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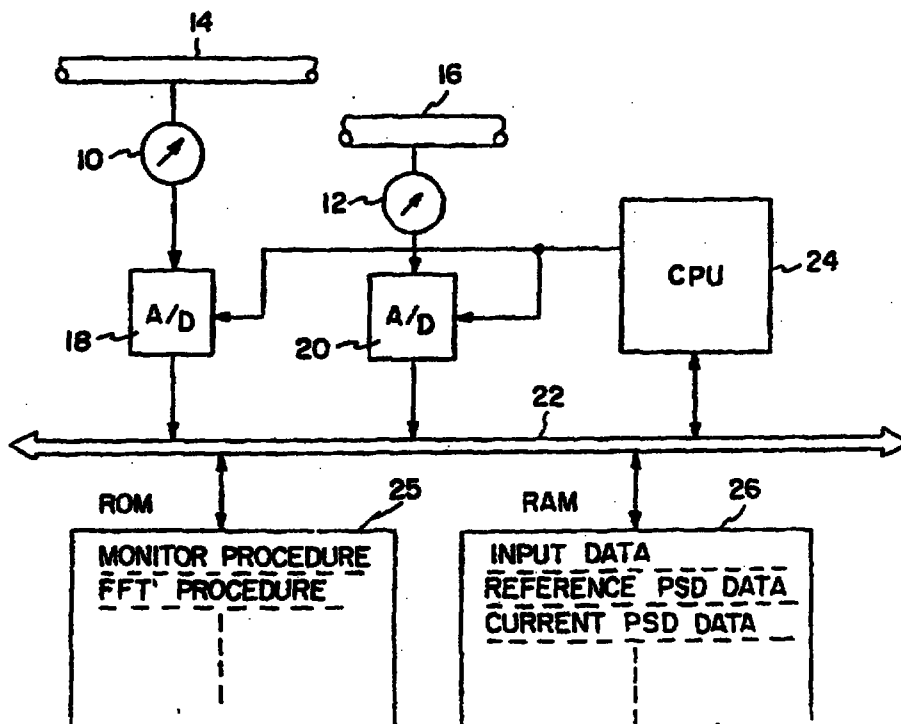
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(54) Title: **PLANT PARAMETER DETECTION BY MONITORING OF POWER SPECTRAL DENSITIES**

(57) Abstract

A method for determining whether a current state of a process variable output signal is within acceptable limits includes the following steps: establishing reference data by sampling a plant's process variable output signal when the plant is operating at steady state and analyzing the sampled output signal to derive normalized reference data including an energy content of each of a plurality of frequency components of the sampled output signal. The procedure establishes a current operational data base by sampling a process variable signal when the plant is in operation. The sampled current output signal is analyzed to derive current data including a normalized energy content of each of a plurality of its frequency components. For each common frequency component of the reference data and the current data, the procedure compares their normalized energy contents and issues a non-steady state signal if the comparison indicates that the compared energy contents exceed a predetermined limit.





PLANT PARAMETER DETECTION BY MONITORING OF
POWER SPECTRAL DENSITIES

This Patent Application is a Continuation-In-Part of U.S.
5 Patent Application, Serial No. 08/034,058, filed March 22,
1993.

FIELD OF THE INVENTION

10 This invention relates to process control systems, and more
particularly, to a system for determining whether a process
parameter is in a steady or unsteady state through a use of
the parameter's power spectral density.

15 BACKGROUND OF THE INVENTION

In controlling dynamic plant processes, it is often
necessary to know whether process variables are in a steady
state or in an unsteady state. While, many process control
20 systems monitor plant variables and compare them against
predetermined set points, it is often more important to
know whether deviations of a plant variable, over time,
away from a setpoint are significantly different from
normal. It is also important to be able to predict
25 whether a plant parameter output exhibits an incipient
condition which may lead to an unsteady state.

The prior art contains many teachings concerning plant
parameter monitoring for process control applications. In
30 U.S. Patent 4,744,041 to Strunk et al., the steady state
speed of a dc motor is detected through the use of fast
Fourier transform analysis. Strunk et al employ a current
sensor which measures the current in a test motor and sends
the sampled current signal as data to a computer. The
35 computer then samples and stores measured instantaneous
current values at plurality of discrete times and performs
a fast Fourier transform on the steady state current to
determine its power spectral density. Based on the
computed power spectral density, the speed of the motor is

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determined by detecting the frequency at which maximum power is used.

5 Kato et al., in U.S. Patent 4,303,979, disclose a system for monitoring frequency spectrum variations in output signals. The system initially determines an RMS average frequency value for an input signal. In addition, it determines RMS values for each of a plurality of frequency subranges within the input signal. The system then
10 monitors an input test signal and obtains its RMS value and the average frequency of the overall input signal. If the determined reference and test frequencies differ substantially in their RMS and average frequency values, the RMS value and average frequency of an anomalous
15 frequency component peak is calculated. The average of the anomalous frequency component is then compared to boundary frequency values to determine in which frequency range the anomalous value lies. The RMS value of the thus determined frequency range and the average frequency are then employed
20 to determine correction parameters.

Grassart, in U.S. Patent 4,965,757 discloses a process and device for decoding a received, encoded signal. The received signal is first filtered, sampled and digitized
25 before being stored. Digitized samples of each successive signal block are transposed to the frequency domain by a fast Fourier transform. The thus computed spectra are compared with stored theoretical values for each possible code signal in order to identify the received encoded
30 signal.

Schmidt, in U.S. Patent 3,883,726, discloses a fast Fourier transform algorithm computer that utilizes an attenuated input data window. An input buffer receives input time
35 samples, a cosine square attenuator superimposes a cosine squared shape on the input data samples, and then the resultant signal is passed to the fast Fourier analysis computer. A delay device, adders and an output buffer are

provided for removing the effect of the attenuating input data window.

5 Toda et al, in U.S. Patent 4,975,633, disclose a spectrum analyzer that displays spectrum data and power values of an RF or optical signal. An input signal is directed down one path where it is subjected to a spectrum analysis, and down a second path where its power value is determined. Display means indicates both the spectrum data and the power value.

10

Murphy et al., in U.S. Patent 5,087,873, disclose apparatus for detecting a corrosion state of buried metallic pipe. In Figs. 4-7, a spectrum analyzer receives input signals from a pair of magnetometers. The magnetic field, as a function of frequency, is determined by conducting a fast Fourier transform on the received signals, with the resulting spectrum indicating the amplitude and phase of the magnetic field. Those values are used to determine the condition of the buried pipe.

20

Demjanenko et al. in U.S. Patent 4,980,844 teach a method for diagnosing mechanical conditions of a machine. The Demjanenko et al. procedure is computationally complex and involves the creation of one or more sets of reference signatures (those reference signatures may be power spectrum data). Similar test data is then acquired and a comparison action occurs. The procedure averages the test and reference signatures, determines a distance therebetween (i.e. the Euclidean distance), compares that calculated distance against a computed threshold value, and classifies the distance as being normal or abnormal based upon the comparison. The threshold is established as a function of the mean reference distance and reference and test standard deviations.

35

Toshiba Japanese patent application S62-245931 describes a procedure for determining abnormalities in a rotating pump. A plurality of reference frequency spectra are stored in



memory (called restriction patterns), each reference frequency spectrum indicative of an operational state of the pump under different load conditions. To conserve memory, a "bias" procedure is employed to modify a closest
5 reference frequency spectrum to bring it into the load (i.e. power) range of a test frequency spectrum taken from the pump. If the test frequency spectrum exceeds limits determined from the "biased" reference frequency spectrum, an alarm is given. The Toshiba system thus requires
10 storage of a plurality of reference frequency spectra and accurate modification of a chosen spectrum by application of a bias value thereto to enable its comparison with a test spectrum. Misadjustment of the bias can negate the effectiveness of the test system.

15

Accordingly, it is an object of this invention to provide a method for determining when a process variable output signal is in a steady state condition.

20 It is another object of this invention to provide a method for analysis of a parameter output signal to indicate an incipient unsteady state.

It is still another of this invention to provide a plant
25 parameter output signal detection technique that is dependent upon power spectral densities.

SUMMARY OF THE INVENTION

30 A method for determining whether a current state of a process variable output signal is within acceptable limits includes the following steps: establishing reference data by sampling a plant's process variable output signal when the plant is operating at steady state and analyzing the
35 sampled output signal to derive normalized reference data including an energy content of each of a plurality of frequency components of the sampled output signal. The procedure establishes a current operational data base by

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sampling a process variable signal when the plant is in operation. The sampled current output signal is analyzed to derive current data including a normalized energy content of each of a plurality of its frequency components.

- 5 For each common frequency component of the reference data and the current data, the procedure compares their normalized energy contents and issues a non-steady state signal if the comparison indicates that the compared energy contents exceed a predetermined limit.

10

DESCRIPTION OF THE DRAWINGS

- 15 Fig. 1 is a block diagram of a system for performing the method of the invention;

Figs. 2a and 2b are high level flow diagrams illustrating the method of the invention;

- 20 Fig. 3 is a plot of a variation in flow over time in an exemplary plant;

Fig. 4 is a semi-log plot of energy versus frequency derived from the signal shown in Fig. 3;

25

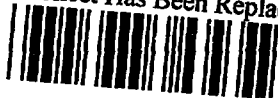
Fig. 5 is a plot of flow vs. time showing a negative-going ramp disturbance;

- 30 Fig. 6 is a semi-log plot of energy vs. frequency of the plot of Fig. 5 indicating that the ramp disturbance produces the most severe violation of plotted energy thresholds in the low frequency range;

- 35 Fig. 7 is a plot of flow vs. time showing a "U" type disturbance in the flow signal;

Fig. 8 is a semi-log plot of energy vs. frequency of the plot of Fig. 7 indicating, at one energy threshold, that a

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disturbance exceeds the threshold.

DETAILED DESCRIPTION OF THE INVENTION

5 The system and method for carrying out the invention determine whether a plant process is operating within a steady state or a non steady state condition. In brief, the system determines a reference power spectral density (PSD) of a process variable, during a time that the process
10 variable is in a steady state. A power spectral density is a representation of an energy content of a signal as a function of its component frequencies and is computed via a fast Fourier transform (FFT) which converts a time-domain signal into its frequency-domain representation.

15

The signal from which the reference PSD is derived is subjected to a first normalization procedure to derive a zero mean basis for the signal. This normalization is accomplished by subtracting the mean process variable value
20 of a time series of sample data values from each time series sample data value. A second normalization procedure is performed on the spectral data by dividing each power value in the spectrum by the number of time series signal samples used compute the spectrum. The first normalization
25 procedure enables a single stored reference PSD to be used as a reference in all subsequent test procedures and eliminates the need for plural reference spectra or for a biasing procedure to adjust the reference spectra. The second normalization procedure enables the reference PSD to
30 be compared to a current PSD, even in the event that the time windows differ during which the current and reference PSD's are derived.

The reference PSD is compared with a current PSD derived
35 when the process variable is in operation. The current PSD is also subjected to the first and second normalization procedures described above with respect to the reference PSD. If the current PSD is too energetic (either with

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respect to slow changes like ramps or with respect to fast changes like spikes) relative to the reference PSD, the process variable is determined to be unsteady and such condition is signaled.

5

Turning to Fig. 1, flow monitors 10 and 12 continuously monitor the state of flow in a pair of pipes 14 and 16, respectively. Pipes 14 and 16 form portions of a plant whose process variables are continuously monitored to
10 determine if any one has moved from a steady state to a unsteady state. Those skilled in the art will realize that the representation of inputs from pipes 14 and 16 is merely exemplary and that a plurality of other types of system variables (e.g. pressure, volume, temperature, etc.) can be
15 monitored. The outputs from each of flow monitors 10 and 12 are fed to respectively connected analog to digital converters (A/D) 18, 20 whose outputs are, in turn, connected to a bus 22 that forms the main communication pathway in a control data processing system.

20

A central processing unit (CPU) 24 is interconnected with bus 22 and also is connected to A/D converters 18 and 20 to enable timed, sample signals to be derived therefrom. A read only memory (ROM) 25 is connected to bus 22 and
25 contains a procedure for operating CPU 24 to monitor sensors 10, 12 and a procedure for enabling CPU 24 to perform a fast Fourier transform (FFT) of input data received from A/D converters 18 and 20. A random access memory (RAM) 26 is connected to bus 22 and contains
30 allocated memory for storing: raw input data from A/D converters 18 and 20; reference PSD data determined during a time that a process variable being monitored is in a steady state; and current PSD data that is determined when the process variable is being currently monitored.

35

The operation of the system of Fig. 1 will now be described in conjunction with the flow diagram shown in Figs. 2a and 2b. Initially, a steady state (i.e. reference) PSD is

determined for a monitored process variable. The steady state PSD is derived by initially time sampling a process variable output signal when the plant is operating in a steady state condition (box 30). To avoid contamination of the steady state PSD, the time sampled output signal is filtered to remove aperiodic signals therefrom (box 32). The filtered output samples are then normalized to a zero mean basis by subtracting the mean process variable value of a time series of sample data values from each time series sample data value. This eliminates any bias that is operating-state dependent (box 33).

The filtered, normalized periodic sample signals are then subjected to an FFT analysis by central processor 24, under control of a procedure read out from ROM 24 (box 34). A second normalization procedure eliminates any bias that results from the time window during which the time series samples were detected. The second normalization procedure divides each spectral frequency data value by the number of time samples so as to achieve a "time" normalization of the frequency data.

The result of the PSD analysis is a series of normalized energy values at frequencies (ω_j) for the filtered steady state signal, each normalized energy value at a frequency (ω_j) having an attribute associated therewith that is proportional to the energy contained in the particular frequency signal. Those frequencies and energy value attributes are stored in RAM 26 as steady state (or reference) PSD data.

At this point, a user-supplied multiplier factor is accessed that is to be applied to each energy value attribute of the steady state PSD. The multiplier factor enables the derivation of an energy threshold which is the amount that a process variable's current PSD must exceed a reference PSD to be considered in an unsteady state (box 36).

The system of Fig. 1 now switches to a "current" monitor state wherein it monitors the outputs of sensors 10, 12, etc. During the time that any one sensor is monitored, its output is converted by an FFT procedure to a PSD representation which is then compared with the previously derived steady state PSD for the same sensor (i.e. is stored in RAM 26). CPU 24 commences the current monitor state by sampling output signals from a sensor (e.g. 10) during operation of the plant (Box 38). After sufficient samples have been accumulated, CPU 24 filters the sampled current output signal to remove aperiodic components (box 39), normalizes the filtered output signal to a zero-mean basis (identically as with the reference PSD) (box 40) and then computes a $PSD(\omega_i)$ for the sampled current output signal using an FFT procedure (box 41). Each spectral frequency data value is now divided by the number of time series samples to achieve a "time" normalization of the frequency data. Time normalizing of both reference and current PSD data enables those data to be compared even if different time windows are used during their detection.

It is now determined whether any current PSD (ω_i) is greater than its corresponding steady state PSD (ω_j), multiplied by the user-inputted multiplier factor (boxes 42,44). If yes, the system outputs the value of ω_i at which the maximum energy ratio is found and a signal is issued that the process variable is in a non steady state condition (box 46).

If the decision indicated in decision box 44 is that no current $PSD(\omega_i)$ exceeds the multiplier factor times the steady state $PSD(\omega_j)$, then it is determined that the sampled current output signal is in a steady state condition and no further action is required. At this point, the procedure terminates and CPU 24 may then monitor another current process variable signal and the procedure is repeated.

Figs. 3-8 contain examples of the procedure described above. In Fig. 3, a process variable (flow) is plotted over a period of several hours (126 minutes). Each dot on the plot trace evidences a sampled flow value that is input to the system. Prior to monitoring the current flow values, a reference flow during steady state of the same process variable was monitored and a reference PSD was derived (e.g. dotted trace 100 in Fig. 4). Reference PSD trace 100 has been quantized into ten "bins" so as to enable averaged comparisons to be made. The PSD for the signal of Fig. 3 is then calculated (trace 102) and is seen to exhibit considerable variations in power over the frequency spectrum.

Turning to Fig. 5, a ramp disturbance 103 is plotted (flow vs. time). Furthermore, for exemplary purposes only, it is assumed that two multiplier factors (e.g. 1.0 and 1.5) have been utilized to derive energy PSD thresholds 108, 110 respectively. The conversion of ramp signal 103 to a PSD results in energy versus frequency trace 106 shown in Fig. 6. Note that the ramp disturbance 103 produces the most severe violation of both PSD energy thresholds 108 and 110 in the low frequency range. Under such conditions, an alarm is generated. The system may be adjusted such that an alarm is inhibited from issuance if only energy threshold 108 is exceeded, however the frequencies at which the energy exceeds threshold 108 may be output for user monitoring of a possibly incipient instability mode.

In Fig. 7, a "U" disturbance 113 is depicted in a plot of flow versus time. Over the span of the time during which the flow is monitored in Fig. 7, the flow difference is not large and yet it is clear that a disturbance does occur. As shown by Fig. 8, such disturbance is picked up by comparison of the peak corresponding PSD trace 112 with energy threshold 114.

It should be understood that the foregoing description is

only illustrative of the invention. Various alternatives and modifications can be devised by those skilled in the art without departing from the invention. Accordingly, the present invention is intended to embrace all such
5 alternatives, modifications and variances which fall within the scope of the appended claims.



1. A method for determining a current state of a process variable output signal and whether the output signal is within acceptable limits, the method comprising the steps of:

(a) establishing reference comparison data for said process variable by sampling a reference output signal over a first period of time when said plant is operating at steady state;

(b) processing said sampled output signal to derive reference spectral data for said process variable, said reference spectral data manifesting a normalized energy content for each of a plurality of frequency components of said sampled output signal;

(c) storing said reference spectral data;

(d) establishing current operational data for said process variable by sampling a current output signal for said process variable over a second period of time when said plant is in operation;

(e) processing said sampled current output signal to derive current spectral data therefrom, said current spectral data manifesting a normalized energy content of each of a plurality of frequency components of said sampled current output signal; and

(f) for each of a plurality of common frequency components of said reference spectral data and current spectral data, comparing normalized energy contents therefor and issuing a signal if said comparing indicates that an energy content threshold of any frequency component of said current spectral data exceeds an energy content of a common frequency

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component of said reference spectral data.

2. The method as recited in claim 1, where in processing steps (b) and (e), each sampled reference output signal and each sampled current output signal is subjected to a first normalization procedure to convert each sampled signal to a zero mean basis, said first normalization procedure dividing each sample value of a sampled signal by a mean value of all samples to derive normalized signal sample values.

3. The method as recited in claim 1, where in processing steps (b) and (e), each reference spectral data value and current spectral data value is subjected to a second normalization procedure, wherein each spectral data value is divided by a sample time related value, a sample time being a window of time during which an output signal is sampled in preparation for deriving spectral data values therefor.

4. The method as recited in claim 3, wherein said sample time related value is a number of samples of an output signal taken during said window of time.

5. The method as recited in claim 1, where in processing steps (b) and (e),

(1) each a sampled reference output signal and each sampled current output signal is subjected to a first normalization procedure to convert each sampled signal to a zero mean basis, said first normalization procedure dividing each sample value of a sampled signal by a mean value of all samples to derive normalized signal sample values; and

(2) each reference spectral data value and current spectral data value is subjected to a second normalization procedure, wherein each spectral data

value is divided by a sample time related value, a sample time being a window of time during which an output signal is sampled in preparation for deriving spectral data values therefor.

6. The method as recited in claim 5 wherein said sample time related value is a number of samples of an output signal taken during said window of time.

7. The method as recited in claim 5 wherein step (f) further indicates the common frequency for which said signal is issued.

8. The method as recited in claim 5 wherein said analyzing steps (b) and (e) perform Fourier analyses of said sampled output signals to determine the frequency components and energy content of each thereof.

9. The method as recited in claim 5 wherein said signal is only issued in step (f) if an energy in a frequency component of said current data exceeds an energy content of a common frequency component of said reference data, multiplied by a set factor.

10. The method as recited in claim 1 wherein, in step (f), said signal is issued after a ratio of energies of each of said common frequency components is determined and it is determined that at least one said ratio exceeds a predetermined factor.

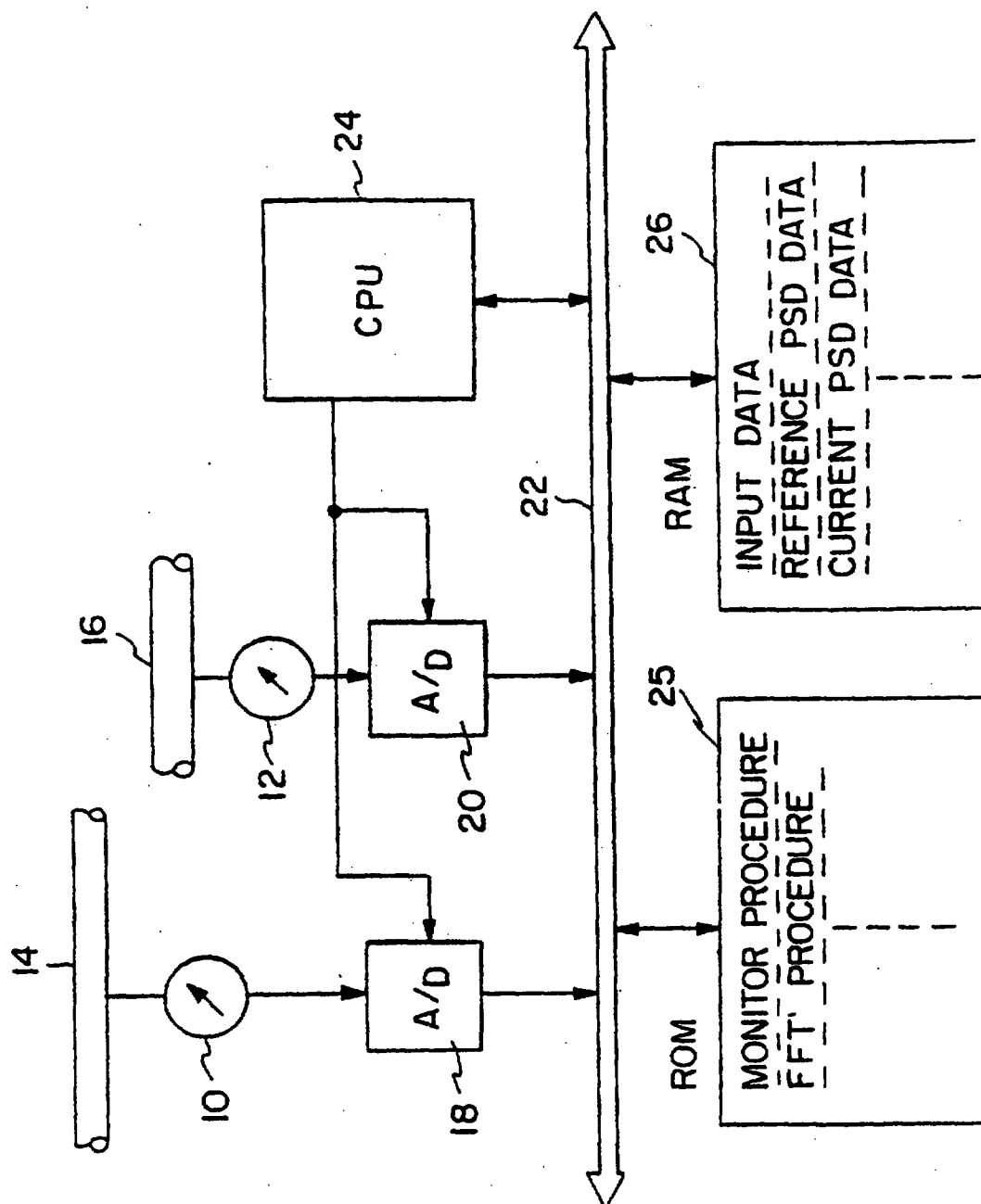


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FIG. 1



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FIG. 2A

STEADY- STATE PSD
DETERMINATION

SAMPLE PROCESS VARIABLE
OUTPUT SIGNAL WHEN PLANT
OPERATING AT STEADY STATE

~ 30

FILTER OUTPUT SIGNAL TO
REMOVE APERIODIC COMPONENTS

~ 32

NORMALIZE OUTPUT SIGNAL TO
ZERO MEAN BASIS. (SUBTRACT
MEAN VALUE FROM EACH TIME
SERIES DATA)

~ 33

-COMPUTE PSD (ω_j) FOR OUTPUT
SIGNAL USING FFT
-NORMALIZE PSD(ω_j) BY
NUMBER OF SAMPLES;
-LABEL AS REFERENCE PSD

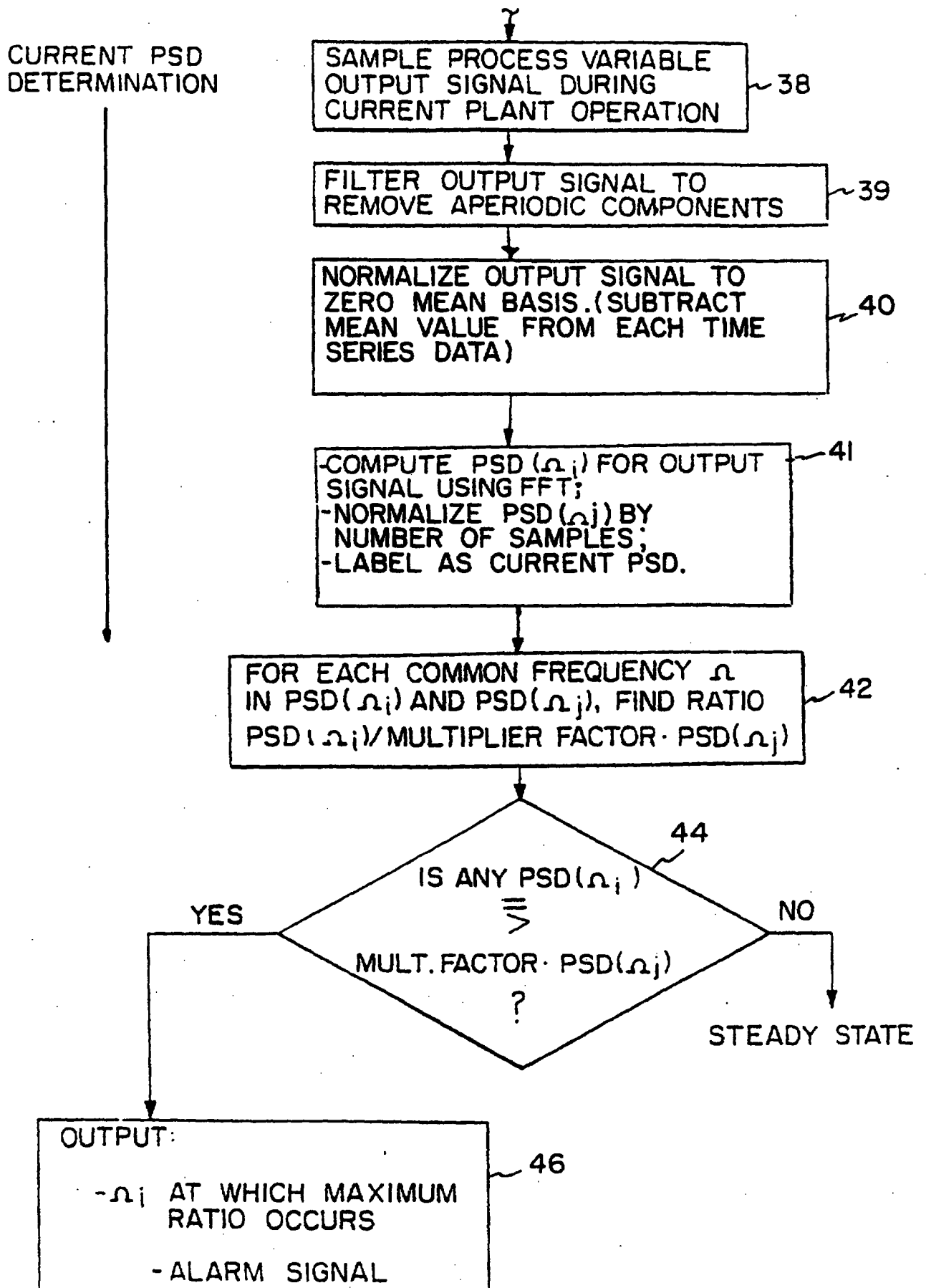
~ 34

ACCESS MULTIPLIER FACTOR

~ 36

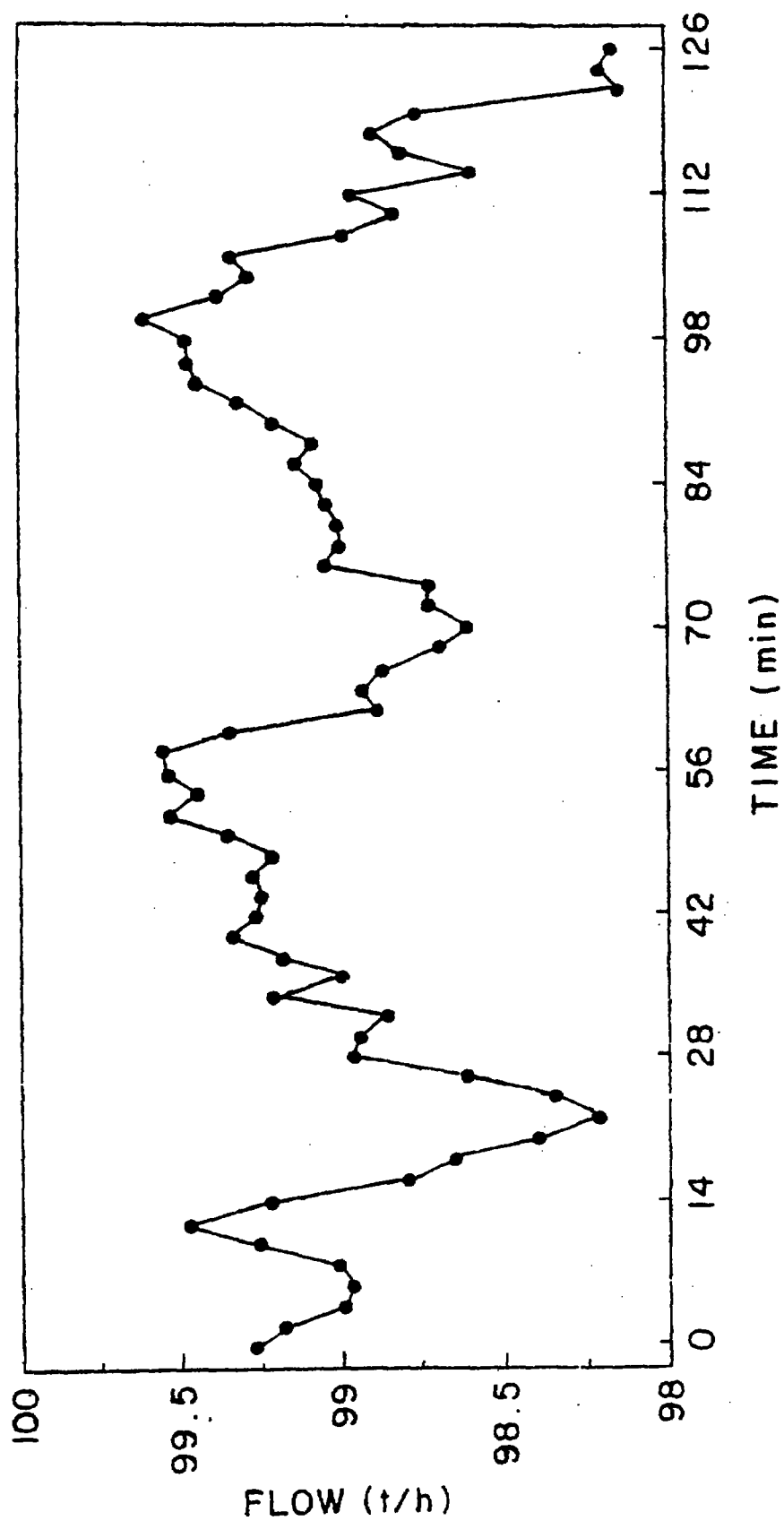
TO FIG. 2B

3 / 9 FIG. 2B



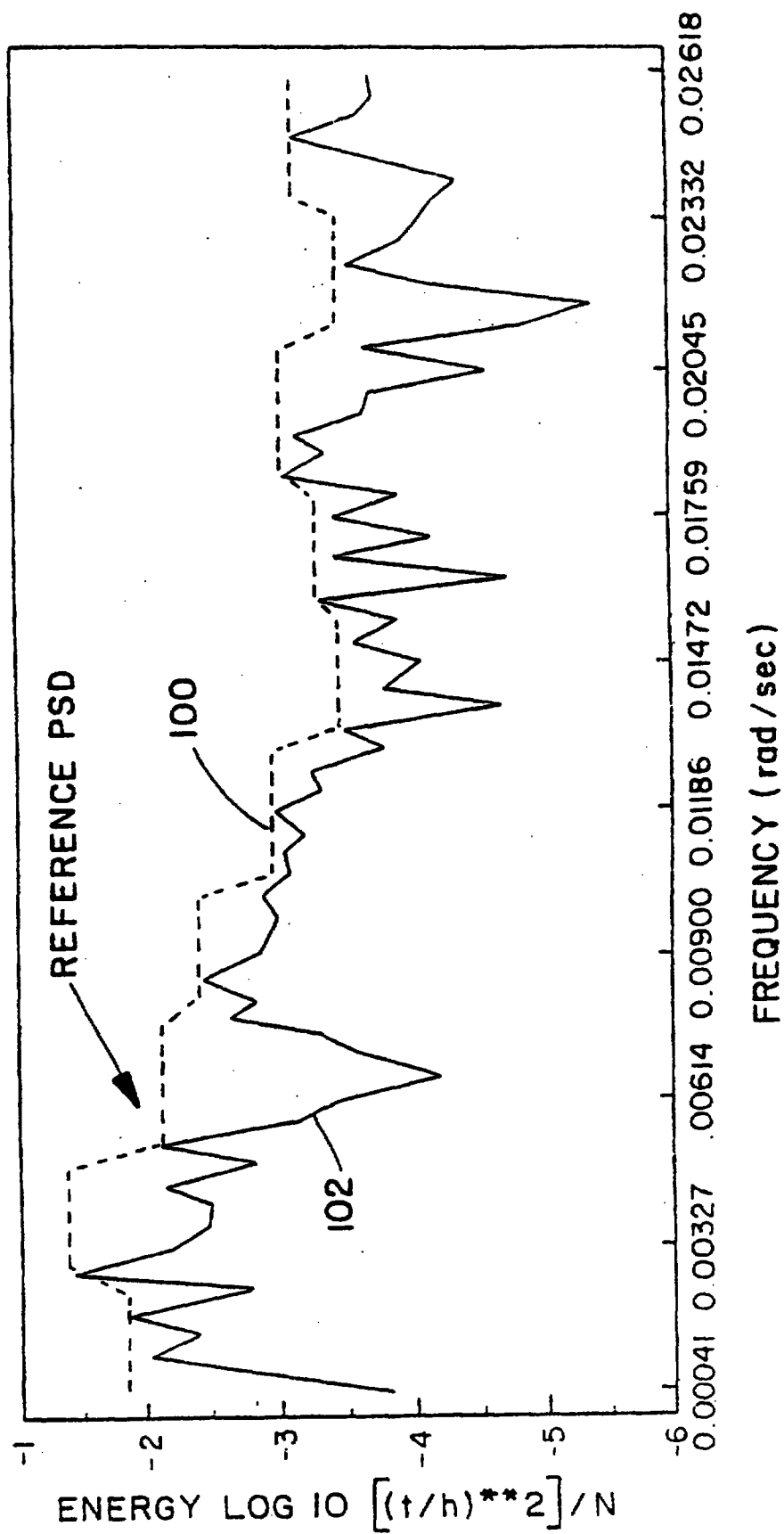
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FIG. 3



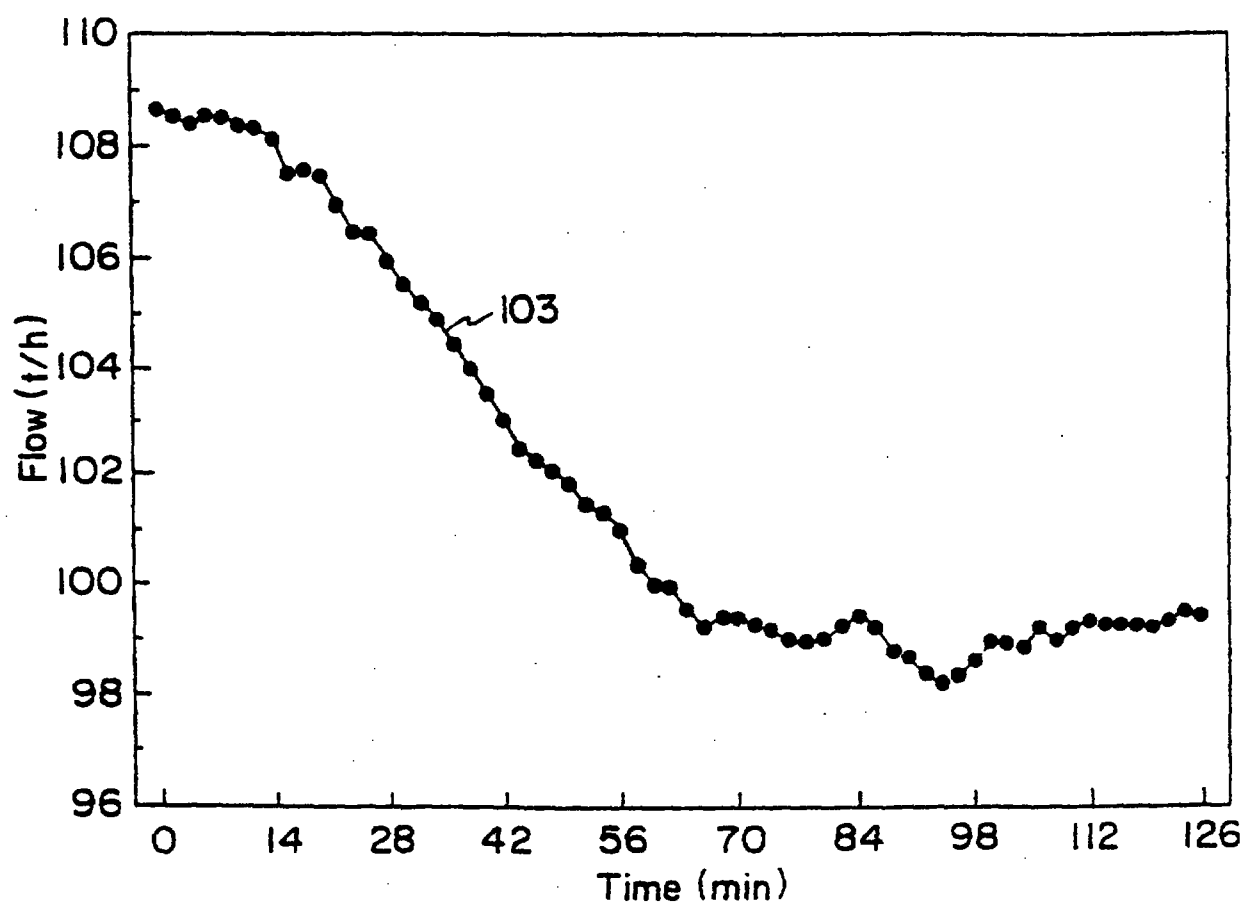
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FIG. 4



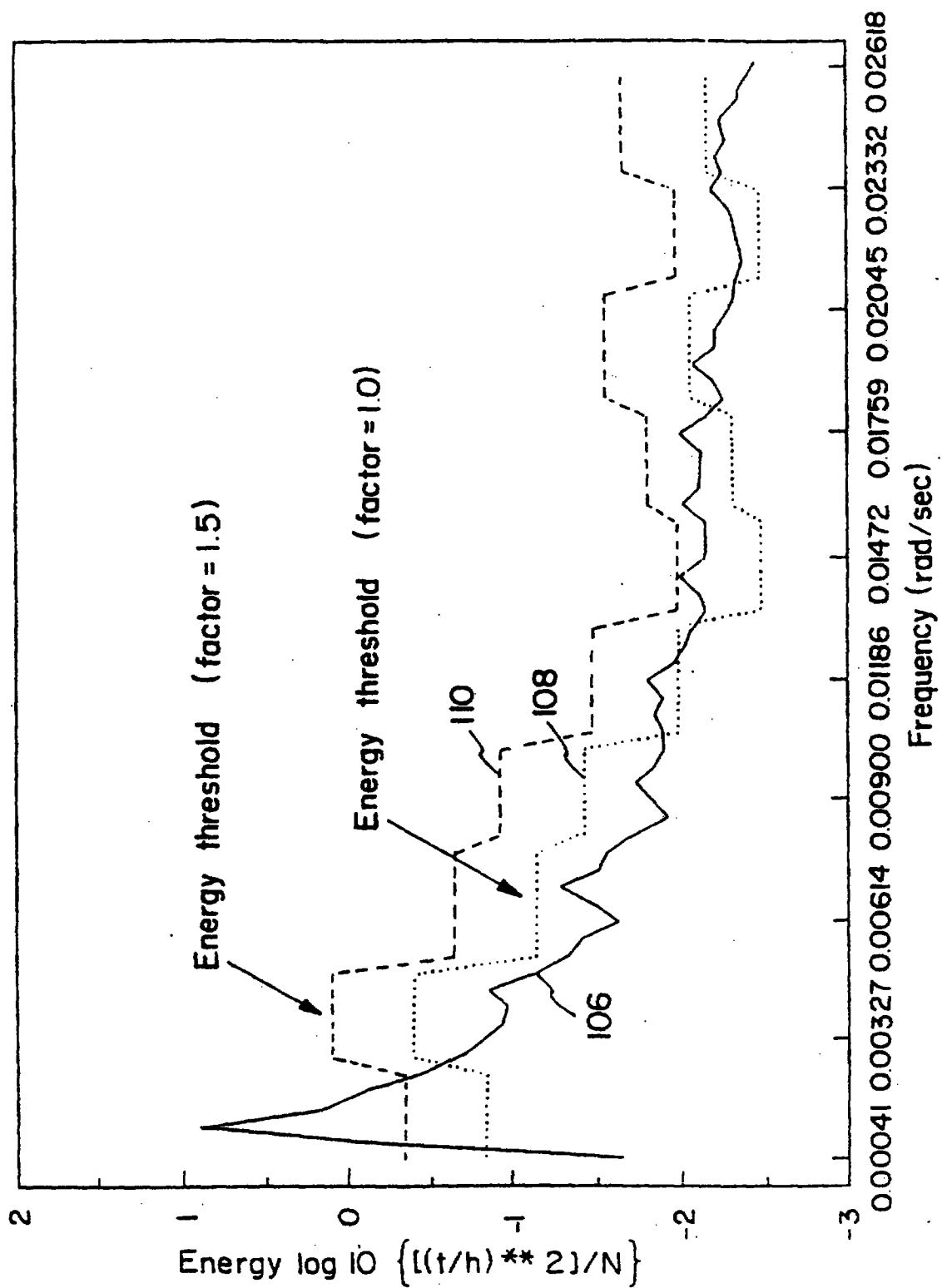
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FIG. 5



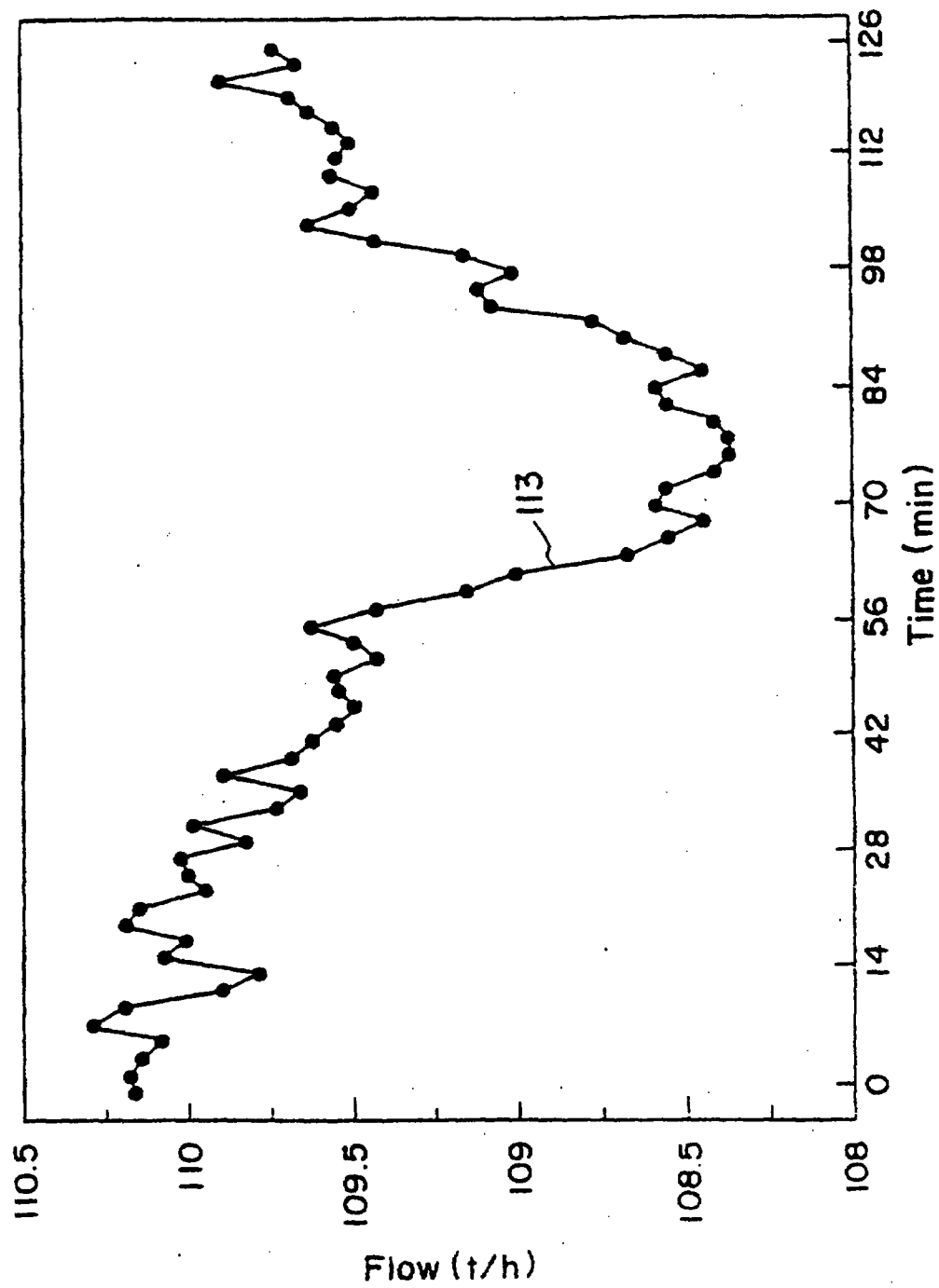
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FIG. 6



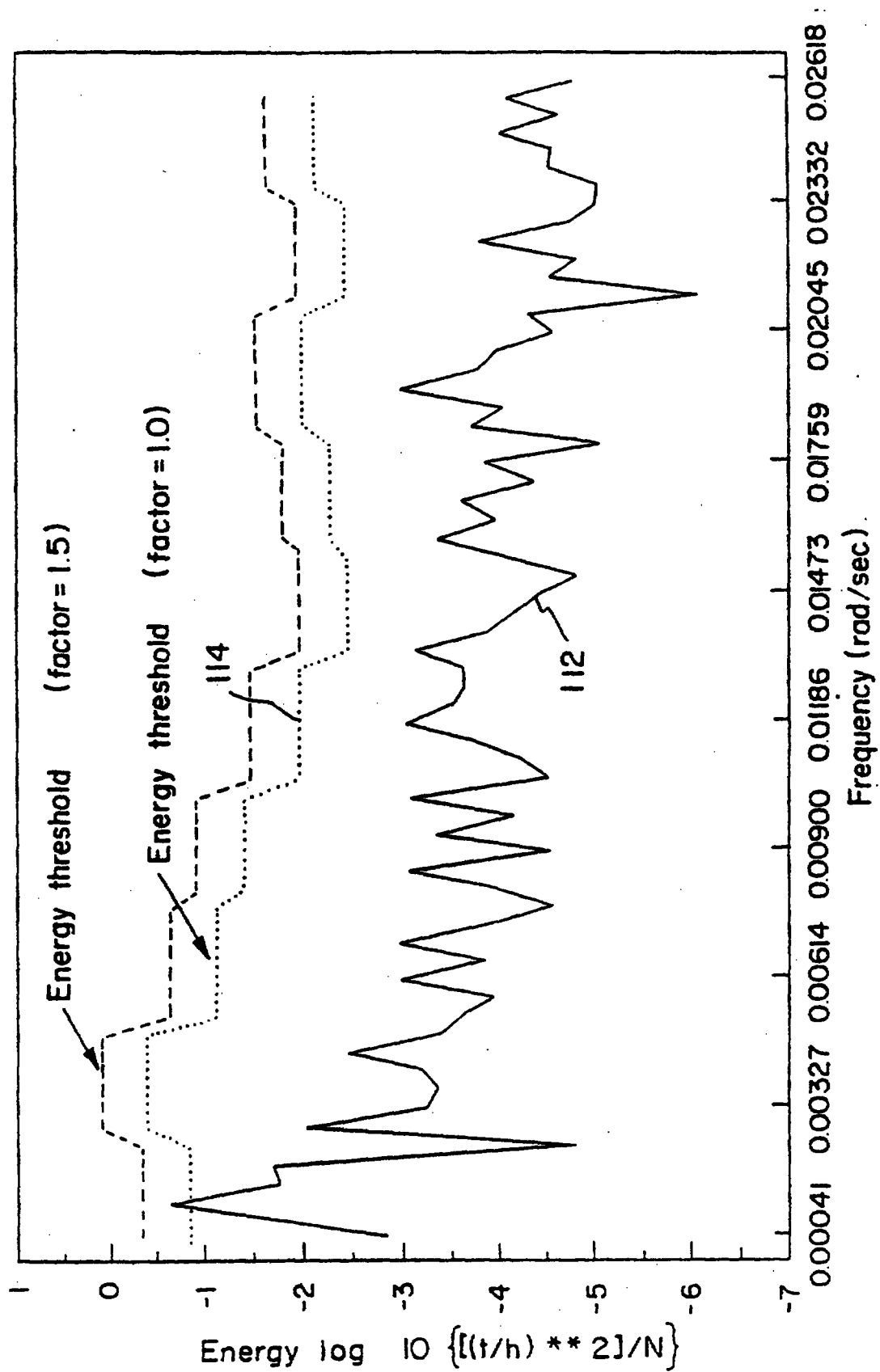
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FIG. 7



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FIG. 8



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PLANT PARAMETER DETECTION BY MONITORING OF
POWER SPECTRAL DENSITIES

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FIELD OF THE INVENTION

This invention relates to process control systems, and more
particularly, to a system for determining whether a process
parameter is in a steady or unsteady state through a use of
the parameter's power spectral density.

BACKGROUND OF THE INVENTION

In controlling dynamic plant processes, it is often
necessary to know whether process variables are in a steady
state or in an unsteady state. While, many process control
systems monitor plant variables and compare them against
predetermined set points, it is often more important to
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whether a plant parameter output exhibits an incipient
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The prior art contains many teachings concerning plant
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a fast Fourier transform on the steady state current to
determine its power spectral density. Based on the
computed power spectral density, the speed of the motor is

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memory (called restriction patterns), each reference frequency spectrum indicative of an operational state of the pump under different load conditions. To conserve memory, a "bias" procedure is employed to modify a closest reference frequency spectrum to bring it into the load (i.e. power) range of a test frequency spectrum taken from the pump. If the test frequency spectrum exceeds limits determined from the "biased" reference frequency spectrum, an alarm is given. The Toshiba system thus requires storage of a plurality of reference frequency spectra and accurate modification of a chosen spectrum by application of a bias value thereto to enable its comparison with a test spectrum. Misadjustment of the bias can negate the effectiveness of the test system.

Bartusiak et al. in PCT published Application WO 94/22025 describe a process signal detection technique that is dependent upon power spectral densities. Reference data is accumulated while a plant operates at a steady state and includes the energy content of each of a plurality of frequency components. A current operational database is then established by sampling a process variable when the plant is in operation. The sampled current output signal is analyzed to derive current data that includes the energy content of each of a plurality of frequency components. For each common frequency component of the reference data and current data, the system makes a comparison of the energy contents and issues a non-steady state signal if a difference between the compared energy contents exceeds a predetermined limit.

Accordingly, it is an object of this invention to provide a method for determining when a process variable output signal is in a steady state condition.

It is another object of this invention to provide a method for analysis of a parameter output signal to indicate an incipient unsteady state.

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It is still another of this invention to provide a plant parameter output signal detection technique that is dependent upon power spectral densities.

5

SUMMARY OF THE INVENTION

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A method for determining whether a current state of a process variable output signal is within acceptable limits includes the following steps: establishing reference data by sampling a plant's process variable output signal when the plant is operating at steady state and analyzing the sampled output signal to derive normalized reference data including an energy content of each of a plurality of frequency components of the sampled output signal. The procedure establishes a current operational data base by sampling a process variable signal when the plant is in operation. The sampled current output signal is analyzed to derive current data including a normalized energy content of each of a plurality of its frequency components. For each common frequency component of the reference data and the current data, the procedure compares their normalized energy contents and issues a non-steady state signal if the comparison indicates that the difference between the compared energy contents exceeds a predetermined limit.

DESCRIPTION OF THE DRAWINGS

30

Fig. 1 is a block diagram of a system for performing the method of the invention;

Figs. 2a and 2b are high level flow diagrams illustrating the method of the invention;

35

Fig. 3 is a plot of a variation in flow over time in an exemplary plant;

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Fig. 4 is a semi-log plot of energy versus frequency derived from the signal shown in Fig. 3;

Fig. 5 is a plot of flow vs. time showing a negative-going ramp disturbance;

Fig. 6 is a semi-log plot of energy vs. frequency of the plot of Fig. 5 indicating that the ramp disturbance produces the most severe violation of plotted energy thresholds in the low frequency range;

Fig. 7 is a plot of flow vs. time showing a "U" type disturbance in the flow signal;

Fig. 8 is a semi-log plot of energy vs. frequency of the plot of Fig. 7 indicating, at one energy threshold, that a

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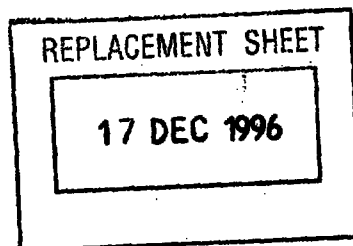
disturbance exceeds the threshold.

DETAILED DESCRIPTION OF THE INVENTION

5 The system and method for carrying out the invention determine whether a plant process is operating within a steady state or a non steady state condition. In brief, the system determines a reference power spectral density (PSD) of a process variable, during a time that the process
10 variable is in a steady state. A power spectral density is a representation of an energy content of a signal as a function of its component frequencies and is computed via a fast Fourier transform (FFT) which converts a time-domain signal into its frequency-domain representation.

15 The signal from which the reference PSD is derived is subjected to a first normalization procedure to derive a zero mean basis for the signal. This normalization is accomplished by subtracting the mean process variable value of a time series of sample data values from each time
20 series sample data value. A second normalization procedure is performed on the spectral data by dividing each power value in the spectrum by the number of time series signal samples used to compute the spectrum. The first
25 normalization procedure enables a single stored reference PSD to be used as a reference in all subsequent test procedures, and eliminates the need for plural reference spectra or for a biasing procedure to adjust the reference spectra. The second normalization procedure enables the
30 reference PSD to be compared to a current PSD, even in the event that the time windows differ during which the current and reference PSD's are derived.

35 The reference PSD is compared with a current PSD derived when the process variable is in operation. The current PSD is also subjected to the first and second normalization procedures described above with respect to the reference PSD. If the current PSD is too energetic (either with



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CLAIMS



1 1. A method for determining a current state of a
2 process variable output signal from a plant and whether
3 the output signal is within acceptable limits, the method
4 comprising the steps of:

5 (a) establishing reference comparison data for said
6 process variable by sampling a reference output
7 signal over a first period of time when said
8 plant is operating at steady state, each
9 sampled reference output signal further
10 subjected to a first normalization procedure to
11 convert each sampled signal to a zero mean
12 basis;

13 (b) processing said sampled output signal to derive
14 reference spectral data for said process
15 variable, said reference spectral data
16 manifesting a normalized energy content for
17 each of a plurality of frequency components of
18 said sampled output signal, each reference
19 spectral data value subjected to a second
20 normalization procedure, wherein each spectral
21 data value is divided by a sample time related
22 value, a sample time being a window of time
23 during which an output signal is sampled in
24 preparation for deriving spectral data values
25 therefor;

26 (c) storing said reference spectral data;

27 (d) establishing current operational data for said
28 process variable by sampling a current output
29 signal for said process variable over a second
30 period of time when said plant is in operation.

AMENDED SHEET

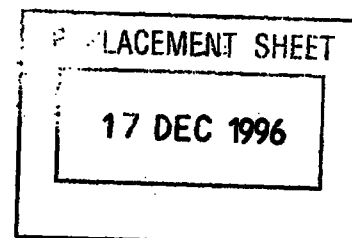


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31 each sampled current output signal further
32 subjected to a first normalization procedure to
33 convert each sampled signal to a zero mean
34 basis;

35 (e) processing said sampled current output signal
36 to derive current spectral data therefrom, said
37 current spectral data manifesting a normalized
38 energy content of each of a plurality of
39 frequency components of said sampled current
40 output signal, each current spectral data value
41 subjected to a second normalization procedure,
42 wherein each spectral data value is divided by
43 a sample time related value, a sample time
44 being a window of time during which an output
45 signal is sampled in preparation for deriving
46 spectral data values therefor; and

47 (f) for each of a plurality of common frequency
48 components of said reference spectral data and
49 current spectral data, comparing normalized
50 energy contents therefor and issuing a signal
51 if said comparing indicates that an energy
52 content threshold of any frequency component of
53 said current spectral data exceeds the energy
54 content of the corresponding common frequency
55 component of said reference spectral data.



AMENDED SHEET



6. The method as recited in claim 1 wherein said sample time related value is a number of samples of an output signal taken during said window of time.

7. The method as recited in claim 1 wherein step (f) further indicates the common frequency for which said signal is issued.

8. The method as recited in claim 1 wherein said analyzing steps (b) and (e) perform Fourier analyses of said sampled output signals to determine the frequency components and energy content of each thereof.

9. The method as recited in claim 1 wherein said signal is only issued in step (f) if an energy in a frequency component of said current data exceeds an energy content of a common frequency component of said reference data, multiplied by a set factor.

10. The method as recited in claim 1 wherein, in step (f), said signal is issued after a ratio of energies of each of said common frequency components is determined and it is determined that at least one said ratio exceeds a predetermined factor.

