VIRTUAL INSTRUMENT for THE ANALYSIS of LOAD CURVES

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Abstract – **This paper presents a virtual instrument (VI) that analyses and processes in situ measured data and determinates the corresponding load curves and their parameters. Firstly, some general aspects regarding load curves and their parameters are presented; further, the characteristic elements of a virtual instrument (graphic user interface, operating modules, etc.) and its working methodology are also pointed out. Finally, an example underlining the utility of the proposed VI is given and conclusions regarding the proposed approach are presented.**

*Keywords***:** *virtual instrument, load curve, LabVIEW environment, energy efficiency.*

1. INTRODUCTION

The virtual instruments (VI) imitate physical instruments such as oscilloscopes, multimeters, etc. Every VI uses functions that manipulate input(s) from the user interface or other sources and display that information in an appropriate form or move it to other files or other components. A virtual instrument consists of three elements: the frontal panel (graphic user interface), the block diagram (source code), and icon and connector pane respectively. The last ones identify the VI so that it could be recognized and used in other VI(s).

The main advantage of virtual instrumentation is the flexibility, because changing a function of a virtual instrument simply requires the reconstruction of a part of the VI. Others advantages offered by virtual instruments refer to the display facilities, data importing and storing information methods. Computer displays can show more colors, and allow user to change quickly the format of displaying the data received by the VI. Computers have more mass storage than stand-alone instruments.

A main disadvantage in implementing virtual instruments is the necessity of specific hardware and software. Advanced software tools like LabVIEW need highly developed hardware computers to work at its maximum parameters. Another disadvantage is the fact that in order to create virtual instruments, quite advanced programming knowledge are needed, thus this technique is not accessible to all engineers.

Latest, the virtual instrumentation became a powerful computer aide tool for power systems' analysis. In practice, VIs are used to determine power losses, to analyze load curves, for signal processing etc.

Considering the huge quantity of experimental data, and the necessity of short – time analysis, authors have studied the possibility of developing a virtual instrument that analyses load curves.

The paper presents a virtual instrument created to process in situ measured data in order to obtain load curves and their parameters. The first section of the paper presents general aspects regarding the load curves: definition, characteristics, importance and parameters. The next sections present the projected VI with its components, the working methodology, and an example respectively. Paper ends with a section of conclusions regarding the proposed VI.

2. LOAD CURVES

During their operation, the loads do not consume constant power, and this fact negatively influences the power system operating characteristics. The variation of consumed power is illustrated by the load curves (figure 1).

A load curve represents the variation in time of electric power in a point of a certain power system. The existence of some relative and of an absolute maxim can be observed; they represent the peak value, e.g. the electric power consumption during the periods of maximum utilization.
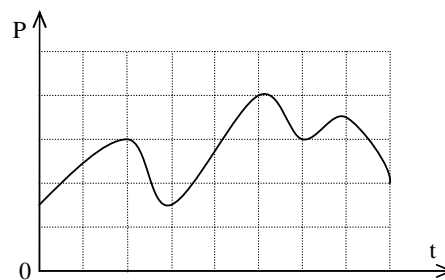

Figure 1: The usual shape of a daily load curve.

The load curves have an important role in power systems, due to the information they carry regarding the variation of the consumption in a specific interval.

The shape of a load curve can rarely be expressed using an analytic function; in fact, to be easily used, a

load curve must be firstly carefully analyzed. This analysis consists in the sampling (steps shape approximation) of the load curve graphic and determination of some parameters (figure 2).
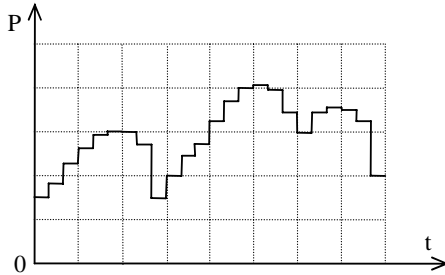

Figure 2: The sampled shape of a daily load curve.

The load curves can be obtained in three ways:
- In situ measurements performed in different points of the power systems. For this purpose specific equipment are used: recorder instruments (active and reactive power recorders), energy meters, numeric acquisition equipment integrated in a data processing system;
- Using calculations: load curves summations, energy survey calculus;
- Load forecasting.

2.1. Classification

The load curves can be classified using different criteria:
- Observation period: daily, weekly, monthly, yearly, etc.
- Recording place: consumer terminals, electric lines ends, substation enter or exit, transformer terminals etc.
- Consumer's type: industrial, domestic, urban and rural.
- Nature of the measured power: active, reactive and apparent.
- Method used to obtain the curves: measurement, calculus and forecasting.

2.2. Load curves characteristics

The load curves are described by some characteristics known as the load curves parameters. These indicators underline the curves' specific features that are very useful for the design engineers and the operation staff.
Further on, the characteristic parameters of a daily load curve are described:
1. Peak load – P_{max} – is the maximum power demanded by the consumer for a period of time of at least 15 minutes during a day;

2. Minimum load – P_{min} – is the minimum power demanded by the consumer at least a period of 15 minutes during a day;
3. Energy consumption – W_{day} – corresponds to the surface between the load curve and the coordination axes x0y. It can be calculated by integrating power's function P = P(t):

$$W_{day} = \int_0^{24} P(t) \cdot dt \ . \tag{1}$$

This integral calculus raises difficulties because of the power function that has not an analytic form. Practically, the following mathematical relationship for a sampled load curve is used:

$$W_{day} = \sum_{k=1}^{24} P_k \ , \tag{2}$$

where P_k is the mean hour demand power.
4. Average load - P_{med} – represents the average of the demand power during a day:

$$P_{med} = \frac{1}{24} W_{day}. \tag{3}$$

5. Uniformity factor – α_{day} – defined as the ratio between the minimum and the peak load:

$$\alpha_{day} = \frac{P_{min}}{P_{max}}. \tag{4}$$

6. Load factor – k_{day} – defined as the ratio between the average power and the load peak value:

$$k_{day} = \frac{P_{med}}{P_{max}}. \tag{5}$$

The closer is the load factor to the value 1 the less is the peak value above the average load. This fact imposes a lower demand for the supply system, and accordingly less equipment investment.
7. Utilization period of the peak load (exploitation time) – T_{Uday} – the period of time during which a constant consumption corresponding to the peak value determinates the existent daily energy:

$$T_{Uday} = \frac{W_{day}}{P_{max}} = 24 \cdot k_{day}. \tag{6}$$

8. Mean power factor - λ_{day} – calculated using the following mathematical relationship:

$$\lambda_{med} = \frac{1}{\sqrt{1 + \left(\dfrac{W_{day}}{W_{rday}}\right)^2}} \ , \tag{7}$$

where W_{rday} is the daily demand of reactive energy and $0 \le \lambda_{day} \le 1$.

3. LC VIRTUAL INSTRUMENT

Considering the huge quantity of experimental data, and the necessity of short – time analysis, authors have studied the possibility of developing a virtual instrument that analyses load curves.

To create this VI authors used the LabVIEW graphic programming environment. LabVIEW environment helps to build applications as test and measurement, data acquisition, instrument control, data logging, measurement analysis and report.

This software tool named "LC Virtual Instrument" reads the measured data and points up the load curves and their characteristics. The user has the possibility to choose the following features regarding the load curves: measurement units for electrical quantities; the interval for averaging; the interval of interest, and the type of displayed power (three-phase power or single-phase power).

Further on the two components of the VI are presented: passive (graphic user interface) and active (operating modules) elements, respectively.

3.1. Graphic User Interface

The graphic user interface (GUI) represents the part of the VI with which the users come in contact, thus a simple and easy to understand GUI was built up. Through it, users can introduce the input data and visualize the obtained results. GUI is made of two windows: the main one illustrates general aspects about the load curves (figure 3), the second one presents the daily load curve and its parameters (figures 4 and 5).
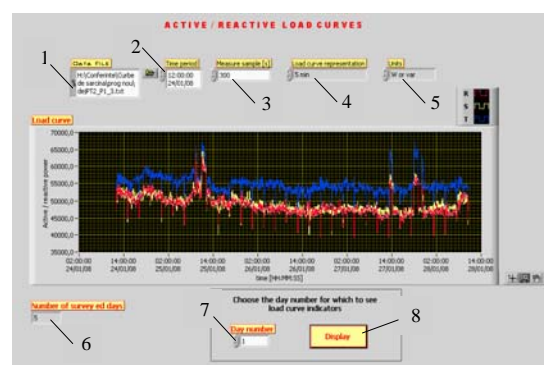
Figure 3: Main window of the virtual instrument GUI

The main window contains the following elements:

1 Data File – is the field where the VI reads the name of the file which contains the

measured data. User must choose the file with its specific path;

2 Time period – represents the field where user introduces the start time of the surveyed period. Time is introduced with the following format: hour :minute :second, day/month/year;

3 Measure sample – represents the interval between two samples. It should be introduced in seconds;

4 Load curve representation – is the field which contains the period of time between two points of the load curves. This time is standardized: 5, 15, 30 and 60 minutes;

5 Units – represents the units of the power: W or var, kW or kvar, MW or Mvar;

6 Number of surveyed days – is the field where the VI indicates the number of surveyed days;

7 Day number – is the filed that must be fulfilled by user with the number of the day for which he wants to visualize the load curves and their indicators;

8 Display – is the button that gives access to the second window where the load curves and their parameters for the chosen day are displayed.
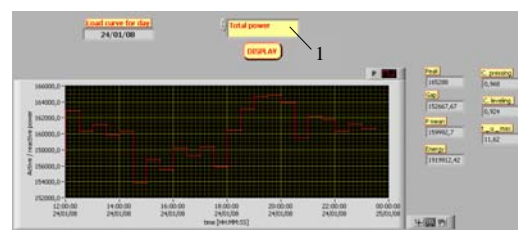
Figure 4: Second window of the VI's GUI. Total (three-phase) power load curve and its parameters
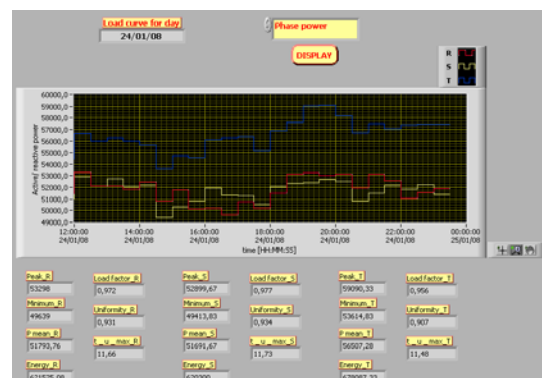
Figure 5: Second window of the VI's GUI. Single phases' powers load curves and theirs parameters

From the above figures can be seen that the second window displays the daily load curve for the total power (sum for the three phases) (figure 4) and the single phases' powers (figure 5). The option of displaying the total power or phases' powers is selected by the user with the help of field 1 from figure 4.

Load curves parameters are the ones presented in subsection 2.2: load peak value, load gap value, total energy, average load, leveling coefficient, load factor and exploitation time.

The characteristics of the load curves display (units, representation) are the same as chosen in the main window.

The running of the VI ends when the user presses button DISPLAY.

3.2. Operating Modules

The operating modules form the active part (engine) of the VI; this part is not reachable to the users.

Figure 6 illustrates the hierarchy tree of the VI; it can be seen that for each module a suggestive icon was build up (excluding the ones already created and assumed). The connections between the operating modules are also indicated.
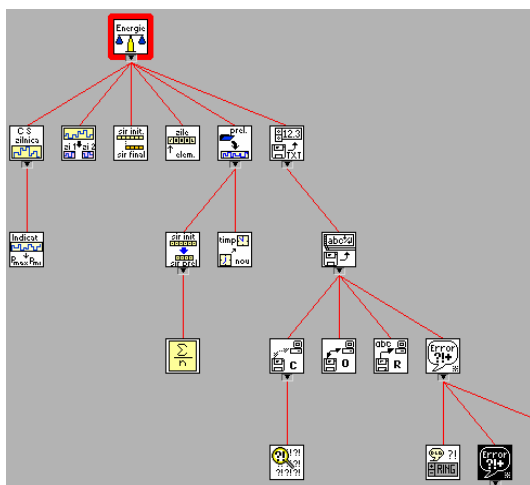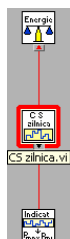

Figure 6: VI's hierarchy tree

The most important modules are further presented (the described modules outlines are thick and red):

"CS zilnica.vi" – is the sub-virtual instrument that contains the code source of the second window; it displays the daily load curve and its parameters.

"indicatori curbe.vi" is a sub-VI used to calculates the parameters of a load curve; for this purpose, the mathematical relationships from subsection 2.2 were implemented.
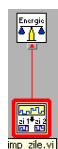
"imp_zile.vi" – is the sub-vi that makes the distribution of days of the measured data. It is used to determine the load curve for the day that was chosen by the user.
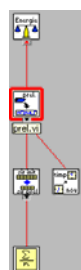
"prel.vi" – represents the sub-virtual instrument that processes data and displays the load curves. The input data for the sub-VI is the data array and the outputs are the load curves for different periods of time.

The working algorithm of the virtual instrument is as follows:

1. The user selects the data file where the measured data were saved;
2. The user introduces the time and the date corresponding to the beginning of the measurement;
3. The user introduces the measure sample time;
4. The user chooses the value of averaging time (practically this is the period of time between two points of the displayed load curve and it must be at least equal with the measured sample time);
5. The user chooses the units for measured quantities;
6. Data are read and processed;
7. Load curves, number of surveyed days are displayed in the main window;
8. The user chooses the number of the day for which the load curves and their parameters will be displayed;
9. In the next step, the VI processes data and displays the second window;
10. The user selects the type of power: single phases' powers or total power;
11. The load curves and the corresponding parameters are shown.

4. EXEMPLE

This section aims to illustrate the utility of the proposed virtual instrument by giving an example. For this purpose, some measurements have been performed to a typical industrial consumer; as a result, a text file with the active powers consumed by this customer was obtained and processed.

Figures 3, 4 and 5 illustrate the displayed curves. The characteristic fields of every window are populated with values obtained by processing the real measured data.

It can be seen that the sample time was 300 sec and the surveyed period is spread on 5 days from the 24th until 28th of January 2008 (figure 3). The daily load curves (figures 4 and 5) are represented for the first day of measurement, 24th January. Figures 4 and 5 illustrate the variation in time of the total power (sum of the phases' powers) and the power on each phase respectively. These figures show also the load curves parameters; for example the hourly factors on the 24th of January on phase R are: P_{max}=53.29 kW, P_{min}=49.63 kW, P_{med}= 51.79 kW, $W_{day} = 621.52\ kWh$, $\alpha_{day} = 0.93$, $k_{day} = 0.97$, $T_{Uday} = 11.66\,h$. On the other hand the three-phase hourly factors are: P_{max}=165.28 kW, P_{min}=152.66 kW, P_{med}= 160 kW, $W_{day} = 1919.9\,kWh$, $\alpha_{day} = 0.92$, $k_{day} = 0.96$, $T_{Uday} = 11.62\,h$.

5. CONCLUSIONS

Load curves are very important in the power engineering due to the information that they contain about the energy demand.

Due to the huge quantity of data, the classical processing techniques are difficult to be implemented and are time consuming procedures; therefore the virtual instrumentation represents an opportune solution to eliminate these disadvantages. On the other hand, a virtual instrument has many supplementary advantages: flexibility, generality, short-time processing, easiness regarding the data importing and storage.

Taking into account these aspects, the authors have build up a virtual instrument capable to process measured data stored into a file and to determinate the corresponding load curves and their parameters.

The given example underlines the usefulness of this VI: data are easily read from the source file, and general or/and typical (daily) load curves along with their parameters are promptly and accurately obtained.

References

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