Artesis

MCM “Motor Condition Monitoring”

Michael Olszewski-Reliability Concepts: Distributor North America

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Artesis simplifies predictive maintenance

Artesis, a key player and a contributor to predictive maintenance world standards

International Organization for Standardization

ISO 20958:2013

ISO 20958:2013 is a standard describing different condition monitoring techniques [4]. MCM technology is mentioned in section 4.3.4 under the title “Model-based voltage and current system”. Artesis was involved directly in the contribution of the standard. It also refers to an article written by Artesis General Manager Prof. Dr. Ahmet Duyar [17].

[17] A. Duyar, A. Bates Motor condition monitoring; MCM; An inexpensive, simple to use model based condition monitoring technology. J. Maintenance Asset Management. 2006, 21 pp. 13–22

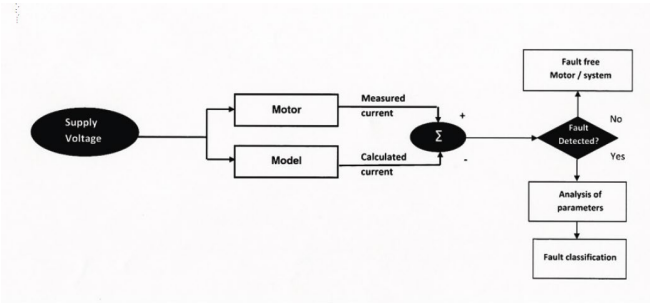

Figure 6 — Model-based voltage and current monitoring system

Lloyd's Register

The book *“Condition Monitoring of Marine Machinery, Guidelines for Shipowners and Managers”* discusses on early fault detection of generators and electrical motors and driven equipment via MCM technology. The book refers to and thanks to Artesis.

Certifications

REACH

ISO 9001:2008

Industrial internet era

Industry 4.0 - IoT

- Machines will be smarter and use analytics to convert big data into useful information through industrial internet and analysis softwares
- 50 billion devices will be capable of communicating within 7 years
- Increase in productivity. 10-15 trillion $ savings within 20 years by preventing unplanned downtime
- Decrease in service costs up to 20 billion $
- **No unplanned downtime is needed**

Sustainable PdM for *"no unplanned downtime"*

Requirements

- Sustainable predictive maintenance is essential for increased production and energy efficiency.
- Although the benefits of a predictive maintenance program is well recognized, only less than 1% of companies have sustainable predictive maintenance program.
- Requirements for a sustainable maintenance program:
  - Effortless condition monitoring
    - Simple and easy to use condition monitoring devices
    - Actionable information for maintenance scheduling
  - Comprehensive fault coverage (mechanical, electrical and process faults)
  - High fault detection accuracy
  - Providing the effects of faults on energy efficiency
  - Integration to 3rd party HMIs

Why monitor motors?

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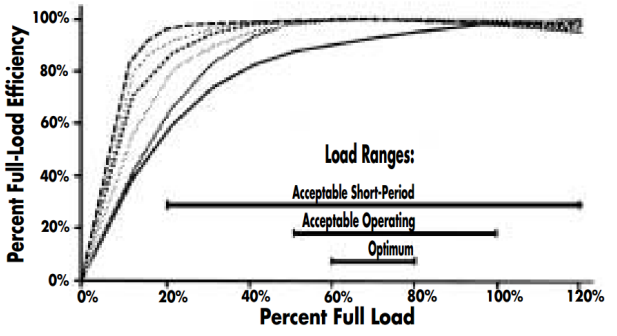
- Majority are out of sight-out, out of mind … until they break.
- For the petroleum and chemical industries the average downtime costs are $87,000 per hour.
- Because they're a major energy consumer!
- In the US alone, 1.2 billion+ motors consume 20% of all energy used in the US.
- These same motors consume 59% of all electricity generated.



Motor efficiency is best at maximum load. MCM measures and reports on motor efficiency. Owners then have the info they need to size a motor correctly for the specific application.

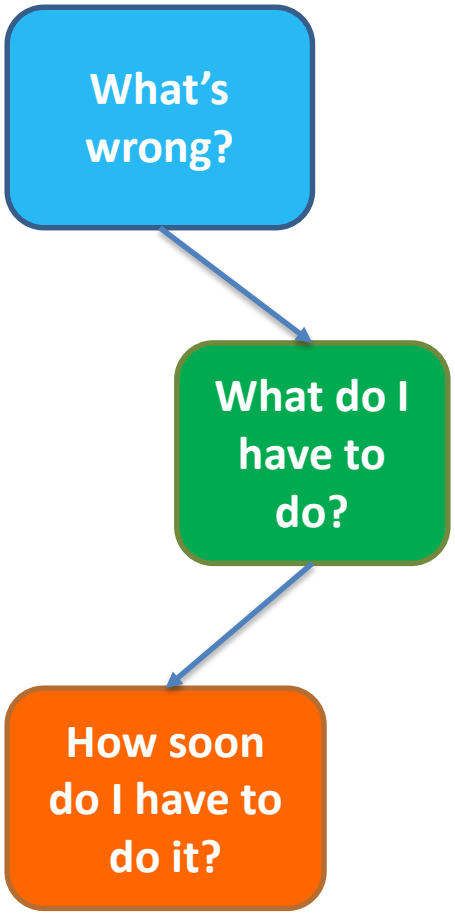
Why monitor motors with MCM

Effortless monitoring with simple and actionable information	“Traffic light” warning systems and automatically delivered fault information on TV screens and emails
Early warning fault detection (3-6 months)	Even before symptoms like abnormal vibration, heat or acoustics emerge
Fault detection accuracy > 90%	Enabling appropriate maintenance actions to be identified and performed
Comprehensive fault coverage and energy efficiency	Detection and diagnosis of electrical, mechanical, operational and energy related faults
Workplace safety	Only solution for inaccessible, hazardous, hard to reach applications. Minimised hand-on testing
Remote monitoring and diagnostic services	Maintenance consultancy via monthly reports covering root cause analysis and work order suggestions

Our value for customers

- We understand maintenance personnel do not have time for monitoring and diagnosis and need answers to the following questions:

- MCM's periodic condition assessment reports can answer these questions in a concise manner with simple work order suggestions for maintenance and repair.



Value case

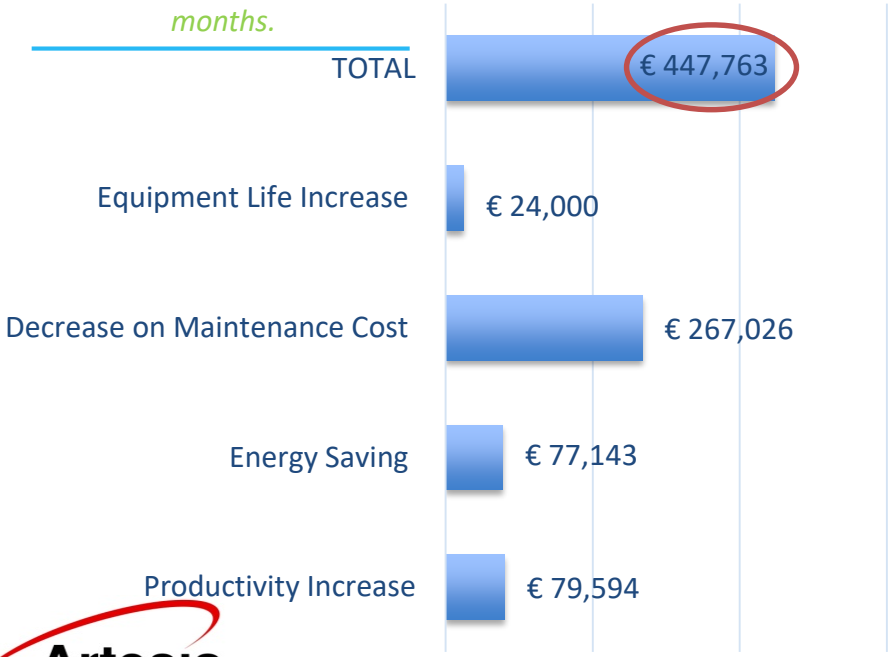
- Up to 5% increase in productivity; reduction in number of equipment downs and increase equipment availability
- 2% - 4% energy savings
- 10% - 50% departmental reduction in maintenance-related OPEX due to avoidance secondary damage and emergency repair
- Up to 10% CAPEX efficiency saving by avoiding redundancy and extending equipment life
- Reduction in performance penalties and damage to image
- Process safety improvements

Cost saving & ROI cases

Mineral processing plant

Approximate annual cost saving during the pilot application for34 equipment

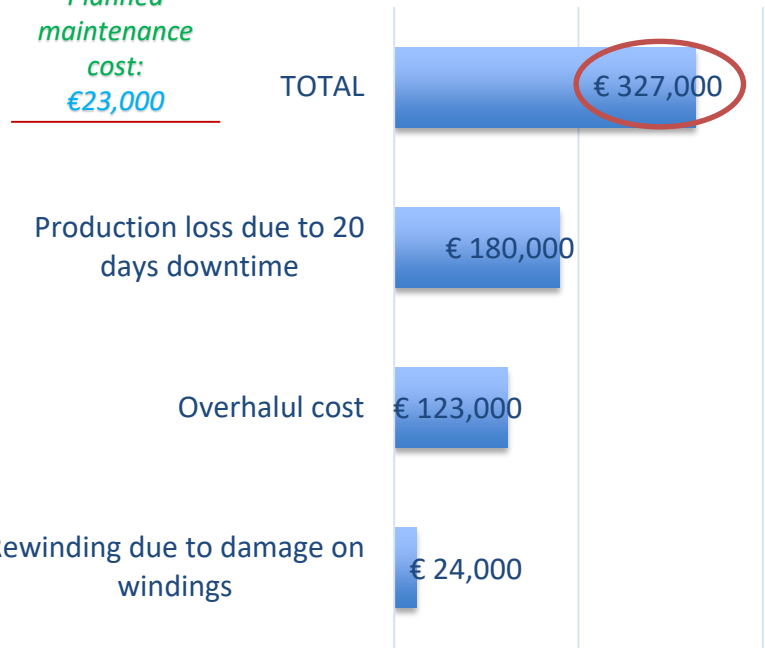
Online monitoring of equipment using AAs yielded at ROI of %500 or a pay-back period of 2.4 months.



Oil refinery plant compressor

Approximate cost saving of prevention of a burned propane compressor (440kW)

Planned maintenance cost: €23,000



What does Artesis offer?

- Artesis **MCM** and **AMT** Portable Units offer continuous condition monitoring and instant condition assessment

Continuous Monitoring	Instant Assessment
Artesis MCM 	**Artesis AMT** 

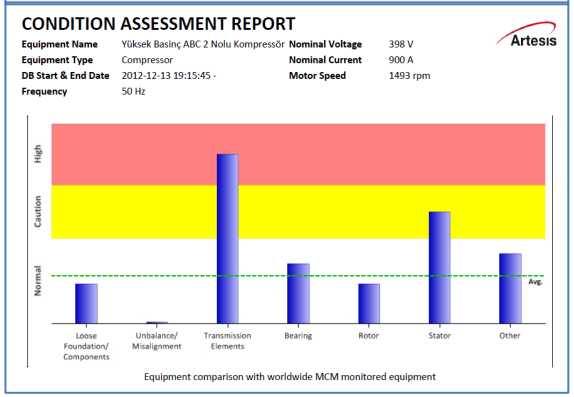
How does MCM work?

MCM Condition Monitoring

- Measures **the current and voltage signals** from electrical supply to the motor to identify existing and developing faults on electric motors and their driven equipment, specifically:
  a) **Mechanical Faults** – e.g. unbalance, misalignment, roller bearings
  b) **Electrical Faults** – e.g. loose windings, short circuits
  c) **Process Faults** – e.g. cavitation, plugged filters and screens
- Provides clear information for fault detection, diagnostics, time to failure and corrective actions, with **MCM software** used to view the data
- Applicable to **3-phase AC fixed and variable speed motors and generators**

Fault Detection

Diagnosis & Assessment



Corrective Actions & Work Order

☑ **WATCH EXISTING FAULTS** These faults should be checked for verification and corrective action should be taken at the next scheduled maintenance but no later than three (3) months.

Mechanical Fault Indications

☑ Belt / Trans. element / Driven equipment. Check for transmission element(s) coupling, driven equipment, belt, pulley, gear box, and fan / pump impeller. ***EEE:*** *Efficiency is dependent on pulley size, driven torque, under or over belting, and V belt design and construction. Efficiency deteriorates by as much as 5% over time if slippage occurs.*

Electrical Fault Indications

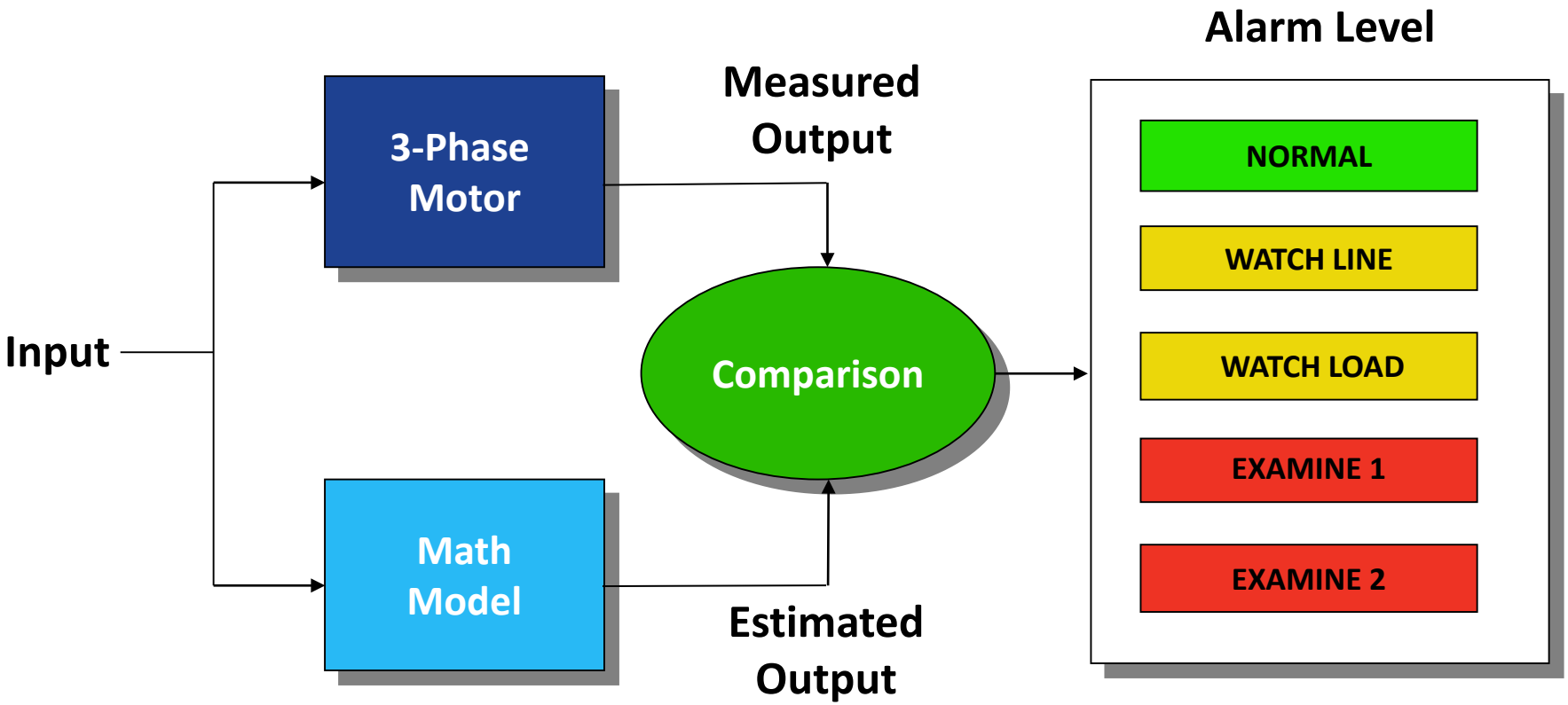
☑ Stator related problem. Check for stator, short circuit, winding slackness, isolation problems, and partial discharge. ***EEE:*** *Heating and increased resistance due to stator, rotor and other electrical faults cause deteriorating conditions and reduced efficiency.*

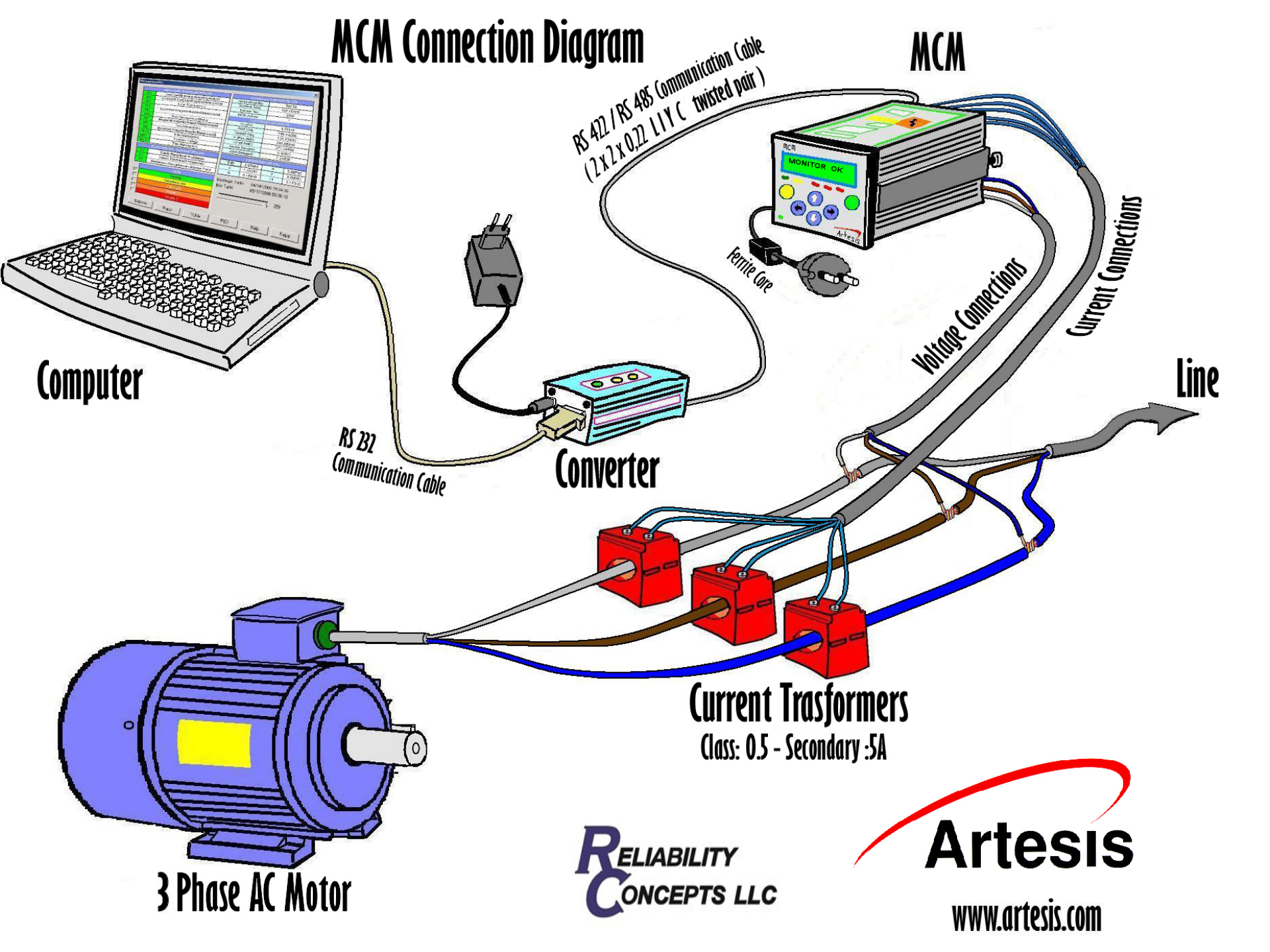
☑ **WATCH ELECTRICAL VALUES** Electrical values are outside of their expected range. They should be noted and watched to identify the cause.

Current and Voltage Unbalance

☑ Current unbalance exceeds 3%. Check for stator problems, short circuits, isolation problems, partial discharge, etc. ***EEE:*** *Voltage and current unbalance cause heat and up to 3% energy efficiency problems.*

Outputs - Alarms




MCM Connection Diagram
MCM
RS 422 / RS 485 Communication Cable
(2 x 2 x 0,22 LIYC twisted pair)
MONITOR OK
Ferrite Core
Voltage Connections
Current Connections
Computer
Line
RS 232
Communication Cable
Converter
Current Trasformers
Class: 0.5 - Secondary :5A
3 Phase AC Motor
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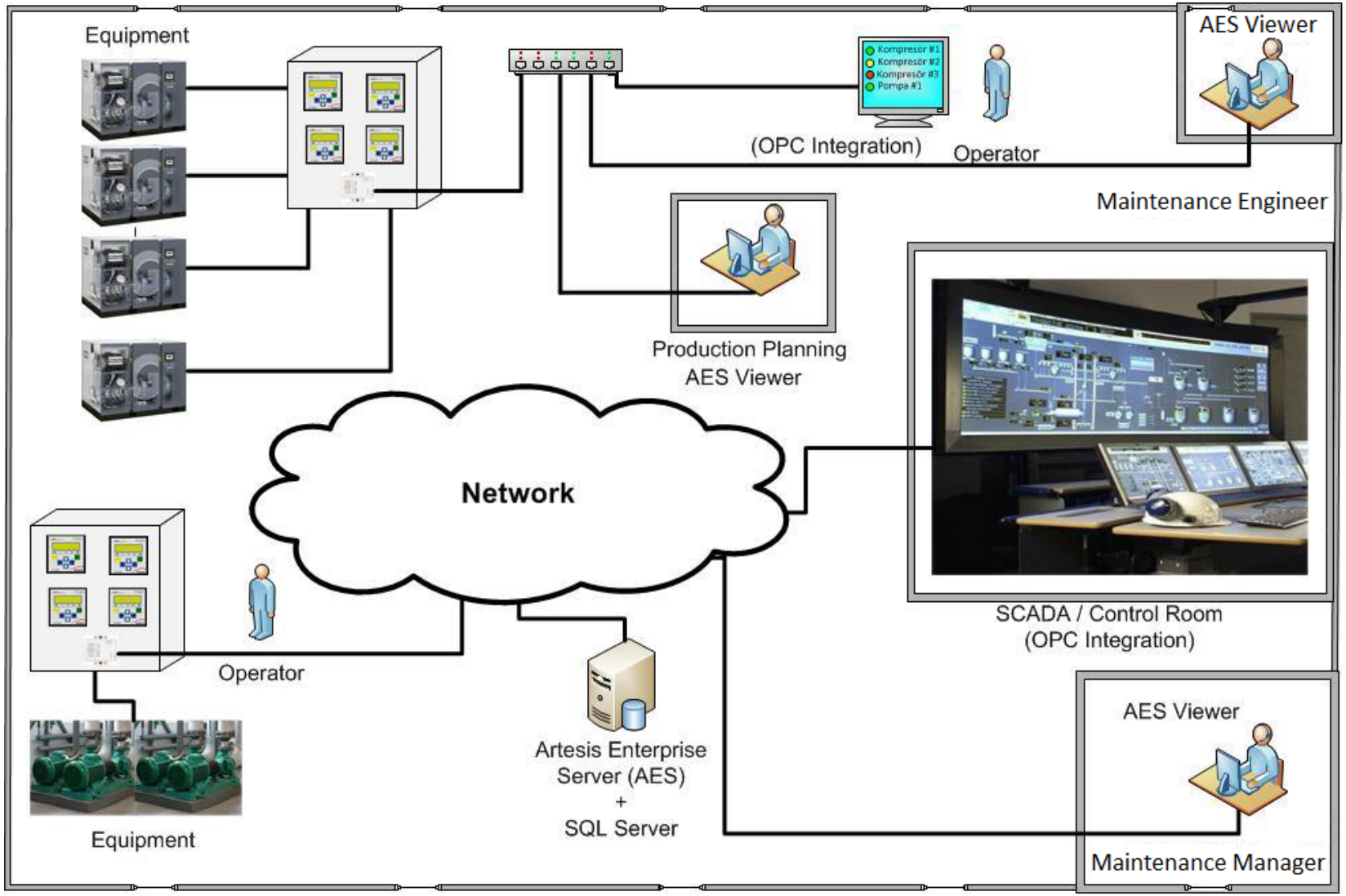
www.artesis.com

Artesis System Integration

Our system


Equipment
AES Viewer
(OPC Integration)
Operator
Maintenance Engineer
Production Planning
AES Viewer
Network
SCADA / Control Room
(OPC Integration)
Operator
Artesis Enterprise
Server (AES)
+
SQL Server
Equipment
AES Viewer
Maintenance Manager

With different displays

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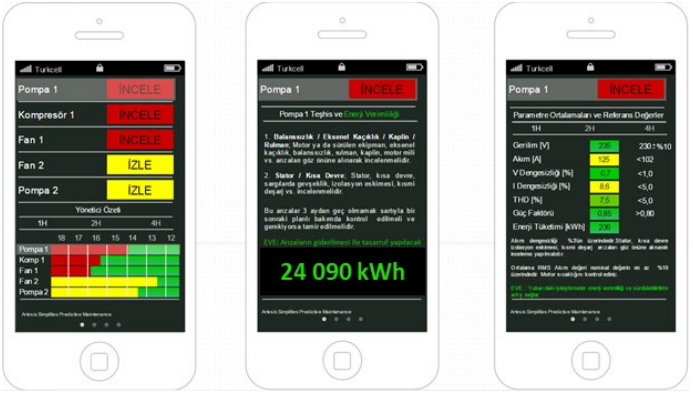
Maintenance office display



Mobile display

User display

Panel display

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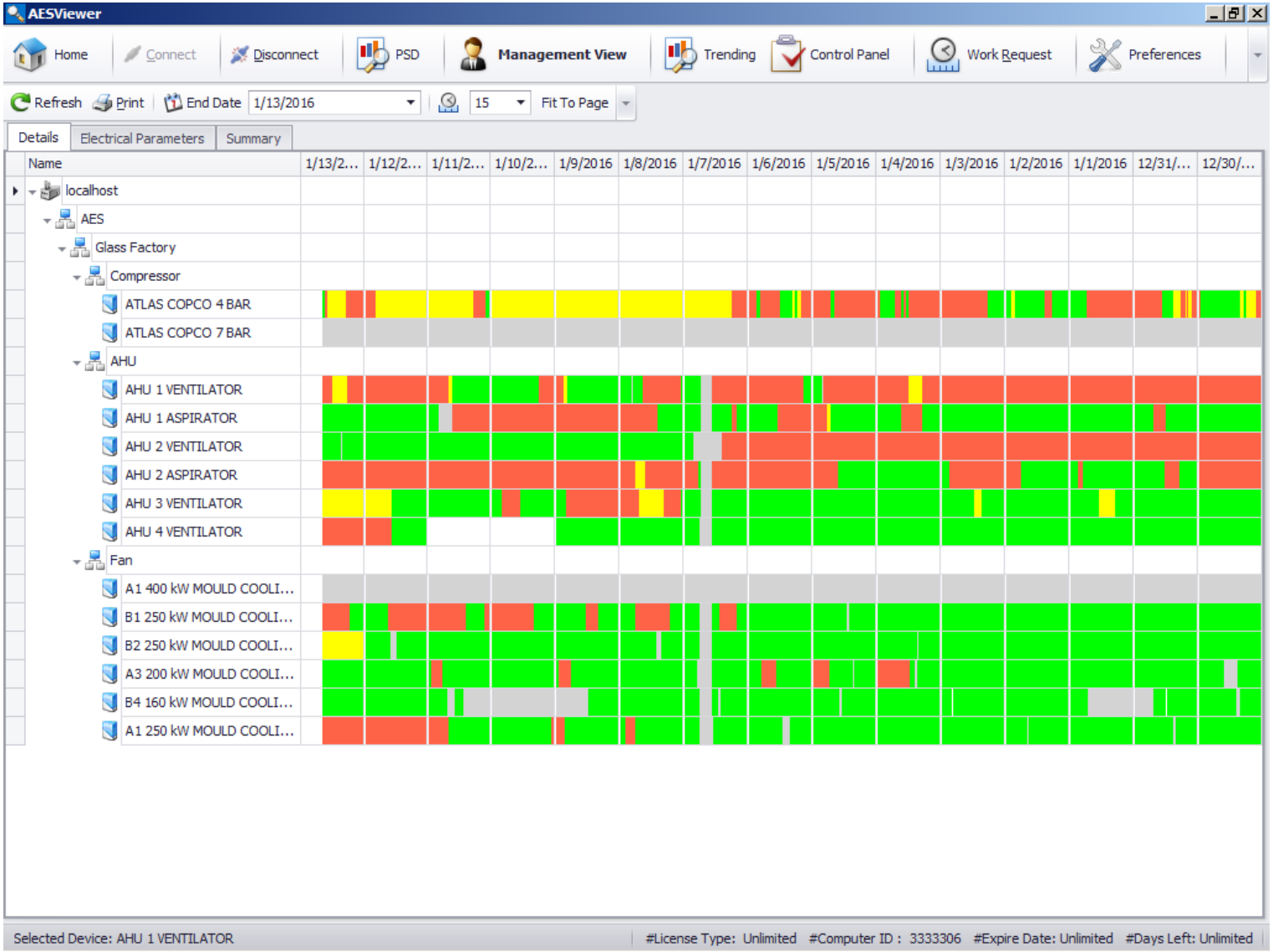
Effortless monitoring:

Equipment condition view



Effortless monitoring:

Suggestions & energy efficiency

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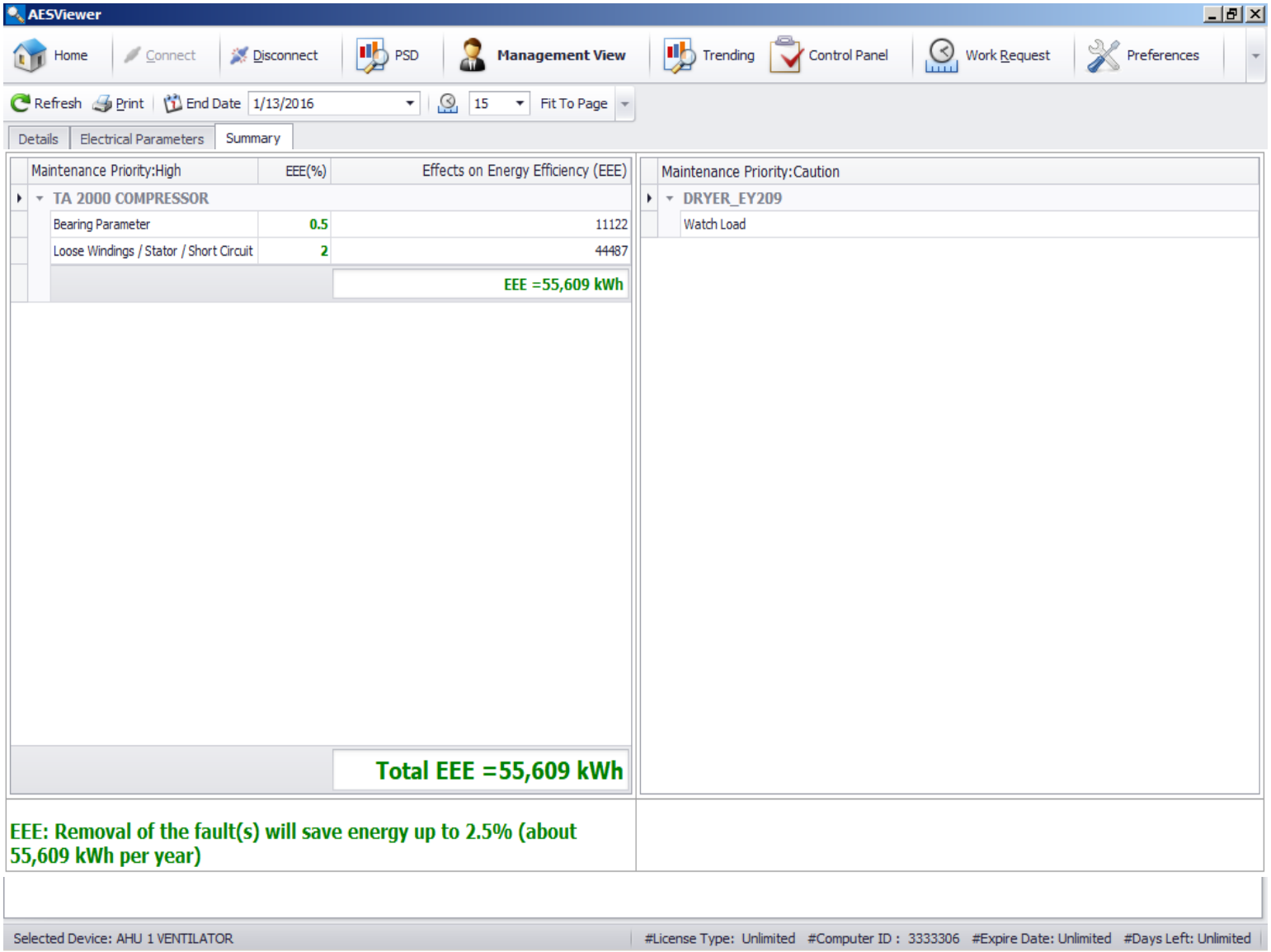
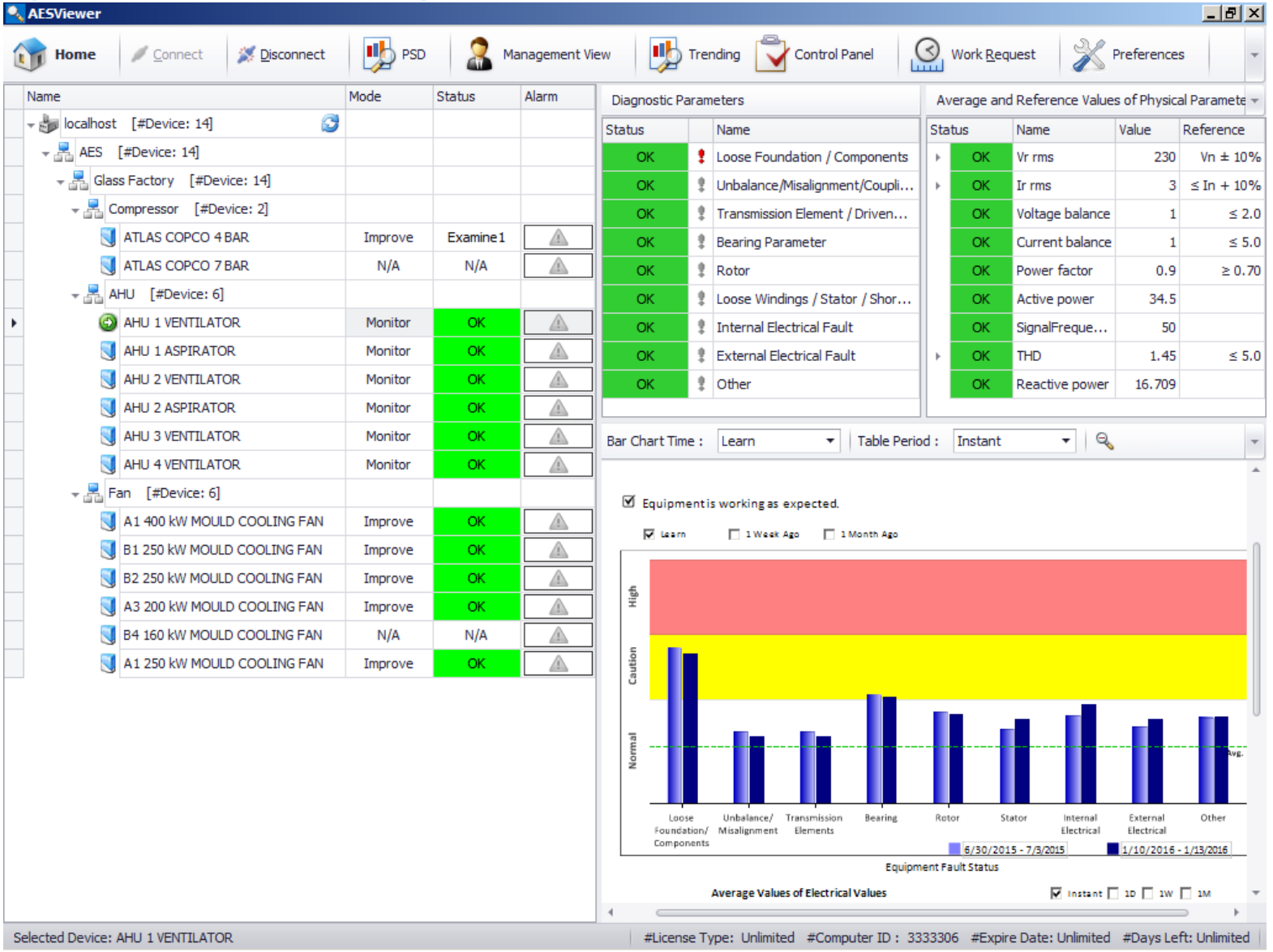


Effortless monitoring:

Equipment summary



For advanced users:

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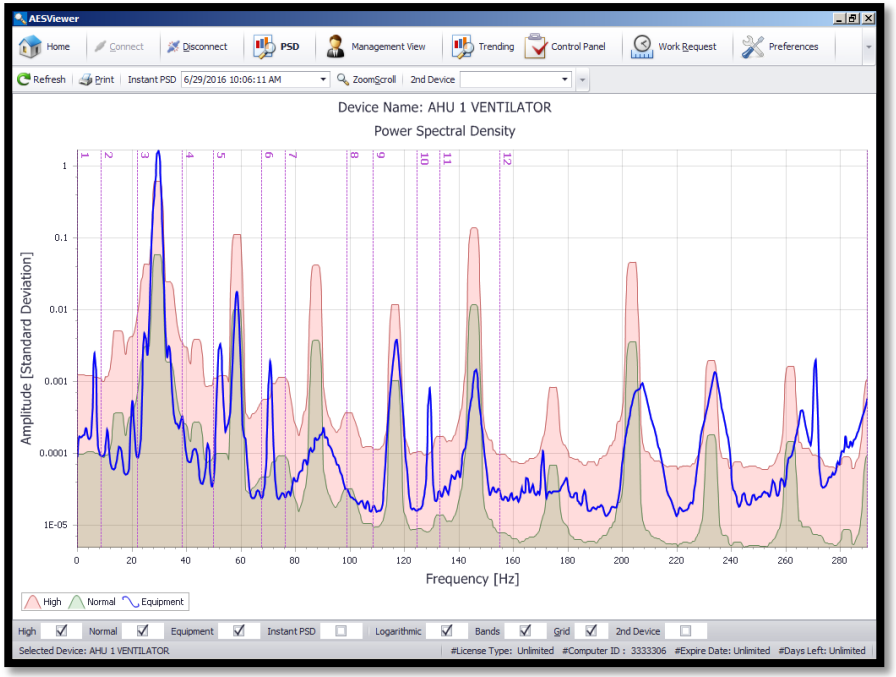
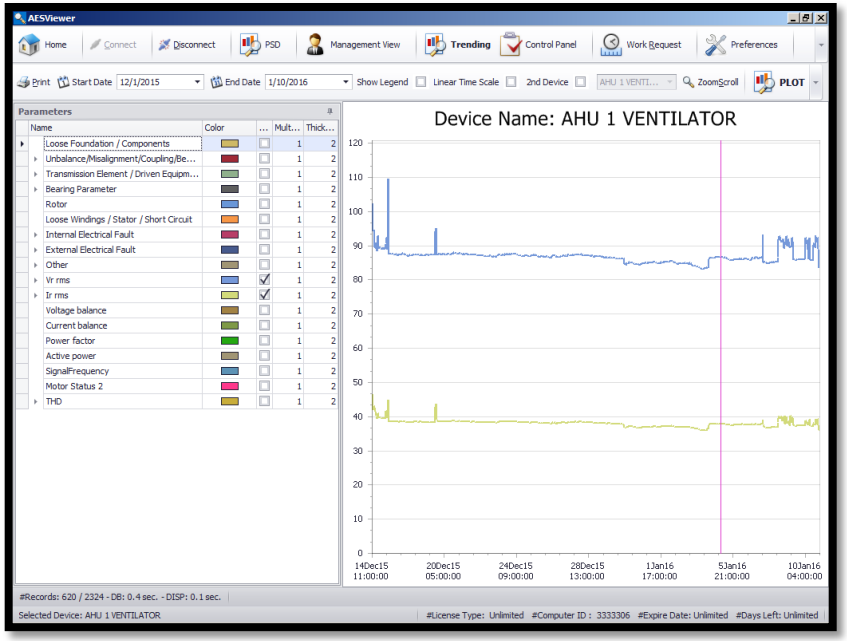
Spectrum analysis



Fault parameter trending



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Email notification

EQUIPMENT STATUS REPORT

This is an automated message generated by the Artesis MCM early warning system.
Report Date: 22 October 2017 Friday Hour: 17:20:35

Motor: E04-CEL-011
Enterprise: IZMIR Site: EFEMCUKURU Segment: TUPRAG

- Misalignment/Unbalance: Misalignment/Unbalance. Check for misalignment, unbalance, bearing, coupling, and motor shaft. EEE: Correct shaft alignment ensures the smooth, efficient transmission of power from the motor to the driven equipment.
- Transmission element/Driven equipment: Check for transmission element(s), coupling, driven equipment, belt, pulley, gear box, and fan/pump impeller. EEE: Efficiency is dependent on pulley size, driven torque, under or over belting, and V belt design and construction. Efficiency deteriorates by as much as 5% over time if slippage occurs.

Disclaimer: The actions and maintenance plans advised in this report are estimated according to past observations, and experience in the field, thus, they are approximations and they reflect the average values of similar equipment. Since equipment and their environmental conditions are different, failure periods vary. Consequently, this report should only be used as a guide to help maintenance planning.

Reporting

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CONDITION ASSESSMENT REPORT OF EQUIPMENT

ABC Car Manufacturing Plant

Report Date : **31 March 2017**

Report Period : **01 March 2017 - 31 March 2017**

Recipient

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EXECUTIVE SUMMARY

This report presents the health assessment results of selected 7 equipment at ABC Car Manufacturing plant to be used for maintenance scheduling. Our report includes detailed information about the current condition and pending faults of the equipment, as well as suggested corrective actions within particular time periods. The results were obtained via unique condition monitoring technology of Artesis. MCM condition monitoring software is used for early warning and detection of mechanical and electrical faults of selected equipment.

Report Period: 01 March 2017 - 31 March 2017

- Equipment working as expected 6.
- Equipment with developing faults 1.

1. Condition Assessment Summary

AES Viewer- Management View

The Management View below shows the equipment condition between 01 March 2017 - 31 March 2017

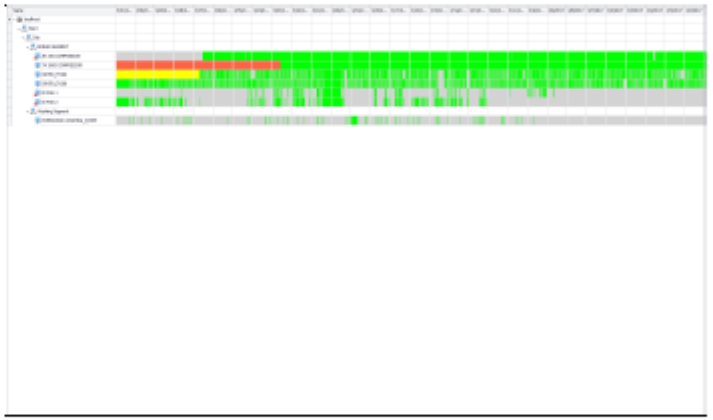

Figure 1: AES Viewer- Management View.
Green: OK, Yellow: Caution, Red: Alarm, Grey: Equipment did not run, White: No connection

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Work Order Suggestion

Condition assessment summary and suggested maintenance action is given below in Table 1

Table 1: Condition Assessment Summary and Work Order Suggestions

Equipment	Condition Assessment	EEE (kWh/y)	ETTF	Suggested Action
TA 2000 COMPRESSOR	Bearing Parameter	11,122	6 Months	Bearing Problem. Bearing(s) should be checked.
	Loose Windings / Stator / Short Circuit	44,487	5 Months	Stator related problem. Check for stator, short circuit, winding slackness, isolation problems, and partial discharge.

ETTF : Estimated Time To Failure

EEE: Removal of the fault(s) will save energy up to 2.5% (about 55,609 kWh per year)

2. Electrical Parameter Averages

Artesis MCM measures the electrical signals of the equipment to assess the condition of equipment and the resulting data is compared with international standards. The average values of the electrical parameters obtained between 01 March 2017 - 31
March 2017 for equipment monitored are shown in the following table. The electrical values that are not within the expected range are marked by bold color.

Table 2: Electrical Parameter Averages

Equipment Name	Nominal Voltage L-N [V]	Avg. Voltage L-N [V]	Nominal Current [A]	Avg. Current [A]	Avg. Motor Load [%]	Avg. Voltage Unbalance [%]	Avg. Current Unbalance [%]	Avg. Power Factor	Avg. Active Power [kW]	Avg. THD [%]
ZR 250 COMPRESSOR	230.0	127.4	540.0	528.5	97.9	0.09	4.73	0.98	198.0	**5.54**
TA 2000 COMPRESSOR	230.0	226.3	460.0	421.6	91.7	0.55	0.50	0.89	254.7	1.55
DRYER_EY209	230.0	221.2	32.0	16.4	**51.3**	0.08	3.02	0.75	8.2	1.40
DRYER_EY208	230.0	221.2	32.0	17.1	**53.4**	0.08	4.06	0.77	8.7	1.42
ID FAN 1	230.0	216.6	280.0	116.8	41.7	0.22	3.93	0.59	44.8	4.60
ID FAN 2	230.0	213.4	280.0	93.9	33.5	0.33	3.10	0.09	5.4	**5.36**
INTERSONIC WASHING_PUM	230.0	231.9	21.4	10.5	**49.1**	0.38	**6.85**	0.85	6.2	0.84

3. Power Quality

Equipment with Total Harmonic Distortion (THD) over 5% are shown below:

Equipment	Avg. THD [%]
ZR 250 COMPRESSOR	5.5
ID FAN 2	5.4

Total Harmonic Distortion (THD) of more than 5% can cause the motor to overheat and vibration. The third harmonic causes heating in the stator winding. Fifth and seventh harmonics cause vibration. Harmonic filter can be used if economic return is suitable for
very high values of harmonics.

4. Recommendations for productivity and energy efficiency improvements

Effects of faults on energy efficiency are indicated on the work order suggestions.

Motor is running at less than 60% of its full load. The optimum operation of a motor is between 60-80%. Hence, its operation is less efficient compared to its optimum operation. It is advised to continue using this motor until a developing fault exists. At that time, consider replacing it with a more efficient and low power counterpart if return on investment (ROI) is acceptable.

Equipment	Avg. Motor Load [%]
DRYER_EY209	51.3
DRYER_EY208	53.4
INTERSONIC WASHING_PUMP	49.1

5. Caution

The following equipment(s) displays "Watch Load" or "Watch Line" alarms.

Equipment	Caution
DRYER_EY209	Watch Load

Watch Line :

Temporary changes in supply voltage cause this alarm. If alarm is persistent check: harmonic levels, capacitors, isolation of cables, motor connector or terminal slackness, loose contactors.

Watch Load :

If the process load has not been altered deliberately, check for leakage, valve & vane adjustment, pressure gauge faults, manometer, dirty filters (fans, compressors). If the process is altered deliberately, MCM should be updated.

Current unbalances are observed to be more than 5% in the following equipment. Current unbalance causes motors to overheat and lose torque. Developing short circuit faults due to the degradation of isolation materials may also cause increasing or decreasing current unbalance over time. Electric motors should not be operated with high current unbalance.

Equipment	Avg. Current Unbalance [%]
INTERSONIC WASHING_PUMP	6.9

Disclaimer: The actions and maintenance plans advised in this report are estimated according to past observations, and experience in the field, thus, they are approximations and they reflect the average values of similar equipment. Since equipment and their environmental conditions are different, failure periods vary. Consequently, this report should only be used as a guide to help maintenance planning.

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DETAILED EQUIPMENT ANALYSIS

Power Spectral Density (PSD) Analysis

TA 2000 COMPRESSOR

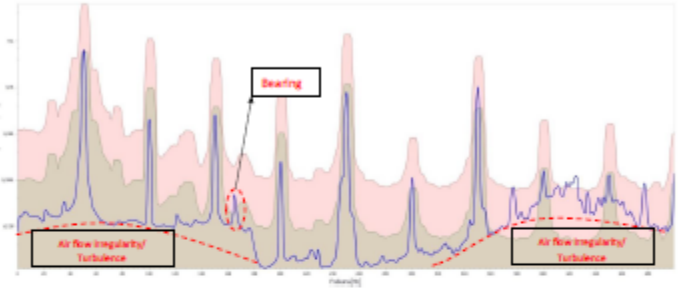

Figure 2: Power Spectral Density (PSD) curve of equipment TA 2000 COMPRESSOR

As can be seen on figure 2, Equipment (Blue), Normal Thresholds (Green) and Critical Thresholds (Red) of the PSD curve of the equipment TA 2000 COMPRESSOR have been plotted on the same figure. The blue curve (Equipment PSD) is the average of 4000 PSD measurements taken during the learn period of MCM and implies the condition of the equipment at the time of the measurement.

The green area on the above figure has been estimated using the previous measurements taken by Artesis MCM and implies the acceptable range for the PSD curve. The red curve, on the other hand, shows the critical thresholds for PSD values and is 8 standard deviations away from the normal (green) curve.

In figure 2, some weak points of the PSD curve of equipment TA 2000 COMPRESSOR have been annotated. These disturbances do not necessarily indicate a fault however, it is recommended to watch these parameters for a possible developing fault in the future.

Bearings: Even if there is no immediate action required at this moment, it is recommended to follow the trend of bearing parameter for a possible developing fault.

Air flow irregularity/Turbulence: Irregularity/Turbulence has been observed with the equipment. The curves of the tubes should be as wide as possible in order to prevent turbulence. Curves should be preferred over elbow couplings since they reduce turbulence and pressure drops to a minimum.

DRYER_EY208 and DRYER_EY209

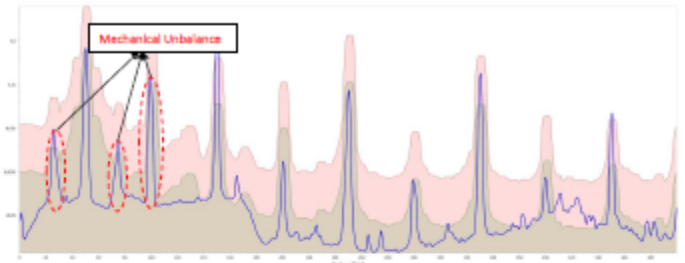

Figure 3: Power Spectral Density (PSD) curve of equipment DRYER_EY208

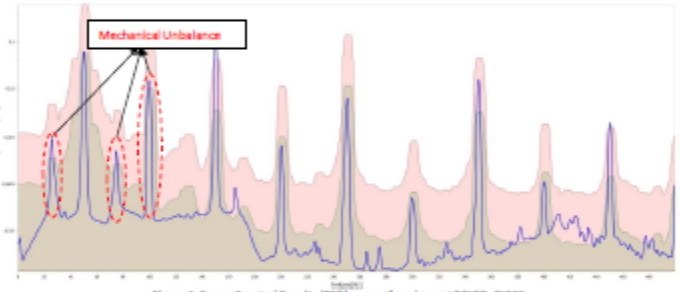

Figure 4: Power Spectral Density (PSD) curve of equipment DRYER_EY209

Figure 5: Comparison of PSD curves of equipment DRYER_EY208 and DRYER_EY209

Reporting

In figures 3 and 4, some weak points of the PSD curve of equipment DRYER_EY208 and DRYER_EY209 have been annotated.

Unbalance / Misalignment/ Coupling: Equipment used in this process is of the spiral (scroll) compressor type. As can be seen in figure 6, these devices are positive displacement machines with orbital movements, comprised of two coaxial elements. In most of the spiral compressors, base of the compressor holds the upper spiral fixed. An eccentric motor shaft moves the underlying spiral in an orbital manner. This results in a mechanical unbalance in the equipment as expected.

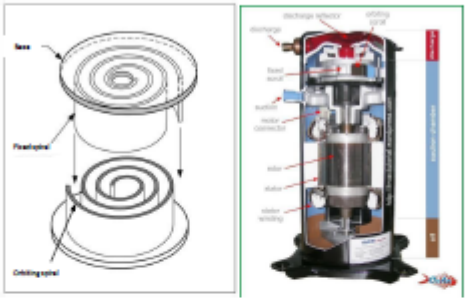

Figure 6: Spiral (Scroll) type compressor

Due to the spiral structure of the equipment, the peaks observed in the PSD curve are considered as equipment characteristics and do not require any immediate action. It is recommended to watch Unbalance/Misalignment/Coupling parameters.

In addition to these, PSD curves of both equipment (DRYER_EY208 and DRYER_EY209) have been plotted in figure 5. Dashed curve belongs to the equipment DRYER_EY208. Both equipment are in a similar condition.

INTERSONIC WASHING EM5537

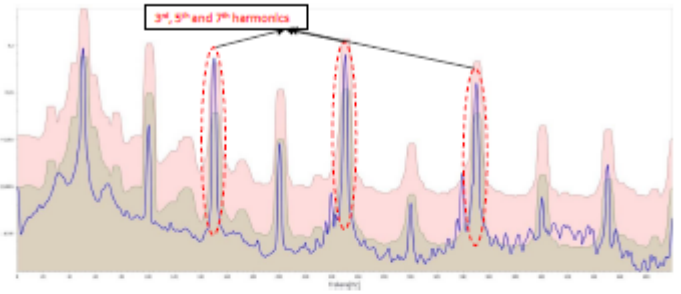

Figure 7: Power Spectral Density (PSD) curve of equipment INTERSONIC WASHING EM5537

The PSD curve calculated during the learn period of equipment INTERSONIC WASHING EM5537 has been plotted in figure 7. No critical points have been observed in the curve.

Equipment is working as expected however, it has been observed that the amplitudes of 3rd, 5th, and 7th harmonics are slightly above their expected ranges. It is recommended to watch THD parameters since high harmonic distortion can cause heating and moment loss in the equipment.

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ID FAN 1

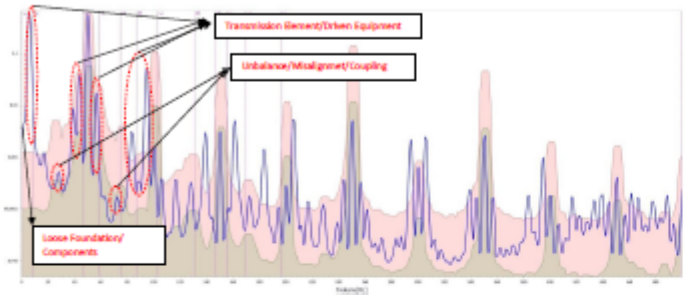


Figure 8: Power Spectral Density (PSD) curve of equipment ID FAN 1

In figure 8, some weak points of the PSD curve of equipment PRESS 1have been annotated

- **Loose Foundation/Components:** Looseness in the base platform or bolts of the equipment, which fix the machine to the ground. Cracks in screws or body. Slackness in bearings, rings or cage, or impellers in pumps can indicate this fault.
- **Unbalance/Misalignment/Coupling/Bearing:** Sudden peaks in the indicated frequencies can be observed in case of an unbalance between rotor and the driven equipment, or disturbances with coupling.
- **Transmission Element/Driven Equipment:** Peaks in the indicated frequencies can be observed in the case of unbalance and cracks in the parts of the driven equipment (pump).

Above mentioned issued do not require any immediate action to be taken however, it is advised to watch Loose Foundation, Unbalance/Misalignment/Coupling/Bearing and Transmission parameters.

ID FAN 2

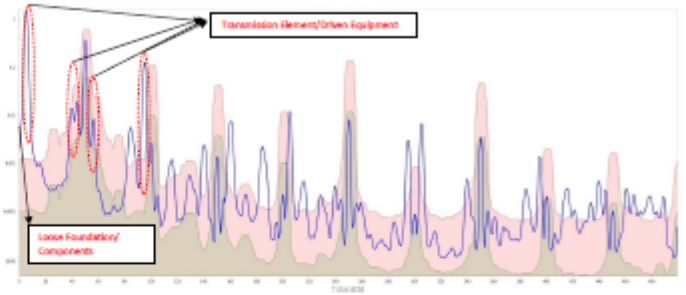


Figure 9: Power Spectral Density (PSD) curve of equipment ID FAN 2

In figure 9, some weak points of the PSD curve of equipment PRESS 1have been annotated

- **Loose Foundation/Components:** Looseness in the base platform or bolts of the equipment, which fix the machine to the ground. Cracks in screws or body. Slackness in bearing, rings or cage, or impellers in pumps can indicate this fault.
- **Unbalance/Misalignment/Coupling/Bearing:** Sudden peaks in the indicated frequencies can be observed in case of an unbalance between rotor and the driven equipment, or disturbances with coupling.
- **Transmission Element/Driven Equipment:** Peaks in the indicated frequencies can be observed in the case of unbalance and cracks in the parts of the driven equipment (pump).

Above mentioned issued do not require any immediate action to be taken however, it is advised to watch Loose Foundation, Unbalance/Misalignment/Coupling/Bearing and Transmission parameters.

Since press equipment generally operate in high mechanical unbalance conditions, above mentioned observations, can be considered the natural process of the equipment.

Reporting

RELIABILITY CONCEPTS LLC

TREND ANALYSIS

INTERSONIC_WASHING_EM553

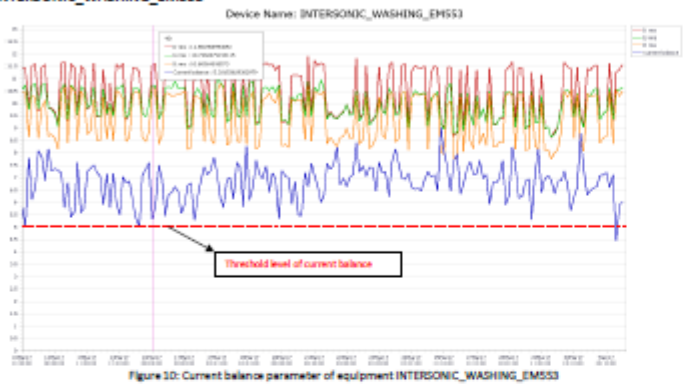


Figure 10: Current balance parameter of equipment INTERSONIC_WASHING_EM553

Figure 10 depicts the current balance and RMS current parameters of equipment INTERSONIC_WASHING_EM553. It has been observed that the 'Current Balance' parameter is above its relevant threshold value (5%). An increase in this parameter indicates that the currents flowing through individual phases are not equal. Current unbalance causes motors to overheat and lose torque. Developing short circuit faults due to the degradation of isolation materials may also cause increasing or decreasing current unbalance over time. Electric motors should not be operated with high current unbalance.

It is recommended to check for slackness and cable insulation burns in the driver and motor terminals first. After checking these terminals, it is advised to measure insulation resistance of stator windings and impedances of each phase for inspection of unbalance if required.

TA 2000 COMPRESSOR

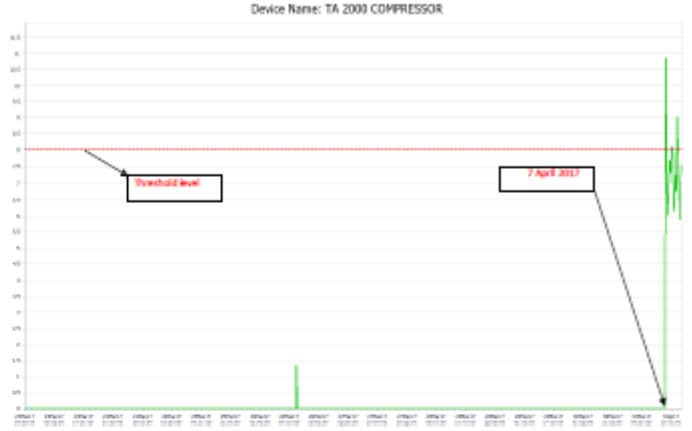


Figure 11: Unbalance / misalignment/ coupling / bearing parameter of equipment TA 2000 COMPRESSOR

As can be seen on Figure 11, Unbalance/Misalignment/Coupling/Bearing parameter of equipment TA 2000 COMPRESSOR has suddenly increased and reached at a value slightly lower than its alarm threshold in 31-March-2017. Shortly after this increase, the equipment has been stopped and restarted in 7-April-2017. Since the equipment has not been operated and parameter has not exceeded its threshold after this increase, no immediate action is necessary however, in order to detect a possible fault of the equipment, it is recommended to watch the trend of Unbalance/Misalignment/Coupling/Bearing parameter.

Reporting

EQUIPMENT STATUS REPORT

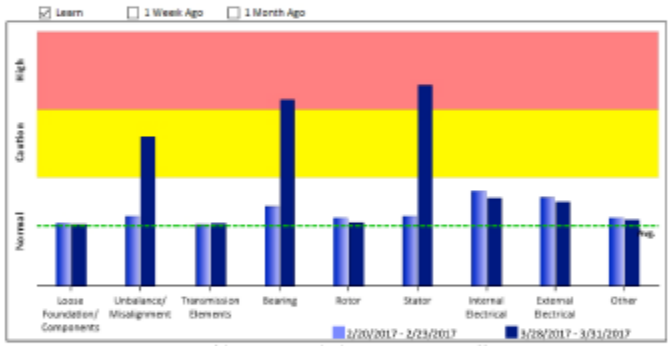
Artesis

Device Name	TA 2000 COMPRESSOR	**Nominal Voltage (L-N)**	230 V
Equipment Type	Other	**Nominal Current**	460 A
Frequency	50 Hz	**Motor Speed**	2960 rpm

Detected Faults and Warnings	Effects on Energy Efficiency (kWh)
Bearing	11122
Stator	44487
TOTAL	55609

Detected faults and their effects on energy efficiency

☑ Corrective maintenance action will save energy up to 55609 kWh per year, increase productivity, reduce maintenance cost, and increase equipment life time.



Comparison of the equipment with other equipment monitored by MCM

☑ **WATCH EXISTING FAULTS** These faults should be checked for verification and corrective action should be taken at the next scheduled maintenance but no later than five (5) months.

Mechanical Faults

☑ Bearing. Bearing(s) should be checked. ***EEE:*** *The presence of bearing defects often results in reduced efficiency, or even severe damage, of the motor under consideration.*

Electrical Fault Indications

☑ Stator. Check stator for short circuit, winding slackness, isolation faults, and partial discharge. ***EEE:*** *Heating and increased resistance due to stator, rotor and other electrical faults cause deteriorating conditions and reduced efficiency.*

Average Values of Electrical Parameters ☐ Instant ☐ 1D ☐ 1W ☑ 1M

Status	Name	Value	Reference
OK	Power Factor	0.88	
OK	Active Power [kW]	254	
OK	Reactive Power [kVAr]	131	
OK	Vrms(L-N) [V]	226	Vn ± 10%
OK	Irms [A]	422	≤ In + 10%
OK	V Unbalance [%]	0.54	≤ 2.0
OK	I Unbalance [%]	0.50	≤ 5.0
OK	Frequency [Hz]	50	
OK	THD [%]	1.5	≤ 5.0
OK	3th Harmonic [%]	0.21	≤ 5.0
OK	5th Harmonic [%]	1.2	≤ 5.0
OK	7th Harmonic [%]	0.77	≤ 5.0
OK	9th Harmonic [%]	0.07	≤ 5.0
OK	11th Harmonic [%]	0.20	≤ 5.0
OK	13th Harmonic [%]	0.16	≤ 5.0
OK	Electrical values are within their expected range.		

EEE: Effects on Energy Efficiency

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…across multiple industries

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