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WHITEPAPER

MACHINE STATE FUNCTIONALITY

Machine state functionality lends itself to today's variable operating conditions

The fundamental concept for machine vibration condition monitoring is relatively simple; detect developing machine faults by monitoring changes in the vibration signature of the machine. Studies and experience have shown that this principle is sound, and it has proven itself time and time again over the years. There is, however, a question that repeatedly comes up that needs to be addressed; are there other factors that will change the vibration signature of a component, other than that of a developing machine fault? The answer is yes. Is there anything that can be done to distinguish vibration changes due to faults and those due to other factors? Fortunately, the answer is yes, and the solution is a monitoring function called machine states!

Process conditions influence the vibration signature

Let's assume a compressor is always operating at the same speed and load, i.e. the gas composition is always the same and the inlet and outlet conditions of the gas do not change. If during monitoring an increasing vibration trend occurs over time (or decreasing), this would most likely mean then that there is a physical change in the machine itself, i.e. there is a developing fault. If, however, the speed or one of the other process operating conditions for this machine is not constant and changes during operation, this could also consequently affect the machine vibration amplitude. It is worth saying that the vibration signature could also be affected by nearby machines starting up, but this is another topic. In such a case we would implement another function called monitoring override, where the monitoring is stopped until the outside vibration subsides.

Let's look at an example for a feedstock pump at an olefin plant, where the pump can handle naphtha, butane, propane or ethane, depending on availability. From a process point of view, the density of these fluids varies by a factor of almost four-to-one from heaviest to lightest. Therefore, changing feedstock could have a significant affect on the power requirements for the pump for a given flow. As a load related parameter, this could in return affect the vibration signature.

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Moreover, the discharge pressures will be different as well as the risk of vapor generation, which will also affect the vibration response. If by chance the alarm limits have been made tight for early detection of faults, a change in feedstock could conceivably result in exceeding the defined vibration limits for the different loads. Such an alarm would in fact be considered as a false alarm, since it is due to a changing process condition, rather than to a fault in the machine itself.

How does the machine states function help?

By defining machine states for a particular machine, the monitoring alarm limits can be changed according to different operating conditions. In the previous mentioned example of an olefin feedstock pump, there can be two individual machine states; one for the denser Naphtha feedstock and the other one for the less dense butane, propane and ethane fluids. There can also be other machine states, such as for speed and load.

In order to implement machine states in your monitoring program, you will have to determine how many relevant machine states are needed for monitoring the machine. In other words which process conditions have a significant affect the vibration signature. After this, you will then have to evaluate the vibration signature response for each machine state in order to set the alarm limits for these. Nearly any process variable can be used for machine states, but the most common are speed and load. Speed machine states typically include transient operating conditions such as run up and coast down.

One important factor to keep in mind for defining machine states, is that a trigger is needed for the monitoring system to automatically recognize each machine state. This is typically defined as a specified range in speed, power, pressure, etc.

Once the machine states are defined, the monitoring data is stored for the individual machine states, and these can be searched and analysed using post-processing functionality.
Now machine states are not only used for condition monitoring, but also for protection. Moreover, it is not only limited to critical machines but can be effectively used for all types of machines, including balance of plant.

Why do process conditions change?

In the past, many machines operated under baseload, and non-changing operating conditions, but this is changing now. In the petrochemical industry, feedstock for many processes can now change according to spot prices and availability, as mentioned in the previous example. As a result, pumps and compressors nowadays have to be designed flexible enough to operate at different duty cycles and should be monitored accordingly. In hydropower, many hydro units are no longer operating at baseload. Instead, they are increasingly being used in peaking and load-following operational regimes. In addition to this, some hydro installations are being designed specifically for pump storage applications, where part of the operation is used for generating, part for pumping, and part for synchronized compensation to stabilize the grid. The vibration response in all these operating conditions will be different.

What is special about the hydro applications is that the units can be more stressed while operating at partial loads and with multiple starts and stops. This means condition monitoring becomes even more important because the machines are now more vulnerable. Just as importantly, the variable operating conditions for the hydro units as well as for all other industrial applications, make it difficult to implement a fixed interval-based maintenance strategy. Once again, condition-based maintenance strategy is the only alternative.

Conclusion

Early fault detection becomes increasingly important to cost-effectively plan maintenance ahead of time. Using properly refined monitoring techniques is the first step in achieving this. Just as importantly, monitoring to tight alarm limits increases the possibility of detecting developing faults earlier. You must remember though, any process changes that occur during monitoring can result in false alarms. This is where machine states help! These will help you get more lead-time to service by early fault detection, and increase monitoring reliability by minimizing the risk of false alarms.

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Figure 1: Screen plot shows five machine states based on speed for a steam turbine starting up twice and being shut down once. The alarm limits for the run up and coast down machine states are shown in the upper plot. The alarm limits are not shown for the running or turning machine states but these too will have individual alarm limits. A fifth machine state shown below has no data yet.

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