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29 NOVEMBER 2018
TECHNIEKHUYS - VELDHOVEN

Integrated Shaker Manager
The Future of Vibration Testing

IMV Europe - Dimitris Karigiannis

29 NOVEMBER 2018
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TOMORROW'S RELIABILITY

IMV CORPORATION

Presentation Agenda

- Emerging Vibration Test Requirements
- Vibration Test System Requirements
- Integrated Shaker Manager
- Energy Manager
- High Velocity Shock
- Service Manager
- User Benefits
- Replacement Amplifier

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, 50g 11ms, 150g 6ms are 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
  - Possibly **two test systems** to cover the wide test requirements

Integrated Shaker Manager

ISM

Integrated Shaker Manager (ISM)

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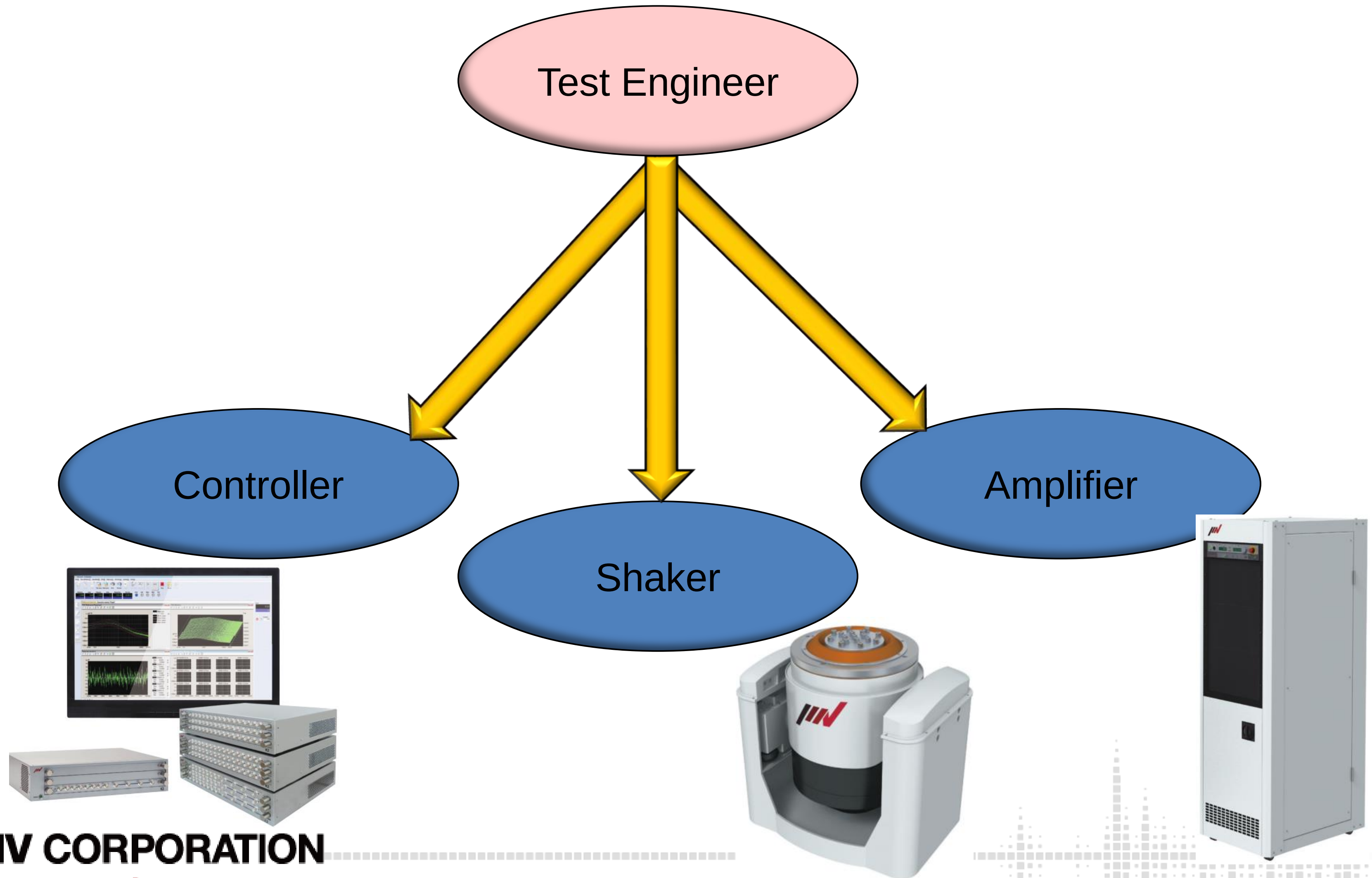
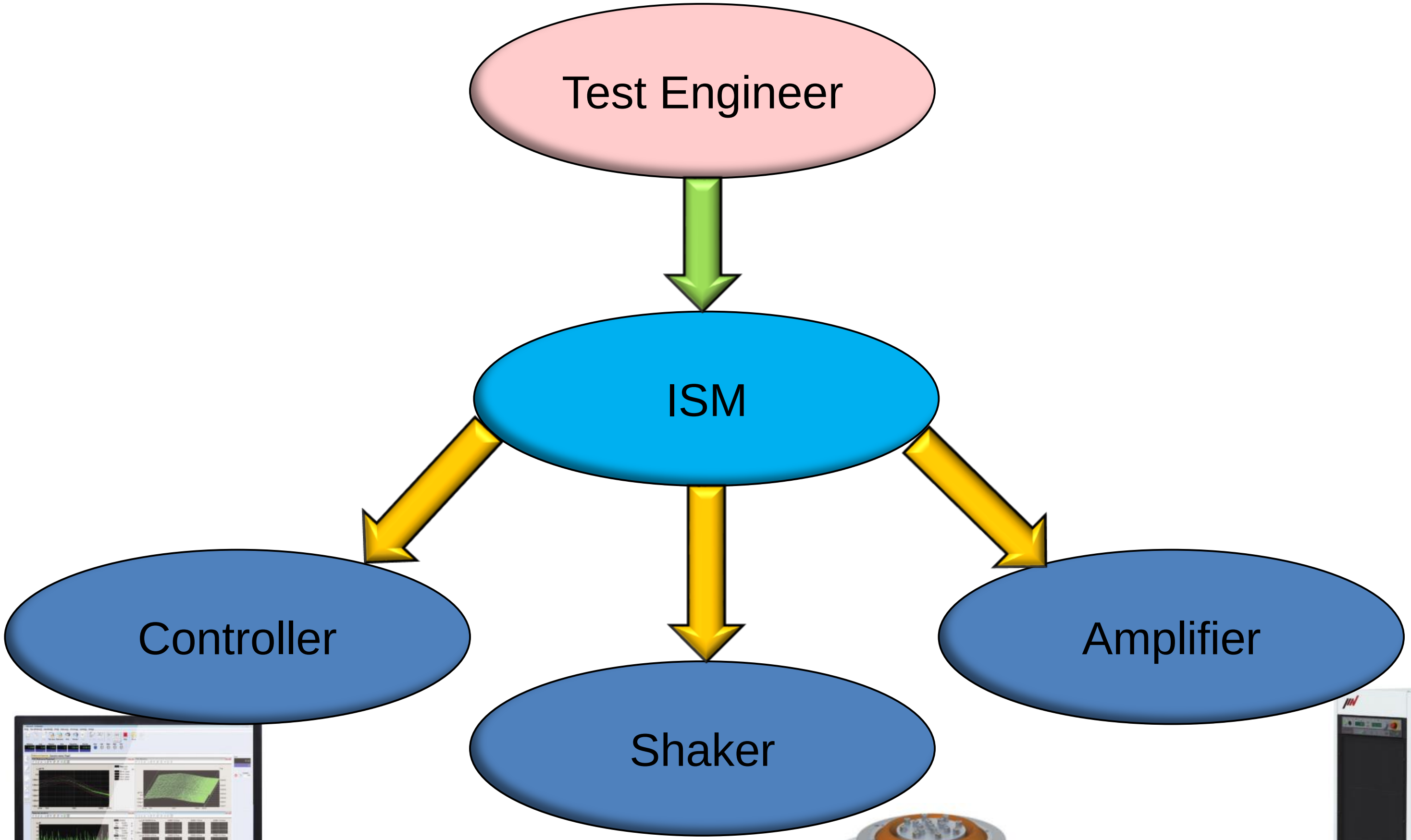
- Vision
  - Start of a journey to make a step change in Vibration Test Systems (VTS)
  - Each technology building block has been developed with the goal of ISM
    - Power Module, Field Power Supply, Cooling blower supply…..
- Traditionally the parts of VTS have been developed by separate departments
  - ISM aims to bring all components of VTS together into one, easy to use Customer interface
- To add additional functionality to a VTS that brings significant benefit to Customers over and above vibration testing
  - For example Diagnostics, Service Support
  - To increase the return on investment for Customers through energy saving and increased system availability

ISM – System philosophy and architecture – non-ISM



ISM –System philosophy and architecture – ISM



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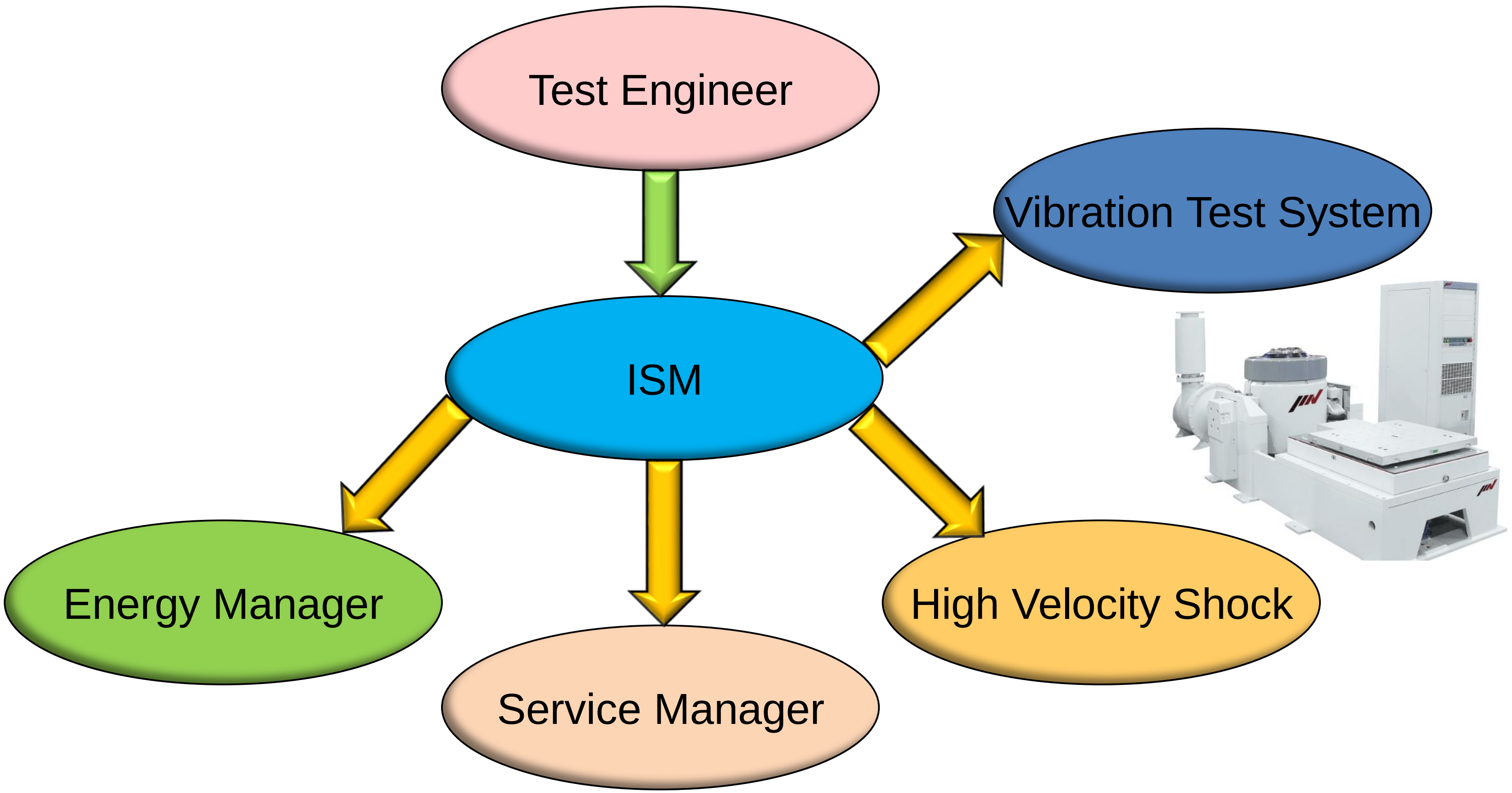
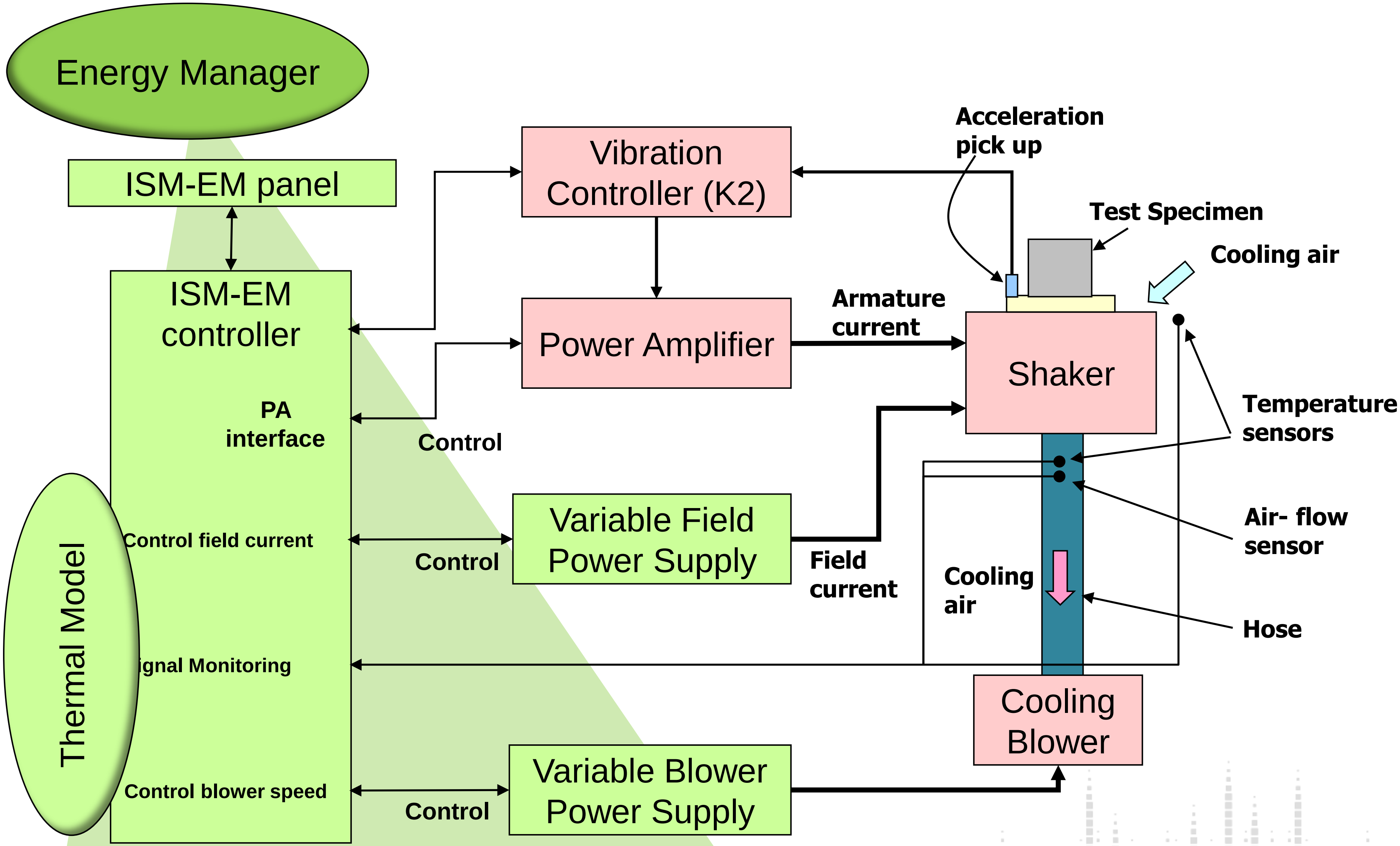
ISM –System philosophy and architecture – ISM



ISM –Architecture



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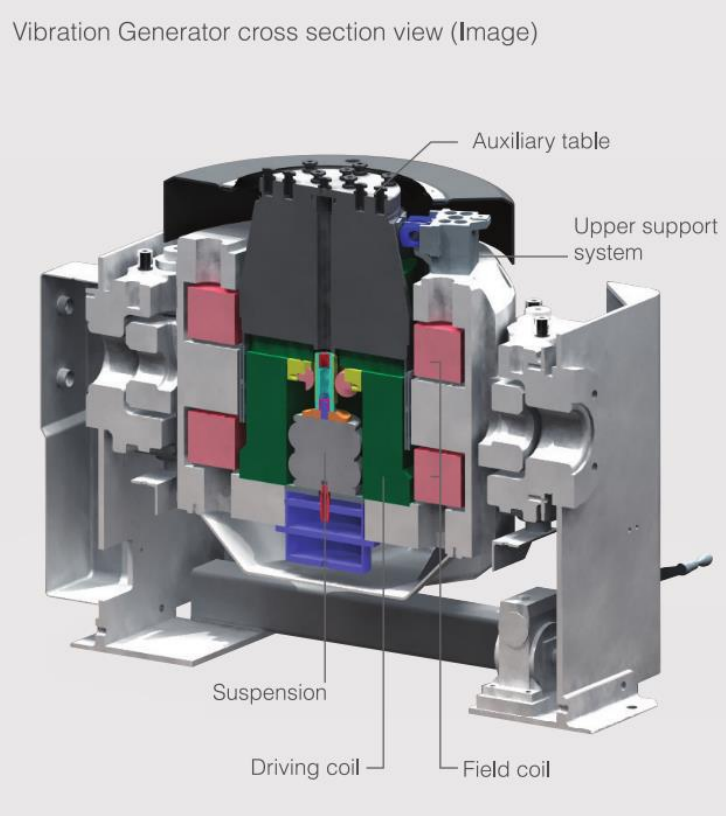
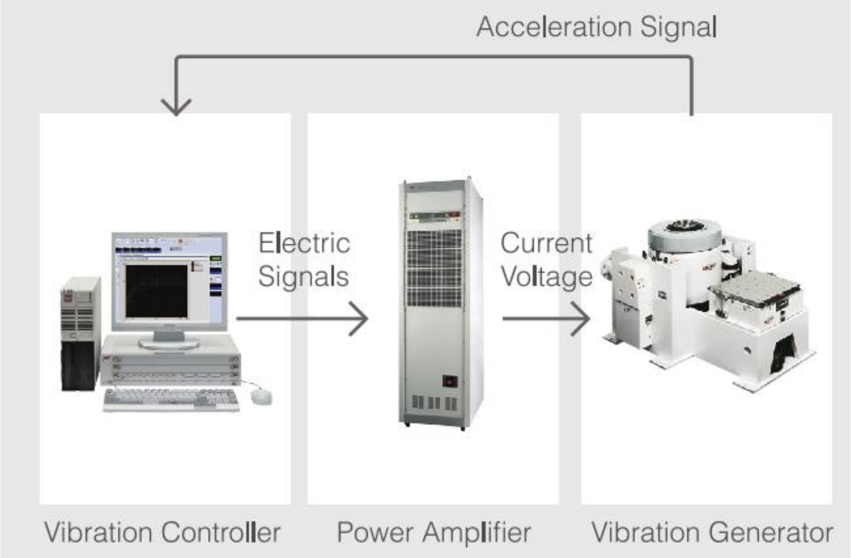
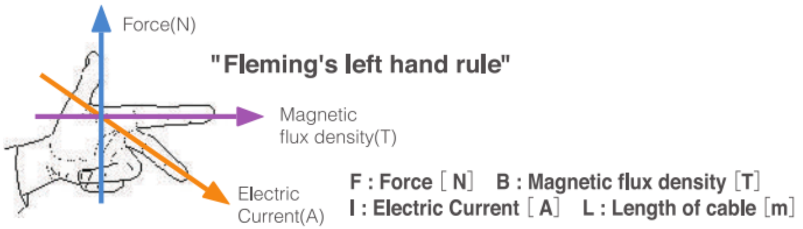
Energy Manager

Energy Manager

How does a shaker work?







How does a shaker work?

$$F = I * B * l$$

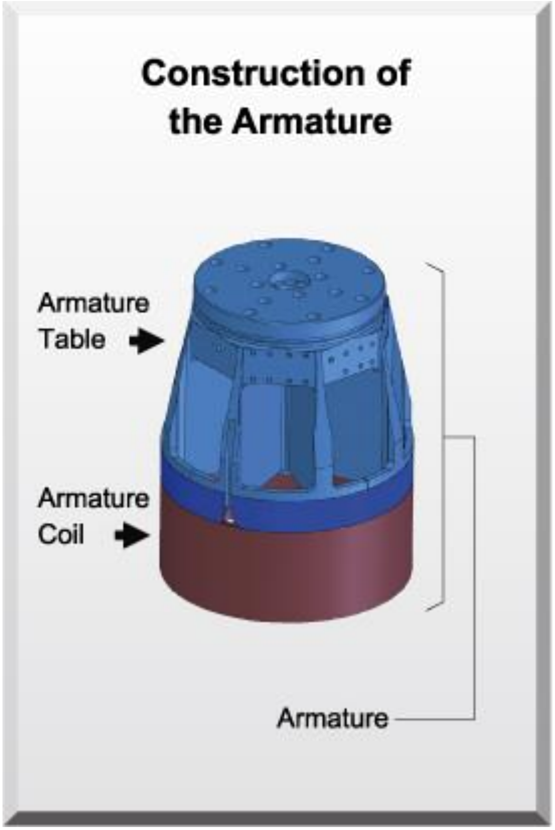
$$F = m * a$$

$$F \sim I$$

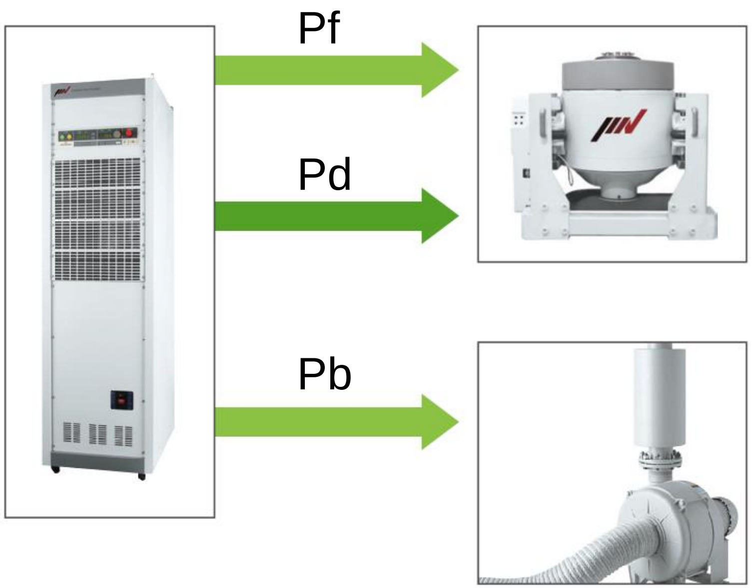
with constant mass:

$$a \sim I$$

$$v = \frac{U}{B * l}$$



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

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, reduces temperature in the shaker, increases reliability and reduces maintenance

Integrated Shaker Manager (ISM)

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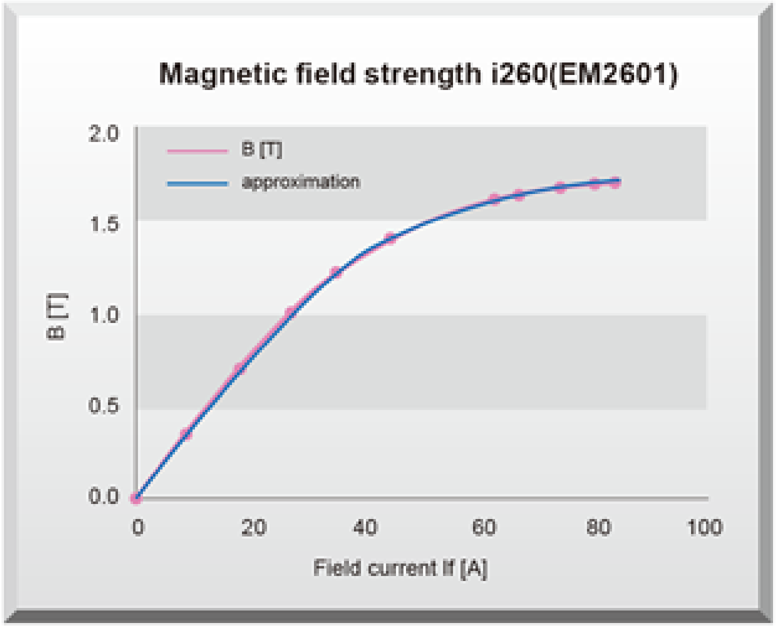
- Manual Setting is possible, but severe limitations
  - How to predict the required levels in advance and during changes in the test
- Optimisation issues
  - P = Pf + Pd + Pb
  - F1 = B*L*Id



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- 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

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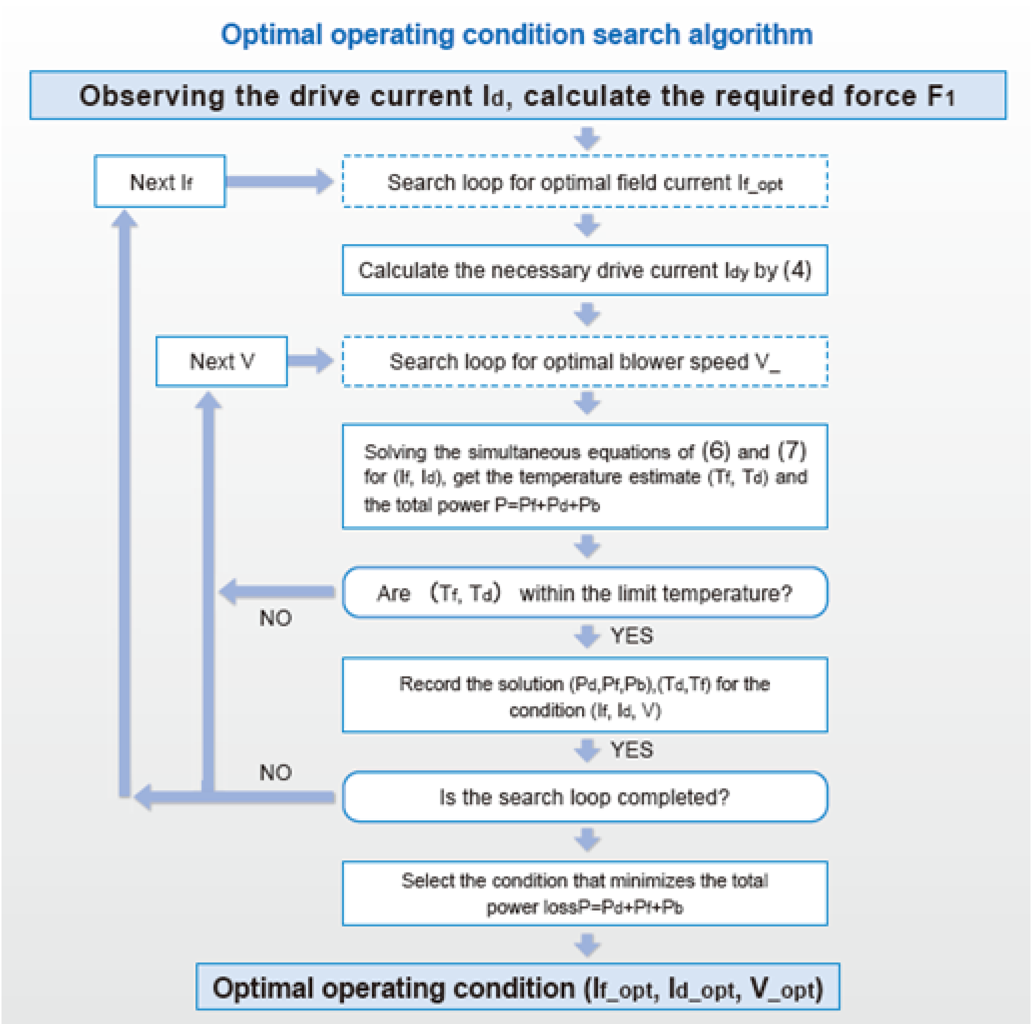

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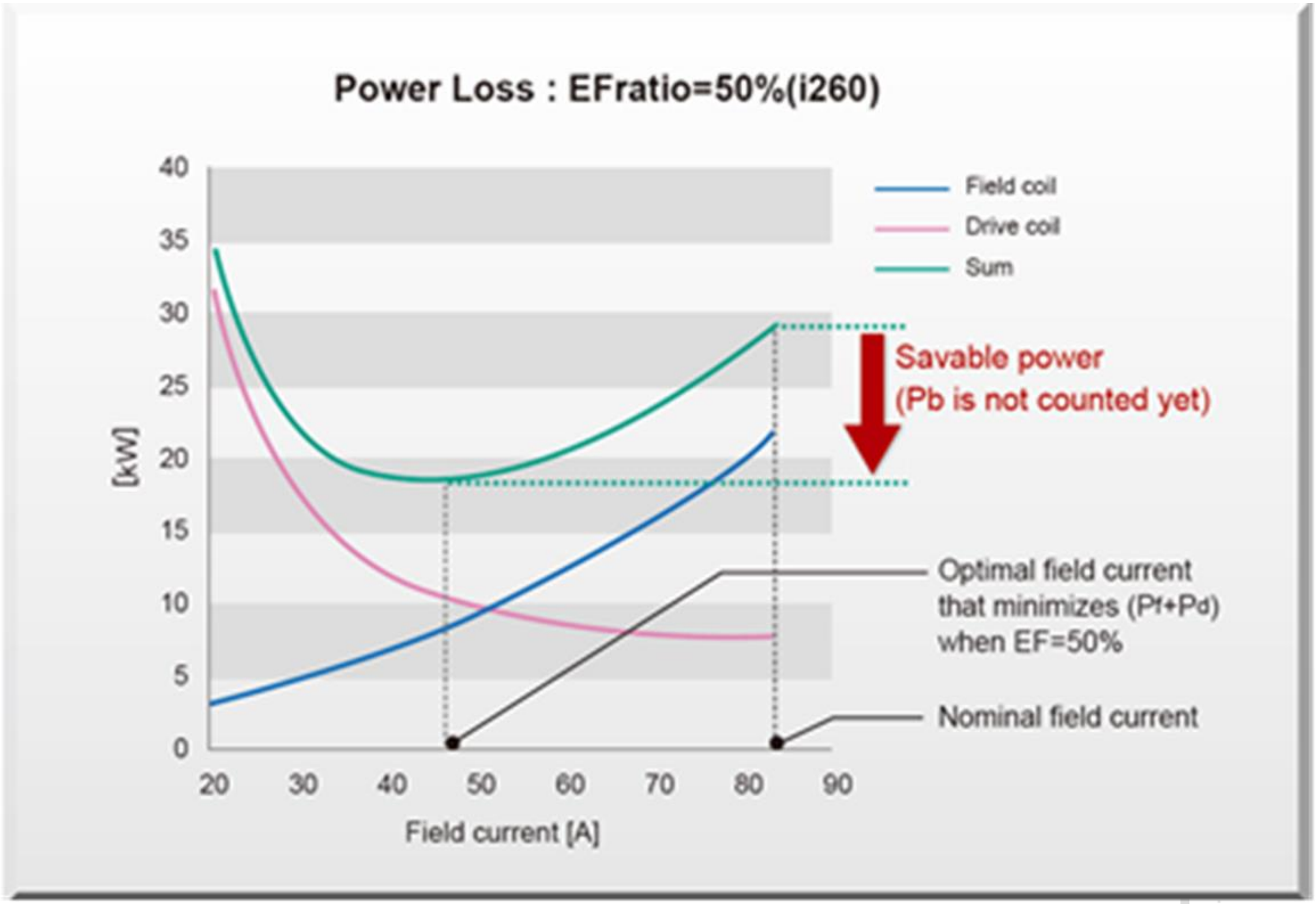
Energy Saving

Optimum value for Armature and Field coil



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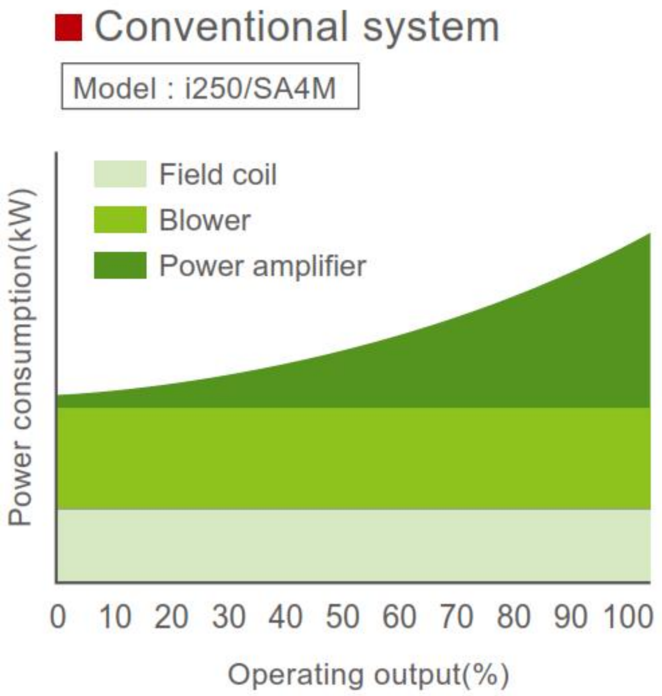
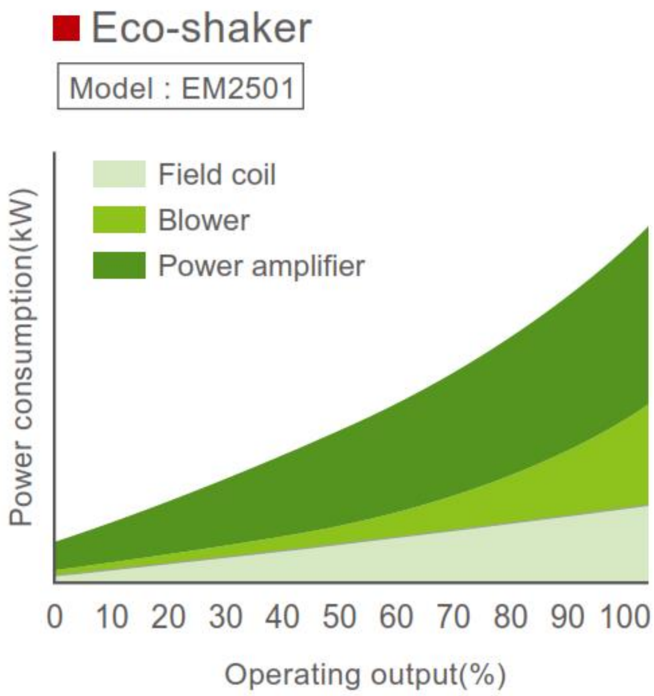
Comparison of Operating Methods

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

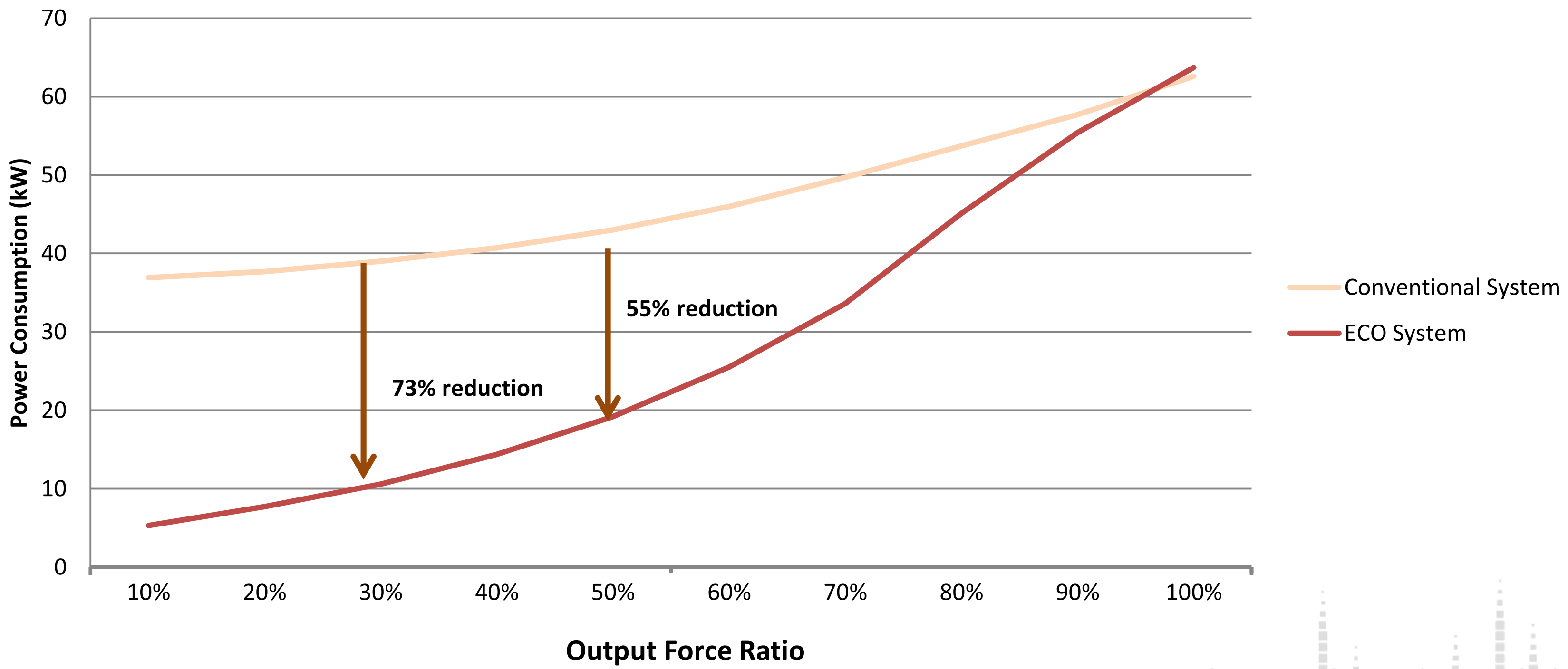




Energy saving

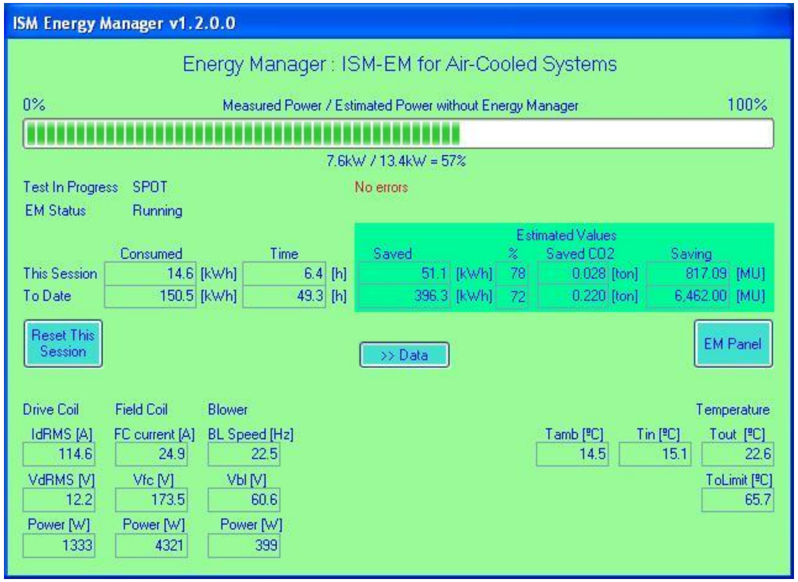
Eco-Shaker achieves 55% reduction of power consumption at 50% output force, and 73% reduction at 30% output force !!

Measurement Comparison of an ISM-EM system and a Conventional System
IMV Model EM2601



Energy Manager

Energy Manager



- Power Management –**<u>Automatically</u>** controls the power needed to run a test
- Energy Manager calculates CO_2 Emissions savings for each test
- Cost savings of power to run the test is automatically calculated
- Eliminates wasting power when the system is in pre test mode
- Reduction in noise pollution is a major benefit

eco-shaker

High Velocity Shock

High Velocity Shock

Key factors in a vibration test system

Armature force (F) = field density (b) x armature coil length (l) x armature current (i) (F = bil)

Armature voltage (e) = field density (b) x armature coil length (l) x velocity (v) (e = blv)

Maximum amplifier **armature voltage (e)** normally determines maximum **velocity** for a shaker

Maximum amplifier **armature current (i)** normally determines the maximum **force** for a shaker

With the above two formulas we can see:

Armature force (F) x velocity (v) = Armature voltage (e) x armature current (i)

This is constant for a given amplifier!

Key factors in a vibration test system

Armature force (F) = field density (b) x armature coil length (l) x armature current (i) (F = bil)

Armature voltage (e) = field density (b) x armature coil length (l) x velocity (v) (e = blv)

Armature force (F) x velocity (v) = Armature voltage (e) x armature current (i)

Therefore with 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.

Key factors in a vibration test system

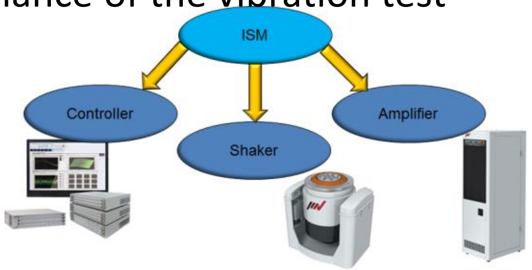
Armature force (F) = field density (b) x armature coil length (l) x armature current (i) (F = bil)

Armature voltage (e) = field density (b) x armature coil length (l) x velocity (v) (e = blv)

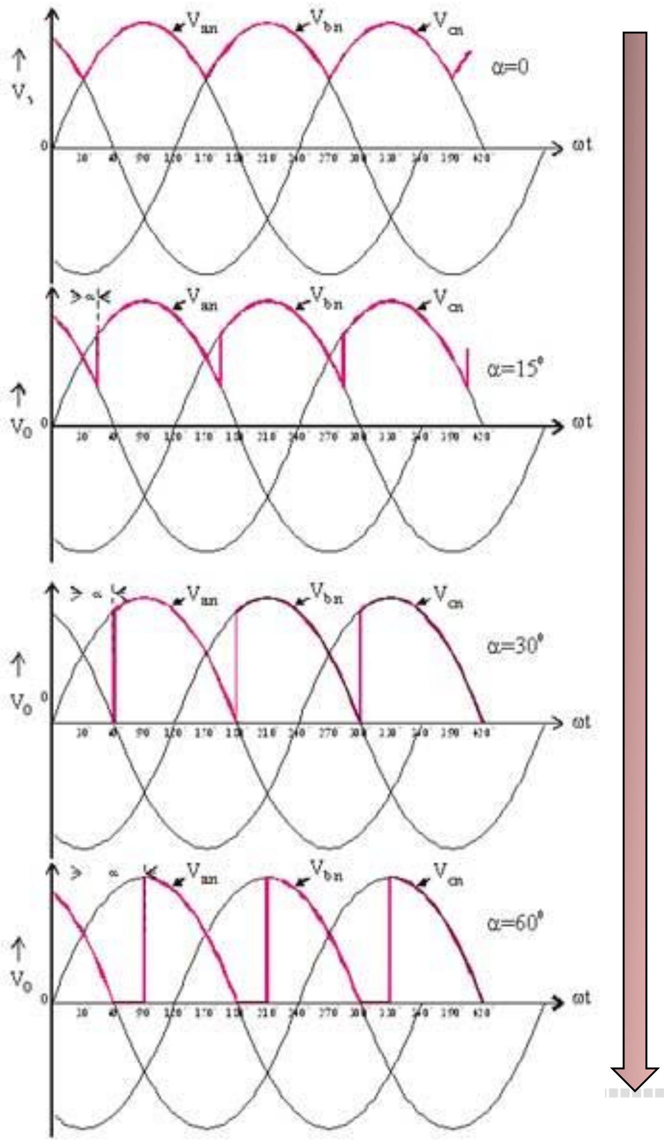
Armature force (F) x velocity (v) = Armature voltage (e) x armature current (i)

Therefore with a given ‘e’ and ‘i’ (amplifier rating) we can ‘trade’ force and velocity to suit a varying test requirement.

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



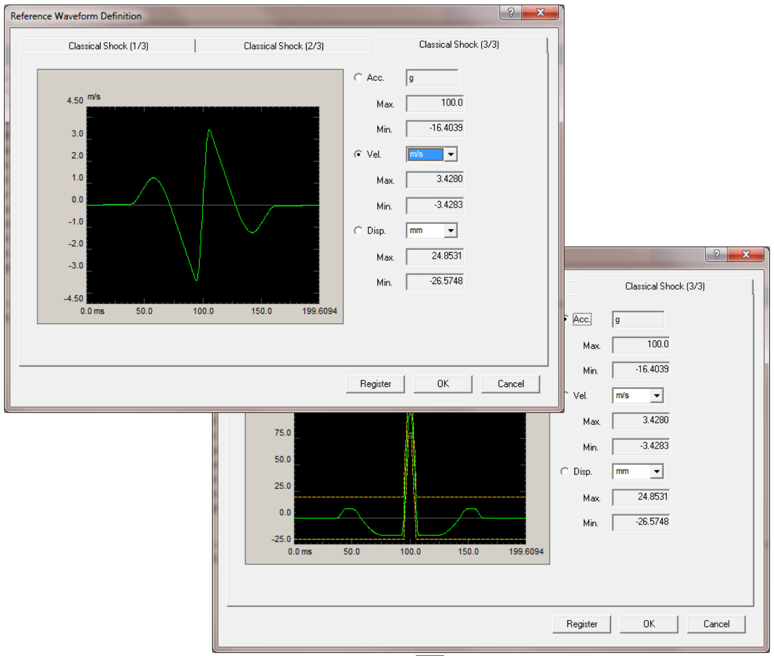
Field Control



- 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



$e = blv$

$F = bil$

- 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

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

Service Manager

Service Manager

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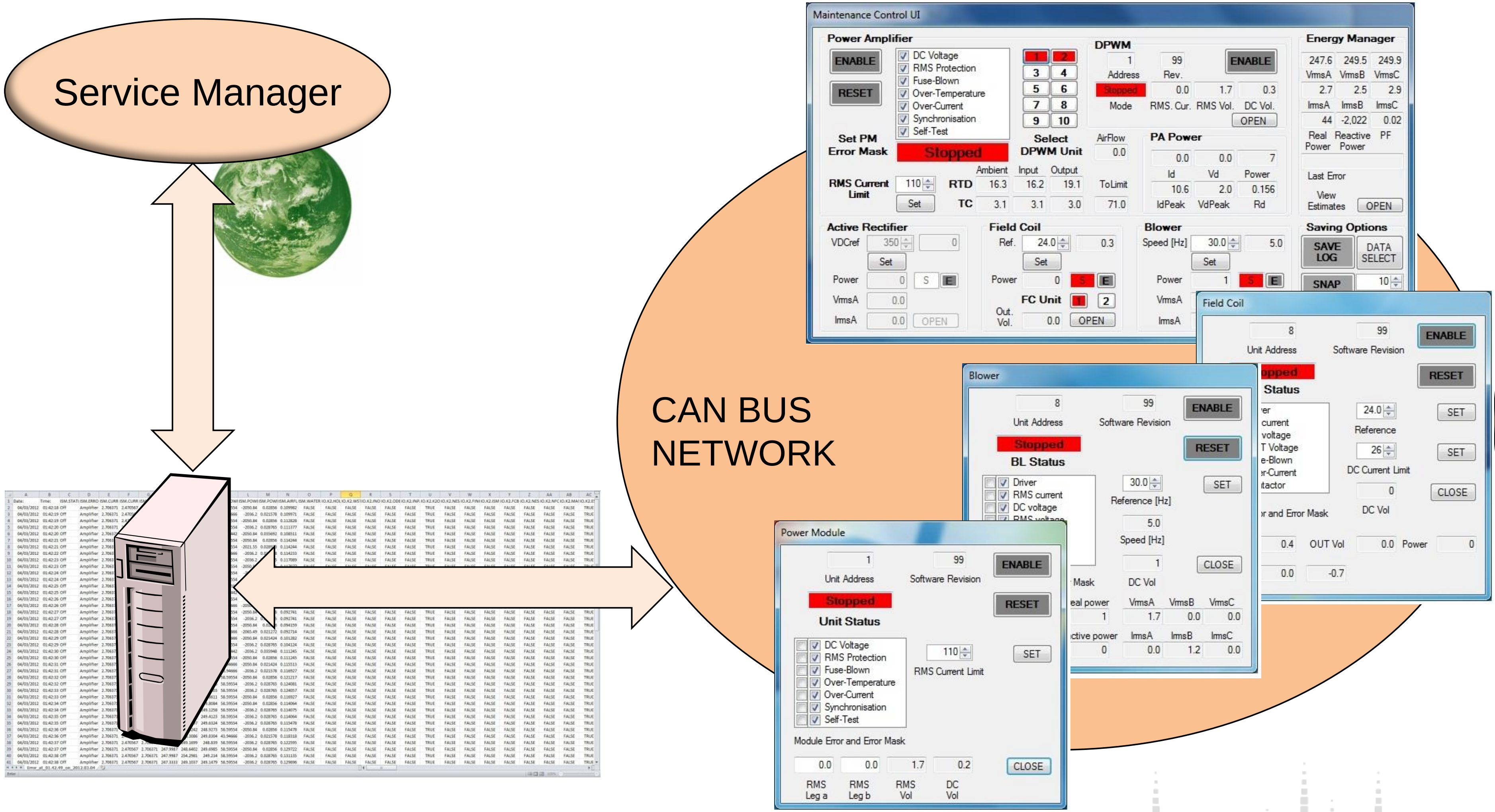
Service Manager



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Service Manager

Service Manager

- All operating parameters of the system are recorded
- Remote system health checking can be performed allowing predictive maintenance
- Problems with tests aborting can be diagnosed remotely
- Providing increased system availability and improved return on investment

User Benefits

User Benefits – System Specification

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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	3.5*
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 test speciation

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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)		
Yearly average working ratio		
Saving charges (€/year)		
CO_2 reduction（tonne/year）		

i260

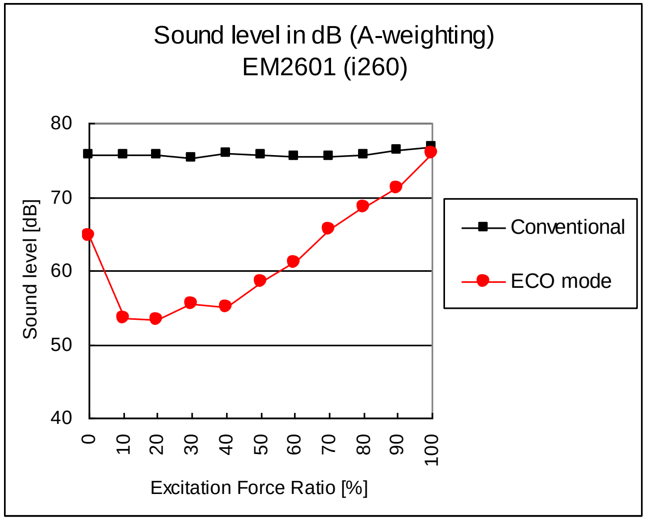
Average force ratio	
Power saved in ECO mode (kW)	
Yearly average working ratio	
Saving charges (€/year)	
CO_2 reduction（tonne/year）	

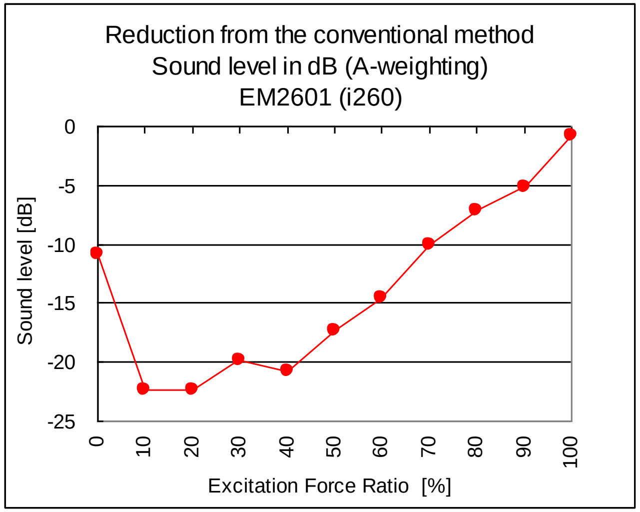
Note: CO_2 emission factor published by DEFRA (UK Government) – Conversion factors 2011

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)





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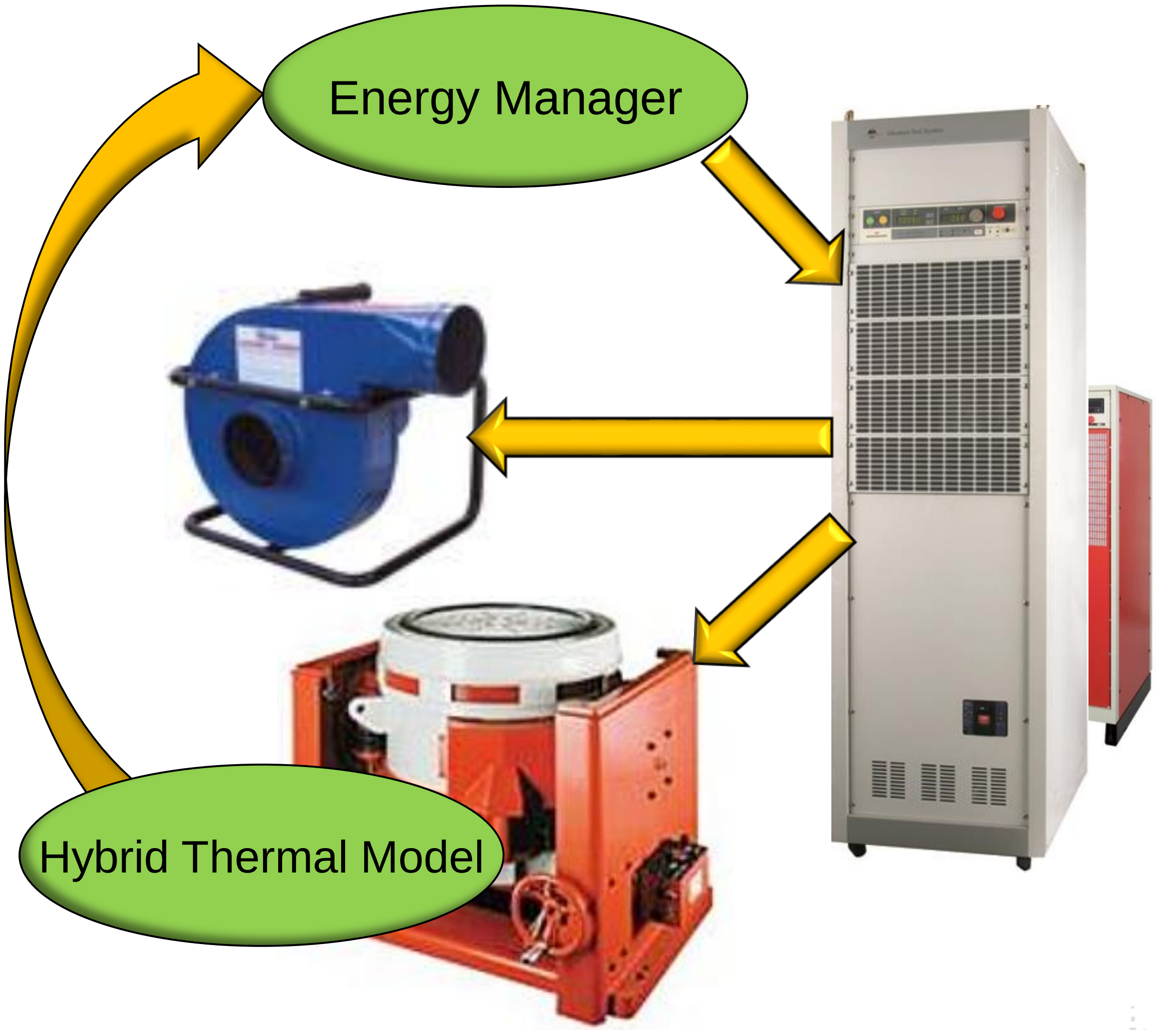
User Benefits

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

Amplifier Replacement



Any Questions?

Thank you for listening to my Presentation

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