Hydropower Preventive Monitoring Action Plan Prophylactic

Marius-Constantin Popescu and Nikos E. Mastorakis

***Abstract*—**Hydropower generators operation can be automatically optimized based on a correct determination of the main performance indices. The same approach is operable for rehabilitation studies. The most important application refers at small and very small hydropower stations, operating completely automatically, and individual or in a waterfall. There were established resistors parameters, adjustment characteristics, efficiency characteristics at different operation regime, and main types of losses at different regime. It is generated a computer of modeling process, considering these parameters, utilizable in mentioned applications. The numerical example is presented for a where small hydropower generator type HVS 288/159-8, working in a hydropower station on the Jiu River. Determining the performance generators goes into hydropower plants is a major landmark in both prophylactic legally and in terms of energy efficiency due to rehabilitation or re-engineering processes.

***Keywords*—** Hydropower, Components, Parameters evaluation, Preventive tests.

I. Introduction

Available hydraulic energy of power station placed on a course can be expressed by the relation:

$$W_h = \rho \cdot g \cdot V \cdot H \quad (1)$$

where:

W_h - energy [J],
H - specific energy [m],
V - water flow mass expressed in [m^3],
ρ - water density in operation conditions [kg/m^3],
g - gravitation acceleration [m/s^2].

or, using an old and not standardized expression:

$$W_h = 9.81 \cdot V \cdot H \quad (1')$$

where:

V - water mass expressed in [kg f].

Hydraulic power represents the energy changed by the water with the turbine rotor and has the expression

$$P_h = \rho \cdot g \cdot Q \cdot H \quad (2)$$

where:

P_h - hydraulic power, offered by the water flow to the turbine.
Q - water flow rate [m^3/s],

Electrical power offered by the generator to the network has the expression:

$$P_{el} = \eta \cdot P_h \quad (3)$$

P_e - electric power, offered by the hydro turbine to the network.
η - generator-turbine ensemble efficiency.

The efficiency can be divided: in turbine efficiency η_t, transmission efficiency η_{tr}, and electrical generator η_g.
Ensemble efficiency is

$$\eta_a = \eta_t \cdot \eta_{tr} \cdot \eta_g \quad (4)$$

water
where, η_a is the total efficiency.

It is obvious that the final generated electrical power is in direct dependency with the total efficiency. Consequency, the generator efficiency is one of the main research directions, taking into consideration the main types of losses. There are specific methods to evaluate the whole efficiency, or focussing on the main types.

II. Determining Performance indicators

The purpose of the work is to establish a method for the correct parameters evaluation in an appropriate form, and to compare these parameters with the parameters indicated by the provider. The numerical example is presented for a small hydropower generator type HVS 288/159-8, working in a hydropower station on the Jiu River. The result application could be in operation monitoring and in refurbishment undertaken.

To establish the performance indices of a hydro test using a package structured as follows: determination of Ohm resistance of rotor windings in cold state, raising the idle characteristics and three-phase symmetrical short circuit of the generator, raising characteristic in V and P=0, clearance adjustment characteristic, determining environmental warming stator winding stator and rotor winding to a total of four

Marius-Constantin Popescu is currently an Associate Professor at the Faculty of Electromechanical and Environmental Engineering, Electromechanical Engineering Department, University of Craiova, ROMANIA, e.mail address popescu.marius.c@gmail.com.
Nikos Mastorakis is currently a Professor in the Technical University of Sofia, BULGARIA, Professor at ASEI (Military Institutes of University Education), Hellenic Naval Academy, GREECE, e.mail address mastor@wseas.org

operating regimes, determining the actual PQ diagram for hydro and determining the nominal yield and the conventional yield curve. Function tests will be conducted under thermal load stabilized at different levels of active and reactive power at rated power factor ($cos\varphi_n$). After running the generator tests, maximum load active and reactive power and thermal considerations yield curve of the conventional generator. Temperature of stator winding and stator core is determined by measuring the temperature resistance that fitted generator mounted in notches generators.

A. Rotor winding resistance determination

To determine the resistance of rotor winding is necessary to measure the reference temperature θ_0 of winding. For this, a precision thermometer 0.1°C set on copper runner after the generator has reached the ambient temperature appreciatively after about 24 hours of downtime. The resistance value R_θ to a value other than that measured temperature thermometer is determined by the relationship:

$$R_\theta = R_{\theta 0} \cdot (235+\theta)/(235+\theta_0) \quad (5)$$

where $R_{\theta 0}$ is the resistance at θ_0 reference temperature; R_θ is resistance at the reference temperature θ.
Rotor winding temperature in the samples heat-stable operating system is determined by resistance change method using the relationship:

$$\theta = (R_\theta - R_{\theta 0}) R_{\theta 0} \cdot (\theta_0 + 235) + \theta_0 \quad (6)$$

The resistance of the winding rotor at the corresponding temperature θ is determined each time by the method of voltmeters and ampermeters. To this end, after determining the heat and after reading the other parameters, it will stop the generator and rotor resistance R_θ will measure θ. Measurement will be made in less than three minutes from the stop so that the temperature θ is determined as close to the real one. Temperature of stator winding and stator core is determined by measuring resistance temperature transducer is equipped with generator mounted in notches generators and using the data obtained experimentally was prepared Table 1.

Tab. 1

Parameter	UM	Hydropower	
		designed	mess
			HG
Rotor winding at 130^0C	Ω	0.208	0.21908
Rotor winding at 75^0C	Ω	-	0.18607
Rotor winding at 15^0C	Ω	-	0.15006
Reactant P	u.r.		0.148
Reactant Syncron X_d	u.r.	1.196	1.436
Short circuit report U_n and f_n	-	0.95	0.74
Excitation report U_n and f_n	A	-	342
Idling voltage at excitation U_n şi f_n	V	53	54
Excitation electrical current at idling and short circuit at I_n	A	-	385
Excitation voltage at short circuit at I_n	V	-	61
Normal current $cos\varphi_n$	A	690	687
Current efficiency P_n $cos\varphi_n$	%	97.77	96.87

B. Adjustment features evaluation

Feature adjustable tension builds to a different voltage rating to obtain the corresponding characteristic Voltage (U_n) and the nominal frequency (f_n) will recalculate feature nominal terms using the following relations:

$$I_{ex} = I_{ex.mas} + (U_n/f_n \cdot f_{mas}/U_{mas} - 1) \cdot I_{ex.on} \quad (7)$$

$$I_{ex.0n} = U_n/f_n \cdot f_{0.mas}/U_0 \cdot I_{ex.0mas} \quad (8)$$

where the excitation current I_{ex} is corrected, $I_{ex.mas}$ current excitation is measured at lifting adjustment feature, f_{mas} is frequency measured at lifting tuning feature, Umas is the voltage measured at lifting tuning feature, I_{ex0n}. current excitation is idling properly rated voltage and frequency of idling not translated curve, $I_{ex.0mas}$ current excitation is measured at raising nominal voltage characteristic corresponding goals and f_{0mas}, U_{0mas} are frequency voltage that measured at raising idle feature.
Corrected value of excitation current (I_{ex}) corresponds to a current value corresponding stator current excitation is measured and presented in Table 2 for different levels of power.

Tab. 2

P	Q	U	U_{ex}	I_{ex}	I
MW	MVAr	V	V	A	A
1.10	-16.97	10.22	92	555.2	960
1,00	-16.28	10.15	90	543.2	920
0,95	-14.20	10.05	84	506.9	820
0,95	-12.47	9.98	80	482.8	700
1,10	-10.39	9.94	74	446.6	600
1,00	-7.97	9.88	68	410.4	480
0.90	-5.20	9.85	62	374.2	360
0.90	-3.12	9.87	54	325.9	200
0.95	-0.35	9.82	48	289.7	0
1.0	+3.46	9.75	38	229.3	200
1.0	+4.50	9.68	36	217.3	260

Measuring values and adjustment of the excitation current are presented in Table 3 and Fig. 1.

Tab. 3

Nr. crt.	I	$I_{ex\ mas.}$	$I_{ex\ recalc.}$	U	f	$cos\varphi$
	A	A	A	KV	Hz	
1.	0		251.5	0	50	
2.	1308	550.2	550.8	9.9	50	0.895
3.	1480	555.2	568.6	10.1	50	0.915

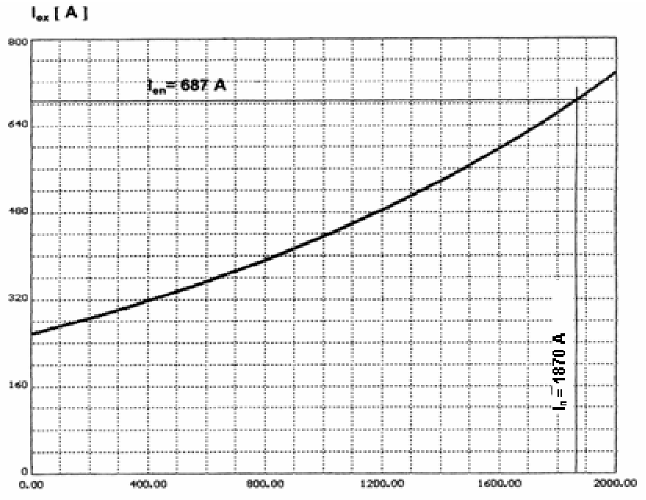

Fig. 1: Adjustment characteristic.

A.1. Determination of P-Q diagram

For the preparation diagram $P=f(Q)$ for hydroelectric generator will use the relations:

$$P=(U_f E_d/X_d)\cdot\sin\theta+U_f^2/2(1/X_q-1/X_d)\sin2\theta \quad (9)$$

$$Q=(U_f E_d/X_d)\cdot\cos\theta+U_f^2/2(1/X_q-1/X_d)\cos^2\theta-U_f^2/X_q \quad (10)$$

where: P, Q are the active power reactive in relative units, U_f is the basic tension in relative units, E_d is the longitudinal electric voltage in relative units, synchronous reactance X_d is longitudinal, synchronous reactance X_q is transverse, and θ is the internal angle.

The origin of excitation current has coordinates

$$P = 0, \qquad Q =- U_f^2/X_q.$$

Natural static stability limit is determined using the criterion dP/dQ, resulting in internal angle values following relations:

$$Q = \arccos[1/8(-a +\sqrt{a^2+32})] \quad (11)$$

$$a = (E_d/U_f)\cdot 2X_q/(X_d-X_q) \quad (12)$$

Practical limit of static stability is determined by graphic method of natural limit for a reserve of 10%. Limit heat supplying sub excited duration is determined by special similarity to determine the actual limit. The limit is determined as indicative. This limit is the straight line joining points of coordinates:

$$P = P_n, \quad Q = - 0.15S_n \; P=0, \; Q = - 0.5S_n. \quad (13)$$

Operating thermal limits under the indicative (if any) is determined from the condition of maintaining mechanical temperature allowable stator windings and core, as follows:
- The experimental diagrams $\Delta\theta_r=f(I_{ex}^2)$,
with $\Delta\theta_{Cu}=f(I^2)$ and $\Delta\theta_{Fe}=f(I^2)$ at $\cos\varphi=\cos\varphi_n$ circuit runner is determined that the stator corresponding maximum allowable temperature for insulation class and the stator core (120°C for winding and stator core 130 and C to carry out these rotor).

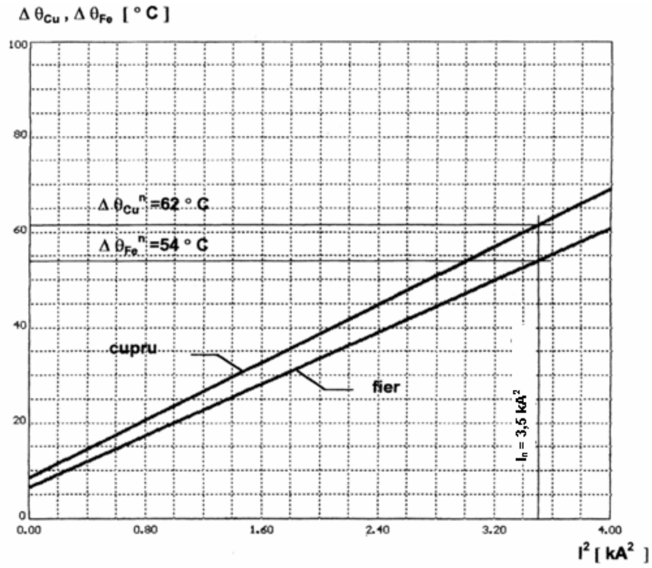

Fig. 2: Characteristic thermal stator winding and stator core of hydro generator.

Temperature values are given in the technical manual generator.
- Calculating the maximum active and reactive power according to:

$$S=\sqrt{3}UI, \quad P=S\cos\varphi, \quad Q=\sqrt{S^2 - P^2} \quad (14)$$

Values of active power, reactive and apparent are presented in Table 4.

Tab. 4

Regim	P	Q	S	$\cos\varphi$	I
	MW	MAVr	MVA	-	A
1	25.0	12.47	27.93	0.895	1660
2	20.2	10.05	22.56	0.895	1308
3	15.2	7.62	17.00	0.894	1000
4	23.8	10.39	26.00	0.915	1480

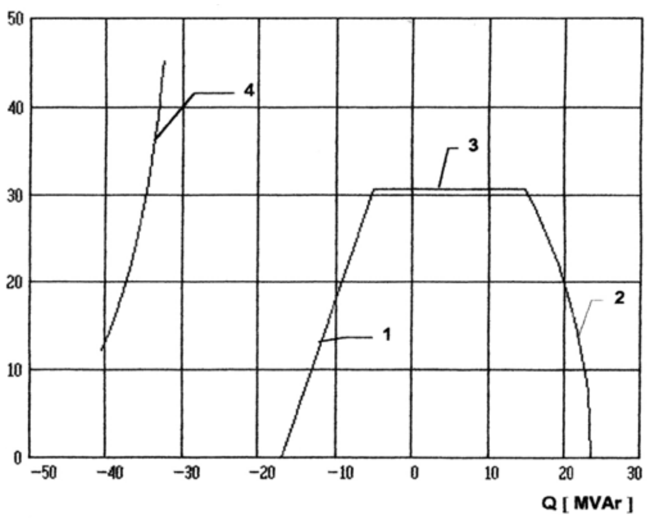

Fig. 3: Standard PQ diagram.

A.2. Efficiency evaluation

In accordance with conventional standards in force output of the generator is determined using the loss separation method, using the general relationship definition.

$$\eta = 100 \cdot P_{charged} / (P_{charged} + \Sigma P_{loss}) \qquad (14)$$

The yield will be determined for 25, 50, 75 and 100% of rated load, considering that the terminal voltage, frequency and power factor are nominal values. The quantitative determination of individual losses and efficiency for all modes of load is obtained by calculation using the following experimental: losses caused by calorimetric method in three modes of operation (idle non excited the rated speed, idle speed and voltage excited to rated the generator terminals and went to a landing load power), the winding Indus resistance and the excitation winding, heating characteristics obtained experimentally induced and the winding of the winding excitation characteristics idle and three phase short circuit, symmetric permanent terminals and resistance Potties. Efficiency values determined for a conventional hydro power of 30.6 MW are presented in Table 5 and the corresponding conventional yield curve is shown in Fig. 4.

Tab.5

K		1/4	2/4	3/4	4/4
$\cos\varphi$	-	0.9	0.9	0.9	0.9
I	A	468	935	1403	1870
I_{ex}	A	484.1	550.2	629.5	706.5
P_{m+vent}	kW	424.2	424.2	424.2	424.2
P_{fe}	kW	285.7	285.7	285.7	285.7
P_{cu1}	kW	5.78	23.08	51.97	92.32
$P_{cu\ ex}$	kW	39.37	50.86	66.57	83.86
P_{aex}	kW	6.95	8.89	11.75	14.80
P_s	kW	3.63	14.47	32.58	57.89
ΣP	kW	765.6	807.3	872.8	958.8
P	kW	7650	15300	22950	30600
η_{conv}	%	88.99	94.72	96.20	96.87

K		1/4	2/4	3/4	4/4
$\cos\varphi$	-	1	1	1	1
I	A	468	935	1403	1870
I_{ex}	A	445.5	482.7	541.0	605.0
P_{m+vent}	kW	424.2	424.2	424.2	424.2
P_{fe}	kW	285.7	285.7	285.7	285.7
P_{cu1}	kW	5.78	23.08	51.97	92.32
$P_{cu\ ex}$	kW	33.34	39.14	49.17	61.49
P_{aex}	kW	5.88	6.91	8.68	10.85
P_s	kW	3.63	14.47	32.58	57.89
ΣP	kW	758.5	793.5	852.3	932.5
P	kW	8500	17000	25500	34000
η_{conv}	%	91.08	95.33	96.66	97.25

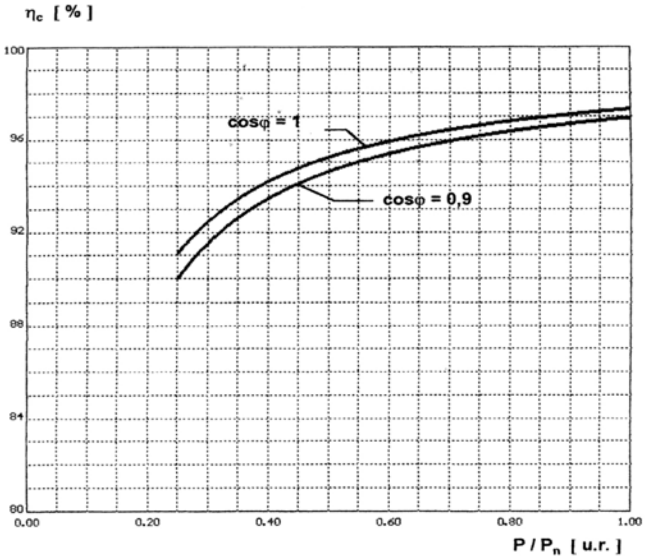

Fig. 4: Efficiency characteristic.

III. Determination of Losses

A. Determination of Mechanical losses

Mechanical losses are determined by calorimetric method to test idle non excite. Radial-axial bearing losses are fully included in the total loss of the generator, and the radical camp lower losses are distributed between the generator and turbine rotating sub-assemblies in proportion to the masses.

Is determined by calorimetric method to test idle excited with rated voltage at the terminals induced. It is considered to be proportional to the square metallic support B_δ induction in δ. For reference to another value than the existing tension in the test is a used relationship:

$$P_{Fe2}=P_{Fe1}\cdot(B_{\delta 2}/B_{\delta 1})^2=P_{Fe1}(E_{\delta 1}/E_{\delta 2})^2 \qquad (16)$$

$$E_\delta^2 = (U+X_p\cdot I\cdot\sin\varphi)^2 + (X_P\cdot I\cdot\cos\varphi)^2 \qquad (17)$$

where E_δ is the corresponding electric voltage induction in metal support B_δ, U, I are the voltage and current induced on the beam, cosφ is the power factor and X_p is the Potier reactance.

The operation of the generator empty (I=0) result is $E_\delta=U$, then:

$$P_{Fe2}=P_{Fe1}(U_2/U_1)^2 \qquad (18)$$

Using relationship (18) is the correction iron losses if the sample excited empty terminal voltage has nominal value.

B Determination of Joule effect losses in the winding Indus

Joule effect losses are determined by the relationship:

$$P_{Cu1} = 3R_1\cdot I_1^2\cdot 10^{-3} \text{ [kW]} \qquad (19)$$

where: R_1 is a phase induced resistance temperature of 75 ºC and I_1 is the current phase of the Indus

C Determination of additional losses in Pregnancy

Is determined by deducting losses and mechanical ventilation, the iron losses, the losses by Joule effect losses in the windings and excitation system of the total losses measured by calorimetric method in operation under load. Are considered to be proportional to the square of the induced current, so with a single experimental determination, they can be calculated for any value of the induced current:

$$P_{s1}=P_{s2}\,(I_2\,/I_1)^2 \qquad (20)$$

where: P_{s1} are determined by calculating the losses for the induced current I_1 and P_{s2} are losses due to current I_2 in experimentally induced.

D Determination of Joule effect losses in the windings of excitation

$$P_{Cu.ex}=R_{ex}\cdot I_{ex}^2\cdot 10^{-3}\ \text{[kW]} \qquad (21)$$

in which R_{ex} is the excitation current for a given system load measured or calculated by standard methods using one of the characteristics idling three phase short circuit and value reactants Potier.

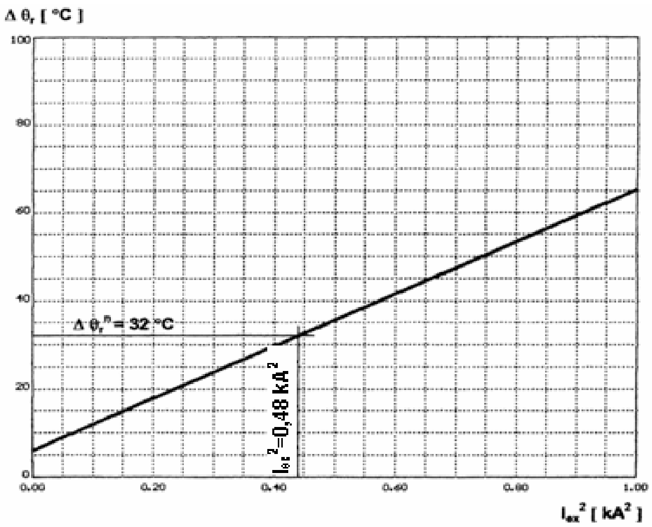

Fig. 5: Thermal characteristic.

E Determination of losses in equipment Excitation

This category includes all losses except the installation of the stator winding losses (circuits, thyristor converter, and transformer excitation). It is considered an overall yield of the plant excitation η_{ex}=85% and we have:

$$P_{ex}=P\cdot_{Cu.ex}(1-\eta_{eg})\,/\eta_{ex} \qquad (22)$$

F Determination of losses evacuated by Coolers

The value of losses carried cooling air flowing through heat exchangers resulting relationship:

$$P=4.18\ c\cdot\Delta t\cdot Q\ \text{[kW]} \qquad (23)$$

where c is the specific heat of air [m³/s] given by

$$c=0.307\cdot(273+\theta_{ar})\cdot H/760\ \text{[kcal/m}^3\text{ degree]} \qquad (24)$$

where, H is the cooling air pressure [mmHg], θ_{ar} would be out of the cold air temperature rise [°C], Δt is warmer temperatures [°C], and Q is the cooling air flow [m³/s].
Cooling air flow is determined by the relationship:

$$Q=v_m\cdot S\cdot n\ \text{[m}^3\text{/s]} \qquad (25)$$

where: v_m is the average air speed [m/s], S is the active area of cooler [m²], and n is the number of coolers.
Air speed is measured with digital anemometer surface coolers and derived parameters are presented in Table 6.

Tab. 6

Regim	cosφ	I_{ex}	I_{ex}^2	θ_{ar}	θ_r	$\Delta\theta_r$
	-	A	kA^2	°C	°C	°C
1	0.895	-	-	22.8	-	-
2	0.985	530.2	0.28	20.5	35.2	14.7
3	0.894	-	-	20.5	-	-
4	0.915	555.2	0.31	21.3	41.1	19.8

IV. Local Data Acquisition Equipment

Electrical signals collected from each of the cells constituting the electric power station are two categories [11], [12]:

- analog signals: 4 current signals directly taken from the measure transformers on the departure of the cell line (depending on the type substations these signals are received at the entrance station I_n / 5A$_{ef}$ type or type I_n / 1 A$_{ef}$, where In is nominal current on the going line of the cell line) and 4 voltage signals talked directly from the voltage converters measuring line (type U_n / 100 V$_{ef}$).
- digital signal type relay contact and describe the position of each electrical equipment installed in the cell (protection, switches, load separators, separators for making the earth).

Analog and digital signals from the measuring transformers are applied to the inputs of each local station data acquisition through specialized adaptation blocks.

To ensure accuracy for analog signals taken from the process they are applied to the entry in your local data acquisition in two distinct ways: to the entry of energy metering quantities and to the block entry adapting analog signals. This think is necessary because at the time of occurrence of a defect (e.g. a cage on the outlet of a cell) the pack instant for current and voltage can reach very high values which must be measured to achieve an accurate analysis of defect. Because these sizes can have up to 30 ... 40 times then face value of such size is necessary to provide a separate block adjusting input signals that can retrieve these values. Accuracy of measurement in these cases is not large, but significant flaws in the analysis is to reproduce as accurately waveform signals from entering the station less important is the precision with which we take these quantities. For these practical considerations in the local station data acquisition system is implemented two energy value applied measure systems applied to input quantities. An accurate measurement of large-format sizes metering energy central mode that provides energy for the cases of sizes taking normal operation and a measure of energy quantities for emergency situations comprising adjusting block analog signals, Block Converter analog digital, central block. The two measure systems operate in parallel and the central unit extracts data from one of them according to actual situation (normal operation or fault). The block sizes as energy is a complex block which ensures the acquisition of the current energy (3 current and 3 voltages) during the operation without damage of electrical cell supervised. Block provides a more accurate measure, accept at the input signals in 0 ...1.2 I_n and 0...1.2 U_n and is able to perform the following functions: electrical isolation of the analog input to your local procurement process, adjustment signals received at the entrance with the entrance into account the current energy blocks in an area of 0 ... 1.2 I_n (for the currents) and 0 ... 1.2 U_n (for voltages), filtering input signals, continuously calculating actual values for pack applied to the input, continuously calculating the quantities of direct quantities (active power, reactive power, power factor), always calculating the derived quantities (active power, reactive power, voltage line, line current, maximum values of measured and derived quantities for a preset time), sending the processed data to the central unit module whenever it is requested. Time of acquisition in this case is large, important being accuracy of data acquisition.

Adaptation block analog signals received at input the same information as the block size as energy, but provides for a range of input signals as much (for 0 ... 40 I_n currents and for voltages 0 ... 2.2 U_n) and provides the following functions: electrical isolation of the analog input to your local procurement process, adjustment to input signals received by the entry in block digital analog converter in a range of 0 ... 40 In (for current) and for 0...2.2 U_n (for voltages). Time of acquisition in this case is very small, important being taking a large number of samples for each the size of entry during damage.

Digital signal adaptation block provides the following functions: electrical isolation of the digital input to your local procurement process, adjustment the input signals received by the input of the module unit and filter input signals. Analog digital converter is made by a 8 to 14 bit digital analogue high speed. Acquisition of data from order entry module is synchronous to UC so that subsequent analysis of data acquired can allow recovery of as a precision waveform signal applied to the entry block converter. For analysis of finesse is absolutely mandatory simultaneous acquisition of data from the 8 block entry of numerical analog conversion. Block contains in addition to the specific modules of 8 converters and signal conditioning modules, input and numerical data transfer to UC module.

The central unit module ensures the proper functioning of the local station data acquisition. The module is built around a powerful 32-bit processor from Motorola 8086 family and provides the following main functions:

- purchase order synchronous data taken from the process when an event occurs (a certain number entry or a value greater than the amount prescribed for a pack of analog input);
- store acquired data in its memory work (its maximum capacity is 16 MB) and transmission to the dispatcher computer system in the shortest possible time (normally within 30 s) recorded data such that state to be prepared to answer a new event
- transmission to the dispatcher computer system, any timing errors Station after time over the subsystem Universal GPS (Global Position System) devices to synchronize local data [11].
- processing, under normal working (missing events) energy information specific to the cell supervised and their transmission to the dispatcher to track the on-line activity energy

The communication block is a specialized module that ensures information transmitting from and to the dispatcher in minimum time with maximum safety and maximum protection from electromagnetic disturbances. The block ensures the identification of a maximum of 255 local data acquisition

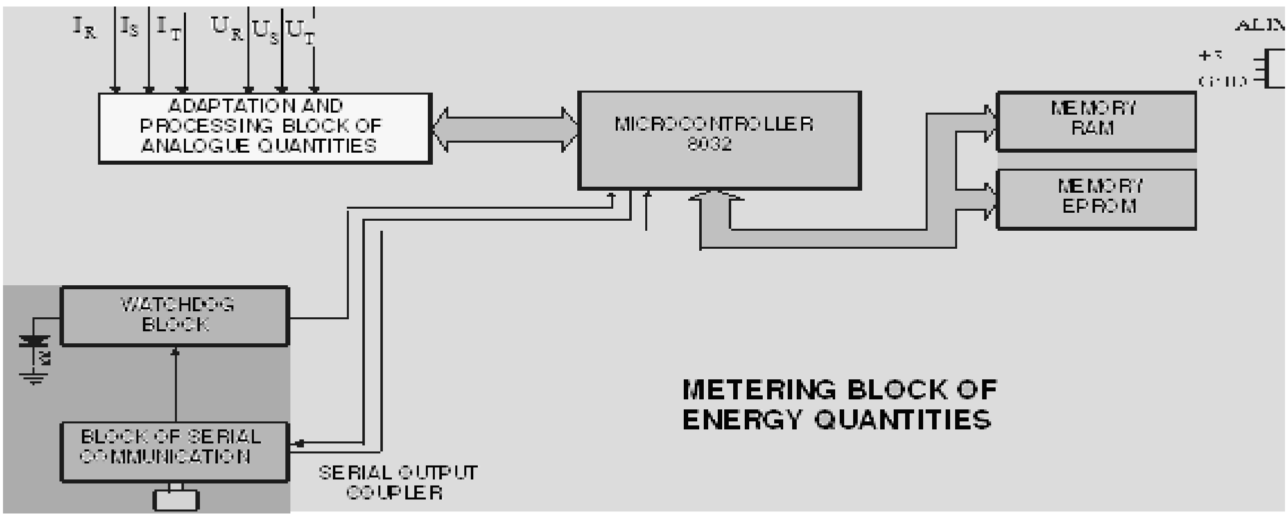

Fig. 4: Block sizes measuring energy.

stations that can be mounted simultaneously in a power distribution station electrical. The speed of transmitting information on optical medium that provides the link between local stations and purchase computer equipment from the dispatcher, is 10 ... 100 Mbps. Proper functioning of the station is ensured by a power source that provides the necessary supply voltages system of each building blocks station. The source is the special construction equipment operating in industrial environments with greater tolerance to electrical and electromagnetic disturbances.

V. The Measure Energy Quantities

Energy metering size is designed for taking specific electrical quantities of electrical distribution stations being used for their monitoring and energy measurement**.** The measurement block performed the following main functions [1], [2], [3]:

- takeover a number of 6 sizes from transducers mounted analogue stations supervised electrical (voltage, current), primary processing of quantities purchased and working memory storage period of time, in accordance with an own algorithm included in the program memory of the equipment (typical values during storage and processing results is that between two successive data transmissions to the dispatcher), and values of type sizes to save energy for a period of time much greater;
- transmitting acquired and stored data in central module of the station local data acquisition through a high-speed serial links.

Diagram of this component of the local station data acquisition is shown in Fig.4. The block operation is ensured by a 8032-type microcontroller, around which are located a number of other electronic circuits which function module properly and all equipment.

The program is part of EPROM memory with a capacity of 32 kB and is given by a single integrated circuit and data memory RAM module 32 also has the ability kB and ensures an integrated circuit, which is used to maintain the values acquired the process during the second data to the central unit of the local stations. Communication with the central unit is done through the serial communication block. It provides data communication between the two components of the station at high speed so that when the central unit is busy taking data from metering is minimal. A essential block for the proper functioning of the block is watchdog module) which is to issue a RESET signal to the microcontroller when a step included in the program EPROM memory is not running a certain time frame, and automatically reinstituted its implementation the end. The module is extremely useful especially for data acquisition equipment working in environment with high levels of disturbance on power circuits which can penetrate the food source, disturbing the operation of equipment.

Adaptation and processing block is a block size analog complex electrical quantities witch measured and calculated all of the network of cell-phase electric power station which is connected (Fig. 5). The block is built around the integrated circuit ADE 7758 (ANALOG DEVICES), which is a complex circuit able to calculate all sizes specific power three phase network. Analog input signals are applied to enter the circuit through signal adapter. Three-phase currents are applied by means of current transformers which are adapting to the 5A level signal to 500 mV. Output voltage signal from current transformers is applied to the inputs of three amplifiers PGA1 are variable gain amplifiers with differential input. Amplifiers accept to the input differential signal with maximum amplitude of 500 mV. Range of amplification for these amplifiers is 1.2 or 4. Amplifier output is applied to the 3 analogue inputs 24 bit synchronous digital sign which differential input can be set to turn in three areas (+0.5, +0.25 V or 0125 V) in accordance with the gain set for amplifiers Entry PGA1. Change fields for entering the converters are achieved by changing the voltage reference to the converter. Voltage signals are applied through resistive dividers at the entrances of three amplifiers PGA2 which are variable gain amplifiers with differential input. Amplifiers accept to the input differential signal with maximum amplitude of 500 mV. Range of amplification for these amplifiers is 1.2 or 4. Amplifier output is applied to the 3 analogue inputs 24 bit synchronous digital sign which differential input can be set to turn in three areas (+0.5, +0.25 V or 0125 V) in accordance with the gain set for amplifiers entry PGA2.

At the analog outputs of the 6 synchronous digital converters we obtain the numerical value at any time with mark of applied voltages and currents from entering the circuit. The numeric value at the out converters may vary between 0xd7AE14 (HEX) (-2,642,412) and 0x2851EC (HEX) (2,642,412). As of now all calculations which are made for obtaining energy parameters are numerical. To can perform these calculations in time as small, the circuit is constructive with a DSP processor inside. At the each out of the 6 CAN it obtain samples of the quantities entering the circuit with variable sampling rates. Are possible, depending on subsequent calculations required, use one of the following sampling rates: 26 KSPS, 13 KSPS, 6.5 KSPS and 3.3 KSPS.

Current channels. Sampled signal is obtained in three different sizes used for subsequent calculations: a size which is used to calculate the RMS value of current on each phase, one size to save in a special register containing the current waveform and a magnitude that later use in calculating active and reactive power. Each of these sizes is scaled by multiplier CM1 with a value contained in register AIGAIN following relationship*:*

$$\text{Current waveform} = ADCout \times \left(1 + \frac{AIGAIN}{2^{12}}\right) \tag{24}$$

This applies to all three current inputs. The value scale is applied as a filter entry number goes up FTS to eliminate DC offset, and leaving it to the entry of an integrator.

Voltage channels. Appropriate signals for each channel voltage input channels are applied in two directions: for active and reactive power measurement, the signal from the ADC output goes directly into two multipliers CM2 and CM4, the signal is applied to enter the circuit for calculating the RMS voltage (CM3 multiplier entry). The circuit is equipped with detectors applied to the input signal crossing zero. This is used for calculating the phase angle between voltage and current in each phase and it's still effectively used to calculate active and reactive powers. Also, zero crossing detection signal input is used to calculate the frequency of signals applied to input. For each of the signals applied to the input (current and voltage) circuit is able to detect and save the maximum amount of signal on a defined number of times each of the three phases. Signals using zero crossing detection signal circuit are able to detect the correct sequence of phases and transmit it to subsequent processing.

The calculation of RMS values of input quantities. RMS value of a continuous signal is calculated by the relationship:

$$F_{RMS} = \sqrt{\frac{1}{T}\int_0^T f^2(t)dt} \qquad (25)$$

For signals sampled in time, the calculation involves raising squared RMS value of the samples, obtaining their environment and then extracting the square root.

$$F_{RMS} = \sqrt{\frac{1}{N}\sum_{n=1}^{N} f^2(n)} \qquad (26)$$

The method used for calculating the RMS value of signals applied to the ADE 7758 circuit entrance is passed through a low-pass filter (FTJ1, FTJ3) of the square input signal and then extracting the square root of the result.

If $\quad i(t) = \sqrt{2} \times I_{RMS} \sin(\omega t)$

then

$$i^2(t) = I_{RMS}{}^2 - I_{RMS}{}^2 \cos(\omega t) \qquad (27)$$

RMS calculation is done simultaneously for all six input channels. Each result is saved in registry AIRMS, respectively AVRMS the current tension on phase 1, BIRMS, respectively BIRMS the current tension on phase 2, CIRMS, CVRMS for current voltage on phase 3 respectively. The circuit has the possibility to compensate the offset error for each of these values by the values contained in registers AIRMSOS, AVRMSOS for phase 1, BIRMSOS, BVRMSOS for phase 2 and CIRMSOS, CVRMSOS for phase 3.

Calculation of power and active energy. Electrical power is given by the product of the waveform of voltage and current. The resulting waveform is called the instantaneous value of power and is equal to the energy consumed per unit time. The following equations describe the instantaneous power signal expressions in an alternative system [8]:

$$\begin{aligned} u(t) &= \sqrt{2} \times U_{RMS} \times \sin(\omega t) \\ i(t) &= \sqrt{2} \times I_{RMS} \sin(\omega t) \end{aligned} \qquad (28)$$

where U_{RMS} is the value of RMS voltage and I_{RMS} is the value of RMS current.

$$\begin{aligned} p(t) &= u(t) \times i(t) = \\ &= I_{RMS} \times U_{RMS} - I_{RMS} \times U_{RMS} \cos(2\omega t) \end{aligned} \qquad (29)$$

power consumed by a number of n cycles is given by the equation:

$$P = \frac{1}{nT}\int_0^{nT} p(t)dt = U_{RMS} \times I_{RMS} \qquad (30)$$

where, t is the time signal and P is defined as active power or real power.

Active power is equal to the DC component of instantaneous active power signal $p(t)$, $U_{\mathrm{RMS}} \times I_{\mathrm{RMS}}$. This is in fact the relationship with the circuit ADE7758 calculates active power for each of the three phases. DC component for each of the three phases is extracted using low-pass filters applied FTJ2 out multiplier CM2. Active power on each of the three phases is acquired in three registers AWATTHR, BWATTHR and CWATTHR. If given that the circuit continuously accumulate registry AWATTHR, BWATTHR and active power CWATTHR samples then will write the relationship:

$$Energy = \int p(t)dt = \lim_{t \to 0} \left\{ \sum_{n=0}^{\infty} p(nT) \times T \right\} \qquad (31)$$

where n is the number of samples and T is the distance between two samples.

Calculation of power and reactive power. The following equations give the instantaneous reactive power expression in alternative systems the current phase is shifted by 90^0.

$$\begin{aligned} u(t) &= \sqrt{2}U \sin(\omega t - \theta), \\ i(t) &= \sqrt{2}I \sin(\omega t), \\ i'(t) &= \sqrt{2}I \sin(\omega t + \frac{\pi}{2}) \end{aligned} \qquad (32)$$

where: U is RMS value of voltage, I is the RMS value of current and θ is the phase shift caused by the reactive elements of the load.

Under these conditions the instantaneous reactive power $q(t)$ is given by the following equation:

$$\begin{aligned} q(t) &= u(t) \times i'(t) \Rightarrow \\ q(t) &= UI\cos(-\theta - \frac{\pi}{2}) - UI\cos(2\omega t - \theta - \frac{\pi}{2}) \end{aligned} \qquad (33)$$

or

$$q(t) = UI\sin(\theta) + UI\sin(2\omega t - \theta) \qquad (34)$$

where i' is the current with phase shifted by 90^0.

The mean reactive power consumed by a number of cycles (n) is given by the following equation:

$$Q = \frac{1}{nT}\int_0^{nT} q(t)dt = U \times I \times \sin(\theta) \qquad (35)$$

where T is the signal period alternately, and Q refers to the average reactive power.

The value of instantaneous reactive power $q(t)$ is generated by multiplier CM4 at which entry applies the signal voltage and current signal offset 900 for each of the stages of entry. DC component of the instantaneous reactive power signal is extracted by low-pass filter to obtain information FTJ4 the average reactive power on each of three phases. Reactive power on each phase is accumulated in some special registers (AVARHR for phase L1, L2 and BVARHR phase CVARHR phase L3). Data from these registers can be used for further processing. Reactive power is defined as the integral of reactive power. Similar to the calculation circuit ADE7758 active energy integral signal carried by accumulating reactive power reactive power signals in some special registers. This accumulation at discrete intervals of values of reactive power is equivalent to the signal integration time. Relationship describes this:

$$\mathrm{Re}\,activeEner\;gy = \int q(t)dt = \lim_{T\to 0}\left\{\sum_{n=0}^{\infty} q(nT)xT\right\} \quad (36)$$

Calculation of power and apparent power. There are two ways to calculate the apparent power. The method uses mathematical product of voltage and current RMS values as shown in the following equation:

$$S = U_{RMS} \times I_{RMS} \quad (37)$$

where S is apparent power.

Vector method uses the square root of sum of squares extraction of active and reactive power:

$$S = \sqrt{P^2 + Q^2} \quad (38)$$

where, S is apparent power, P is active power and Q is reactive power.

If the system is purely sinusoidal two methods give the same result. The circuit (ADE7758) using the first method of calculation. Values for apparent power on each phase are accumulated in registers AVAHR phase L1, L2 and BVAHR phase CVAHR stage L3. Apparent power is defined as the integral of the apparent power. Similar to those shown in the active and reactive power calculation of this integral is the apparent power by accumulating values in special registers. Relationship describes this:

$$AparentEnergy = \int S(t)dt = \lim_{T\to 0}\left\{\sum_{n=0}^{\infty} S(nT)xT\right\} \quad (39)$$

VI. CONNECTING THE SYSTEM FOR MONITORING

The device takes electrical variables. The module is an electronic device with a microcontroller that communicates through a RS485 bus with the computer that controls the system. The device is connected for measuring the currents with current transformers, and the charging voltages are actually the three phases. On the measurement, supplying and also communication sides, the device is optical galvanic isolated or isolated through the transformer. The device has a unique address in the system which is hardware configured with jumper-e when is connected. The addresses are from 0 to 255 for this type of devices [19], [20].

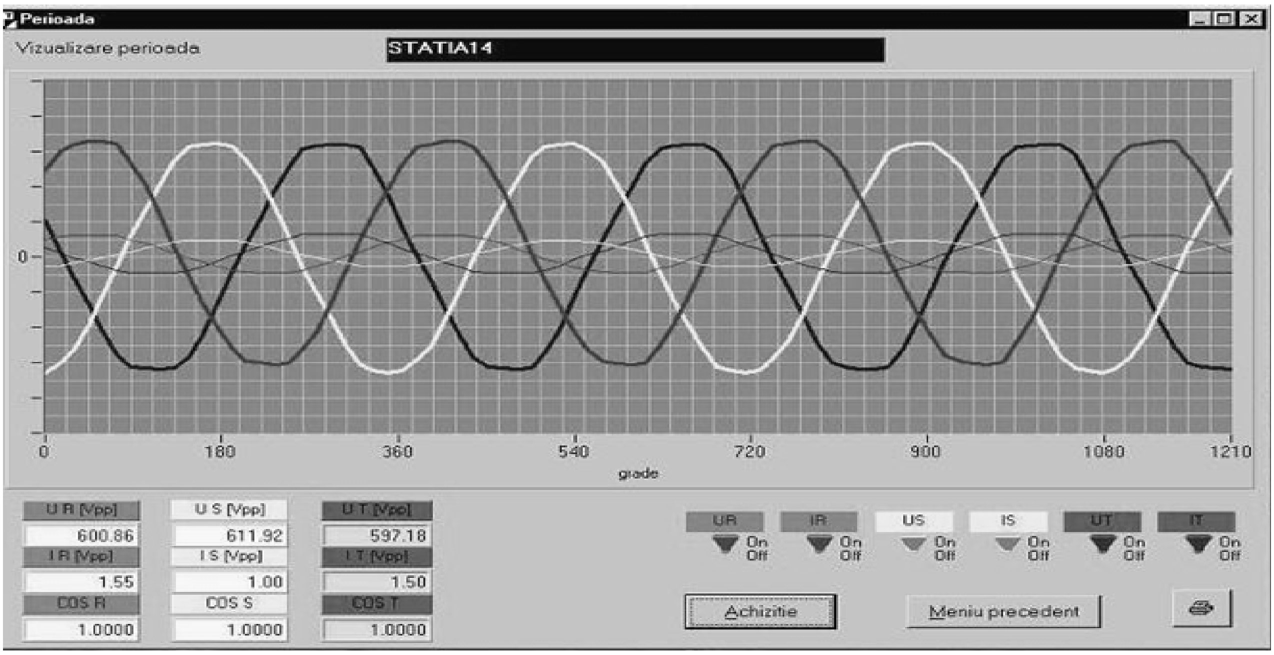

Fig. 7: Interface - records.

Module is the most complex module; it monitors the electricity consumption, power pack and even waveforms which are provided by a network of devices. Each device has a different address and the application interrogates them asking for necessary information. The information which is received by a point of measurement is very well summarized by a screen which represents that point of measurement.

As we can observe, this screen shows momentary values currents, $cos(\varphi)$, powers, voltages for each phase and the daily and monthly values (Fig. 7).

All these values are recorded daily in a file every quarter of an hour or if the system configuration is chosen for all records, then the information from each query of that point are saved. The information stored in a daily report file are: address, name, date and hour, minute, second of the point of measurement; active and reactive power cost of energy for the phases; active and reactive power at that time.

All these quantities are stored for each measurement point and for certain groups of points of measure or the whole system if the application was configured to do so. They will appear in relation to the assigned name of the configuration and virtual addresses that are not found in the domain addresses for points of measurement (for the system is used the 999 address and this may be baptized with the name of the enterprise "Company"). Besides the above measurement it can view the statistical curve for current day and current month. An interesting element is represented by the possibility of viewing waveform of voltage and current.

VII. Conclusion

Since completion of the work to the following conclusions:
- Hydro genitor can operate at rated power factor and rated on a permanent basis, without exceeding the maximum allowable temperature for insulation class of active elements;
- Values of temperatures that reach active elements of the generator at rated load is 107 ºC for winding the stator, stator core 94 ºC to 72 °C for winding and rotor when the cooling air temperature is 40 °C. If the cooling air temperature is lower, temperatures active elements in operation under nominal duration is reduced accordingly;
- electrical parameters and characteristics of the generator have the appropriate values to the values of the technical. The deviations are within acceptable limits;
- hydropower is operating under a nominal yield of 96.87%, a figure close to the value indicated in the technical documentation.

References

[1] Borcosi I, Onisifor O**.,** Popescu M.C., Dincă A., *A Method to Protect from no Pulse for a Three-Phase Rectifier Bridge Connected with the Resistive-Inductive Load,* Proceedings of the 10th WSEAS International Conference on Mathematical and Computational Methods in Science and Engineering (MACMESE'08), pp.146-152, Bucharest, Romania, November 2008.

[2] Borcosi I, Olaru O, Popescu M.C., Antonie N., Dinca A., Ionescu M. *Method to Protect from no Pulse for as Three-Phase Rectifier Bridge,* International Journal of Mathematical Models and Methods in Applied Sciences, pp.473-482, 2008.
Avaible: http://www.naun.org/journals/m3as/mmmas-115.pdf

[3] Borcoşi I., Olaru O., Popescu M.C., Dincă A., Antonie N., Ionescu M., *Device with Analogical Circuits for Protection to the Lack of the Pulse for the Three-Phase Rectifiers in Electrical Drive*, International Journal of Mathematical Models and Methods in Applied Sciences, pp.483-492, Issue 4, Vol.2, 2008.
Avaible: http://www.naun.org/journals/m3as/mmmas-116.pdf

[4] Ilie F., Bulucea C.A., Popescu M.C., *Simulations of Oil-filled Transformer Loss-of-Life Models,* Proceedings of the 11th International Conference on Mathematical Methods and Computational Techniques in Electrical Engineering (MMACTEE'09), Published by WSEAS Press, pp.195-202, Vouliagmeni Beach, Greece, September 28-30, 2009.

[5] Grigoriu M., Popescu M.C., *Hydropower Preventive Monitoring Action Plan*, Proceedings of the 5th IASME/ WSEAS International Conference on Energy&Environment (EE'10), Recent Advances in Energy & Environment, pp.265-270, Cambridge, February 22-25, 2010.

[6] Grigoriu M., Popescu M.C., Popescu L.G., Dinu D.C., Popescu C., *A Wind Farm Balancing Analysis*, Proceedings of the 5th IASME/WSEAS International Conference on Energy & Environment (EE'10), Recent Advances in Energy & Environment, pp.261-264, Cambridge, February 22-25, 2010.

[7] Mastorakis N., Popescu M.C., Bulucea C.A., *Analysis in Time-Frequency Domain of Asynchronous Motors Control with Inverter Switching at Zero Voltage*, Proceedings of the 8th WSEAS International Conference on Education and Educational Technology EDU'09: Advanced Educational Topics and Technologies, pp.126-132, Published by WSEAS Press, Genova, October 2009.

[8] Mastorakis N., Bulucea C.A., Popescu M.C., *Transformer Electromagnetic and Thermal Models*, Proceedings of the 9th WSEAS International Conference on Power Systems (PS`09): Advances in Power Systems, pp.108-117, Budapest, Hungary, September 2009.

[9] Nicola D.A., Bulucea C.A., Cismaru D.C., Brandusa C., Manolea Gh., Popescu M.C., *Energy Saving in Electric Trains with Traction Induction Motors*, Proceedings of the 4th IASME /WSEAS International Conference on Energy & Environment, pp.226-231, Cambridge, February 2009.

[10] Olaru O, Popescu M.C., Balas V. *A Study of Oscillation for Signal Stabilization of Nonlinear System*, Proceedings of the 10th WSEAS Int. Conf. on Automation & Information (ICAI '09), pp.430-437, Prague, 23-25 march 2009. Avaible: http://www.wseas.us/books/2009/prague/ICAI.pdf

[11] Popescu M.C., *Aplicaţii* in informatica, Editura Universitaria Craiova, 2009.

[12] Popescu M.C., *Telecomunicaţii,* Editura Universitaria Craiova, 2008.

[13] Popescu M.C., *Telecomunicaţii*, Tipografia Universităţii din Craiova, 2005.

[14] Popescu M.C., Mastorakis N., Borcosi I., Popescu L., *Asynchronous Motors Drive Systems Command with Digital Signal Processor*, International Journal of Systems Applications, Engineering & Development, Issue 2, Vol.3, pp.64-73, 2009.
Avaible: http://www.universitypress.org.uk/journals/saed/19-170.pdf

[15] Popescu M.C., Mastorakis N., Popescu-Perescu L., *Electromagnetic and Thermal Model Parameters*, International Journal of Energy, Issue 4, Vol.2, pp.51-65, 2008.
Avaible: http://www.naun.org/journals/energy/19-141.pdf

[16] Popescu, M.C., Balas, V.E., Popescu, L. *Heating Monitored and Optimal Control of Electric Drives,* 3rd International Workshop on Soft Computing Applications, Proceedings IEEE Catalog Number CFP0928D-PRT, Library of Congres 2009907136, pp.149-155, Szeged-Hungary-Arad-Romania, July -August 2009.

[17] Popescu, M.C., Balas, V.E., Popescu, L., *System Decentralized for Tracking Control and Data Acquisition Using*, 3rd International Workshop on Soft Computing Applications, Proceedings IEEE Catalog Number CFP0928D-PRT, Library of Congres 2009907136, pp.155-161, Szeged-Hungary-Arad-Romania, July -August 2009.

[18] Popescu M.C., Mastorakis N., T*he behaviour of a thermal unit*, Proceedings of the 3 rd International Conference on Circuits, Systems and Signals (CSS'09), pp.232-240, NAUN International Conferences, Vouliagmeni, Athens, Greece, December 29-31, 2009.

[19] Popescu, M.C., Balas, M.M., *Thermal Consumptions: Control and Monitoring*, 3rd International Workshop on Soft Computing Applications, Proceedings IEEE Catalog Number CFP0928D-PRT, Library of Congress 2009907136, pp.85-91, Szeged-Hungary-Arad-Romania, July - August 2009.

[20] Stoenescu E., Popescu M.C., Bulucea C.A., *Assessment of Improved Transformer Thermal Models,* Proceedings of the Applied Computing Conference (ACC'09), Published by WSEAS Press, pp.189-195, Vouliagmeni Beach, Greece, September 2009.