SPPA-D3000 Plant Monitor
Technical Description

Model-based monitoring and early fault detection for components and processes

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Introduction

Applications

SPPA-D3000 Plant Monitor is one of the solutions in the SPPA-D3000 Diagnostic Suite portfolio (SPPA Siemens Power Plant Automation). It permits continuous evaluation of the conditions of components and processes.

Condition evaluation is performed with the help of a model-based description of the conditions of the components and processes to be monitored. The data-driven neural models which are employed here make it possible to dispense with costly engineering. The models are generated and completely engineered based exclusively on archived measured data, as all the relevant information about the physical interaction between components and processes, as well as the entire history, are already available in full.

System components

Only two components are required for the operation of SPPA-D3000 Plant Monitor:
A Plant Monitor license and a technology server from the Siemens I&C system SPPA-T3000.

The license is determined by the number of tags (points coded with tags from an appropriate identification system) used. Plant Monitor licenses are available in different denominations on a graduated scale from 300 to 10,000 tags. This offers users the ability to generate any number of models of different sizes for a wide variety of applications based on this number of tags, and to use or change these models as required without any problems.

Model generation and data-driven engineering are performed on the SPPA-T3000 technology server, which fulfils all the requirements for operation, data management, training, analysis and reporting of models and condition changes.

Interfaces and integration

Plant Monitor is basically used in two different ways:

- As a fully integrated component in release R4 or higher of the SPPA-T3000 I&C system or
- In stand-alone operation with all older Siemens I&C systems and I&C systems from third-party suppliers

If Plant Monitor is used in conjunction with release R4 or higher of the SPPA-T3000 I&C system, it seamlessly integrates into the existing architecture and uses the same planning and engineering specifications. Plant Monitor can therefore be operated from any thin client within the framework of SPPA-T3000 user rights. Furthermore all results and analyses from Plant Monitor can be immediately incorporated in existing plant displays.
Even if Plant Monitor is not used with SPPA-T3000, the entire engineering, operation and analysis is still retained thanks to the technology server platform. If, for example, the measured data are exported via OPC from another I&C system or from a PI archive, for example, the technology server then constitutes an autonomous SPPA-T3000 system. It can make use of all the convenient features and advantages available to the integrated version.

*Topology of network interface of Plant Monitor on the technology server with SPPA-T3000 projects - Release 4 or higher*

*Topology of network interface of Plant Monitor in the case of connection to older Siemens I&C systems or I&C systems from third-party suppliers*
Model-based condition description

Method of operation of Plant Monitor

SPPA-D3000 Plant Monitor is a model-based solution which is able to determine the condition of a component or process based solely on archived measured data, to compare the condition with the current condition and to judge whether this condition can still be regarded as normal. The use of a data-driven neural network provides it with this capability.

The basis for this condition evaluation is a model which has been generated for this task based on archived measured data and activated on the technology server. The schematic representations below are designed to briefly illustrate the basic method of operation.

The value displayed in red in the graphic below represents a real measured signal from the component or process under consideration. Over time, it assumes many different values that may fluctuate greatly from operating mode to operating mode. Up to now signals of this type have generally been monitored for violation of simple limit values. In many cases the operator will only take note of upward limit value violation, whereby such high values are not unusual in certain operating situations.

If the Plant Monitor model has been adequately trained with historical measured data, it will provide an expected value in real time, shown in blue here, parallel to the measured values from the plant (red). In well-trained models, the real measured value and the expected value will therefore be nearly identical for normal behavior.

![Schematic representation of the measured value and the expected value in Plant Monitor operation](image)

Let us now assume there is a deviation between the real measured value (red) and the expected value (blue). Based on the behavior previously learned from the archived measured data, the Plant Monitor model concludes that the measured quantity shown here should be higher – in the light of all the other measured values in this model. In other words, Plant Monitor recognizes that the behavior at this measuring point, even though it is quite "high" in places, has previously been evaluated as "normal" in relation to all the other measuring points in the model. Plant Monitor also indicates when behavior exhibits values which are lower than those previously derived from normal behavior.

Deviations from normal behavior, i.e. points where the real measured value and the expected value calculated by Plant Monitor do not match, are most easily recognized by considering the residual, i.e. the difference between the measured value and the expected value. The associated residual for this schematic example is shown in the diagram below.
As expected, the residual on the left is almost zero, as the measured value and the expected value are almost identical. The residual on the right is significantly greater than zero, thus indicating a deviation from the measured value at this point. Plant Monitor monitors the residual in real time and immediately issues an alarm for each deviation. Plant Monitor would also output the deviation to the alarm sequence display in this example. The user is informed about the possible problem and can immediately navigate to the associated plant display or initiate a preliminary analysis without delay as he or she can jump directly to the abnormal measured value from the alarm sequence display.
Generate model and learn normal behavior

Generating models

Plant Monitor is capable of monitoring the normal condition of all processes and components in the power plant. The conditions included in one or more Plant Monitor models and monitored as a consequence depend entirely on the measured values selected by the user. The source of these values in the power plant is of no significance. For example, all the blowers in a subsystem can be grouped together, as can individual machines or entire process or plant sections. The only important thing is that the phenomena which change normal operating behavior and which must therefore be detected are reflected in these measured variables.

Up to now it has proven meaningful for practical applications to take into consideration all of the data tags which are actually acquired on the machine under consideration when modeling and monitoring individual machines. Also included are measured values which have an effect on the condition and the control of these machines. For example, when monitoring a gas turbine, in addition to the values measured on the gas turbine, values which have an effect on power output, condition or service life but which are not measured directly on the gas turbine should also be taken into account, e.g. ambient temperature and pressure.

Unlike most classical systems, Plant Monitor actually generates the model fully automatically from the list of available tags with the help of Plant Monitor's neural network.

If Plant Monitor is operated in an integrated application, i.e. in conjunction with SPPA-T3000, all the tags currently defined in the project container are displayed for selection. The user selects the tags of interest from this list.

In all other applications, the archived tags are read out using the medium acting as an interface to the technology server, e.g. OPC, and are displayed for selection in a process similar to that for the integrated application. This selection actually generates the model, i.e. it defines what is to be monitored by Plant Monitor.

Selection of instrumentation channels used for modeling in the Plant Monitor input mask
The model is represented in the form of so-called blocks or automation functions. In SPPA-T3000, each sensor is represented by a separate block, a so-called state estimator. All of these blocks, in addition to a header block used for model administration and parameterization, are linked to form a model.

Editing of the signals used in the model in the SPPA-T3000 Workbench editor (function diagram of model)

Training models

Once the model has been defined by selecting the relevant tags for the component or process under consideration, it must be trained. Training here means that a time range from the archive during which the component or process of interest was in a condition regarded as normal is made available to the model. Normal usually means "unimpaired", but not necessarily "optimal". For example, irregular operating behavior of a component can be regarded as normal if it has been identical for many years and has not become any worse.

This time range is selected in exactly the same way in the Plant Monitor in integrated and non-integrated applications, i.e. using the calendar function or a graphical display.
Selection of normal behavior for training a model (marked in blue) in the operating window of Plant Monitor

The selection of training times allows the model to familiarize itself with the normal behavior of the component or process in the initial training phase. The time required for this training phase is usually a few hours or days, provided no extremely changeable behavior spanning several months needs to be taken into account (in this case a longer training period is required). Once a satisfactory result has been obtained and Plant Monitor only detects comparatively minor deviations between the measured value and the model value when new training data are introduced, the initial training phase can be concluded.

Display of training results with overview of deviations in the upper window in the form of red error bars
If greater deviations occur, a decision must be made as to whether the deviation points to an incipient fault or whether it is normal behavior which has not previously been taken into consideration. In this case the area can simply be defined as normal by means of selection and added to the model information. As a rule, this so-called retraining is rarely necessary provided the initial training period is sufficiently long. If an abnormal condition is incorrectly included during training, it can be selected and removed from the training information at any time without problems.

**Upper window:** Display of deviations (red error bars), classified by the user as normal behavior which has not previously been taken into consideration

**Lower window:** Retraining of the model for this normal behavior which has not previously been taken into consideration by selecting the time range (marked in blue)
Changing models

Because the components and processes in the power plant are subject to continual change due to technical changes and normal aging, the model must occasionally be changed.

Two basic options are available here:

1. **Adaptation to aging or changes in operation and operating modes**

   Changes in the behavior of the component or changes in operation and operating modes are incorporated by means of a change in the stored normal behavior. In this case the new operating behavior can be learned following an inspection and overhaul, for example.

2. **Adaptation to new or changed tags**

   If new measuring points are added, removed or configured with new instrumentation equipment, this can be represented graphically using Plant Monitor. Since each tag is represented by a separate block, it can easily be deleted, added or parameterized by the user.

*Structure of a Plant Monitor model in the editor of SPPA-T3000 Workbench*
Parameterization of models

Once the required tags have been selected and the training has been carried out, the Plant Monitor model can be put into operation immediately. The defaults limit values for the residual and other default settings are used, thus permitting satisfactory work in the first approximation.

The user can easily change these settings at any time, however, and adapt them to fit the given situation. Plant Monitor offers a facility for displaying parameters directly in overview fashion with a view to editing.

Parameterization of models within Plant Monitor

It is also possible to export all the definable parameters to Excel, to edit them there and then to read them back in. All the Excel features can be used in this case.

Spreadsheet engineering with Excel for parameterization of Plant Monitor models
Networking of models

Plat Monitor is capable of describing and monitoring any process or component with the aid of a model. The scope of these models can be defined freely and can also go beyond the boundaries of an engineering complex.

However it must be noted that the larger the number of different components and processes that are grouped together which are independent with respect to information (i.e. which are not interdependent), the more the accuracy of the condition description suffers due to the nature of the group. This can always be remedied by representing different components and processes using separate models, e.g. one model each for boiler, gas turbine, NH3 conditioning, etc.

Naturally enough, important variables common to all models can also be used several times in different models. This makes it possible to achieve significantly higher accuracy for early fault detection and can also clearly channel responsibilities in alarm situations.

Training a single model to monitor a component or process in a number of different applications should also be avoided. Although a model for a machine is capable of monitoring both steady-state operation and rundown, for example, the condition description will be significantly more accurate, as will the possible analyses derived from it, if an existing model is duplicated and trained on the one hand for steady-state behavior, e.g. for a fixed speed band, and parallel to this for the rundown procedure.

Plant Monitor can then automatically activate the correct specialized model depending on the situation. Parallel operation of such models is also possible.

In addition Plant Monitor makes it possible to operate models with different levels of detail in cascaded fashion. If, for example, a small manageable model for a process reports a deviation at a boiler, another previously prepared model which takes all the tags for that boiler into consideration can be activated. This reduces the possible flood of information for the operator while at the same time ensuring that no condition is left out of consideration.
Operation and analysis

Alarm annunciation and operation

If the Plant Monitor detects deviations from normal behavior, it outputs these deviations in the standard views of SPPA-T3000:

- In the alarm sequence display
- In the header information
- In the plant displays

Any value used in Plant Monitor, i.e. any measured value, model value, deviation or alarm, can report an alarm condition. The form and priority of alarm annunciation can be changed at any time and adapted to suit requirements.

The information content is greatest in the case of alarms displayed in the alarm sequence display. This lists in tabular form the type of alarm which has been issued, its location and status. The alarm sequence display can also be used as a jump to the associated plant display, trend display or setup dialog.

List of alarms which have occurred and their sequence in the SPPA-T3000 alarm sequence display (ASD)

In addition to the general alarm sequence display, Plant Monitor alarms are also listed in the header. From here the user can jump directly to the plant displays in which the Plant Monitor alarms occurred.
Selection of plant displays indicating a Plant Monitor alarm which can be displayed by means of selection

The third option allows the user to jump directly from a plant display showing a Plant Monitor alarm to a trend display of the alarm values, to the function diagram of the model or to the Plant Monitor view itself.
Analysis

An analysis generally begins with a message from Plant Monitor that a measuring point is exhibiting a deviation from normal behavior. This information is displayed in the alarm sequence display and simultaneously in the plant display itself. A range of information is therefore already available for the analysis of correlations and background reasons for this report and thus for an analysis of the possible problem:

- The model in which the deviation occurred and the associated component or process
- The measuring points which are exhibiting irregularities and those which are not
- The sequence in which the deviations occurred
- The severity of the deviations relative to the measured value

In addition to this accurate information, the user has two basic analysis options which can be combined as required.

1. **Analysis in Plant Monitor view**

   All the tags associated with a model are displayed one below the other for the same time range in the Plant Monitor view. An overview with the exact times of all the deviations which have occurred is also displayed in the header in the form of red error bars. Simply select one of these error bars to switch the Plant Monitor display to the associated tag and residual. A large number of causes can be detected in this display. More importantly, a time range defined as exhibiting normal behavior can be added to or removed from the model in this view.

*In the upper window: Display of current deviations by means of red error bars
*In the lower window: Associated measured values (red), expected values (blue) and below these the residuals*
2. Analysis in trend display view

Behind every display of values by Plant Monitor, i.e. measured value, model value and residual, lies a stored preconfigured trend display containing these values. Like any other trend display, this trend display can be used for the purposes of analysis in any plant display.

Trend display of all the information necessary for a detailed analysis directly in the plant displays

The advantage of this type of display is that, depending on the analysis, values can be dragged and dropped into any diagram from other displays using the mouse. This makes it very easy, for example, to analyze vibration values in the context of process variables. Combinations which have proven useful for analyses can also be stored as views, allowing them to be used again at any time.

The deviations from normal behavior and the causes of each deviation identified by Plant Monitor put the operating and maintenance personnel in a position to analyze correlations intuitively and to make decisions about changes in operating modes and planning of maintenance measures.
Technical data

SPPA-T3000 Technology Server

The SPPA-T3000 Technology Server is the hardware and software platform for SPPA-D3000 Plant Monitor, as well as for a large number of other applications devoted to the diagnostics and optimization of plants and processes.

If we first look at the technology server independently of all other components and interfaces, it is an autonomous SPPA-T3000 component which is usually not redundantly configured (not fault-tolerant) but which can be configured as a redundant (fault-tolerant) server in the event of increased availability requirements.

Unlike an I&C system used for power plant automation, the Technology Server does not feature automation interfaces and cannot therefore be used for automation applications. The Technology Server does, however, feature a component called the Technical Calculation Container, or TCC for short. Applications like Plant Monitor run in this TCC, which means that it is fully integrated in the Embedded Component Services ECS™ of SPPA-T3000.

All the applications executed in the TCC can therefore benefit from the functions and advantages of SPPA-T3000.

The most important of these include:

- Shared user interface for HMI, analyses and engineering
- Integrated engineering
- Archive
- Log function and
- All blocks and display forms

All interfaces and operations are also implemented in SPPA-T3000 via the TCC. This means that outputs from the application are completely homogenous, with the result that externally visible outputs have the same appearance and the same operating philosophy as SPPA-T3000.

Another advantage of implementing all applications as an SPPA-T3000 function in the TCC is that all applications use identical engineering and the same editor. Not only does this produce the same "look & feel", it also means that engineering data are only entered once (one-time, consistent data input) and complete integration of applications is achieved.

Unlike classical platforms, the technology server does not represent a collection of applications which simply share the same operating system on a server, whereby each application is implemented independently of all others. All the applications implemented on the Technology Server platform use all the services supplied by the Technology Server. There is only one editor, one user interface, one archive, and so on.

The Technology Server thus makes real and complete integration of applications possible.

In the stand-alone version, i.e. without the SPPA-T3000 I&C System (DCS), the Technology Server comes ready-equipped with the licenses for engineering and operation. Only the licenses for Plant Monitor need to be added. If the technology server is used in conjunction with the SPPA-T3000 I&C system, however, the SPPA licenses are used as required. Needless to say, these licenses can be added to at any time within the framework of the I&C system.
SPPA-D3000 Plant Monitor

- License based on the number of tags used for model generation, possible in the following denominations: 100 tags, 300 tags, 500 tags, 1,000 tags, 2,000 tags, 5,000 tags and 10,000 tags
- Cycle time: less than 3 seconds
  Monitoring of steady-state conditions: Yes
  Monitoring of transient conditions: Yes
- Number of models: Any number within the framework of the total number of licensed tags
- Networking of models: Yes
- Use of data sources: Different data sources possible in parallel
  Connection via interfaces: OPC DA and HDA
- Integration in SPPA-T2000 possible: Yes, by means of OPC link (via OPC server)
  Integration in SPPA-T3000 possible: Yes, with Release 4 or higher, otherwise via OPC link
- In the case of integrated use of Plant Monitor with SPPA-T3000 R4 or higher, operation and engineering is performed based on the existing thin client workplace licenses. Other licenses for engineering and operation can be added in the form of a license upgrade.
- In applications without the SPPA-T3000 R4 I&C, a so-called stand-alone technology server is employed for operating and engineering tasks. The licenses required for operation are included in the scope of supply of the stand-alone technology server.
- If other thin client workplaces are required on the stand-alone technology server, a license upgrade can be implemented on the technology server. The existing I&C is not affected by this upgrade.

Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ECS™</td>
<td>Embedded Component Services</td>
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<tr>
<td>OPC</td>
<td>OLE for process control</td>
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<tr>
<td>DA</td>
<td>Data access (life data)</td>
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<tr>
<td>HDA</td>
<td>Historical data access</td>
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<tr>
<td>ASD</td>
<td>Alarm sequence display in SPPA-T3000</td>
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<tr>
<td>PI</td>
<td>Real-time database from OSI-Soft</td>
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<tr>
<td>PM</td>
<td>SPPA-D3000 Plant Monitor</td>
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<tr>
<td>R4</td>
<td>SPPA-T3000 Release 4</td>
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<tr>
<td>SPPA</td>
<td>Siemens Power Plant Automation</td>
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<td>TCC</td>
<td>Technical Calculation Container</td>
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<tr>
<td>TS</td>
<td>SPPA-T3000 Technology Server</td>
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