



Integrated Shaker Manager The Future of Vibration Testing

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29 NOVEMBER 2018
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Presentation Agenda



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

- 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)



- 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



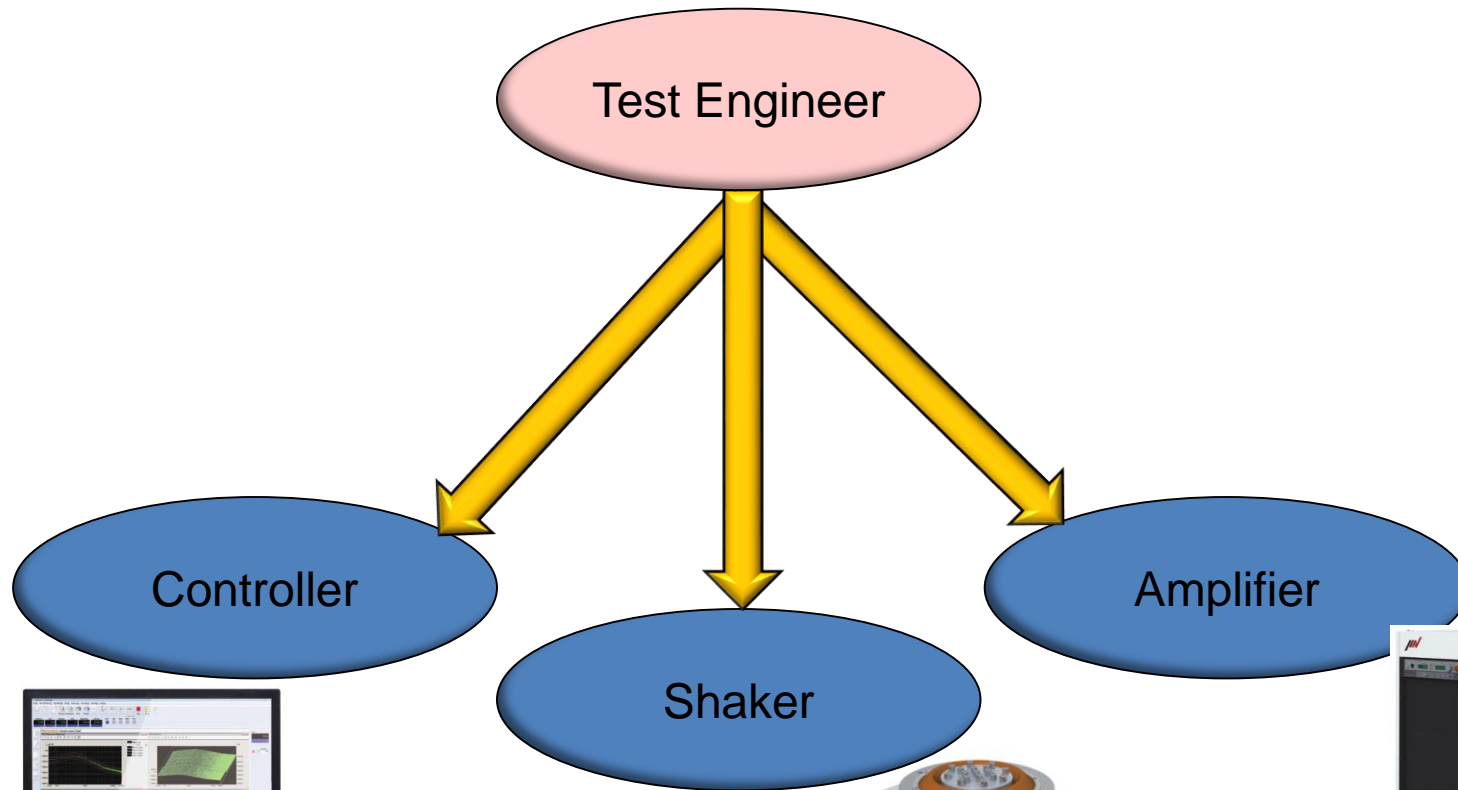
Integrated Shaker Manager



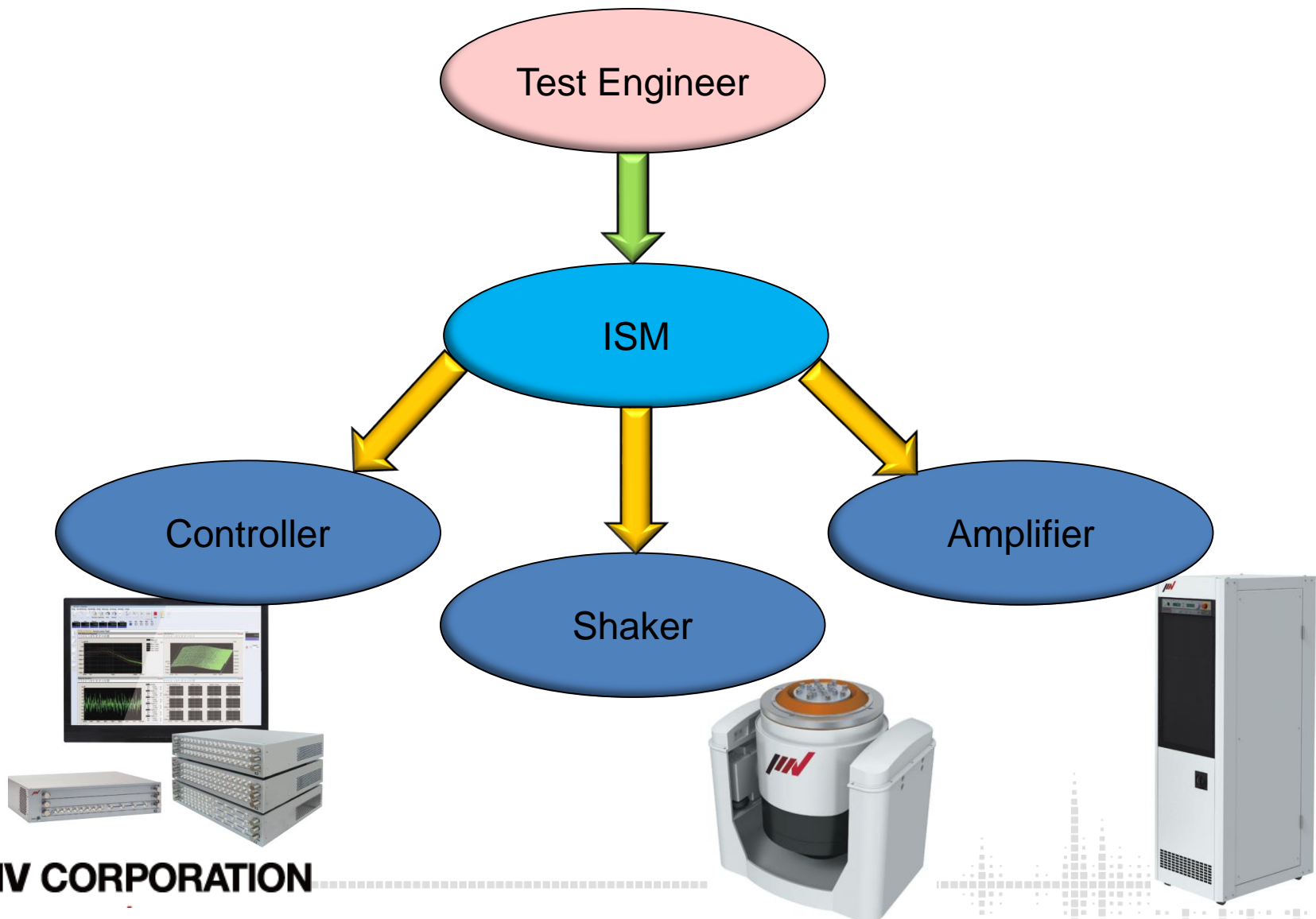
ISM



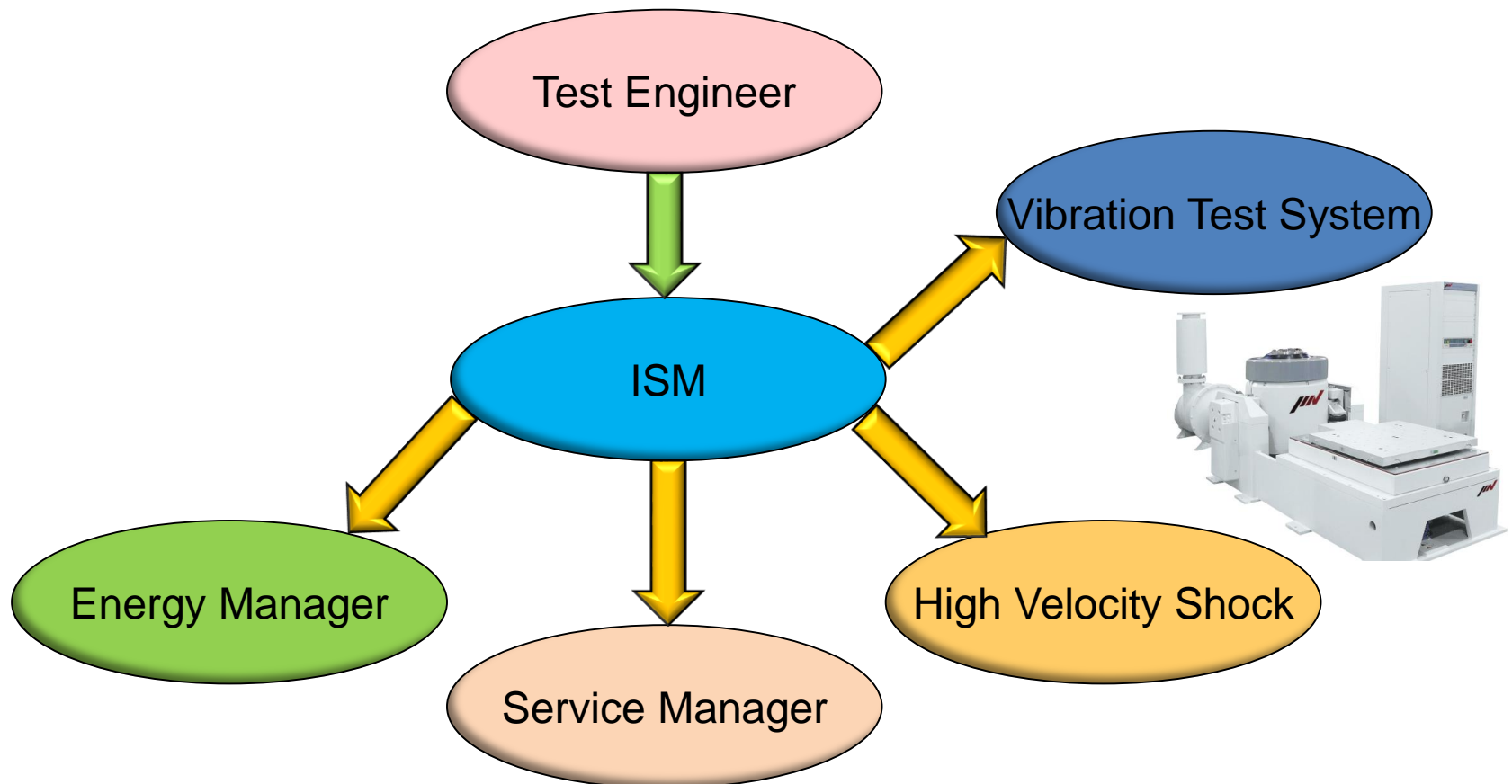
- Vision
 - Start of a journey to make a step change in Vibration Test Systems (VTS)
 - Each technology building block has been developed with the goal of ISM
 - Power Module, Field Power Supply, Cooling blower supply.....
- Traditionally the parts of VTS have been developed by separate departments
 - 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



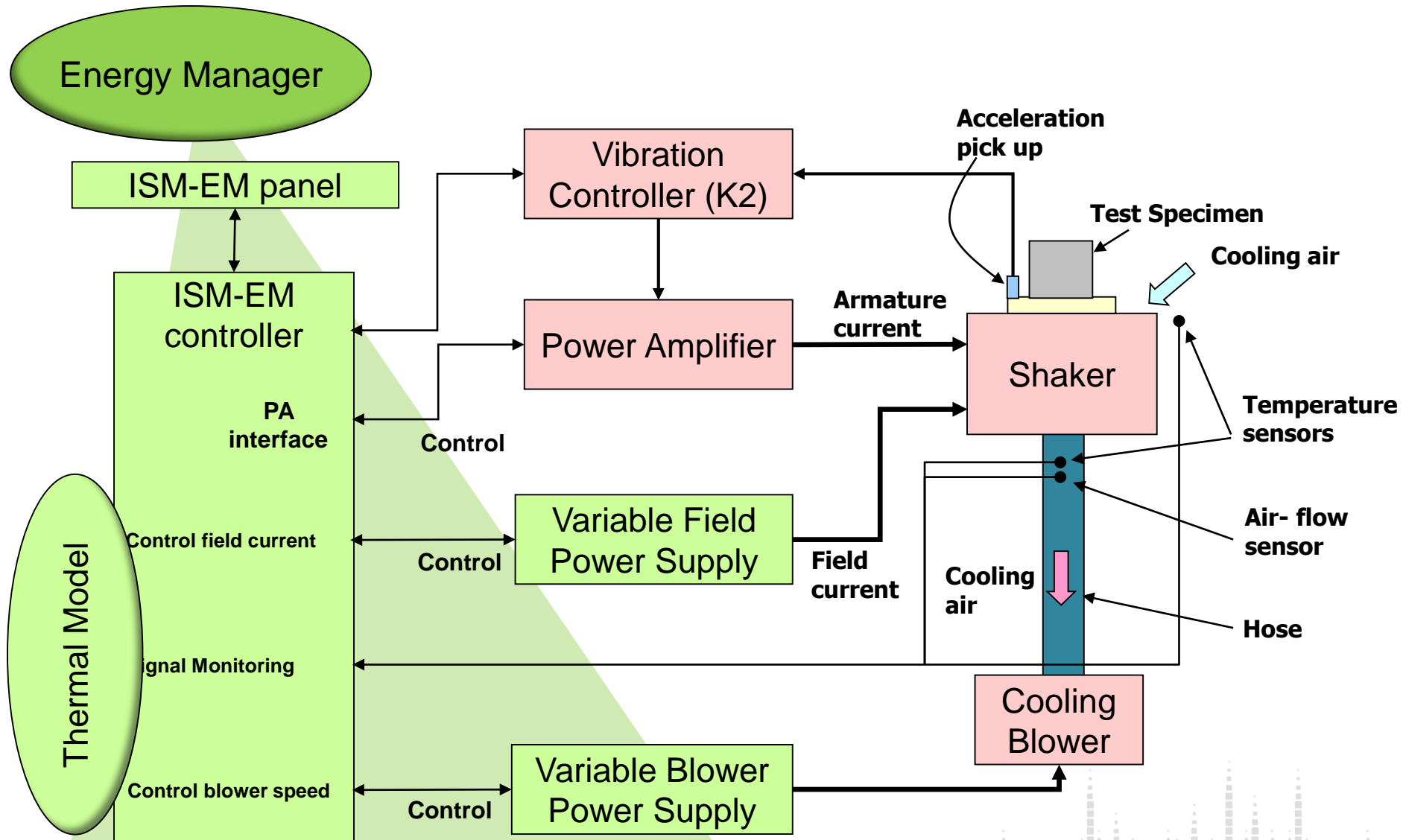
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ISM –Architecture



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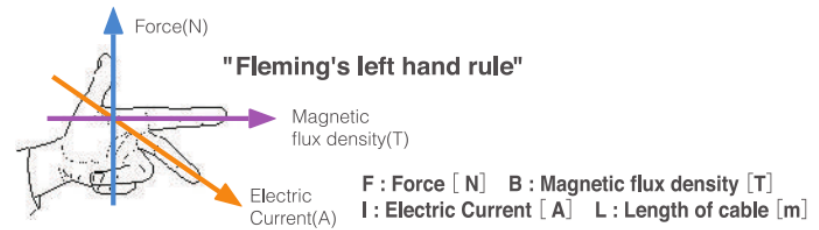
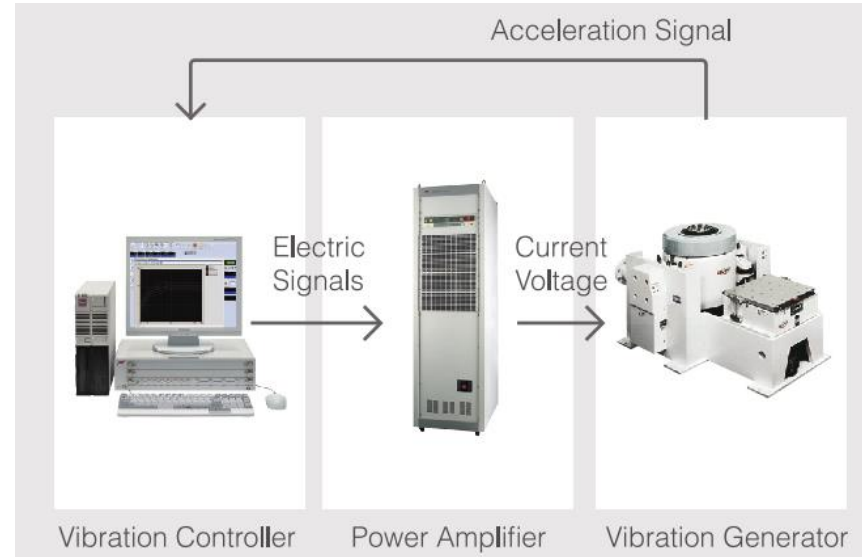
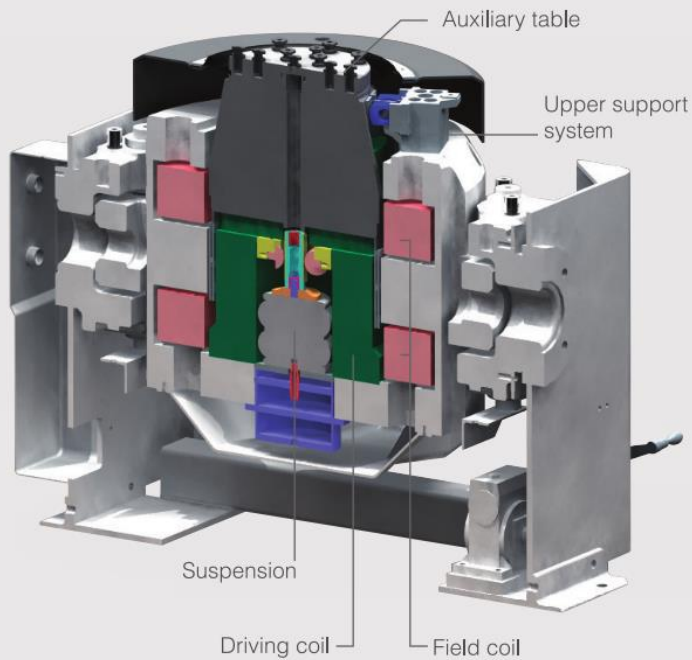
Energy Manager



Energy Manager

How does a shaker work?

Vibration Generator cross section view (Image)



How does a shaker work?



$$F = I * B * l$$

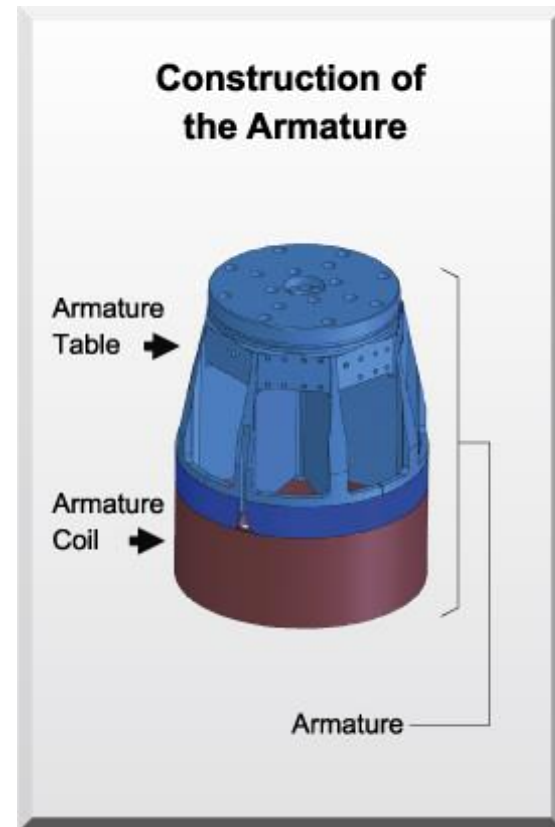
$$F = m * a$$

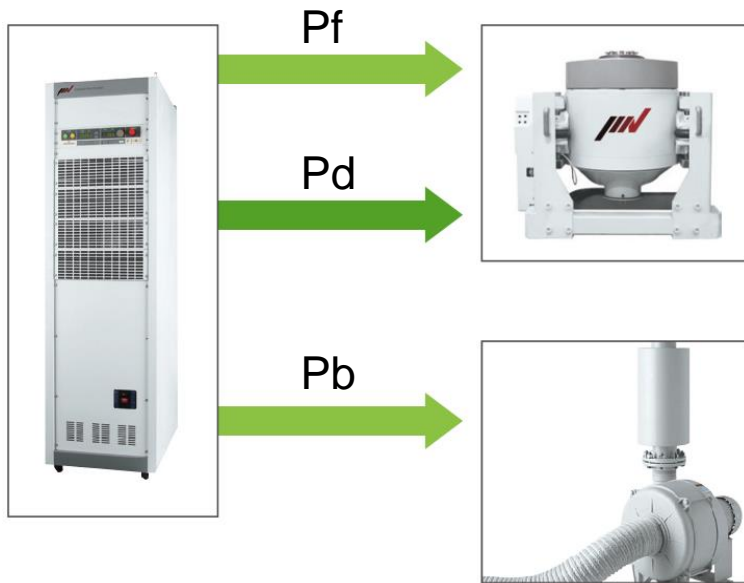
$$F \sim I$$

with constant mass:

$$a \sim I$$

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





Conventional Vibration system

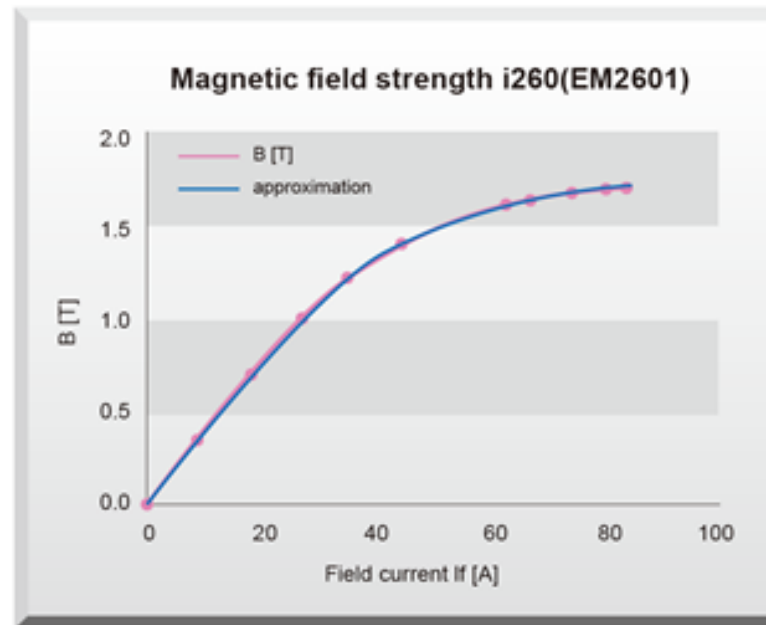
- Field current and blower speed are always set to nominal values
- This always gives maximum power loss in the field and blower
- Only the armature power loss varies in proportion to the output force

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

Energy Manager

- Manual Setting is possible, but severe limitations
 - How to predict the required levels in advance and during changes in the test
- Optimisation issues
 - $P = P_f + P_d + P_b$
 - $F_1 = B \cdot L \cdot I_d$



- Optimisation issues

$$I_d = \frac{F_1}{B(I_f) \cdot L}$$

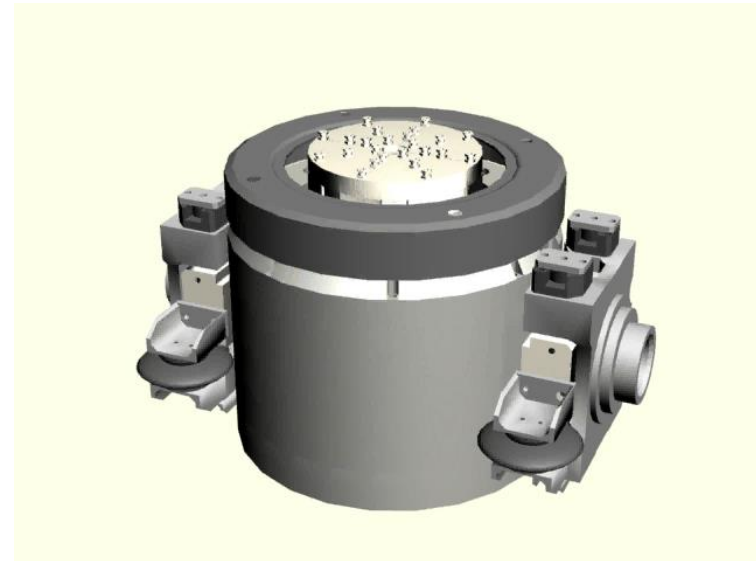
- $P_f = R_{f0} \cdot I_f^2$
- $P_d = R_{d0} \cdot I_d^2$
- $P_f = R_{f0} \cdot [1 + C_f \cdot (T_f - T_{f0})] \cdot I_f^2$
- $P_d = R_{d0} \cdot [1 + C_d \cdot (T_d - T_{d0})] \cdot I_d^2$

- Temperature model

- $T_f = f(P_f, P_d, V) + T_{in}$
- $T_d = g(P_f, P_d, V) + T_{in}$
- Winter and summer have different optimisation points

- Outlet air temperature check

- $T_{out} = h(P_f, P_d, V) + T_{in}$

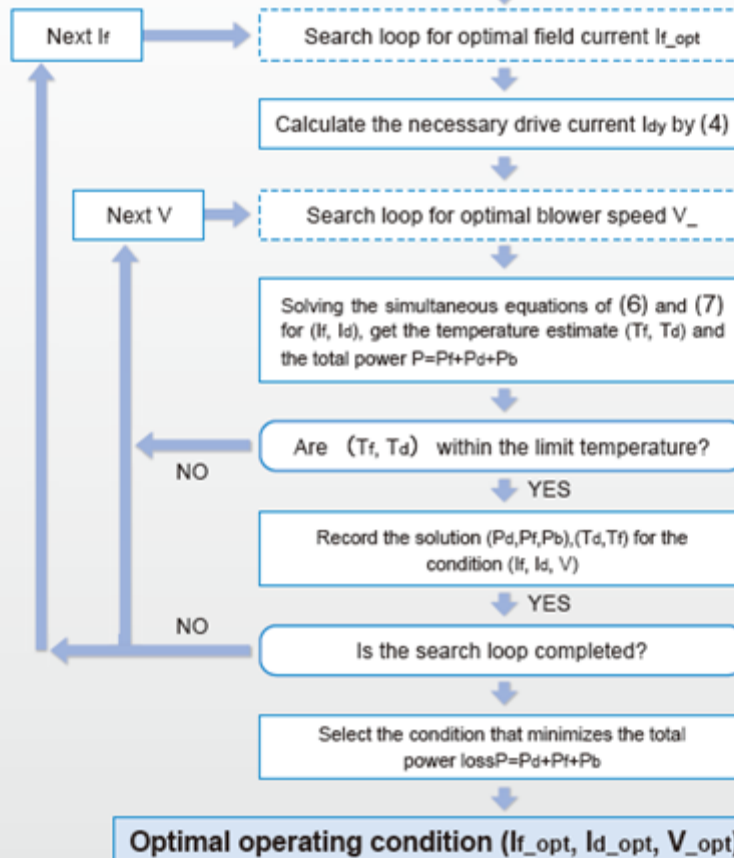


Integrated Shaker Manager (ISM)



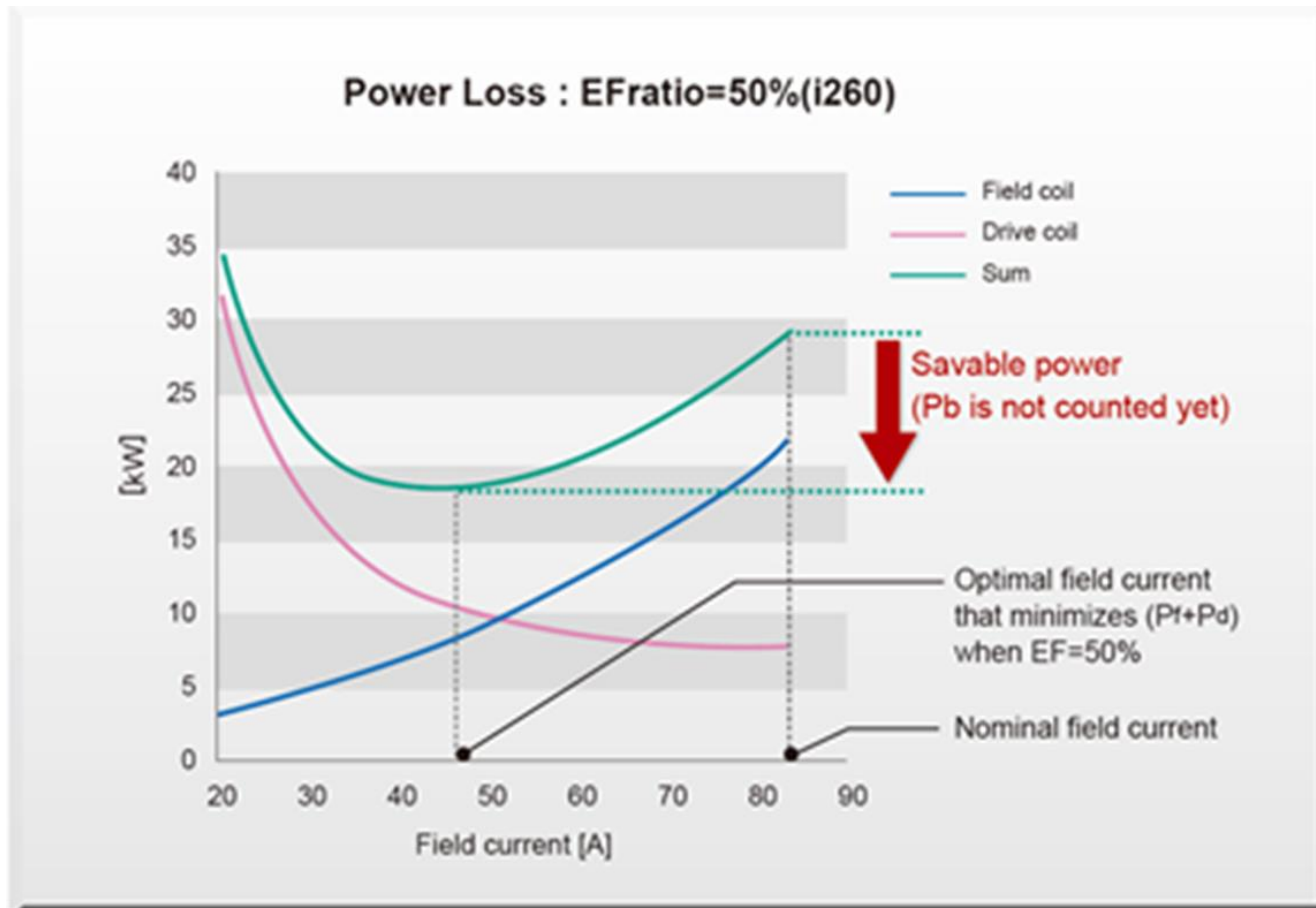
Optimal operating condition search algorithm

Observing the drive current I_d , calculate the required force F_1



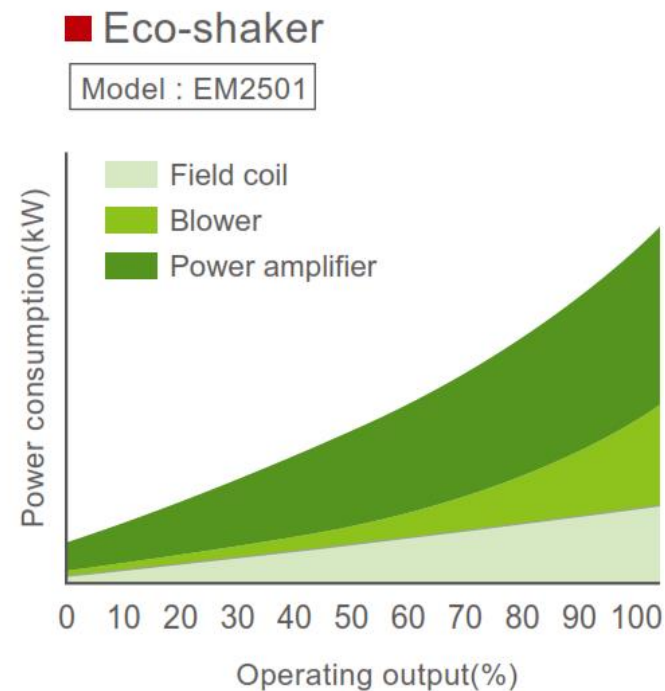
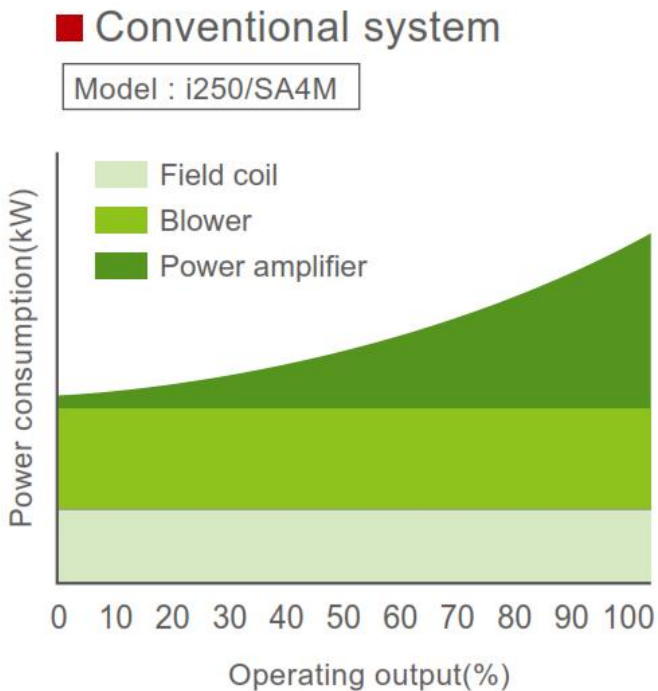
Energy Saving

Optimum value for Armature and Field coil



Comparison of Operating Methods

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

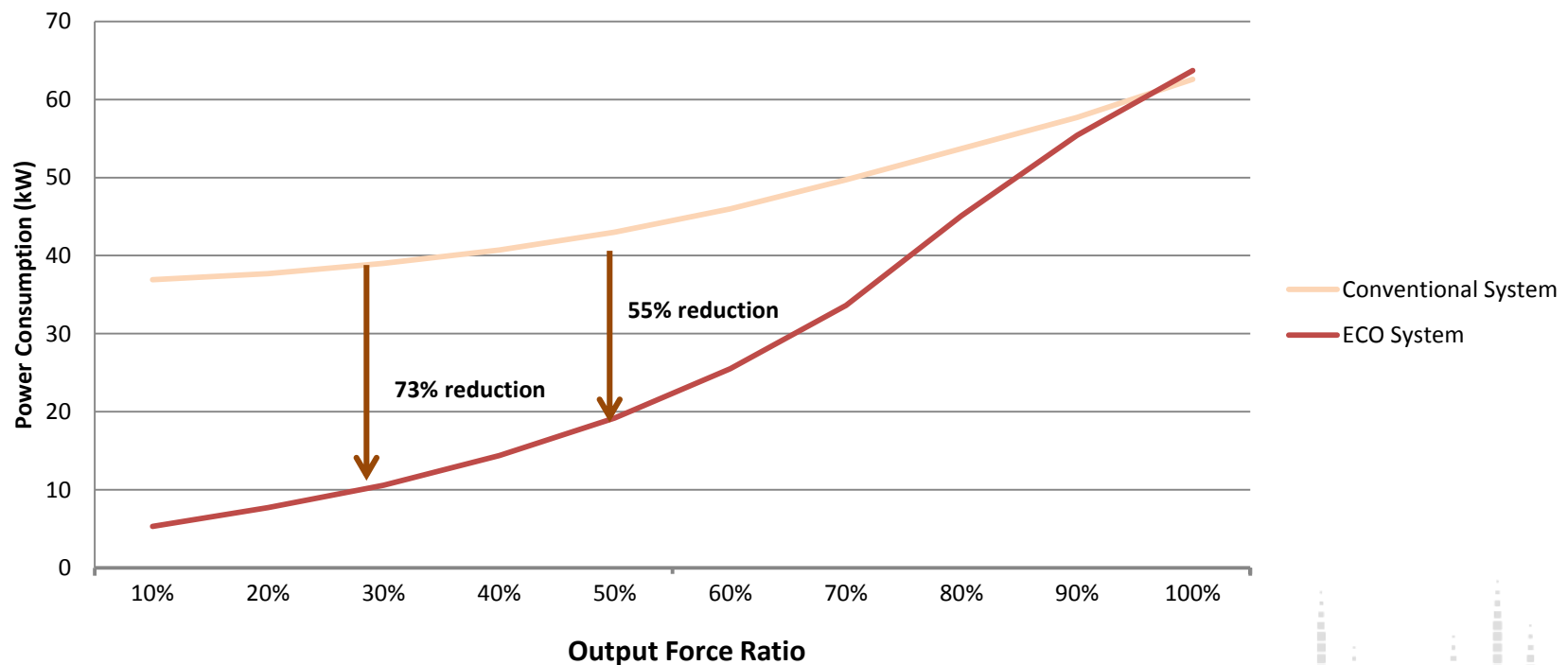


Energy saving



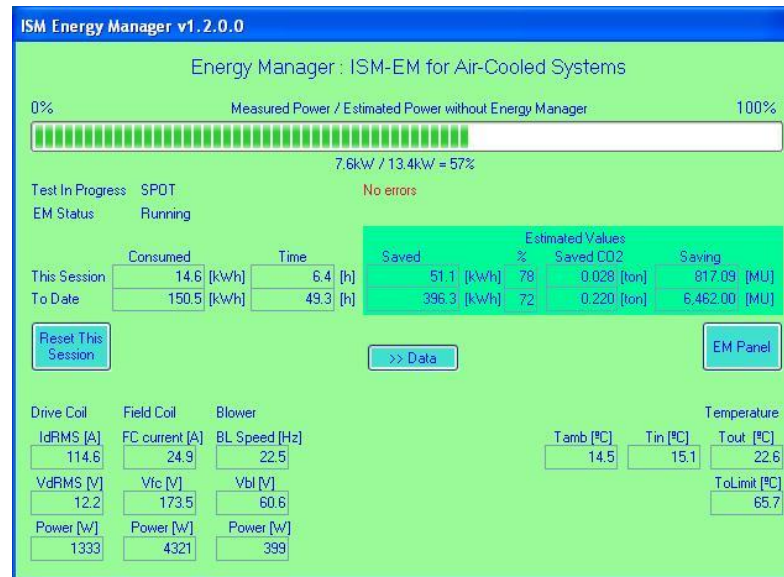
Eco-Shaker achieves 55% reduction of power consumption at 50% output force, and 73% reduction at 30% output force !!

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



Energy Manager

Energy Manager



- Power Management –**Automatically** controls the power needed to run a test
- Energy Manager calculates CO₂ 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



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

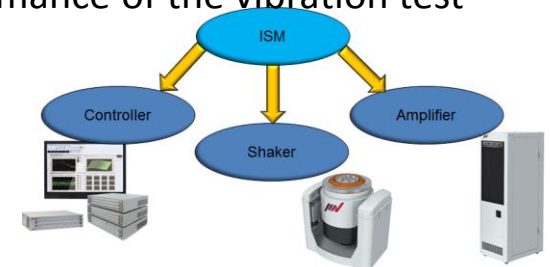
Armature force (F) = field density (b) x armature coil length (l) x armature current (i) (F = bil)

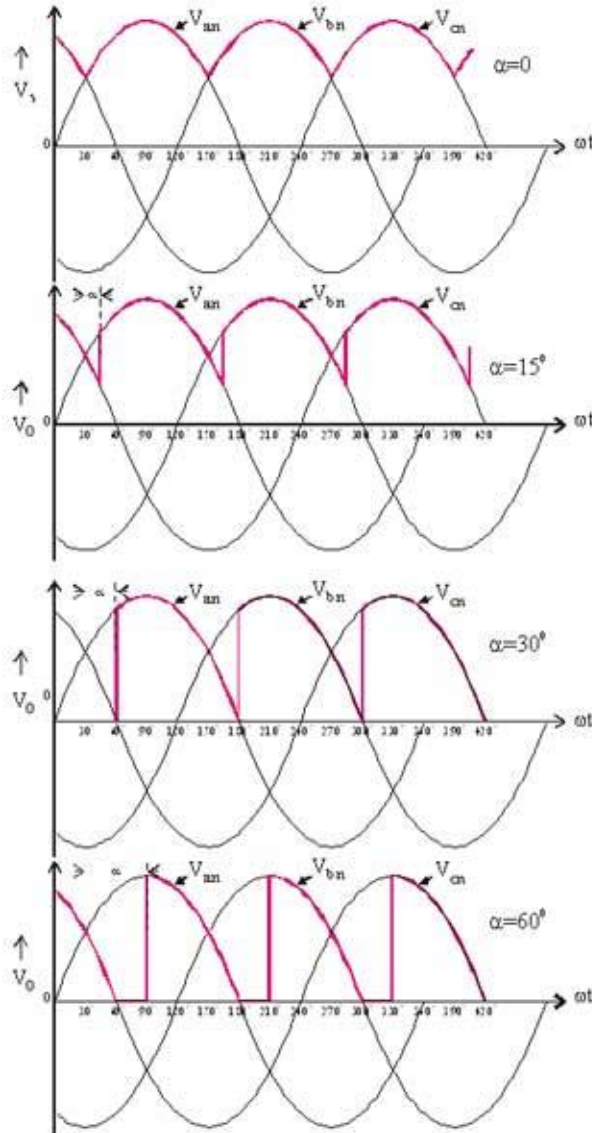
Armature voltage (e) = field density (b) x armature coil length (l) x velocity (v) (e = blv)

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

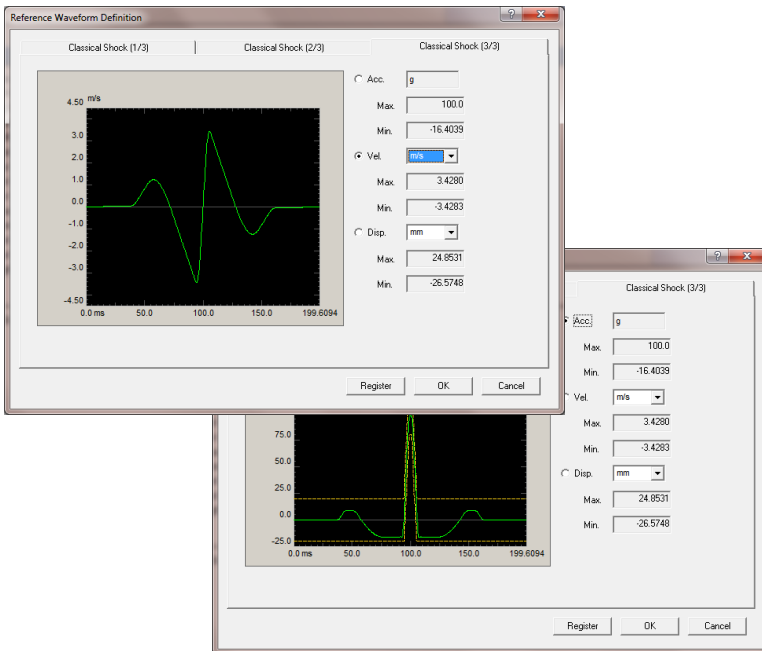




- Standard field supply voltage waveform is shown left – 3-phase half-controlled rectifier giving 300Hz ripple
- 300Hz ripple is within the test frequency bandwidth of most tests
- It is clear that as the field voltage is reduced (to control 'b'), the 'ripple' or disturbance on the field supply voltage 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

- 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



$$e = blv$$
$$F = bil$$





Service Manager

Service Manager

Service Manager



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Service Manager

CAN BUS
NETWORK

Maintenance Control UI

Power Amplifier

☒ DC Voltage
☒ RMS Protection
☒ Fuse-Blown
☒ Over-Temperature
☒ Over-Current
☒ Synchronisation
☒ Self-Test
Set PM Error Mask **Stopped**
RMS Current Limit 110
Active Rectifier
VCref 350
Power 0
VrmsA 0.0
IrmsA 0.0

DPWM
Address 1 99
Rev. 0.0 1.7 0.3
Mode **Stopped**
RMS Cur. **RMS Vol.** **DC Vol.**

Select DPWM Unit
AirFlow 0.0
ToLimit 71.0
Ambient 16.3
Input 16.2
Output 19.1
TC 3.1
Field Coil
Ref. 24.0
Power 0
Out. Vol. 0.0

Energy Manager
247.6 249.5 249.9
VrmsA VrmsB VrmsC
2.7 2.5 2.9
IrmsA IrmsB IrmsC
44 -2.022 0.02
Real Reactive PF
Power Power
Last Error
View Estimates

PA Power
Id 0.0 **Vd** 0.0 **Power** 7
10.6 2.0 0.156
IdPeak **VdPeak** **Rd**
Blower
Speed [Hz] 30.0
Power 1
VrmsA
IrmsA

Saving Options

 10

Blower
Unit Address 8 Software Revision 99
Stopped
BL Status
☒ Driver
☒ RMS current
☒ DC voltage
☒ RMS voltage
Reference [Hz] 30.0
Speed [Hz] 5.0
DC Vol 1
Mask 1
real power 1 **VrmsA** 1.7 **VrmsB** 0.0 **VrmsC** 0.0
active power 0 **IrmsA** 0.0 **IrmsB** 1.2 **IrmsC** 0.0

Power Module
Unit Address 1 Software Revision 99
Stopped
Unit Status
☒ DC Voltage
☒ RMS Protection
☒ Fuse-Blown
☒ Over-Temperature
☒ Over-Current
☒ Synchronisation
☒ Self-Test
Module Error and Error Mask
0.0 0.0 1.7 0.2
RMS Leg a **RMS Leg b** **RMS Vol** **DC Vol**

Blower
Unit Address 8 Software Revision 99
Stopped
Status
er current 24.0
reference voltage 26
T Voltage
s-Blown
r-Current
tactor 0
DC Current Limit
DC Vol
and Error Mask **DC Vol**
0.4 **OUT Vol** 0.0 **Power** 0
0.0 -0.7

Time	Unit Address	Software Revision	Unit Status	DC Voltage	RMS Protection	Fuse-Blown	Over-Temperature	Over-Current	Synchronisation	Self-Test	Module Error and Error Mask
2	1	99	Stopped	0.0	0.0	1.7	0.2				
3	2	99	Stopped	0.0	0.0	1.7	0.2				
4	3	99	Stopped	0.0	0.0	1.7	0.2				
5	4	99	Stopped	0.0	0.0	1.7	0.2				
6	5	99	Stopped	0.0	0.0	1.7	0.2				
7	6	99	Stopped	0.0	0.0	1.7	0.2				
8	7	99	Stopped	0.0	0.0	1.7	0.2				
9	8	99	Stopped	0.0	0.0	1.7	0.2				
10	9	99	Stopped	0.0	0.0	1.7	0.2				
11	10	99	Stopped	0.0	0.0	1.7	0.2				
12	11	99	Stopped	0.0	0.0	1.7	0.2				
13	12	99	Stopped	0.0	0.0	1.7	0.2				
14	13	99	Stopped	0.0	0.0	1.7	0.2				
15	14	99	Stopped	0.0	0.0	1.7	0.2				
16	15	99	Stopped	0.0	0.0	1.7	0.2				
17	16	99	Stopped	0.0	0.0	1.7	0.2				
18	17	99	Stopped	0.0	0.0	1.7	0.2				
19	18	99	Stopped	0.0	0.0	1.7	0.2				
20	19	99	Stopped	0.0	0.0	1.7	0.2				
21	20	99	Stopped	0.0	0.0	1.7	0.2				
22	21	99	Stopped	0.0	0.0	1.7	0.2				
23	22	99	Stopped	0.0	0.0	1.7	0.2				
24	23	99	Stopped	0.0	0.0	1.7	0.2				
25	24	99	Stopped	0.0	0.0	1.7	0.2				
26	25	99	Stopped	0.0	0.0	1.7	0.2				
27	26	99	Stopped	0.0	0.0	1.7	0.2				
28	27	99	Stopped	0.0	0.0	1.7	0.2				
29	28	99	Stopped	0.0	0.0	1.7	0.2				
30	29	99	Stopped	0.0	0.0	1.7	0.2				
31	30	99	Stopped	0.0	0.0	1.7	0.2				
32	31	99	Stopped	0.0	0.0	1.7	0.2				
33	32	99	Stopped	0.0	0.0	1.7	0.2				
34	33	99	Stopped	0.0	0.0	1.7	0.2				
35	34	99	Stopped	0.0	0.0	1.7	0.2				
36	35	99	Stopped	0.0	0.0	1.7	0.2				
37	36	99	Stopped	0.0	0.0	1.7	0.2				
38	37	99	Stopped	0.0	0.0	1.7	0.2				
39	38	99	Stopped	0.0	0.0	1.7	0.2				
40	39	99	Stopped	0.0	0.0	1.7	0.2				
41	40	99	Stopped	0.0	0.0	1.7	0.2				
42	41	99	Stopped	0.0	0.0	1.7	0.2				
43	42	99	Stopped	0.0	0.0	1.7	0.2				
44	43	99	Stopped	0.0	0.0	1.7	0.2				
45	44	99	Stopped	0.0	0.0	1.7	0.2				
46	45	99	Stopped	0.0	0.0	1.7	0.2				
47	46	99	Stopped	0.0	0.0	1.7	0.2				
48	47	99	Stopped	0.0	0.0	1.7	0.2				
49	48	99	Stopped	0.0	0.0	1.7	0.2				
50	49	99	Stopped	0.0	0.0	1.7	0.2				
51	50	99	Stopped	0.0	0.0	1.7	0.2				
52	51	99	Stopped	0.0	0.0	1.7	0.2				
53	52	99	Stopped	0.0	0.0	1.7	0.2				
54	53	99	Stopped	0.0	0.0	1.7	0.2				
55	54	99	Stopped	0.0	0.0	1.7	0.2				
56	55	99	Stopped	0.0	0.0	1.7	0.2				
57	56	99	Stopped	0.0	0.0	1.7	0.2				
58	57	99	Stopped	0.0	0.0	1.7	0.2				
59	58	99	Stopped	0.0	0.0	1.7	0.2				
60	59	99	Stopped	0.0	0.0	1.7	0.2				
61	60	99	Stopped	0.0	0.0	1.7	0.2				
62	61	99	Stopped	0.0	0.0	1.7	0.2				
63	62	99	Stopped	0.0	0.0	1.7	0.2				
64	63	99	Stopped	0.0	0.0	1.7	0.2				
65	64	99	Stopped	0.0	0.0	1.7	0.2				
66	65	99	Stopped	0.0	0.0	1.7	0.2				
67	66	99	Stopped	0.0	0.0	1.7	0.2				
68	67	99	Stopped	0.0	0.0	1.7	0.2				
69	68	99	Stopped	0.0	0.0	1.7	0.2				
70	69	99	Stopped	0.0	0.0	1.7	0.2				
71	70	99	Stopped	0.0	0.0	1.7	0.2				
72	71	99	Stopped	0.0	0.0	1.7	0.2				
73	72	99	Stopped	0.0	0.0	1.7	0.2				
74	73	99	Stopped	0.0	0.0	1.7	0.2				
75	74	99	Stopped	0.0	0.0	1.7	0.2				
76	75	99	Stopped	0.0	0.0	1.7	0.2				
77	76	99	Stopped	0.0	0.0	1.7	0.2				
78	77	99	Stopped	0.0	0.0	1.7	0.2				
79	78	99	Stopped	0.0	0.0	1.7	0.2				
80	79	99	Stopped	0.0	0.0	1.7	0.2				
81	80	99	Stopped	0.0	0.0	1.7	0.2				
82	81	99	Stopped	0.0	0.0	1.7	0.2				
83	82	99	Stopped	0.0	0.0	1.7	0.2				
84	83	99	Stopped	0.0	0.0	1.7	0.2				
85	84	99	Stopped	0.0	0.0	1.7	0.2				
86	85	99	Stopped	0.0	0.0	1.7	0.2				
87	86	99	Stopped	0.0	0.0	1.7	0.2				
88	87	99	Stopped	0.0	0.0	1.7	0.2				
89	88	99	Stopped	0.0	0.0	1.7	0.2				
90	89	99	Stopped	0.0	0.0	1.7	0.2				
91	90	99	Stopped	0.0	0.0	1.7	0.2				
92	91	99	Stopped	0.0	0.0	1.7	0.2				
93	92	99	Stopped	0.0	0.0	1.7	0.2				
94	93	99	Stopped	0.0	0.0	1.7	0.2				
95	94	99	Stopped	0.0	0.0	1.7	0.2				
96	95	99	Stopped	0.0	0.0	1.7	0.2				
97	96	99	Stopped	0.0	0.0	1.7	0.2				
98	97	99	Stopped	0.0	0.0	1.7	0.2				
99	98	99	Stopped	0.0	0.0	1.7	0.2				
100	99	99	Stopped	0.0	0.0	1.7	0.2				

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



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 specification

User Benefits - Energy saving



Electricity charges and CO₂ reduction

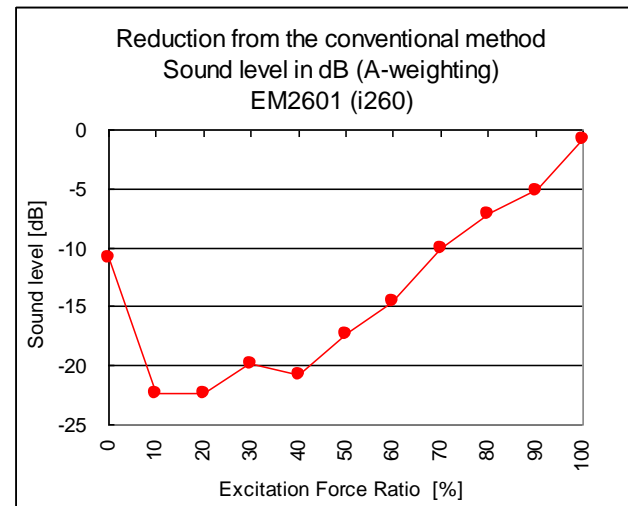
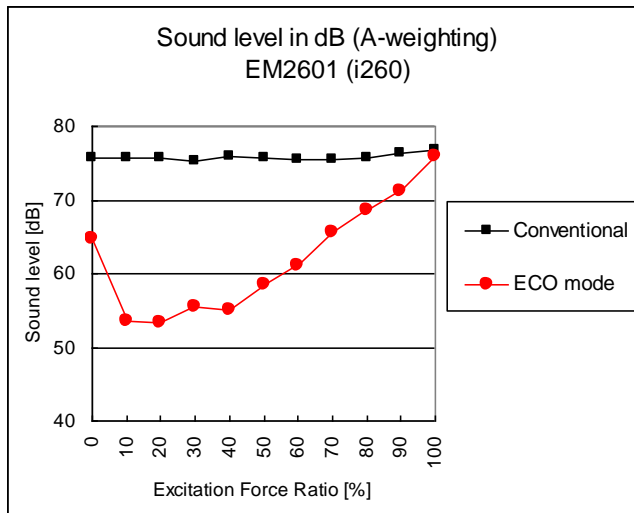
The table below shows the estimated electricity savings and CO₂ reduction using the ECO-power saving for i240/SA3M(rated force : 24kN) and i260/SA7M (rated force : 54kN)

Unit price of electricity : 0.15 €/kWh
CO₂ 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)		

Cooling Blower Acoustic Noise Reduction

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



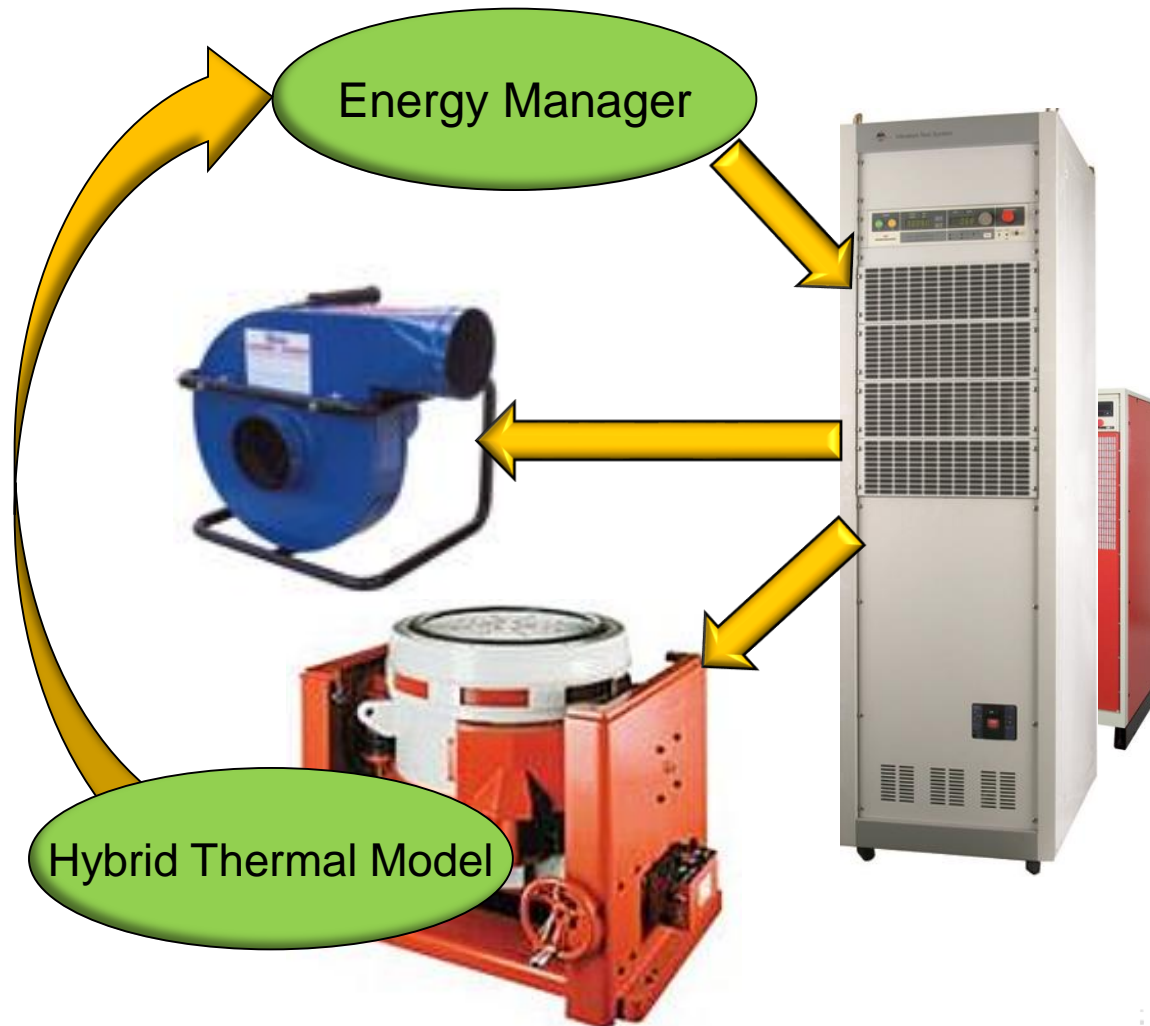
User Benefits

- Reduced energy, CO2 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



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Any Questions?

Thank you for listening to my Presentation

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