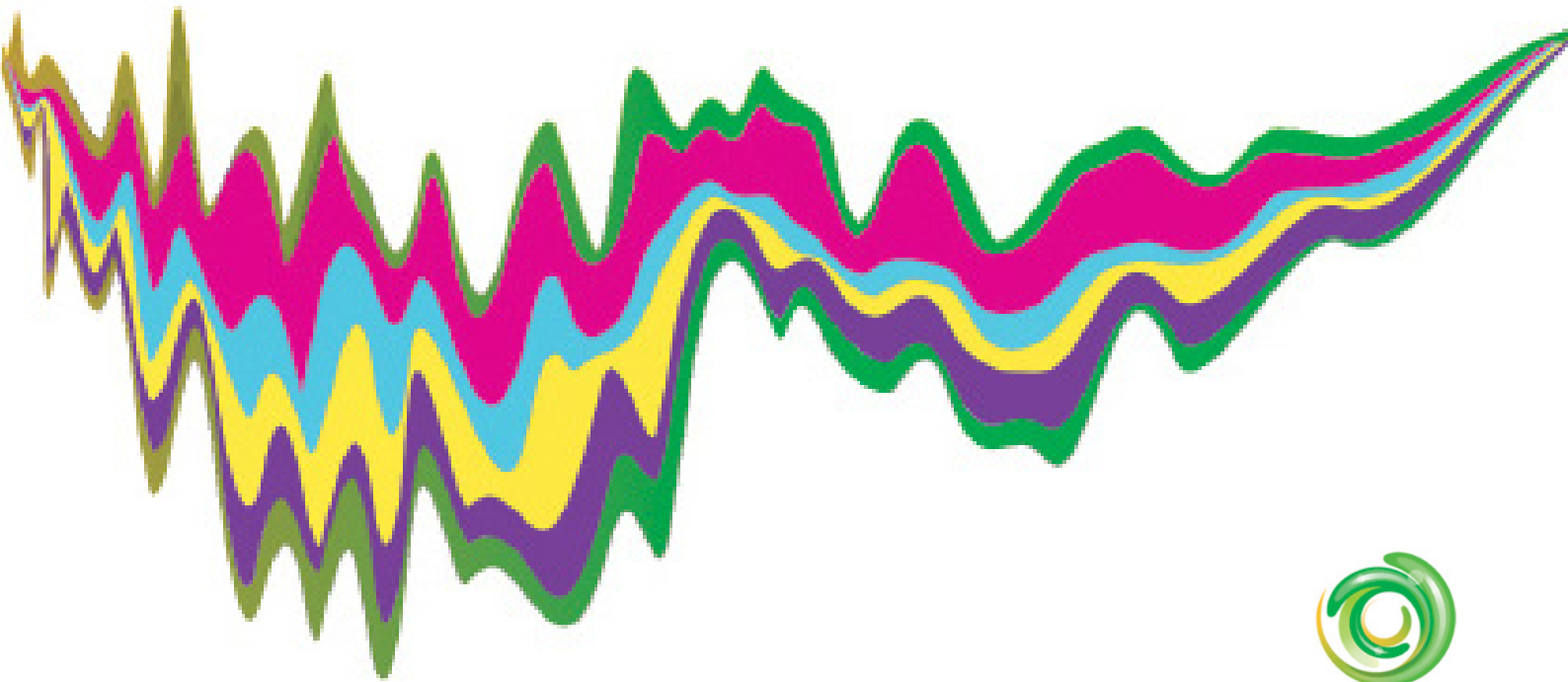# predictive maintenance strategy

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galileo

Your world is our world.

Why galileo?

The search for an alternative maintenance methodology is a result of general lack of visibility on asset's reliability, its behaviour over the period of time and the cost associated in maintaining the asset when the facility is subjected to a conventional calendar based maintenance regime.

It's often a challenge to the service provider and to the client to implement any changes on to their existing maintenance regime as it involves changing their attitude or view on maintenance.

galileo, supported by Integral, proposes a solution to this challenge through an alternative maintenance model, based on a fusion of Condition Based and Reliability Centred Maintenance (RCM), which offers greater visibility on asset condition and failure pattern, enabling greater control on maintenance tasks, allowing the service provider to answer the following key questions.

- How reliable my life critical assets are at the moment?
- What is the failure pattern?
- What is the optimum time of replacement or intervention?
- What is the optimum stock level of critical spares that should held be in my inventory?
- When to Increase or Decrease the inspection interval of an asset?

Maintenance frequencies and techniques may be adjusted by galileo, offering better value and working efficiencies, ensuring an optimum maintenance solution is delivered. galileo exceeds the expectations of alternative maintenance solutions, supplying the client advantages, which include:-

- Exceeding, Minimum Maintenance Standards.
- Increased resilience.
- Provide Real time, Asset condition, risk assessment.
- Reduces asset interruption and manual maintenance activities.
- Reduces reactive maintenance activities and plant failures,
- Supply trained and competent personnel are employed to undertake the predictive tasks.
- All solutions presented in real time, using latest tablet technology.
- Prediction on asset health undertaken by Galileo software applications.

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Reliability Centered Maintenance

The term "Reliability Centred Maintenance" has various definitions and the most suitable one is defined as "The process used to determine the maintenance requirements of any physical asset in its operating context", In simple words, it means the maintenance tasks are performed only when its required by identifying failure modes for the particular asset and collating ages to failure data to determine Predictive (PdM) and Preventive (PM) inspection intervals. It is a method that identifies applicable and effective maintenance tasks required to maintain the inherent reliability of an asset with minimum cost.

Galileo follows a methodology which has been widely acknowledged within the process industries, hospitals and by the aviation manufacturers where reliability and business continuity is the life line for these industries and any unscheduled downtime can cause serious financial or health & safety impact. In an ideal world, RCM should be a key process in facility maintenance (FM) industry but unfortunately FMs perspective towards RCM is not very optimistic as it has been classified as a "complex" process with too many "variables".

Myths surrounding RCM

#1 Operational cost is high during RCM implementation.

The answer is yes, but it is a one off cost, in RCM world this surge in the operational cost is called "Start-up Cost" which is caused during hardware acquisition process i.e. buying the tools and setting up training required for the engineers to implement and maintain the desired RCM standards. It has been proven and acknowledged by the reliability engineering community, the Return on Investment (ROI) from RCM is on average between 25%-30%.

#2 Sounds good in theory but in reality performing less maintenance in a critical assets poses greater threat to asset's operational efficiency and it is vulnerable to failures

Surprisingly NO, over 80% of asset failures are not due to age therefore performing conventional calendar based maintenance, replacements or overhauls do not increase asset's reliability, In addition to that performing calendar based maintenance might increase the risk of maintenance induced failures which are often hidden. Failure rate of an asset subjected to RCM is far less compared to an asset that undergoes conventional calendar based maintenance because sometimes "Less is more".

#3 Replacing PPM tasks with predictive inspections has a negative impact on the maintenance model

Performing predictive tasks does not replace the original preventive tasks; it is an efficient decisive method that allows engineers to identify when to perform the specified intrusive maintenance.

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galileo Deliverables

Maintenance strategies are devised to improve the operational efficiency of assets, reduce downtime and enable facility managers to allocate their resources more efficiently by providing clear visibility on asset KPIs, i.e. how well they are performing at any given state?

Does a conventional calendar based maintenance model deliver these aspects?

Sadly no, all it does is carry out tasks at a regular interval i.e. constantly intervening with the asset, and creates an optimistic view that "failures are reduced or eliminated because maintenance was carried out before any failures could occur", the statement above is not aimed to dismiss preventive maintenance strategy (PM) and say "It is all wrong". PM is the most essential aspect in asset maintenance and its full efficiency can be only achieved, if it's utilised in part. Constantly intervening with an asset acts as a catalyst during asset deterioration process and in most cases makes assets prone to premature failures.

Therefore galileo, propose a maintenance model which is a fusion of performance based partnership model and reliability centred maintenance, where the latter is used to identify the failure modes, key performance indicators and reliability parameters via ages to failure data and the former is used to identify the minimum maintenance conditions and the PM and PdM tasks intervals to meet its specified performance level. By combining the two maintenance models, some of the major disadvantages of performance based partnership approach such as loss of flexibility and the ability to deal with changes is mitigated as the model is devised to evolve constantly based on its performance.
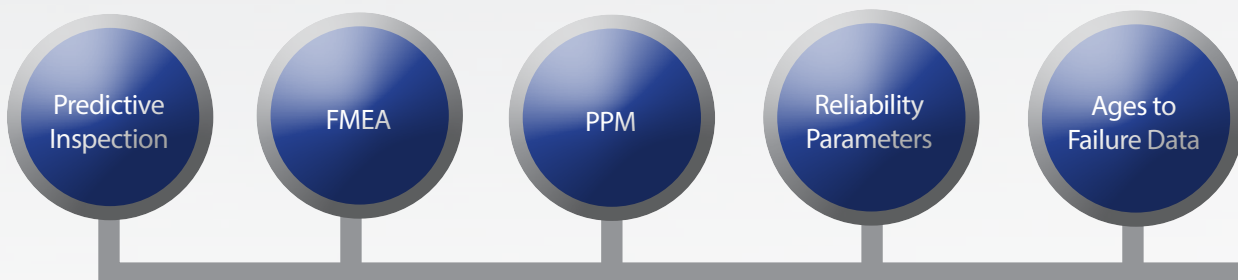

Graphical representation of RCM inputs and service outputs.

The galileo model allows the user to identify Key Performance Indicators (KPIs) on critical assets by identifying the possible causes that could affect the specified KPIs. Once failures modes are identified, the appropriate maintenance tasks (PdM, PM) are selected to be performed at appropriate intervals. Based on these parameters a minimum operating condition can be devised which provides a clear objective for the engineers that would allow them to address some of the key questions:

- How the asset should be maintained?
- The level of maintenance required?
- What are Key Performance Indicators (KPIs) to be monitored?
- What are the potential causes that could affect the specified KPIs?

Our model is aimed to:

- Improve the performance of critical assets
- Increase asset availability and reliability
- Reduce asset downtime
- Increase cost savings
- Optimise asset replacement strategy
- Identify hidden failures and monitor current use of time and resources

RCM Reliability Centered Maintenance

Reduced Downtime

Savings

Availability
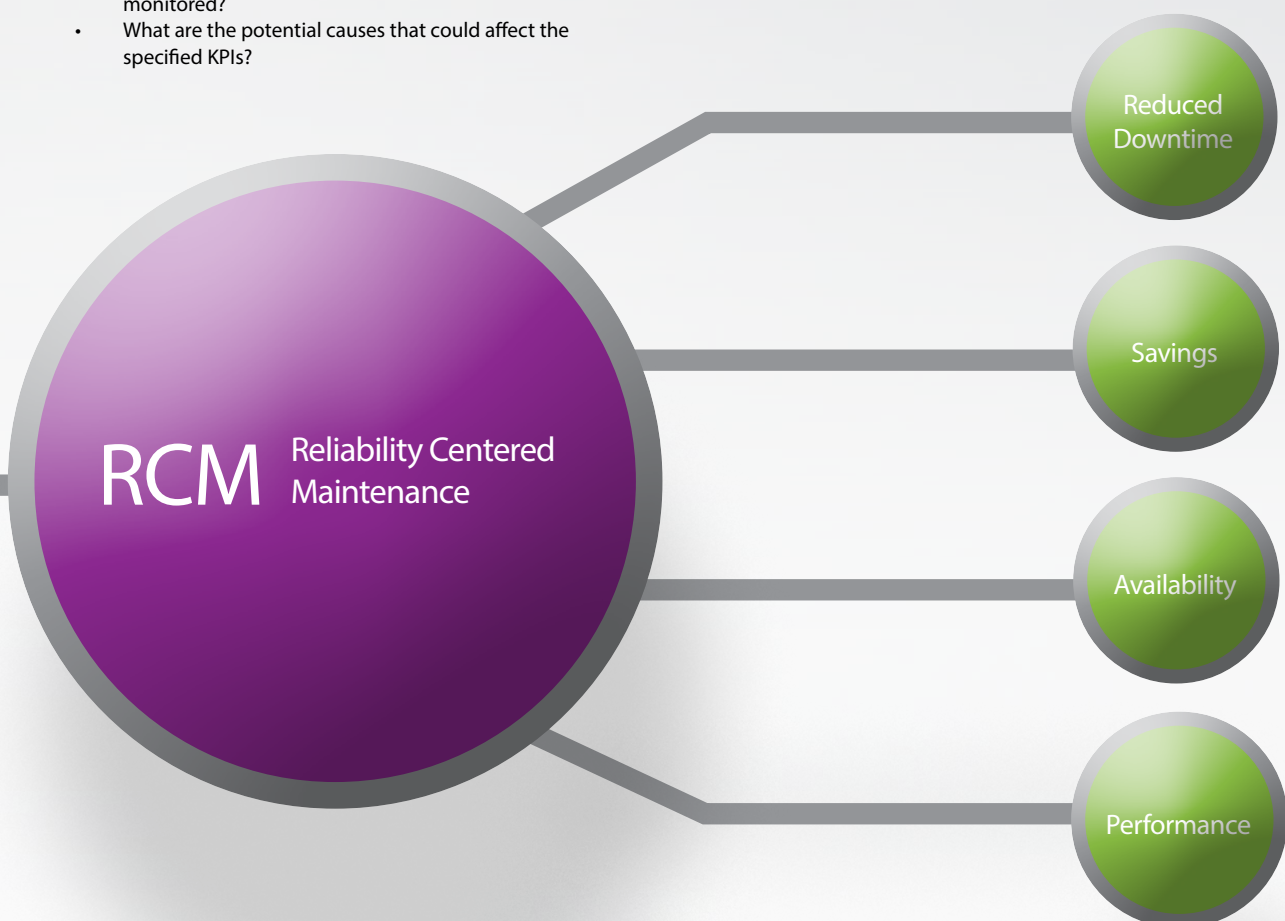
Performance

Prognostic & Diagnostic tools

A quintessential aspect in both RCM and performance based partnership approach is the condition assessment.

Visual inspection is often the primary method to access the operational status of the asset, but the amount information that can be extracted via this method is limited as there are constraints that limit its efficiency (e.g. human errors, spurious alarms).

In some cases, detecting failures can often challenge even the most experienced engineers since some of the early signs of deterioration are hard to detect or almost impossible during visual inspections. With the rapid growth of sensors and signal processing technology engineers can now have a much broader spectrum of their asset's operational status and allows them to detect early deterioration signs and even some of the hidden failures.

Thermal Imaging, (Thermography) is one of the efficient non-intrusive methods to detect any thermal anomalies on electrical assets, and works on the principles of joules heating effect, these heat signatures increase when the current in a particular conductor increases (overloaded) and it can be easily be detected by Infra-red scanning. It is suitable for detecting over-loads and loose connections in fuses, switch gears, transformers and bus bars.

In HVAC, thermal imaging is used to detect refrigerant leaks, leaking pressure gauges where the method can be used to replace the quarterly intrusive leak detection checks on chillers. In rotary assets, it is ideal for locating the root cause of overheating. It is suitable for identifying overheated bearings or rollers, misalignment of shaft, pulley or coupling and lubrication failure

Deterioration in fuel tanks, oil filled transformers and pipe works can be identified via fluid sampling that basically detects any fluid contamination and provides indication on the level of deterioration.

Partial Discharge (PD) is an electrical discharge that does not completely bridge the space between two conductors. The discharge may be in a gas filled void, in a solid insulating material, in a gas bubble, in a liquid insulator. When partial discharge occurs in a gas, it is usually known as corona. Partial discharge is accepted as a standard protocol test for high voltage assets by power sectors. In addition to that partial discharge detectors are equipped with ultrasonic sensors where they are used to detect arcing and corona in HV/MV switchgears and transformers.

Vibration analysis is an efficient non-destructive testing tool for the building's rotary assets, basically the tool analyses the vibration signature of high speed rotary equipment's such motors, pumps which has a on board diagnosis tool with the clever algorithm that can prioritise repair recommendations. The vibration analyser is equipped with tri-axial accelerometer and a two- point laser tachometer (speed measurement) for precise vibration sampling to identify bearings looseness, misalignment, unbalance, gear problems and bent shaft.

Reliability engineering

Life Data Analysis

Galileo calculates reliability parameters and predicting asset failures aimed to provide accurate data to the following questions:

1. When an asset is going to fail?
2. What is the asset's failure pattern?
3. How much time do I have to perform the remedial actions?
4. What is expected number of failures?
5. What is the reliability of the asset?

Snap shot of reliability parameters dialog box from galileo Predictive Maintenance Management (PMM) tool.

Flexing PdM Inspections Intervals

Competing maintenance strategies don't allow the user to change the inspections interval as it could have perceived impact on the cost, availability or resilience of the facility. However galileo, using our defined RCM strategy allows the "Flexing" of the PdM inspection interval based on the following parameters:

- Asset's Failure Pattern
- Age
- Operational life

Failure pattern of an asset is dependent on the failure rate, and there isn't a definitive pattern for all assets, it varies based on the load, environmental condition, temperature, design, shipping, and installation. But most assets follow a failure pattern called "Bathtub-Curve".
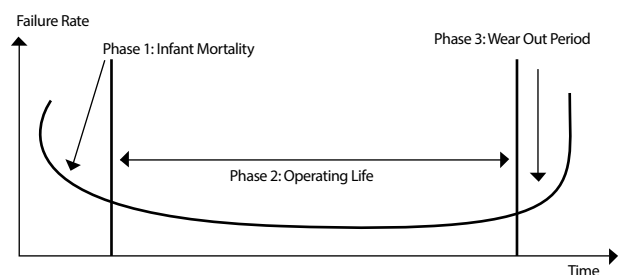
P-F Curve

galileo provides a visual representation of the behaviour of an asset as it approaches failure; The P-F Curve is plotted against two parameters asset condition and time. Once a failure has been identified (Via PdM or Visual Inspection) it is labelled as Point 'P' called Potential Failure, which means the asset or its components had shown an early sign of deterioration and it can lead to the Catastrophic or Functional Failure point 'F' where an asset can no longer be in operation or can no longer perform its specified function

Usually the potential failures become visible at around 70% of asset's operational life, and the interval between potential failure and functional failure is called as "P-F Interval". The general rule is, during the P-F interval the asset must be inspected at least once; the inspection can be predictive, intrusive/visual.
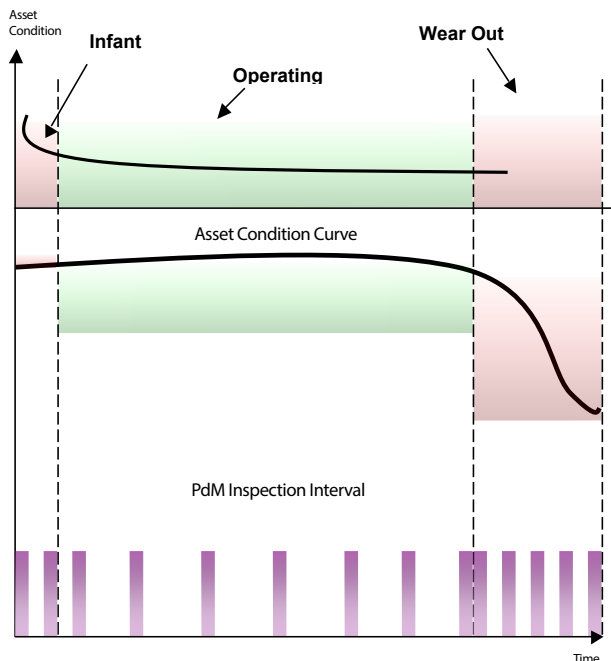
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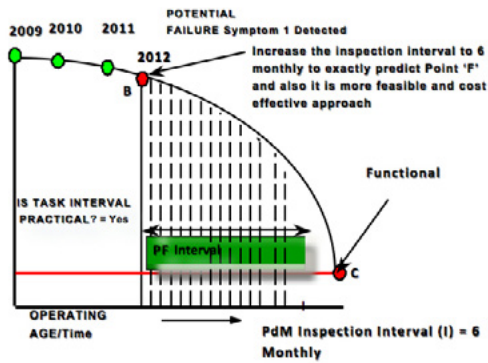
Typical P-F Curve

Based on the asset's failure and deterioration pattern, the predictive inspection frequency is varied. Intrusive maintenance is performed only when the asset operational condition is in amber to red transition period, i.e. the optimum point of intervention and the maintenance interval is tuned accordingly so that engineers do not lose the visibility of the source. It is a manual process and carried out by a PPM manager based on the reliability and the field information provided by the RCM facilitator

The failure pattern illustrated below is a typical bath tub curve, but it is very unlikely that all the assets will follow this pattern as there are six different types of failure pattern. As discussed in the earlier section, based on the ages to failure data asset specific failure pattern can be identified and can be used during the flexing process.

Asset Behaviour Characteristics vs. Inspection Interval

Predictive Inspection interval (PdM) flexing

Key performance indicators and the level of maintenance required to satisfy the specifications will be derived by Uptime Plus facilitators. After the agreement, a bespoke maintenance model will be devised and sent to the client for final approval. In the execution phase, completion of each task will be reported back to the client where all the tasks and its execution frequency will be monitored and assessed by the client. In the assessment period, the audit results of both parties will be compared and evaluated whether to confirm the Service Level Agreements (SLA) and the specified performance requirements which were agreed during the specification phase are met.

Performance and Data Analysis

The galileo, performance monitoring tool is the most essential aspect in the software model, where all the ages to failure data, current operational status, asset information and their hierarchy are stored. The tool allows the user to edit or add an asset and provide a visual representation of asset's operational status and keep track on the existing PPM planner, remedial actions. In return the tool enables the user to acquire the valuable historic data that would allow the RCM facilitator to determine asset's failure pattern consequently results in devising bespoke maintenance strategy

Client can now derive bespoke asset replacement and deliver a critical spares strategy now made possible by this software as low MTBF doesn't necessarily means that the asset should be replaced because asset replacement is entirely age related not on MTBF, having the historic information of critical assets enables the user to distinguish between MTBF and asset life expectancy, resulting in optimising the existing asset replacement model.

Snapshot of the PMM database and asset life expectancy window.

In a world where Science and Engineering merge
- Reliability is Everything

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Risk Focused Maintenance

Galileo derives its risk model by combining both the information provided by the virtual tools and live inputs from the assets deployed on the site monitored, which provides a Risk Model that that combines traditional risk management techniques with real time risk status software management of the critical engineering assets incorporating all three key elements namely People, Process and Technology.
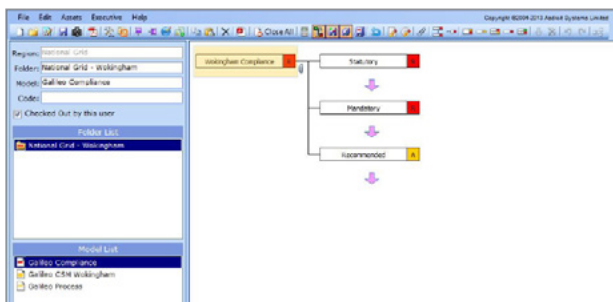
Risk assessment should be seen as a real time process. Thus, the adequacy of control measures should be subject to continual review and revised if necessary.

Real Time Risk Monitoring Tools

Galileo provides real time management and monitoring to enable to identify key risk issues and illustrate these clearly and concisely to colleagues and process managers as and enabler to decision making and management process.

Key factors to the success of critical engineering environments are:

- Visibility
- Transparency
- Accountability
- Auditability
- communicate quickly and accurately

It is Galileo's proposed model that for businesses to fully understand their risk across a range of systems real time monitoring systems are the way forward.
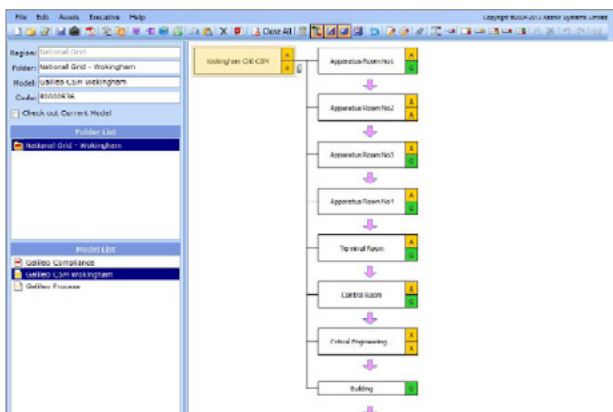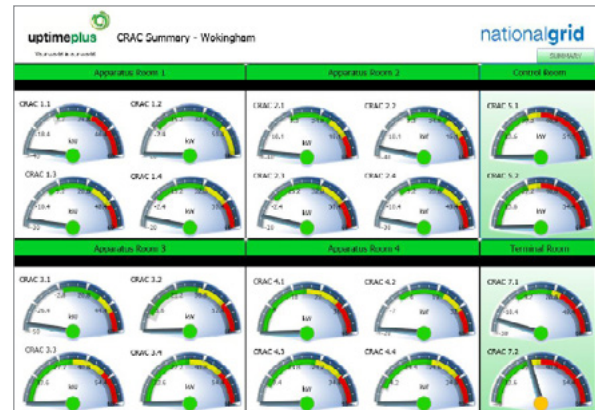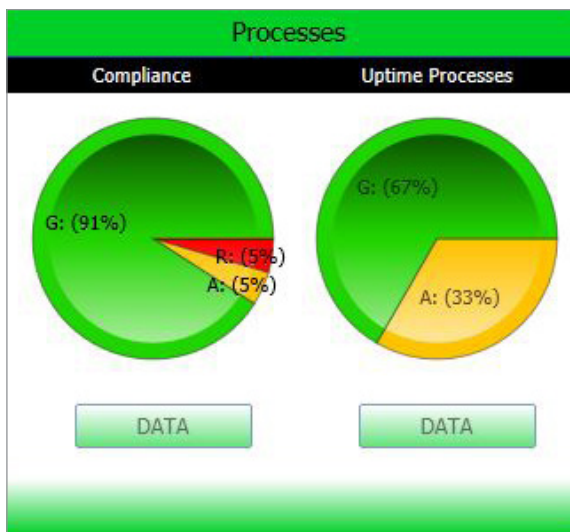
Critical Systems

Galileo, links live status information from critical engineering systems to a visual risk dependency model which will provide the building manager with accurate real time information regarding the operating status of his plant. In addition to this the visual risk dependency model would provide clear indication of the risk to the failed assets and ultimately the risk to his business operations. Having this information available to key staff will ensure that consensus is quickly obtained regarding the correct course of action, to mitigate or remove the risk whether it be changes to the M&E systems themselves or moving critical workflows to other sites.
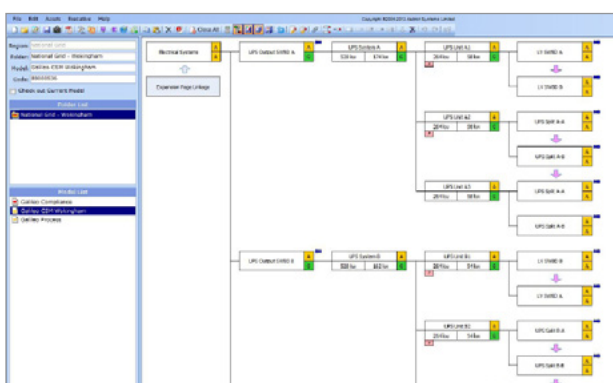
Compliance

Galileo provides businesses with real time visual data for regulatory compliance coupled with workflow systems that will automatically issue reminders of inspection and testing dates will reduce the need for frequent time based audits and so reduce resource.

Global View of Business Operations

By providing a global view of the real-time risk levels to an entire business portfolio will ensure that appropriate decisions are made with respect to any implementation that may compound an identified risk. If a single critical site is at risk and this is immediately highlighted, having the ability to understand what has caused the risk will ensure that it is a) not repeated at other sites and b) gives you the opportunity to stop scheduled work that may impact your contingency.
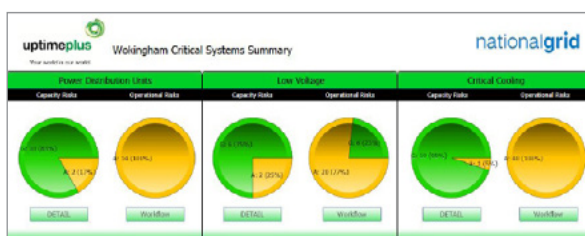

Providing real time risk monitoring tools with clear visual indication of status will ensure businesses have confidence that there risk has been omitted or reduced to an acceptable level and also provide the visibility, transparency, accountability, auditability required for critical environments. As the information is globally available it will increase the ability to communicate quickly and accurately so the correct decisions can be made when an incident occurs.

Ultimately this would reduce resource for both the Business and its support staff as the system would be self-policing.

Conclusion

The proposed software if introduced, provides complete transparency over critical asset's KPIs and with aid of reliability predictions supported by performance & condition monitoring tools, asset failures are detected at an early stage where the cost of intervention is minimum, consequently enabling facility owners to achieve substantial cost savings and enables them to maximise asset's service life and in certain case extends asset's life expectancy. In addition to that asset's failure pattern is determined in order to identify the desired maintenance frequency consequently resulting in a dynamic maintenance planner which is mapped against asset's failure pattern, operational status and age. This approach increase asset's reliability, availability and maintains downtime well below the threshold level. Overall the reliability and performance based approach for asset maintenance is an effective replacement to the conventional calendar based maintenance.

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