Linguistic variables for identification of photovoltaic matrix

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***Abstract*: The paper presents the problems of assessing the effect of changes in the properties of a photovoltaic matrix (photocells) induced by its faulty operation. The principles of determining the degree of changes in matrix properties in order to identify its parameters is proposed. A factor of variations of the matrix properties induced by random hazards is defined. The method of taking into account the linguistic variables is defined. A measurement example is presented.**

***Keywords*: photovoltaic matrix, linguistic variables, Shannon, classifying coefficient.**

I. INTRODUCTION

Photovoltaic conversion is considered as the most perfect way of converting the solar power.

More and more frequently early cell aging, temporary and partial shading of photovoltaic module surface due, for example, to masts and telecommunication equipment, weather phenomena, and reduction of effective module surfaces caused by deposits or other weather or environment processes, give rise to the problem of operation of these devices. Special attention should be paid to icing, frosting, or snow covering of a part of the photovoltaic module. Such processes may often occur under our latitude. They not only delimit the light access to the effective module surface but, additionally, reduce the working surface temperature of the photovoltaic matrix.

More often to opinion of "time of life" devices it was used "untechnical" variables. Experts' opinions are this often. It is possible it to describe as sequences of linguistic variables. The process of transfering the information in traditional conception is well-known (Fig.1) as the communication diagram of Shannon [1].

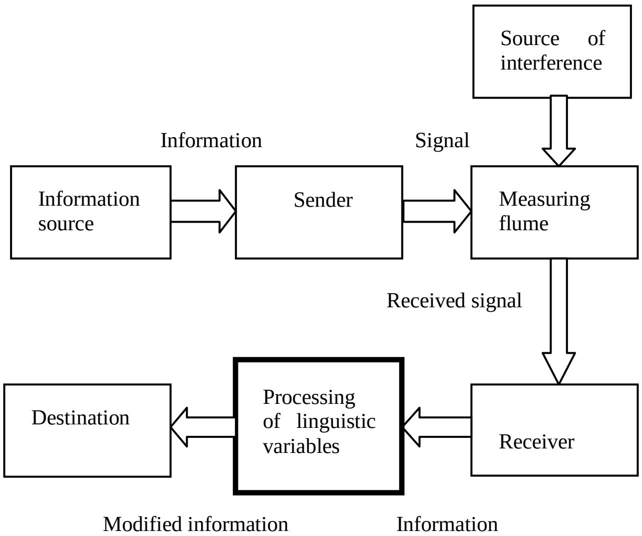

Fig.1. Modified diagram of the communication of Shannon

The additional information in form of linguistic variables can be introduced between receiver and destination, e.g. by the classifying method. Above principles were applied often intuitively. The making a decision on the basis of human experience in relation to similar devices can be an example.

II. SIMULATION OF THE FAULTY OPERATION

A basic part of the module is a photovoltaic cell. In the connection systems of such cells many kinds of faults may appear, e.g.:

- the ones related to the manufacturing technology – faulty connection, statistical spread of the cell properties;
- the ones related to the operation conditions – uneven illumination, heating or cooling, or considerable statistical spread of other excitations (with regard to the matrix dimensions);
- the ones related to aging of the matrix parts – induced by electromagnetic, mechanical, thermal hazards, etc.

The laboratory studies are useful as they enable simulating the real conditions in a laboratory. Such a procedure speeds up the measurements and makes them independent on unpredictable weather conditions. Additionally, dynamic character of such changes in operation conditions like the illumination quality (luminous flux density) or temperature, differs not much from possible actual changes in these parameters, provided that appropriate measures are undertaken.

During the laboratory measurements the natural operation conditions of the module are simulated by:

- varying illumination quality (e.g. by switching on or off artificial light sources);
- varying temperature (applying crumbled ice on the module surface);
- varying load (by changing resistance of the receiver);
- switching off a part of the module (simulation of a fault or shading, by total screening of the module working surface);

The disturbances should be confirmed and eliminated e.g. with the help of a filtration processes, of which with the aid of classifying coefficients.

A benefit resulting from the simulation studies (as opposed to the measurements in natural environment) consists in possible "preferred" changes induced by changing conditions of the module operation.

III. PRINCIPLES OF DEFINING THE FACTORS OF HAZARD RESULTS

According to the information theory the parameters of the observation space points are of random character. The space may be described by a random field.

Parameters of the random field are estimated based on the measurements carried out in the time T, thus obtaining a random environment.

Consideration of the matrix as a series-parallel system of concentrated elements is conducive to the account of their geometric distribution, e.g. on a plane [2].

Then, for a random field describing the random fault excitations, the following factor may be proposed for a k_J^U change in a given parameter K_n of the cell model in the n-th measurement window:

$$k_J^U = K_{Emp} \frac{J_n(U) - J_{n-1}(U)}{J_{n-1}(U)} \qquad (1)$$

where: J_n – the Shannon's information measure (information quantity) defined in the n-th window [1]; U – the vector of fault hazards, K_{Emp} - classifying coefficient.

Hence, the classification value of the K_n parameter in the n-th window amounts to

$$W_{class} = K_n k_J^U = K_n K_{Emp} \frac{J_n(U) - J_{n-1}(U)}{J_{n-1}(U)} \qquad (2)$$

The Shannon's entropy was used by the authors as an information measure with the assumption that the observations are carried out through a real transmission channel [1,3].

IV. LABORATORY MEASUREMENT AIMED AT DETERMINING THE FACTORS OF HAZARD RESULTS

It is assumed that a matrix is determined by the parameters of known probability distributions [4]. The laboratory stand includes a photovoltaic module Shell ST20 of external dimensions 748×328×35mm (of the weight 4100g), a decade resistor D14, a TH-03 converter (with temperature measurement: an EL015 sensor of the resolution ±0.01 for -30÷70ºC and the accuracy of ±0.3%; and with measurement of illumination quality - an EL031 sensor of the resolution ±0.1%), connection wires with the plugs, a PC computer with the software of the Pico converters manufacturer (the temperature and illumination quality measurements), the PIC18F8722 controller (the AC converter: voltage measurement by means of a voltage divider, current measurement with a shunt), digital meters (for checking correctness of the AC readings), an intermediate IN/OUT system (including a voltage divider provided with a Zener diode for overvoltage protection of the AC converter and a shunt for current measurement) for physical connection of the photovoltaic module, resistor, meters, and the microcontroller.

The parts of the patterns may be here distinguished that correspond to simulation of permanent fault of a group of cells. In the time t=6.7s the k_J^U factor amounts approximately to 0.18. The value was estimated with the use of the following relationship defining the information quantity [4, 5]:

$$J(U) = -0{,}5\ln[1-\rho^2(U)] \qquad (3)$$

where: $\rho(U)$ – a correlation (normalized) coefficient defined by the expression:

$$\rho(U) = \frac{\mathrm{cov}(u)}{\sigma_{x_n}\sigma_{x_{n-1}}} \qquad (4)$$

where: cov(u) – the covariance; $\sigma_{x_n}, \sigma_{x_{n-1}}$ – standard deviations of the voltage

Additionally, several measurement series have been carried out in order to determine the current-voltage characteristics of the photovoltaic cell under various illumination conditions and varying active (illuminated) surface, and under varying weather conditions (icing simulation). All the characteristics have been determined with variation of the resistance load in the range from 0 to 10000Ω with the step of 1000Ω.

Classifying coefficient $K_{Emp} = 1.03$ was established and considered (this photovoltaic matrix is three years old).

Voltage and current variance values under operation conditions for example Inefficient 25%, T=24.5ºC gove for efficient 100% the value cov(U)=9.29, cov(I)= 2.42.

V. CONCLUSION

The variation factor depicting changes of the voltage output of a considered photovoltaic module proposed in the present paper enables defining, with the use of a standardized correlation factor, the degree of variations of photocell matrix properties. It is worthy to notice that simulation of icing of a part of the module does not allow to draw qualitative (i.e. determined by relationships or factors) but only quantitative conclusions. The fact is due to inability of accurate depicting of the environment conditions occurring in such a case.

VI. REFERENCES

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