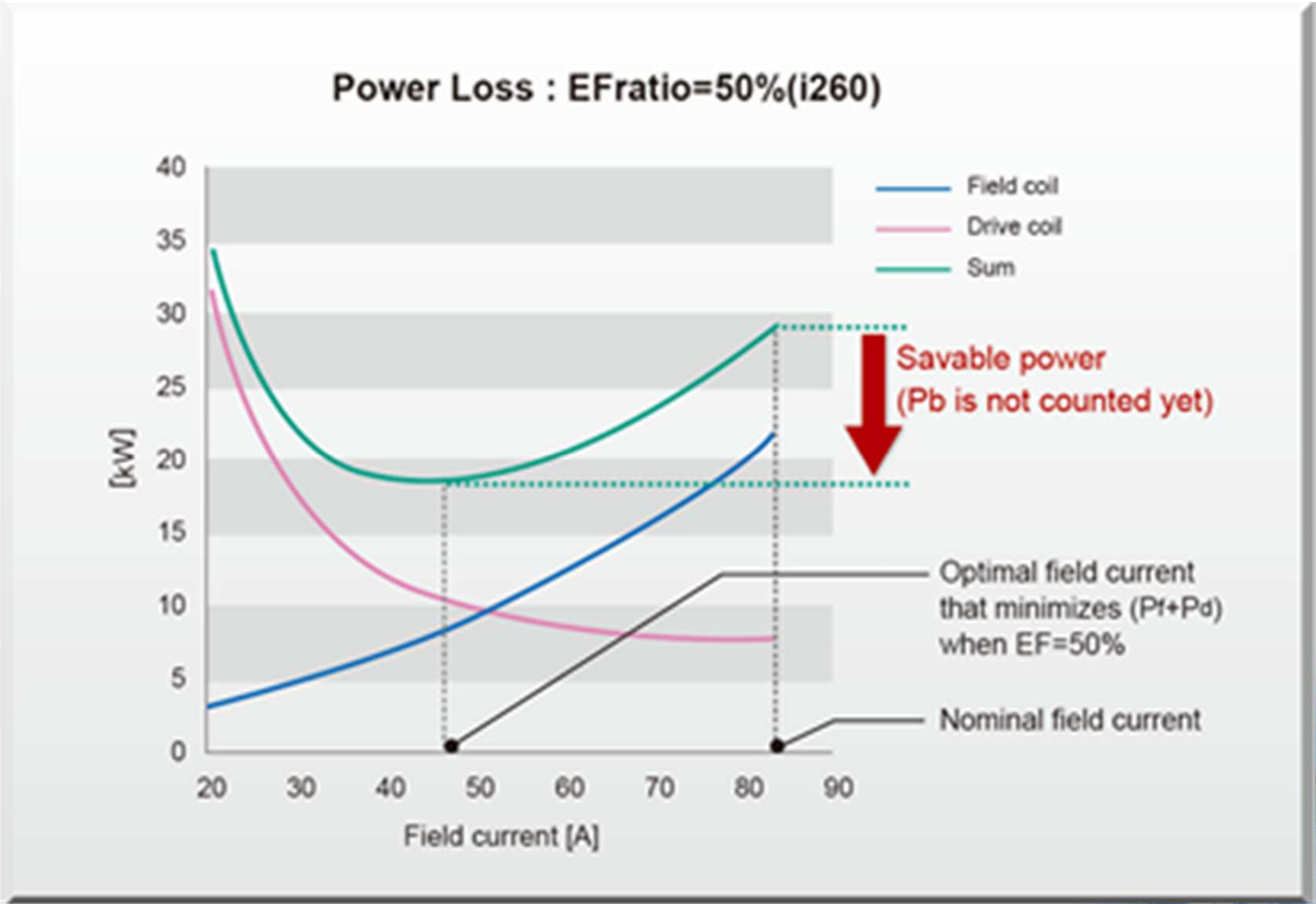
- Economical Vibration system
  - We saw from the early discussion that durability testing could be much lower force requirement than shock testing – a lot of wasted energy!
  - Actual power required for the test should equal input power
  - Reducing power consumption in the shaker, reduces the cooling requirements, saving more power in the blower
  - Reducing power consumption in the shaker increases reliability and reduces maintenance

Energy Optimisation in the Shaker System

- Optimisation issues
  - $I_d = \frac{F_1}{B(I_f)*L}$
  - Pf = Rf0*If^2
  - Pd = Rd0*Id^2
  - Pf = Rf0*[1+Cf*(Tf -Tf0)]*If^2
  - Pd = Rd0*[1+Cd*(Td -Td0)] *Id^2
- Temperature model
  - Tf = *f* (Pf, Pd, V) + Tin
  - Td = *g* (Pf, Pd, V) + Tin
  - Winter and summer have different optimisation points
- Outlet air temperature check
  - Tout = *h* (Pf, Pd, V) + Tin

Energy Saving

Optimum value for Armature and Field coil

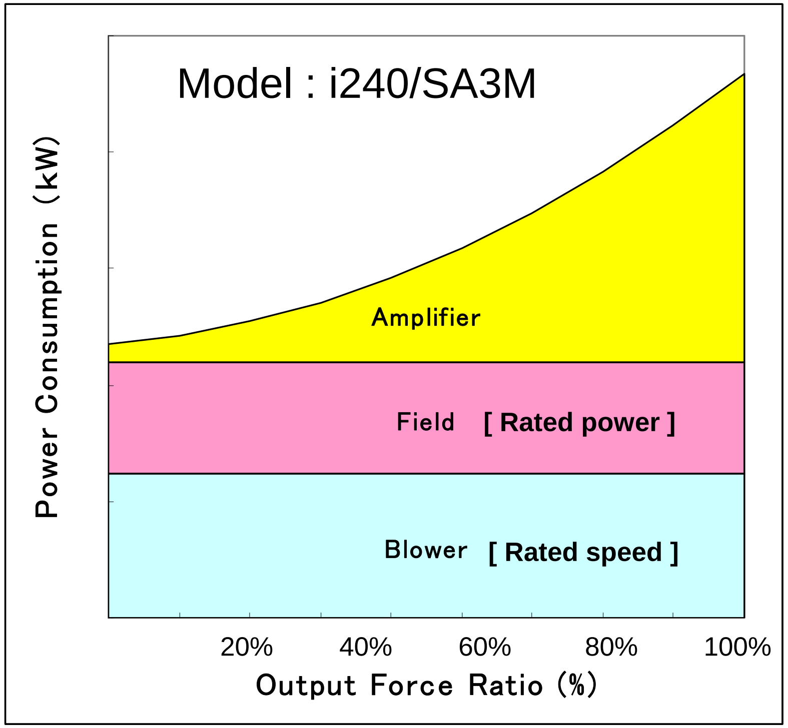


Energy Saving

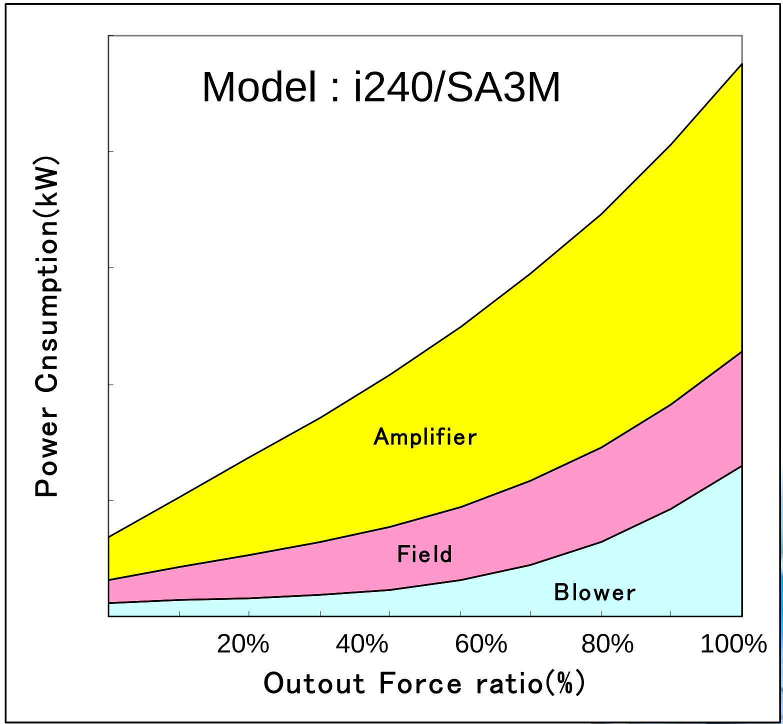
Comparison of Operating Methods

Figures below show the power consumption at each method of operation for a Random vibration test.

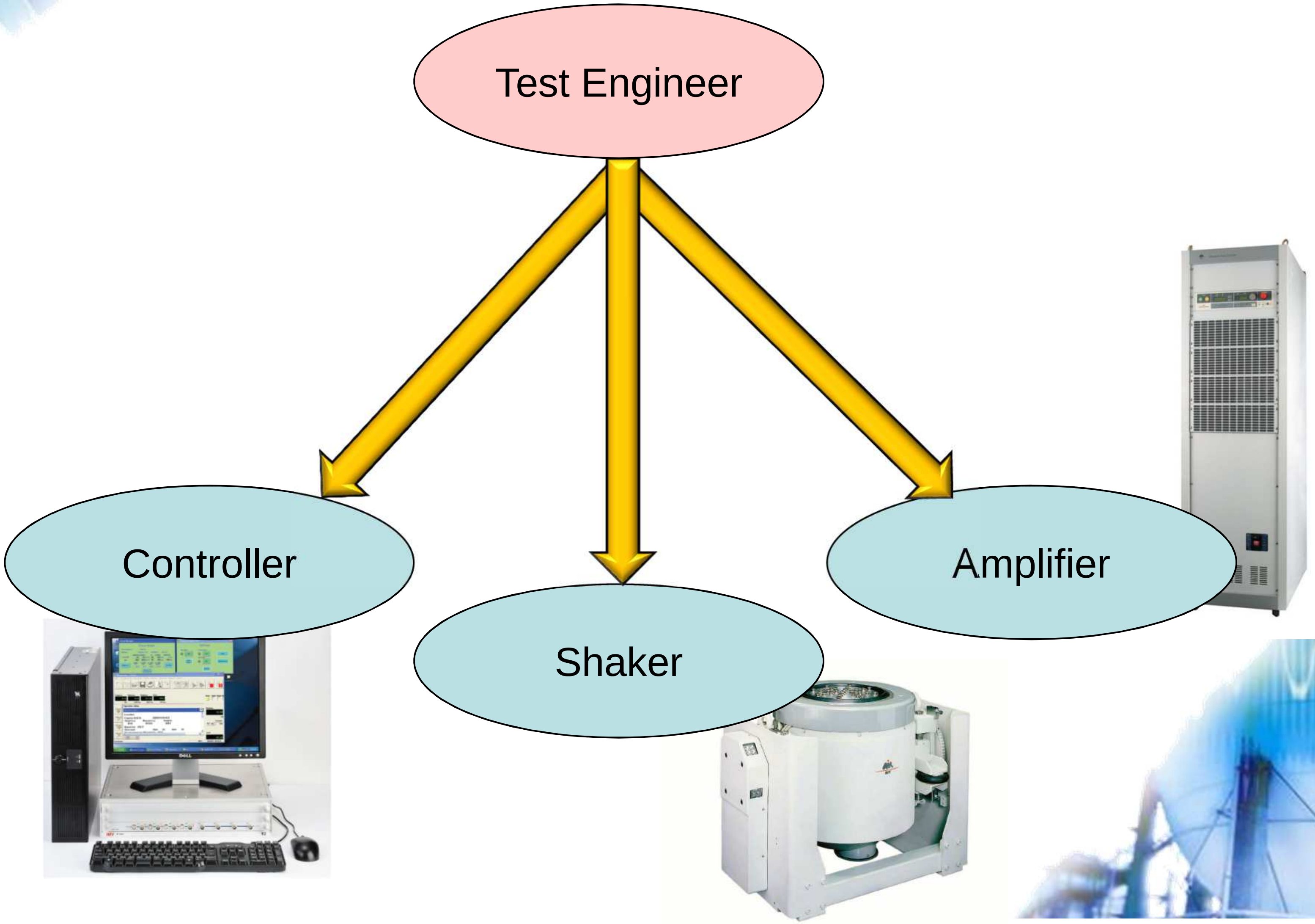
Conventional System



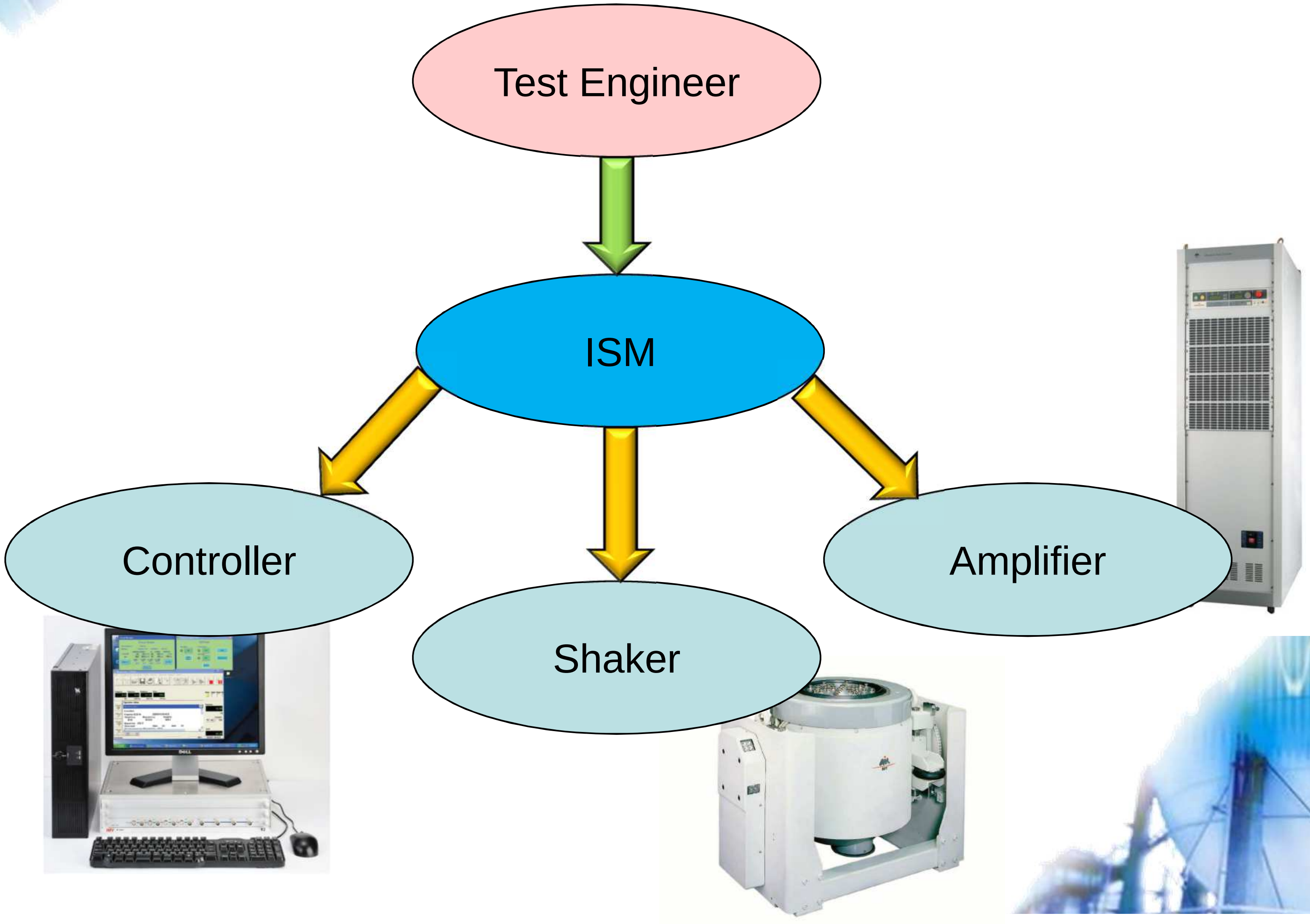
ISM-EM (Eco-Shaker)



ISM – System philosophy and architecture – non-ISM



ISM –System philosophy and architecture – ISM



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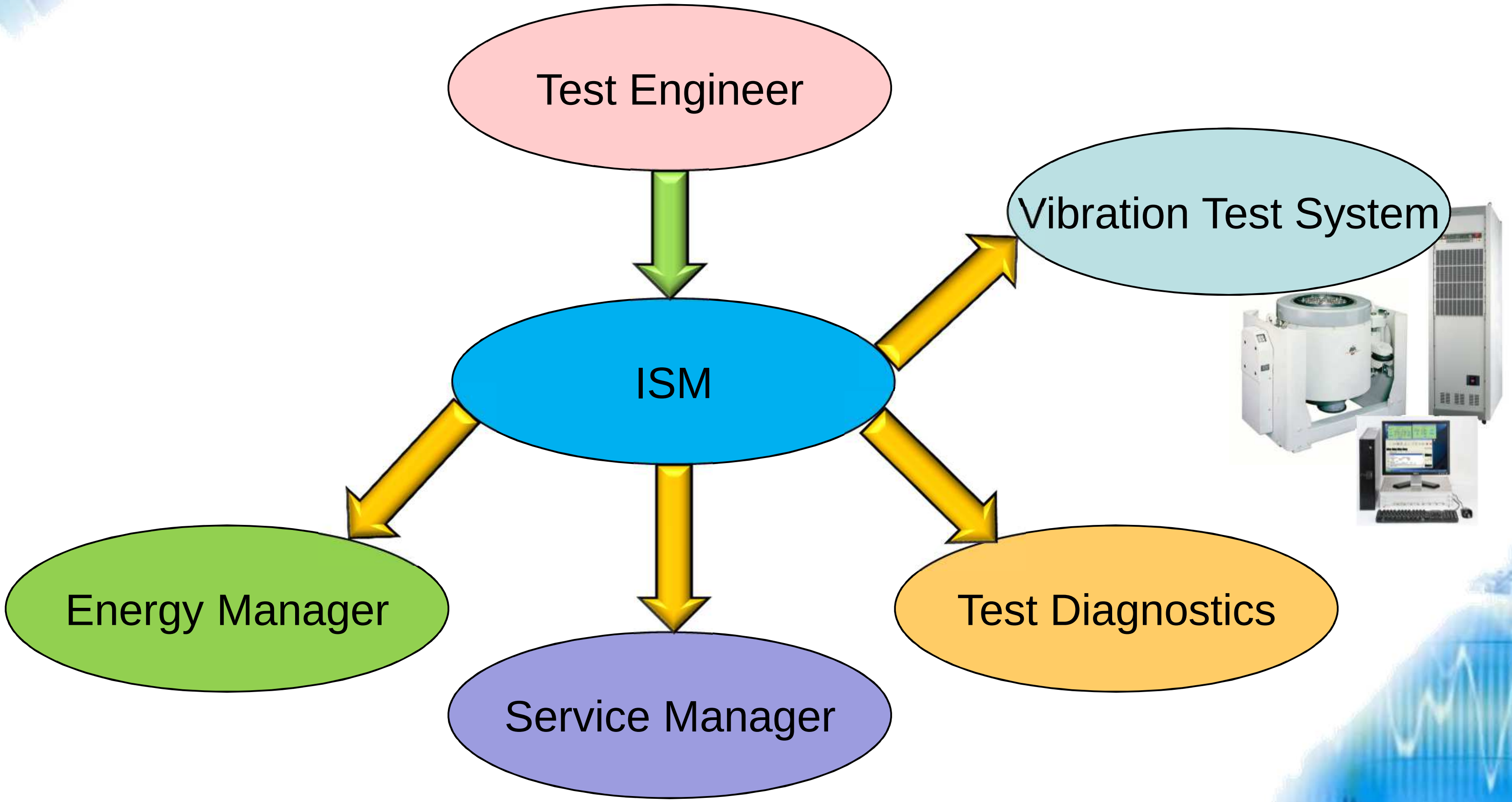
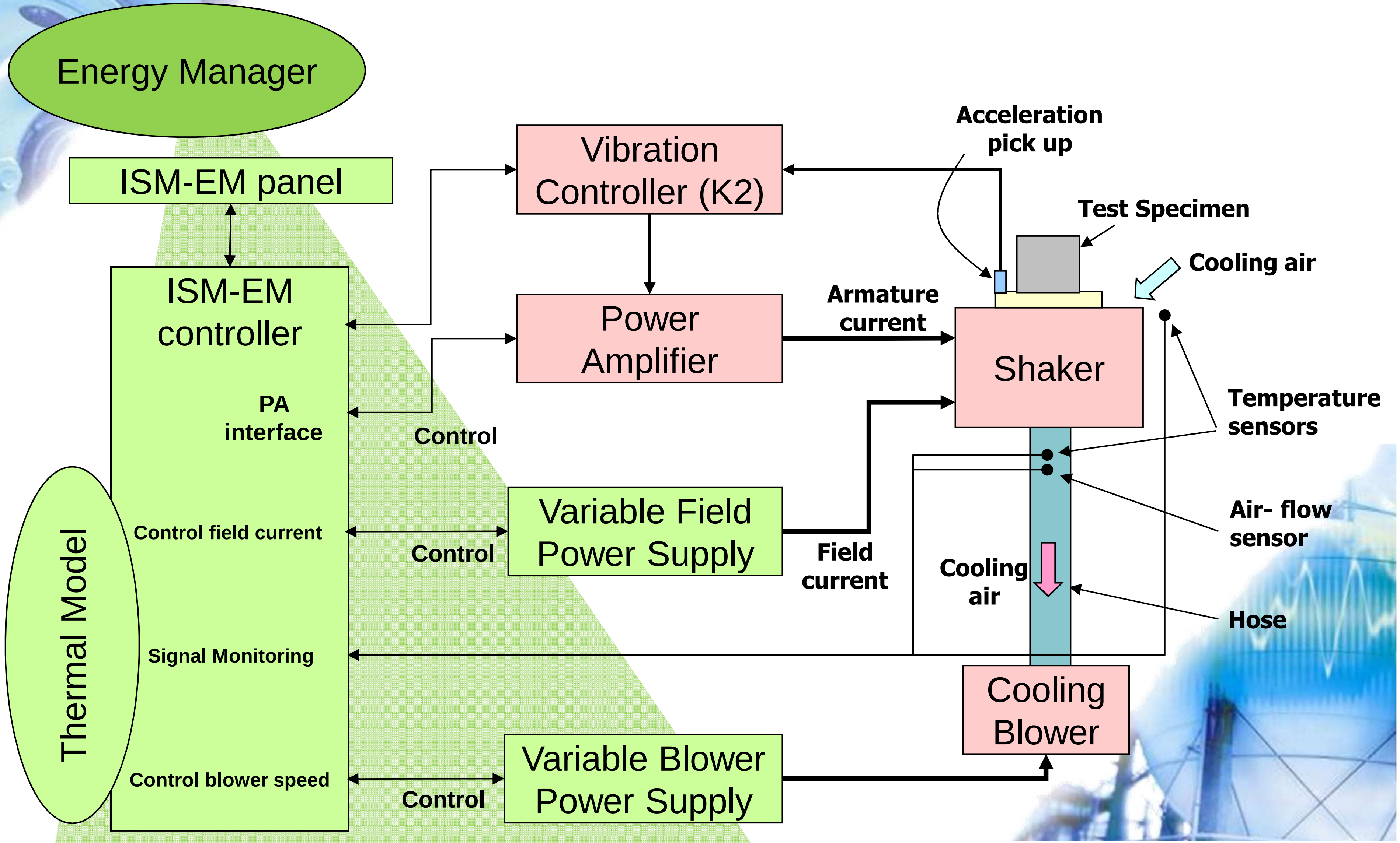


ISM –Architecture



User Benefits

User Benefits – System Specification

The table below shows a comparison between IMV's J260 (standard) and EM2605 (ECO) vibration test systems. Both systems are direct-coupled

	Standard System – J260	ECO-System – EM2605
Shock Force (kN)	108	154*
Velocity (m/s)	2.4	4.6*
Displacement (mm)	100	100
Sine/Random Force	54	54
Power required (kVA)	86	86

*These values are the maximum possible and must be traded one against the other depending on the test specification

User Benefits - Energy saving

Electricity charges and CO_2 reduction

The table below shows the estimated electricity savings and CO_2 reduction using the ECO-power saving for i240/SA3M(rated force : 24kN) and i260/SA7M (rated force : 54kN)

Unit price of electricity :	**0.15**	**€/kWh**
CO_2 emission factor :	**0.000525**	**tonne/kW**
Total hours during year :	**8760**	**Hours**

i240

Average force ratio	25%		50%	
Power saved in ECO mode (kW)	7.0		5.3	
Yearly average working ratio	25%	70%	25%	70%
Saving charges (€/year)	2,299	6,439	1,741	4,875
CO_2 reduction（tonne/year）	8.1	22.5	6.1	17.1

i260

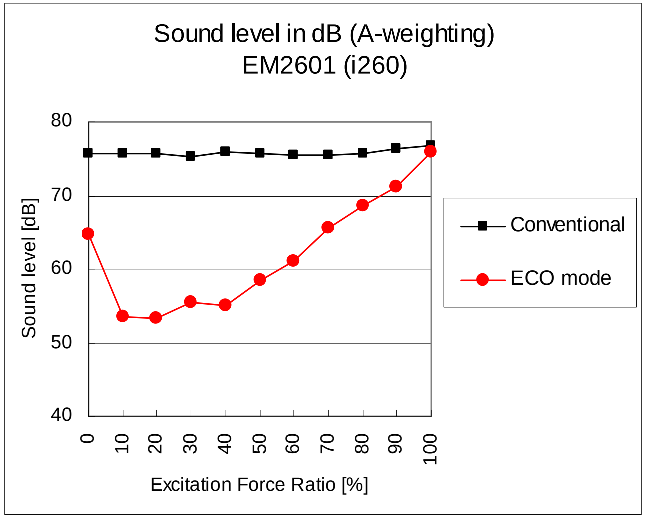
Average force ratio	25%		50%	
Power saved in ECO mode (kW)	28.1		22.8	
Yearly average working ratio	25%	70%	25%	70%
Saving charges (€/year)	10,140	28,392	8,239	23,069
CO_2 reduction（tonne/year）	32.3	90.3	26.2	73.4

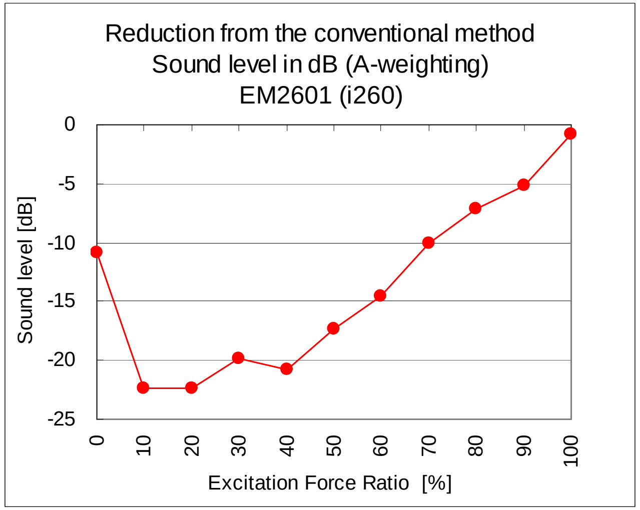
Note: CO_2 emission factor published by DEFRA (UK Government) – Conversion factors 2011

User Benefits - Noise Reduction

Cooling Blower Acoustic Noise Reduction

The table below shows the measured sound levelsthe ECO-power saving for i240/SA3M(rated force : 2.4kN)





User Benefits

- Reduced energy, CO_2 and cost of operation
- Reduced operating noise
- Improved system protection
- Increased system availability
- Increased return on investment