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DATA PROCESSING SYSTEM FOR TEST DATA ANALYSIS

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I. INTRODUCTION

Process instrumentation techniques have a long record of achievements and are contributing greatly to the automation of the industrial world. However, considering process system design, there are often cases when simplified system design through human experience will not suffice. In such cases as,

1) complex process characteristics, poor controllability
2) disturbances are large and rapid, response of the controller is poor,
3) demand for control accuracy is severe,

studies by process simulation, estimation, identification and experimentation are required. Especially, studies by experimentation are vital to support the reliability of system design and for expansion of system design in the future.

Moreover, a knowledge of process characteristics is a prerequisite of the maximum princple, dynamic programming, multivariable control, and other modern control theories, and complete indentification techniques are desirable for practical application of these theories.

We fully realize the necessity of a data processing system based on test data and have been developing applying systems for

1) automation of automatic data acquisition
2) automation of automatic data processing, analysis and synthesis

for several years. This equipment is introduced here for reference of utilization in a wide range of fields.

II. ANALYSIS RECORD

Processes to be analyzed can be roughly classified into processes related to instrumentation and processes related to electric power. The former has a time constant of from several tens of seconds to several tens of minutes and 1), 2), and 3) below are examples. The latter has a time constant on the order of msec and 4), and 5) are examples. Their differences are not only based merely on the different time constants, but are also represented by the method of measuring the signal at the time of data recording and calculation method.

1) Analysis of the dynamic characteristics of a cement kiln

A rotary kiln has an inner disturbance such as peeling off of the cement ring clinging to the inner wall. Also, it is a process in which the stagnation of the raw material is long and the controllability of quality is poor. For this reason, the amounts of variation of each part of the kiln are recorded over a long period of time, and the correlation function between these many variables is found and control system study and computing control study is obtained.

2) Calculation of calories of a blast furnace

Blast furnace exhaust gas and converter-furnace exhaust gas are used in addition to LPG as the fuel of the blast furnace of an iron works. The transfer function (time constant from 40 seconds to 160 seconds) of exhaust gas line and calory variation required in control for the production of a constant calory by mixing these 3 kinds of gases are stuides.

3) Dynamic characteristics analysis of a 2-component distillation column

Since the dynamic characteristic of a distillation column has a clear nonliearity, and since the test time becomes too long with the inditial response

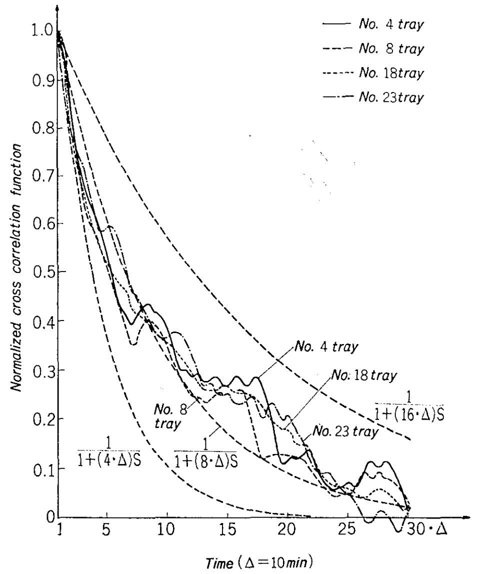

Fig. 1 **Cross correlation function of M-sequence method for distillation column**

method, the average time constant within a small variation was found by varying the operational value in accordance with the M-sequence signal at that time was produced by generator of arbitrary outer noise using paper tape.

The time constant (*Fig. 1*) with the M-sequence almost coincided with the average of the various dynamic characteristics found by inditial response.

4) Characteristic analysis of flicker of an electric arc furnace

There is a large trend toward expanded installation of steel making arc furnaces because of their economical profitability, but because the arc is unstable, noise is generated in the voltage of the line. This is called voltage flicker and there are various mothod of countering this, but we use a rotary condenser.

In order to study the effect when a rotary condenser is installed, the electrical characteristics of the arc furnace were calculated. The contents are the active power, reactive power, phase, voltage variation distribution, correlation function, spectral density, etc. found from data obtained by on-site recording of the instantaneous value of voltage and current. Further, the value of flicker assumed when the rotary condenser was installed and the value of flicker when the arc furnace was installed were also found by making this data a model load.

5) Analysis of load variations of mill driving equipment

The variations of the electric power for mill driving are large and a flicker voltage is generated in its line the same as with this arc furnace. This flicker voltage can be effectively reduced by the use of a rotary condenser. In order to study the effect, the load variations of a hot strip mill and slabbing mill were recorded and computed in the same manner as described in 4) above.

III. DATA RECORDING DEVICE AND COMPUTER COUPLING SYSTEM

The recording device can record the process data 24 hour on 1 reel of tape. On the other hand, 24 hour is required to record this data at the same recording speed and rerecording speed must be high. Moreover, the recording tape records data continuously to record the process data. Therefore, since it differs from the general record formula for magnetic tape of computer, the recording tape cannot be directly read by the computer. For this reason, the recording data computer input method is one problem.

One method of rerecording is to output the data in paper tape and then to read the paper tape into the computer, but this method requires a large amount of paper tape. Consequently, this system uses a system in which the data recording device and computer are coupled directly by electrical signal at the time of rerecording and the contents of the data recording device are directly converted to the magnetic tape of the computer.

When asynchronously continuous data is processed as computer input, the following problems arise:

1) When the conversion speed is increased, there is a lack of data produced by the computer processing time relationship.

2) Data correction when there are errors in the continuous data.

3) Unusual processing when there are errors in the magnetic tape of the computer.

In processing a large volume of continuous data, the tremendous amount of labor required before analysis is eliminated at one stroke.

IV. DATA ANALYSIS FLOW

A DATAC is carried to the site of the process and the characteristics of the process are converted to ±10 V and recorded on magnetic tape.

The DATAC has the following specifications:

(1) Input: Analog quantities, 30 channels, ±10 V
(2) Scanning speed: 30chs/10 ms, 30chs/20 ms, 30chs/0.5 sec, 30 chs/1 sec, 30 chs/2 sec
(3) Input impedance: ±500 Ω, balance type, neutral grounding
(4) Magnetic tape: Digital mode
(5) Equipment: Portable

In order to delimit the types of data on the magnetic tape, each case is given a data number and a frame number at each sampling and high speed or low speed recording of the data is performed in accordance with the type of analysis. When recording at high speed, 1 magnetic tape is required per each several cases and when the number test items is large, the corresponding magnetic tape is required and management of the DATAC use magnetic tape is required. Next, an outline of the software for conversion of the recorded data to computer data is described. This software is divided into 5 items. The reason for the 5 items is that step 1) requires a long computer run time and 2), 3), and 4) processing of errors must be capable of starting from each step.

1) The magnetic tape recorded at the site is loaded on the DATAC and connected to the paper tape reader of the computer through a code converter and converted to FACOM230–50 magnetic tape. The contents of this tape can only be handled by FASP (assembler language).

2) The data produced in 1) is converted to data which can be handled by FORTRAN, and becomes data represented integer type by signal decimal (3 digits). When errors are generated at the time this data is read, they are still not corrected in this program.

3) Errors in the produced in 2) are processed and a data tape for which in computing is produced. There are two cases, automatic correction in accordance with the kind of error and the other which

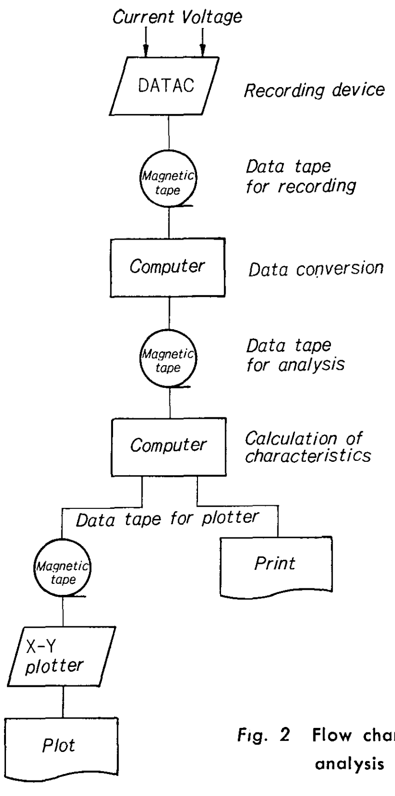

Fig. 2 Flow chart of data analysis

requires input of correct data from the card reader.

4) Since the data tape produced up to 3) is an integer type, it is converted to a floating type and in this program, the analysis use data tape is produced by scaling the actual value data of the characteristics of the process.

5) Since 1 data tape is short, the data tapes of a number of cases are compiled into a single tape. The data recorded at the site is converted to data usable by the computer for analysis of process characteristics by executing the 5 above item in order. Various characteristics anaysis are performed using this data. *Fig. 2* is a data analysis flow chart.

V. DATA PROCESSING SYSTEM

Since this system records a large volume of data, processes the recorded data with a computer, and plots the results in an easy-to-understand form, statistical analysis is its main purpose.

However, graphic display, by computing the physical values which cannot be written at the site with a recoder or oscilloscope from the recorded data and matching it with the original data is easy and it plays a large role in analyzing process characteristics. The main parts of the analysis system are described below.

1) Method which finds the transfer function which describes the dynamic characteristics

Of the transfer functions, the gain is easy to find by means of any method, but finding the time constant and type of delay is fairly difficult. When studying control system or when intending to record dynamic characteristics data to determine the constants after deciding upon the system, data recording methods are divided as follows from the situation at the site.

(1) when experiments for recording dynamic characteristic data are permissible and fairly large variations in the process are possible,

(2) when experiments for recording dynamic characteristics data are permissible, but variations are not large,

(3) when data must be recorded during normal

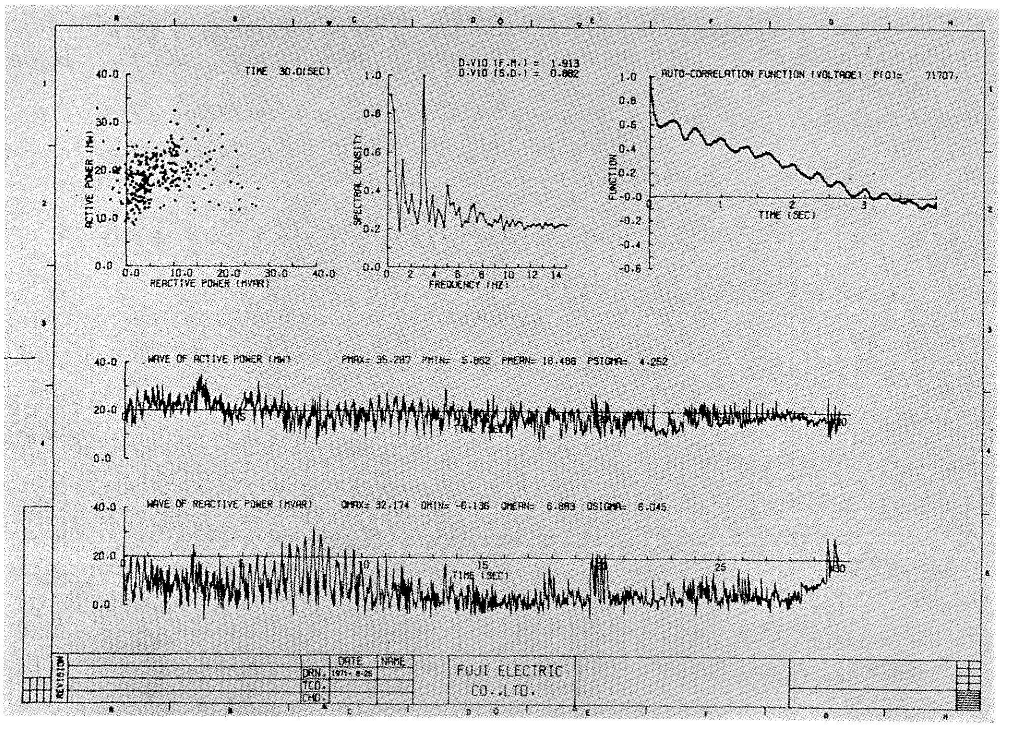

Fig. 3 Fluctuation of voltage and power of an arc furnace

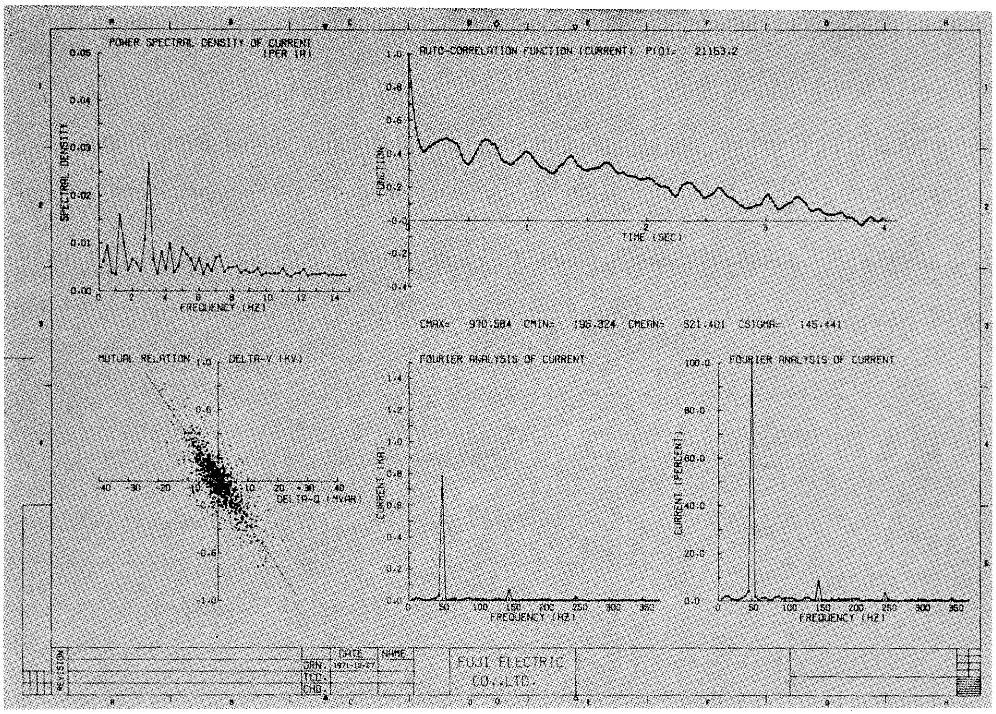

Fig. 4 **Fourier analysis of current and ΔV–ΔQ mutual relation of an arc furnace**

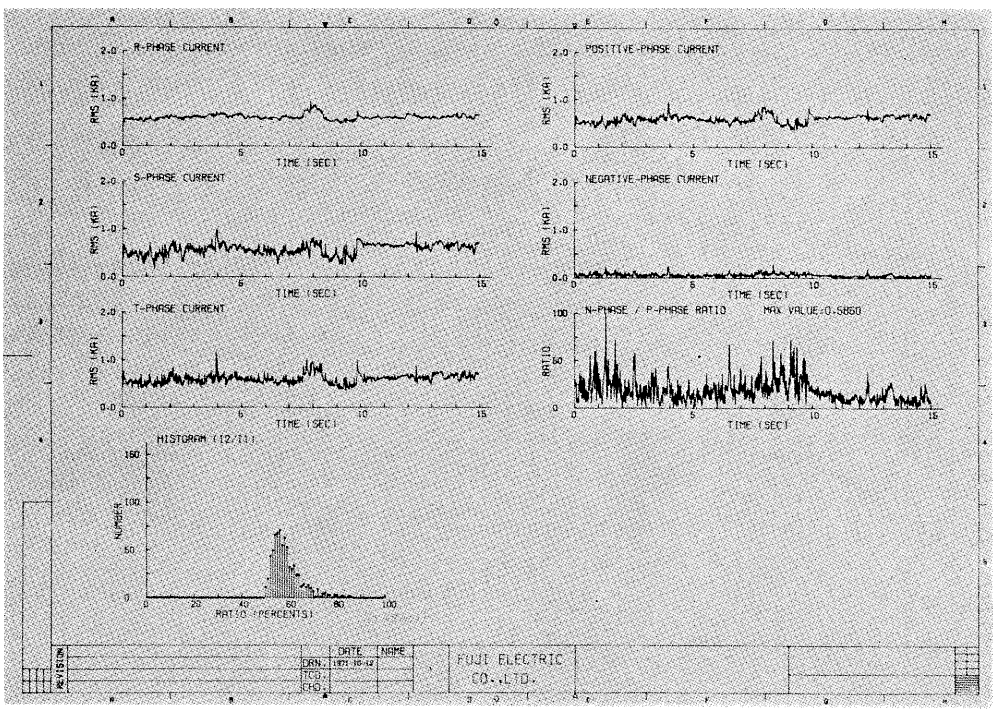

Fig. 5 **Unbalance analysis of 3 phase current of an arc furnace**

operation because special experiments are not permissible.

Naturally, (1) is best and the dynamic characteristics can be clearly understood if inditial response are obtained. In (2), a rough outline of the time constant can be obtained if the operating amount is varied by the M-sequence signal. In (3), a general estimate can be obtained from the auto correlation function and cross correlation function. Further, theoretically the characteristic should be obtained if the power spectrum is found by proceeding with actual data.

2) Method which finds stational characteristics

Because this is a so-called statistical culcutation, the feature of the computer are utilized to the fullest. Not only mean value, variance, and standard deviation but the histogram (*Fig. 5*) to find the frequency distribution of the subject, auto correlation function (*Fig. 3*) to find the periodic component, and spectral density function (*Fig. 3*) can also be easily obtained. Moreover, the harmonic component of processes which vary periodically can also be easily obtained. (*Fig. 4*)

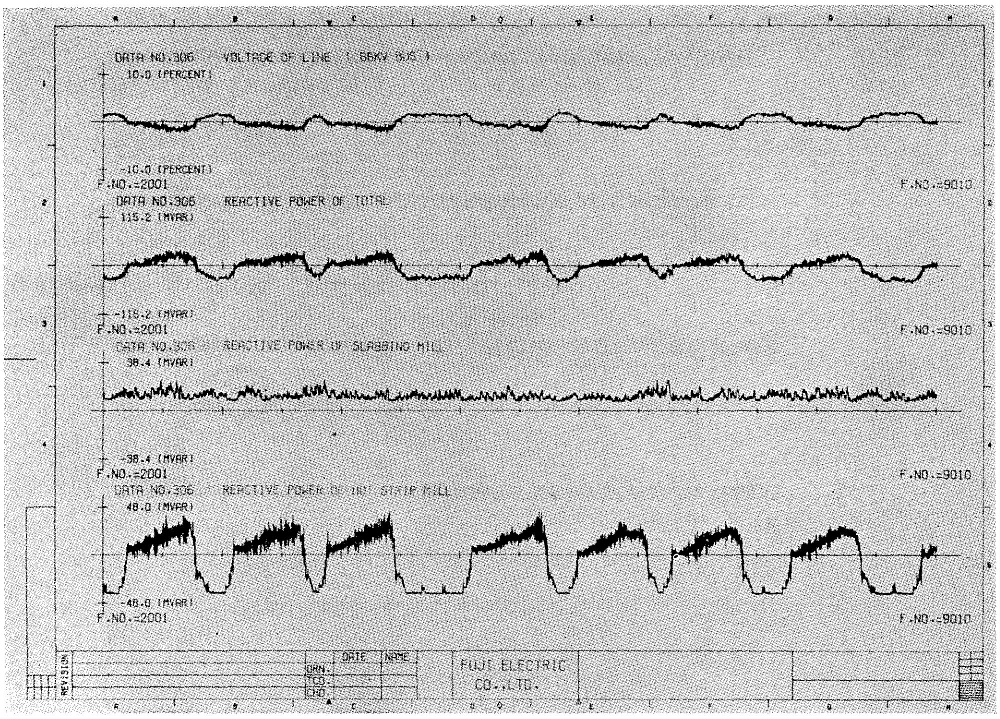

Fig. 6 **Wave form of voltage and power of mill driving system**

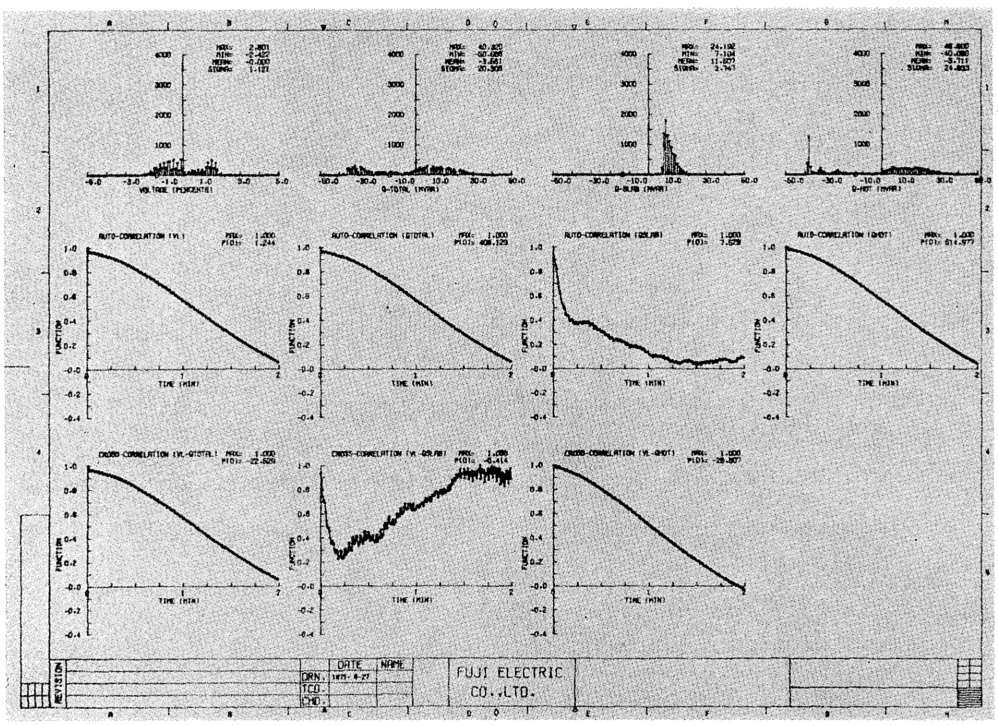

Fig. 7 **Histogram and correlation function of voltage and power of mill driving system**

3) Forecasting of data which cannot be obtain at the site.

Since the active power or reactive power can be easily obtained from the voltage and current in an AC circuit, forecasting of data is possible if our converter is used.

However, finding the positive phase or negative phase of 3-phase AC and their ratio is dfficult. The above is an example for an electrical circuit, and things difficult to prepare with a converter are easily calculated with a computer program and this is also a big feature.

Further, since simulation which forecasts the state after process improvement and expansion uses actual data, high reliability is possible.

VI. ANALYZED RESULT OUTPUT METHOD

There is a wide variety of process data characteristics analysis method, but there are only the following two methods of outputting the results of characteristics analysis. One of these is output to a line printer and the other is output by an X-Y plotter.

Recently, the waveform of the characteristics results of the process has been graphically illustrated to understand the outline of the characteristics by merely looking at the results of a line printer.

In order to eliminate this labor and for other reasons, output by an X-Y plotter is demanded more that output by a line printer. Because of this demand, output is gradually being switched to the graphic output of the X-Y plotter and the size of the graph is uniform so that the arrangement of results and copy are easier. There are also various graphs made by the X-Y plotter depending on the method of analyzing the characteristics of the process. For example, taking analysis of the characteristics of an electric arc furnace as an example, the active power, and reactive power waveform, the correlation between the active power and reactive power, the auto correlation of the voltage, and its spectral density are graphically displayed in *Fig. 3.* The auto correlation function of the current and its spectral density, the correlation function of ΔV and ΔQ, and the harmonics obtained by Fourier analysis of the current are shown in *Fig. 4.* The waveform of the RST 3-phase current, positive phase current culculated from the RST 3-phase current, waveform of the negative phase current, and the waveform of the positive current and negative current and its histogram are shown in *Fig. 5.*

The result of calculation of the characteristics of the arc furnace can be immediately seen by studying *Figs. 3, 4,* and 5.

The contents of the characteristics results differs with the process, but as separate example, we performed a test to determine the effect of the rotary condenser delivered to an iron work and the results of analysis are given in *Fig. 6.* and *Fig. 7.*

From our experience up to now, when not desiring to study an outline of the process and detailed data by studying the graph of an X-Y plotter, we fell that an understanding can be easily obtained by dividing the results of analysis of the characteristics of the process into two output such as viewing the value of the output of a line printer.

VII. CONCLUSION

The effect of use of this system is that the various analyzed results output automatically by the computer and various considerations on these results are extended by human being.

There are various expansions of analysis depending on each process. Taking flicker control test of synchronous condenser for steel plant as an example, one problem is the synchronous condenser installed and the qualitative analysis wether the HOT mill load or SLAB mill load can be installed any more. Since the cross correlation function of $V\text{–}Q_{\mathrm{HOT}}$ and the auto correlation function of Q_{HOT} or the cross correlation function of $V\text{–}Q_{\mathrm{SLAB}}$ and the auto correlation of Q_{SLAB} are similar, the correlation coefficient K_{HOT}, K_{SLAB} relative to V of Q_{HOT}, Q_{SLAB} can be logically simplified without handling them as time dependent functions. In orther words,

$$V = K_{\mathrm{HOT}} * Q_{\mathrm{HOT}} + K_{\mathrm{SLAB}} * Q_{\mathrm{SLAB}} \cdots\cdots\cdots \quad (1)$$

with respect to Q_{HOT}

$$\frac{1}{T}\int_0^T V(t)^* \, Q_{\mathrm{HOT}}(t+\tau)\, dt$$

$$= \frac{1}{T}\int_0^T K_{\mathrm{HOT}} * Q_{\mathrm{HOT}}(t)^* \, Q_{\mathrm{HOT}}(t+\tau)\, dt$$

$$+ \frac{1}{T}\int_0^T K_{\mathrm{SLAB}} * Q_{\mathrm{SLAB}}(t)^* \, Q_{\mathrm{HOT}}(t+\tau)\, dt$$

$$\cdots\cdots\cdots \quad (2)$$

and since Q_{HOT}, Q_{SLAB} are independent, the second term of equation (2) is 0. Therefore, considering the figure resemblance previously mentioned,

$$\overset{\mathrm{CROSS}}{\phi}_{V.Q_{\mathrm{HOT}}} = K_{\mathrm{HOT}} * \overset{\mathrm{AUTO}}{\phi}_{Q_{\mathrm{HOT}}} \cdots\cdots\cdots \quad (3)$$

Therefore, the correlation coefficient K_{HOT} is found from the cross correlation function and auto correlation function.

K_{SLAB} is found in same manner. For instance, the results

Synchronous condenser	K_{HOT}	K_{SLAB}	Estimate of flicker	Actual measurement of flicker
Yes	2.38	5.75	0.535	0.444
No	4.03	6.10	0.815	0.943

were obtained. Therefore, the future flicker can be estimated with

$$V = 2.38\, Q_{\mathrm{HOT}} + 5.75\, Q_{\mathrm{SLAB}} \cdots\cdots\cdots \quad (4)$$

A part of this system has been described above, and since processing for analysis is flexible because it is through a computer, a new quantitative estimation method is produced. Moreover, the effect of use of this system is highly praised due to the automatic output of various analyzed results by an X-Y plotter and its wide use is anticipated.