



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

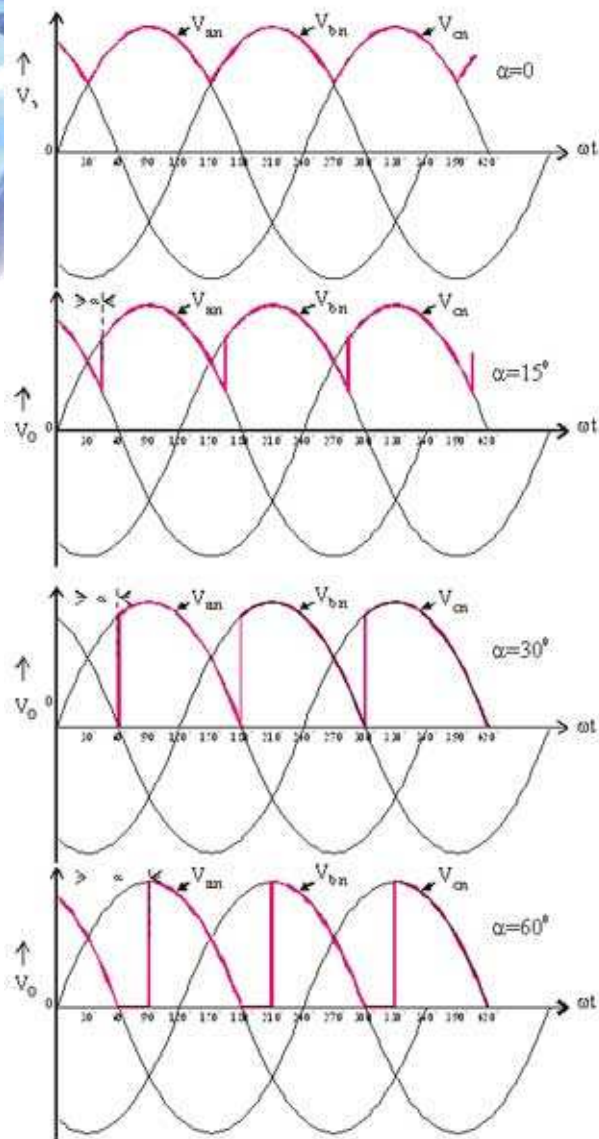
- The development of the required test specifications has a consequent increasing demand on the vibration test system
- High levels for Force, Acceleration, Velocity and Displacement
 - Option to move to a larger (often water-cooled) test system
 - High cost solution, with capital investment for cooling 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 $\propto e \times i = \text{constant}$ (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

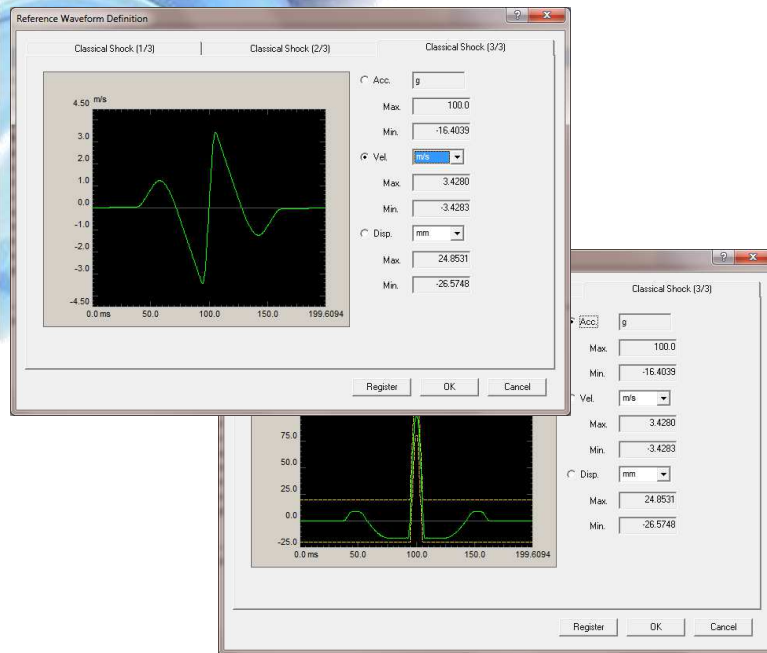
Field Control



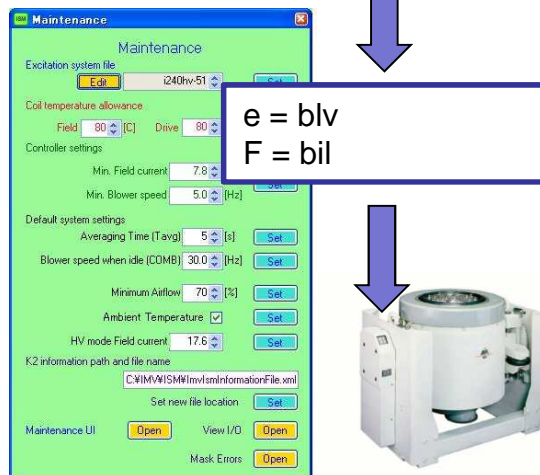
- Standard field supply voltage waveform is shown left – 3-phase half-controlled rectifier giving 300Hz ripple
- 300Hz ripple is within the test frequency bandwidth of most tests
- It is clear that as the field voltage is reduced (to control 'b'), the 'ripple' or disturbance on the field supply voltage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



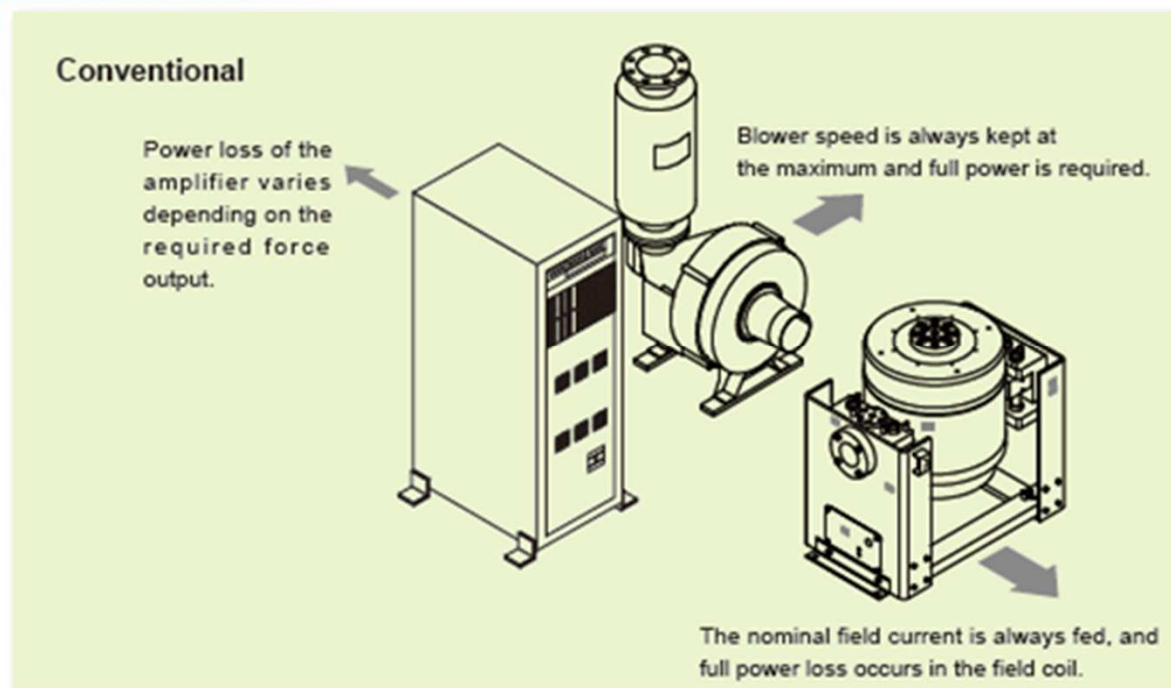
- Vibration test system data is entered in to the controller, including the low-field:high-shock capability
- Shock test specification is entered in to the K2 controller
- K2 controller compares shock specification against system specification and optimises field setting



The figure shows a 'Maintenance' software interface with various settings. A blue box highlights the equations $e = blv$ and $F = bil$. Below the interface is an image of a vibration shaker.

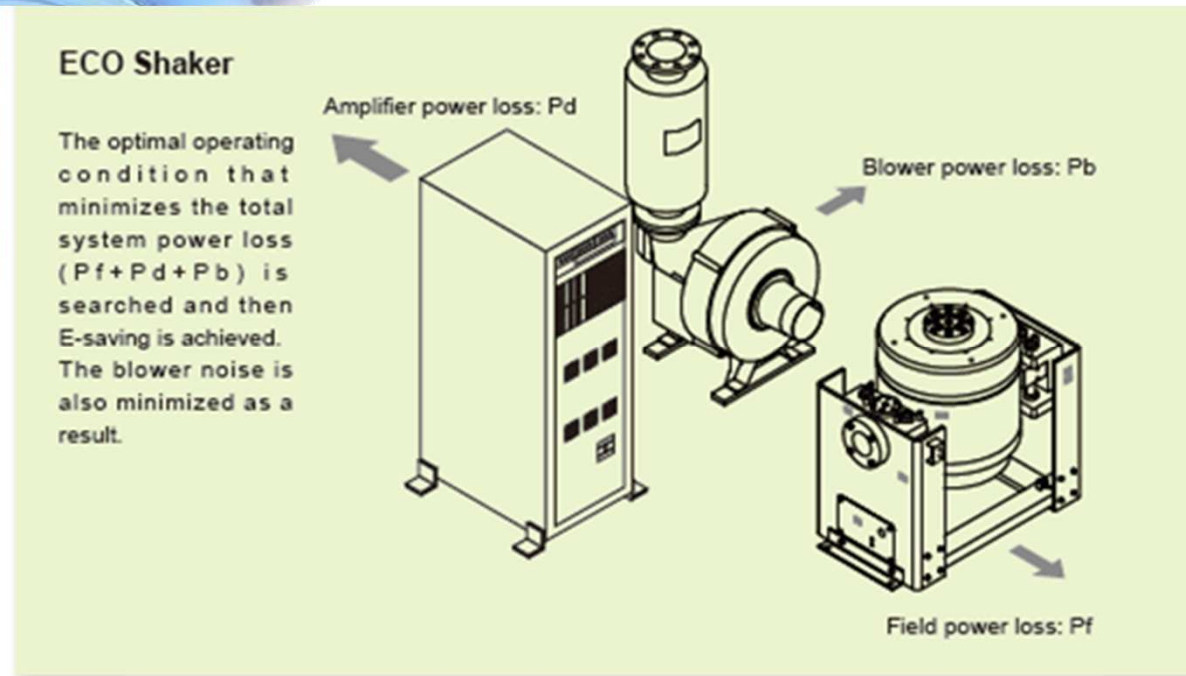
- Optimisation is performed against the two equations
- The optimised field current setting is automatically passed to the vibration test system

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

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

- $P_f = R_{f0} \cdot I_f^2$

- $P_d = R_{d0} \cdot I_d^2$

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

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

- Temperature model

- $T_f = f(P_f, P_d, V) + T_{in}$

- $T_d = g(P_f, P_d, V) + T_{in}$

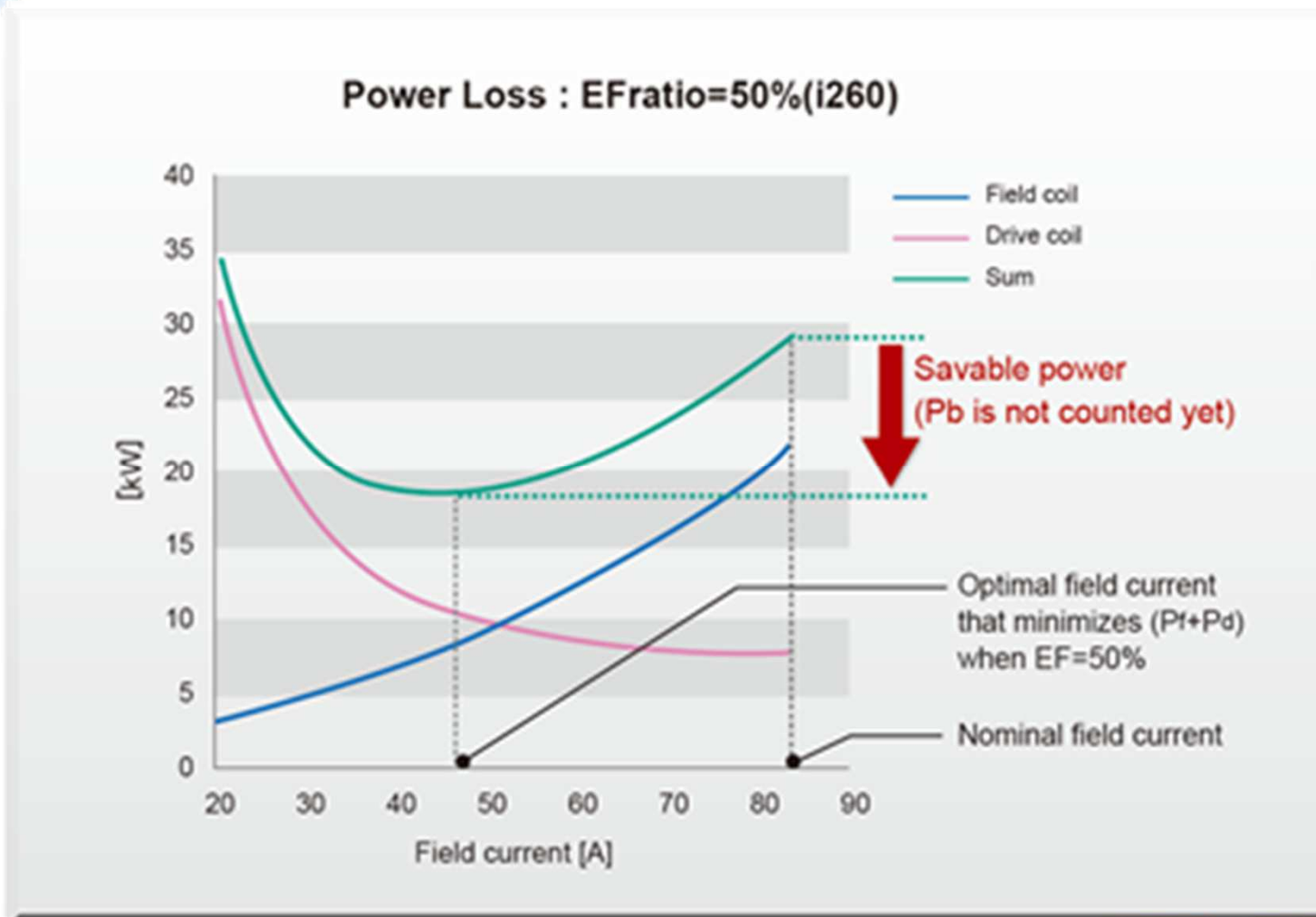
- Winter and summer have different optimisation points

- Outlet air temperature check

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

Energy Saving

Optimum value for Armature and Field coil

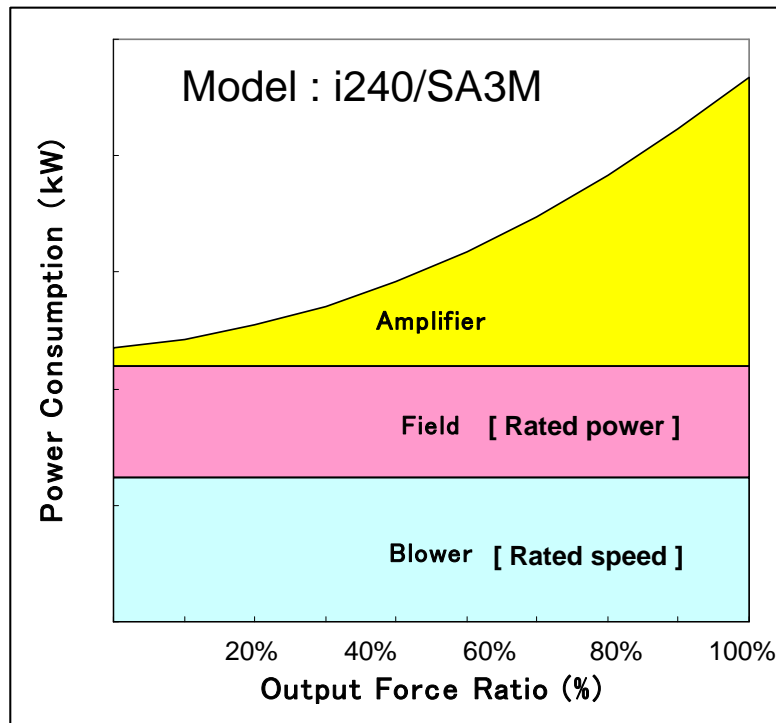


Energy Saving

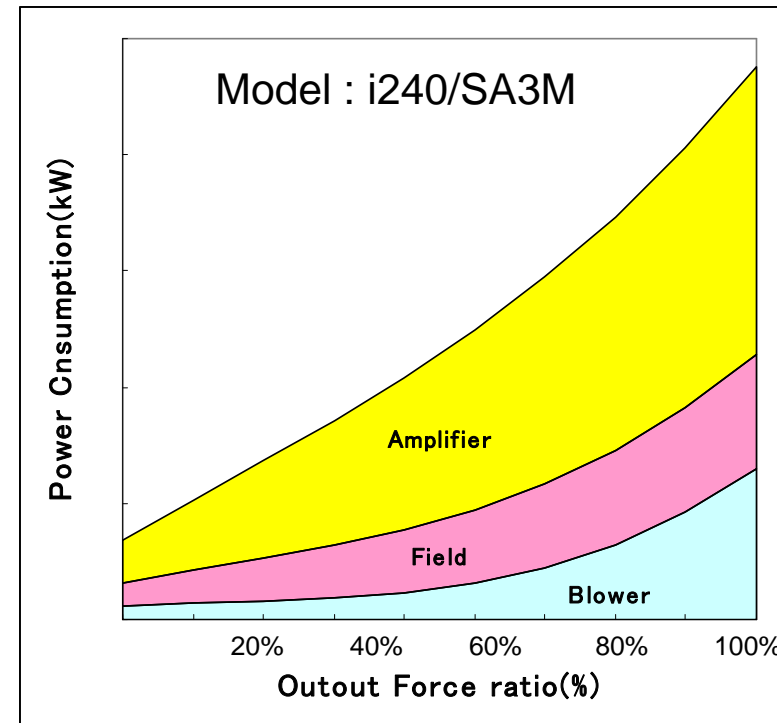
Comparison of Operating Methods

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

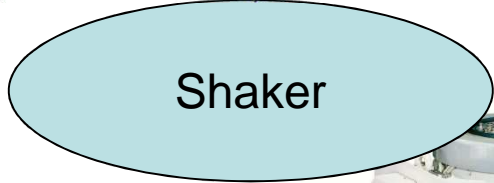
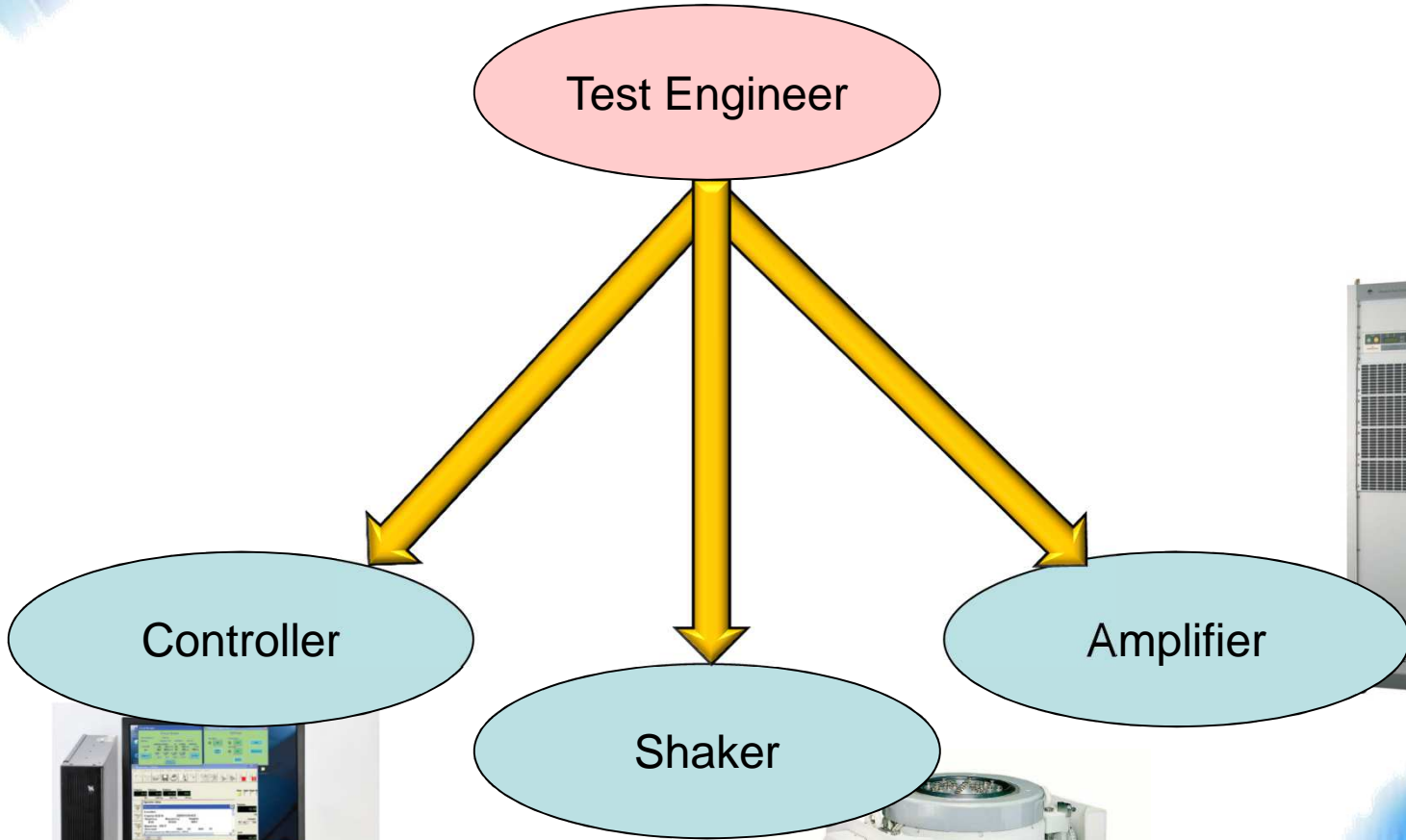
Conventional System



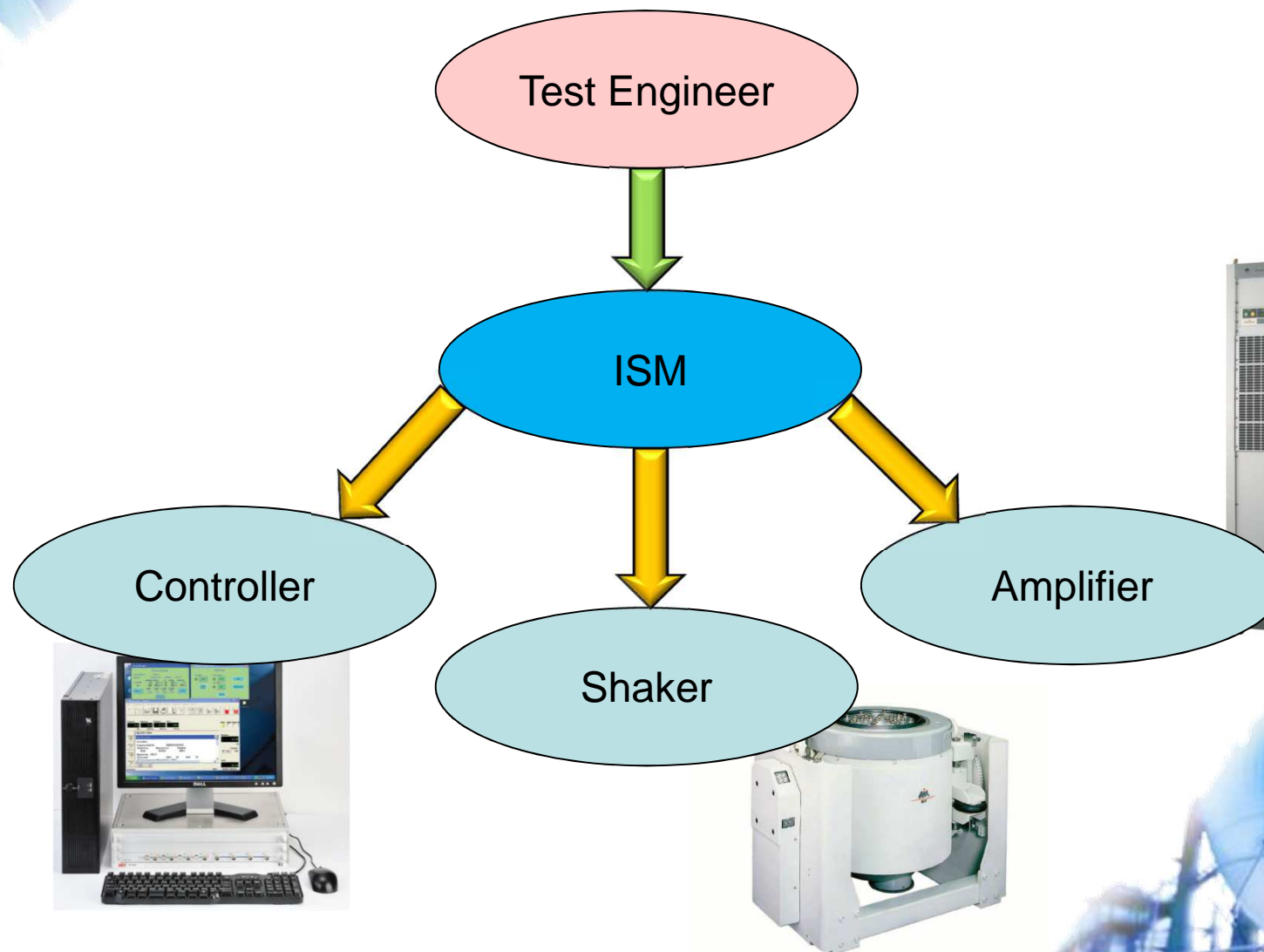
ISM-EM (Eco-Shaker)



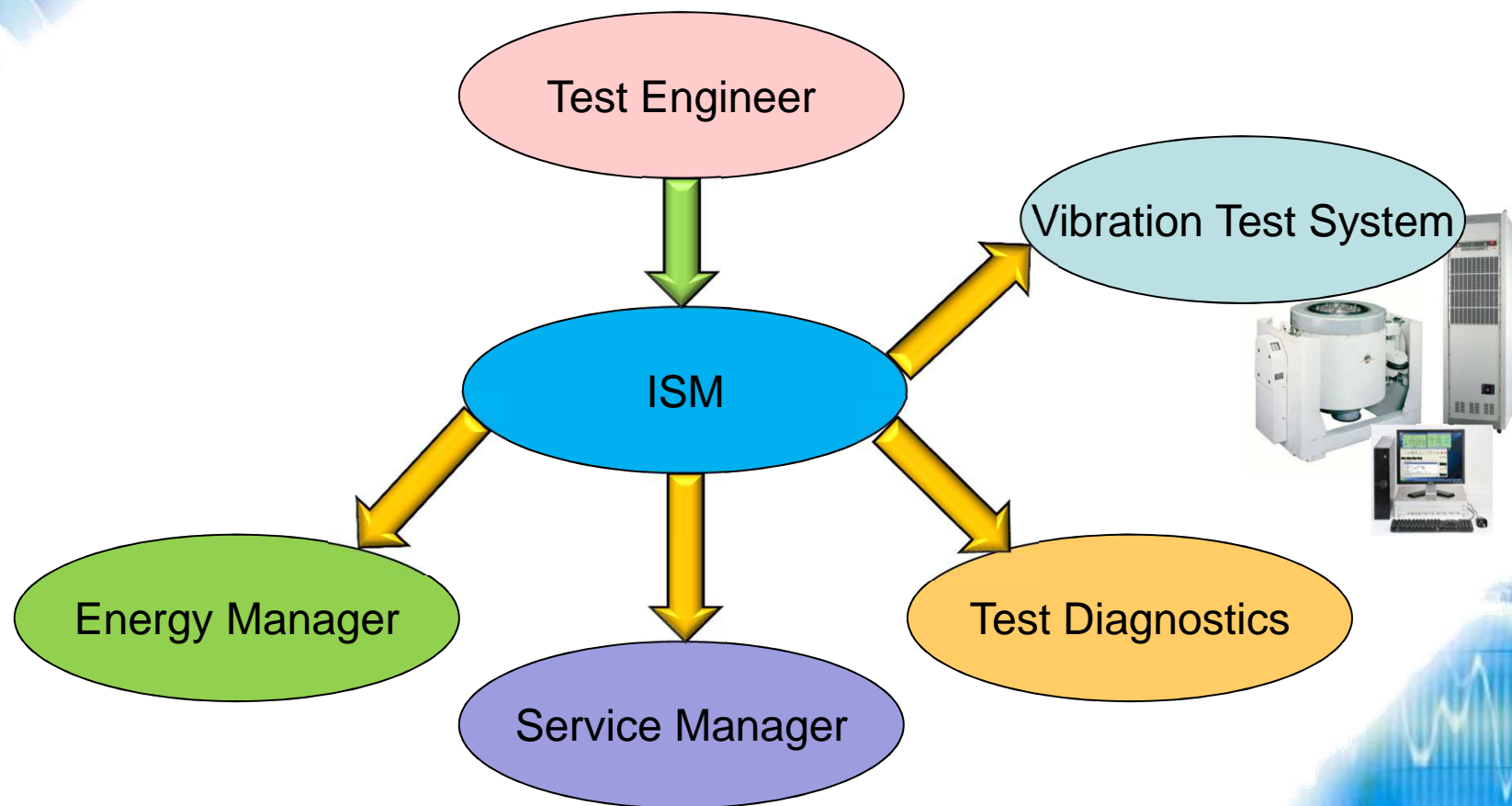
ISM – System philosophy and architecture – non-ISM



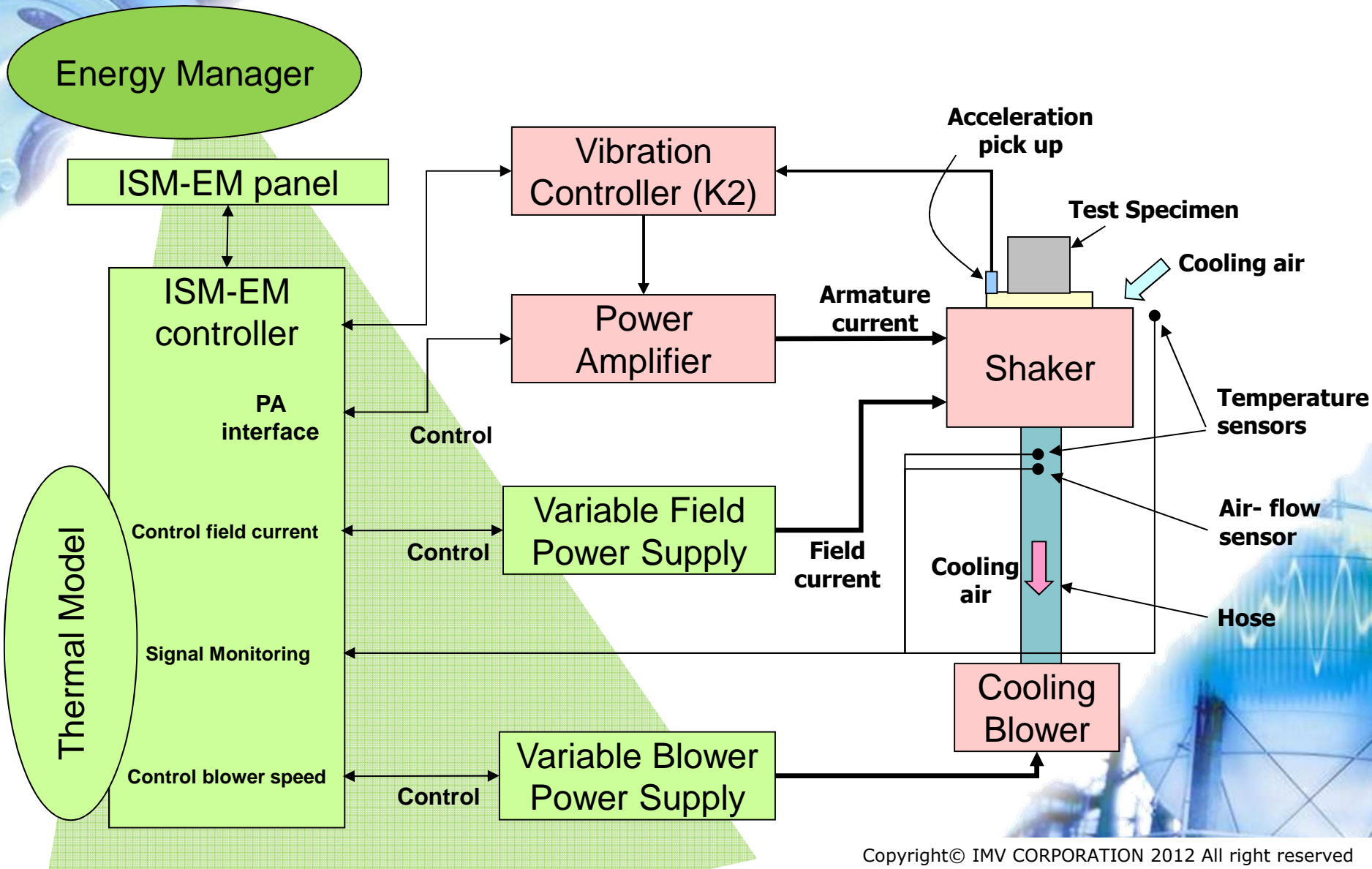
ISM –System philosophy and architecture – ISM



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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 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

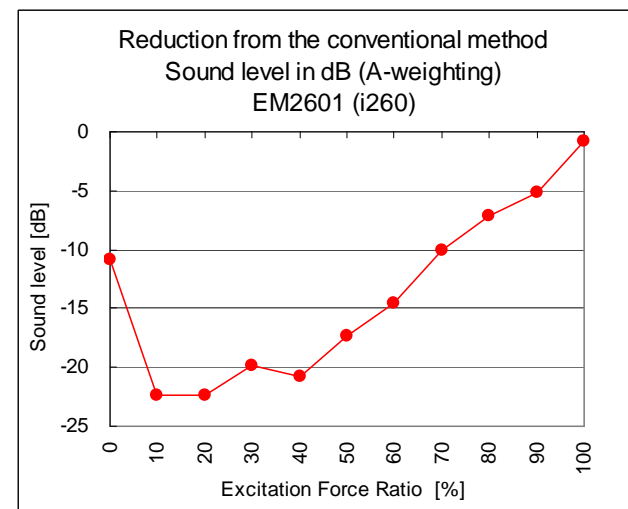
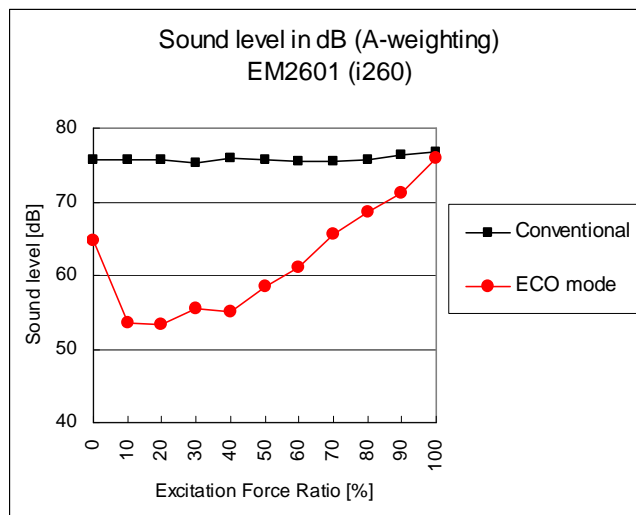
i240	Average force ratio	25%		50%	
	Power saved in ECO mode (kW)	7.0		5.3	
	Yearly average working ratio	25%	70%	25%	70%
	Saving charges (€/year)	2,299	6,439	1,741	4,875
	CO₂ reduction (tonne/year)	8.1	22.5	6.1	17.1
i260	Average force ratio	25%		50%	
	Power saved in ECO mode (kW)	28.1		22.8	
	Yearly average working ratio	25%	70%	25%	70%
	Saving charges (€/year)	10,140	28,392	8,239	23,069
	CO₂ reduction (tonne/year)	32.3	90.3	26.2	73.4

Note: CO₂ 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 level the ECO-power saving for i240/SA3M(rated force : 2.4kN)



User Benefits

- Reduced energy, CO2 and cost of operation
- Reduced operating noise
- Improved system protection
- Increased system availability
- Increased return on investment

