JERZY WIELAND, Assist.Prof.,D.Sc.,E.E.
Gdynia Maritime Academy

# Electric power measurements for integrated ship automation systems

SUMMARY

*Two versions of a hallotron electric power meter elaborated in view of application in the integrated ship automation systems, are presented. The meter can be combined with the actually used or offered programmable controllers which are of a high importance for marine applications. The presented meter which has already passed preliminary tests can be used to measure active, reactive and apparent power. The produced electric energy can be monitored by means of S5-100U programmable controller.*

*The applied concept which makes it possible to perform the measurements by using the single meter is protected by Polish patent (No.116369).*

## INTRODUCTION

The modern seagoing ships are more and more often equipped with integrated automation systems to ascertain their safety, reliability and economic operation [9]. In the systems not only the already known automatic and electric measurement equipment is used but also new, especially elaborated devices are installed. A switchable hallotron meter of three different kinds of electric power (active, reactive and apparent), presented in the paper, is an example of such solutions.

The meter combined with modern, electric generator control systems makes it possible to improve the economic effectiveness of electric power production [12].

The paper summarizes results of many earlier works performed by Gdynia Maritime Academy in the area of modern control and electronization applicable also to measurement problems inclusive of light-pipe technique application to transmission of measurement results (see Bibliography).

The presented meter was designed by combining different electronic units, integrated and discrete ones. ICL-71-07 units, semiconductor rectifying diodes as well as LED diodes and a programmable controller were applied in the device. Operation of the meter can be controlled by hand with the use of BCD code decoder with membrane buttons or automatically controlled by means of S5-100U programmable controller [8]. In the paper two versions of the meter are described :

- the first, earlier version based on the principle of three measuring devices
- second version which utilizes two devices of Aron's configuration.

The presented solution of the meter for measuring the electric power of three kinds by means of one and the same device is connected with the earlier patent [5] as well as research works [6,7,9,11].

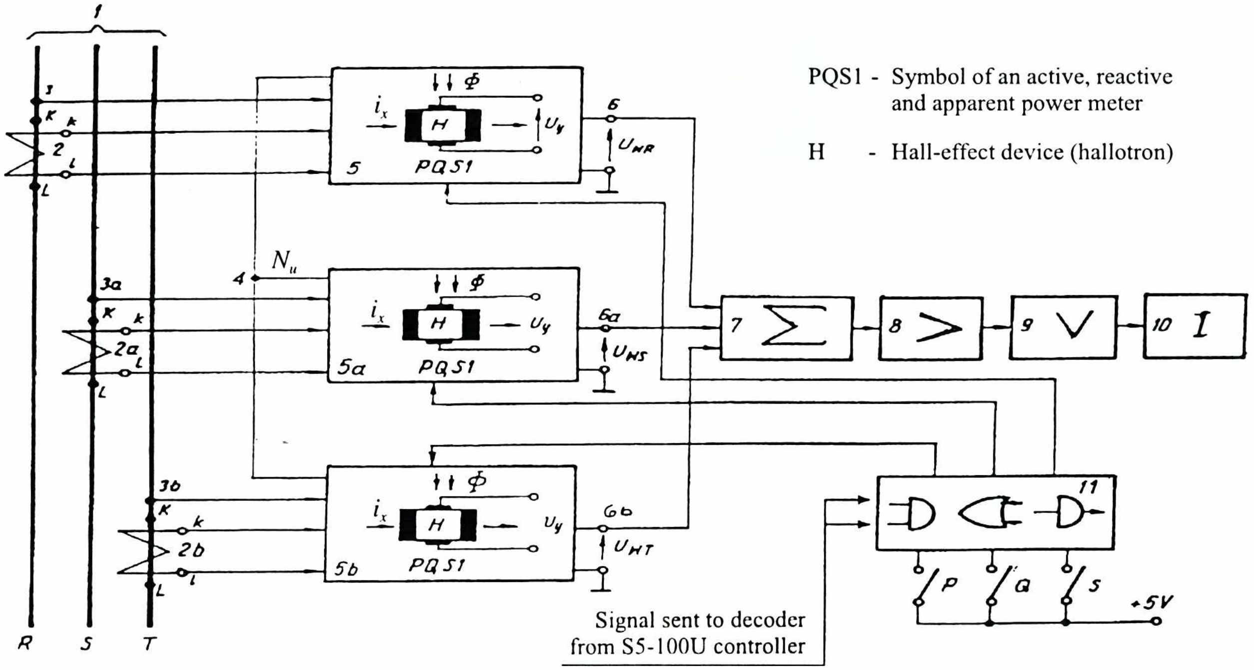
## THE FIRST VERSION OF THE ELECTRIC POWER METER

A preliminary working scheme of the first version of the electric power meter which was completed and passed laboratory tests is shown in Fig.1. The applied principle of „ three wattmeters „ makes it possible to correctly perform measurements in three-phase circuits without accounting for symmetry or assymetry of electric magnitudes in the circuits.

The numbers used in the figure stand for :

1 - Three-phase alternate current network
2 - Current measuring transformers
3 - Voltage supply points for measuring systems
4 - So-called „artifical electric zero"
5 - One-phase power measuring systems in the form of hallotron transducers
6 - Terminals of voltage output signals
7 - Integrated operation amplifier for summing the output signals
8 - Basic amplifier of a high voltage stability
9 - Digital end signal meter
10 - LED diode display
11 - BCD code decoder realizing an appropriate connection within the meter, dependent on a kind of power to be measured (active, reactive, apparent).

The digital display is scaled in watts, wars or VAs dependent upon the kind of connection controlled by the decoder.

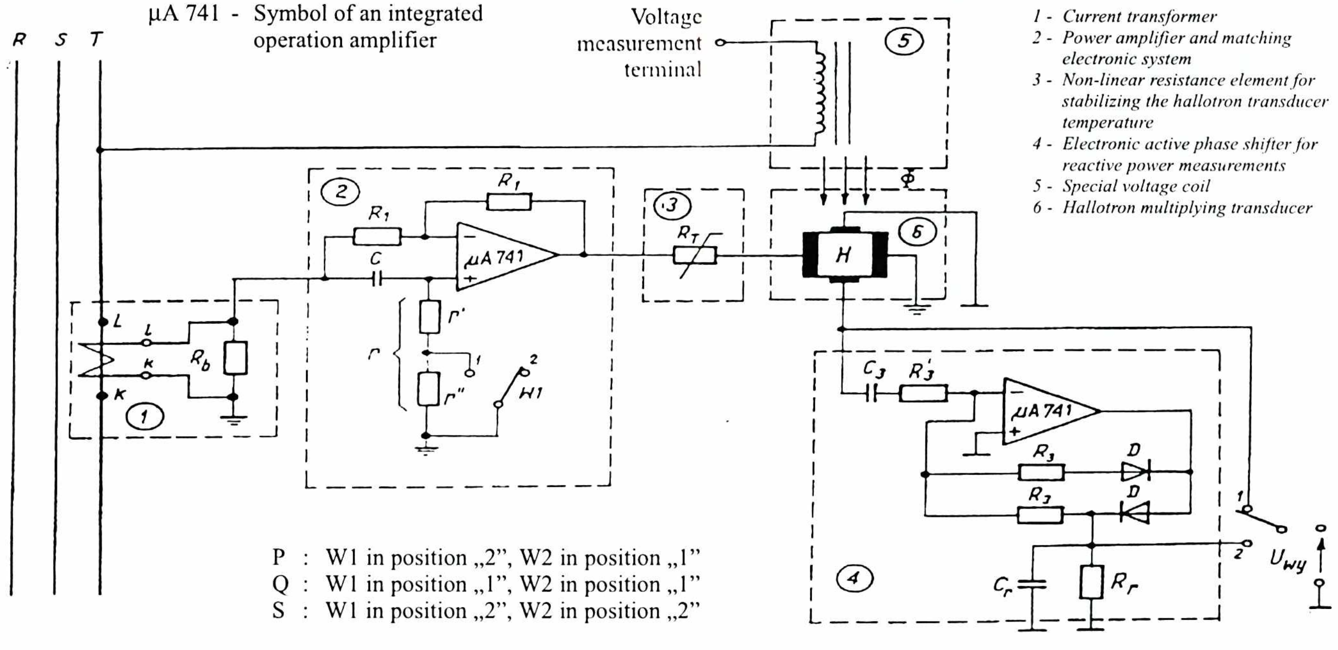


PQS1 - Symbol of an active, reactive and apparent power meter

H - Hall-effect device (hallotron)

Signal sent to decoder from S5-100U controller

*Fig.1. The first version of the electronized, hallotron electric power meter*



μA 741 - Symbol of an integrated operation amplifier

1 - *Current transformer*
2 - *Power amplifier and matching electronic system*
3 - *Non-linear resistance element for stabilizing the hallotron transducer temperature*
4 - *Electronic active phase shifter for reactive power measurements*
5 - *Special voltage coil*
6 - *Hallotron multiplying transducer*

P : W1 in position „2", W2 in position „1"
Q : W1 in position „1", W2 in position „1"
S : W1 in position „2", W2 in position „2"

*Fig.2. Scheme of the basic unit of one-phase, hallotron electric power meter*

A scheme of the basic unit of one-phase hallotron electric power meter is shown in Fig.2.

Switching the unit to measure a selected kind of power is effected by changing some parts of measuring circuits. The same idea was applied to the second version of the meter. To measure the active power the switches „W" should be set into the states indicated in Fig.2. The phase shifter is then switched off and two signals act onto the hallotron. The first one comes from the current transformer and through the transformer's amplifier feeds the hallotron. The second signal is the alternate magnetic induction B which appears in the gap where the hallotron is placed. The induction is connected with the flux Φ generated by voltage action of an appropriate coil. The multiplying performance of the hallotron triggers the voltage signal of the constant component proportional to the measured active power.

Measuring the reactive power is performed in the similar way, however in this case the phase shifter in the hallotron supply circuit is activated due to changing the circuit connections. Different connections of the supplementary circuits are realized during apparent power measurements.

As far as the active power measuring is concerned, the current $i_x$ which flows through the hallotron, can be expressed in function of the current $I_{max}$ of the network in question as follows [6] :

$$i_x = K_i I_{max} \sin(\omega t + \varphi) \qquad (1)$$

An instantaneous value of the magnetic induction B results from the voltage $U_{max}$ in the network in compliance with the following relationship :

$$B = K_u U_{max} \sin \omega t \qquad (2)$$

Product of the instantaneous values brings about the Hall voltage instantaneous value $u_{yH}$:

$$u_{yH} = \frac{1}{2} K I_{max} U_{max} [\cos \varphi - \cos(2\omega t + \varphi)] \qquad (3)$$

where : $K = K_i K_u$ .

The Hall voltage constant component $U_y$ is obtained by means of integration of (3) within one period time limits. Simultaneously amplitudes of the current $I_{max}$ are substituted by appropriate values of I and U.

$$U_y = K \cdot I \cdot U \cos \varphi = K \cdot P \qquad (4)$$

The current which flows through the hallotron, due to switching W1 to the first position, is additionally shifted by 90° in result of operation of the phase shifter which consists of the operation amplifier and RC unit. In that case, by making the substitution similar to that above mentioned, the following is obtained :

$$U_y = K \cdot I \cdot U \sin \varphi = K \cdot Q \qquad (5)$$

The correct phase shift value of 90° can be set by choosing an appropriate element of RC unit.

The output voltage values $U_{yi}$ from the particular measurement instruments can be described as follows [6,7,8] :

$$U_{y1} = aU_{Ro} I_R \cos \varphi \qquad (6)$$

$$U_{y2} = aU_{So} I_S \cos \varphi \qquad (7)$$

$$U_{y3} = aU_{To} I_T \cos \varphi \qquad (8)$$

where: a - an appropriate constant.

The meter must be equipped with an operation amplifier enable to sum the output voltages from the particular one-phase systems, as $P = P_R + P_S + P_T$ . Therefore :

$$U_{y\Sigma} = U_{y1} + U_{y2} + U_{y3} = a(P_R + P_S + P_T) = aP_\Sigma \qquad (9)$$

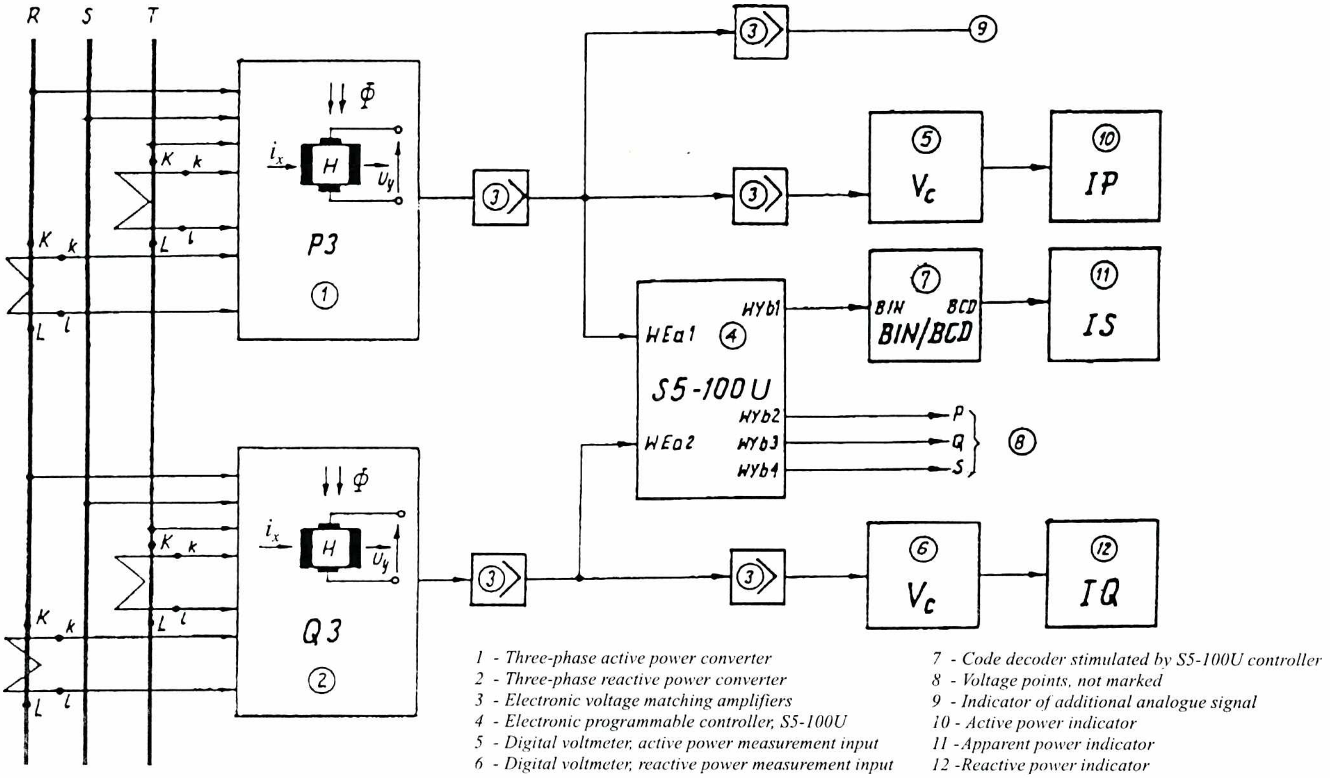
The total voltage $U_{y\Sigma}$ is supplied to a high-stable voltage amplifier whose constant value must be accounted for at scaling the digital meter. The digital display will then indicate a measured electric power value correctly. A kind of power to be measured is selected by means of BCD decoder [2,5,6,7,8]. Activating the magnetic induction B in the hallotron systems is connected with emitting Joule's losses, compensation of which is hardly obtainable as it was confirmed by results of [6,7]. Good results were achieved in result of application of an operation amplifier behind the summing amplifier [8].

The tested prototype of the meter in question revealed some disadvantages. At first three hallotron units of the same parameters are required. The temperature compensation of the units is difficult. Moreover the design solution is expensive as three hallotron units and three current transformers are required.

## SECOND VERSION OF THE ELECTRIC POWER METER

Second version of the meter demonstrated in Fig.3, consists of two measurement units and operates in compliance with Aron principle. A model of the design solution was completed and passed preliminary tests.

Output signals from the applied hallotron units are supplied to the matching amplifiers which compensate influence of input circuits. The signals are sent also to the electronic programmable controller. Moreover the output signals are supplied in parallel to the digital voltmeters which measure the kind of electric power selected by means of BCD code decoder. Measurement results are transferred to the display and eventually to the printer. Application of the programmable controller makes it possible to better utilize the integrated ship automation concept [9]. It was confirmed by results of the first operation period of the LANGUSTA, fishing trawler.



*1 - Three-phase active power converter*
*2 - Three-phase reactive power converter*
*3 - Electronic voltage matching amplifiers*
*4 - Electronic programmable controller, S5-100U*
*5 - Digital voltmeter, active power measurement input*
*6 - Digital voltmeter, reactive power measurement input*
*7 - Code decoder stimulated by S5-100U controller*
*8 - Voltage points, not marked*
*9 - Indicator of additional analogue signal*
*10 - Active power indicator*
*11 - Apparent power indicator*
*12 - Reactive power indicator*

*Fig.3. Scheme of the second version of the electronized, hallotron electric power meter*

The proposed, electric power measurement method is based on results of the research works [6,7] from which it yields that :

$$P_\Sigma = U_{RS} I_R \cos\alpha_R + U_{TS} I_T \cos\alpha_T \qquad (10)$$

$$P_\Sigma = U_{ST} I_S \cos\beta_S + U_{RT} I_R \cos\beta_R \qquad (11)$$

$$P_\Sigma = U_{TR} I_T \cos\gamma_T + U_{SR} I_S \cos\gamma_S \qquad (12)$$

The meter can be connected to a tested network in accordance with any of the above given expressions. The following relationship can be defined by applying the constants $K_i$ and $K_u$ which reflect functioning the current transformers and voltage coils generating the induction applied to the hallotron :

$$U_{yhR} + U_{yhT} = K_i K_u (U_{RS} I_R \cos\alpha_R + U_{TS} I_T \cos\alpha_T) \qquad (13)$$

or otherwise :

$$\Sigma_{Uyh} = K_i K_u P_\Sigma \qquad (14)$$

Detail information on the design solutions applied to the meter can be found in [6,7,8,12].

## SUPPLEMENTARY SUB - SYSTEMS OF THE HALLOTRON POWER METER

Application of the additional sub-systems arises from that the meter has to measure not only the active power but also the reactive and apparent ones. The main of the sub-systems is the phase shifter based on µA 741 integrated operation amplifier with RC unit [12,9]. The exact phase shift by 90° can be obtained by regulating the resistor $R_3$ of the RC unit. The shifter is active because decrements on the passive elements of the RC unit are compensated by the µA 741 operation amplifier. Thus the signal from the hallotron, supplied to the amplifier terminal, is lossless-shifted.

### Electronic switch of kind power

The unit consists of the operation control switches which perform switching the input signals in the BCD code decoder, and gate elements. JK integrated triggers are used in the switches, realized with the use of 7402 integrated circuits. The switches are described in detail in [8,12].

### Rectifying unit with the alternate component filter

The unit is presented in Fig.2 as „block 4". It consists of the rectifying diodes and passive elements inclusive of the operation amplifier. Principles of its design and operation are given in [1,5]. The unit is used for measuring the apparent power [1,2,8,12]. The current from the hallotron unit 6, when the circuit is switched by setting the switch W2 into position 2, flows through the rectifying circuit consisting of the diodes D, filter $C_3$ and resistance $R_3$, and next through the µA 741 operation amplifier.

### Digital voltmeter

The digital voltmeter which indicates an actual value of the measured power, is designed on the basis of ICL-71-07 INTERSIL integrated block. More details of it can be found in [8,12].

Its scheme is demonstrated in Fig.4., and the outputs which control the displays are shown in Fig.5.

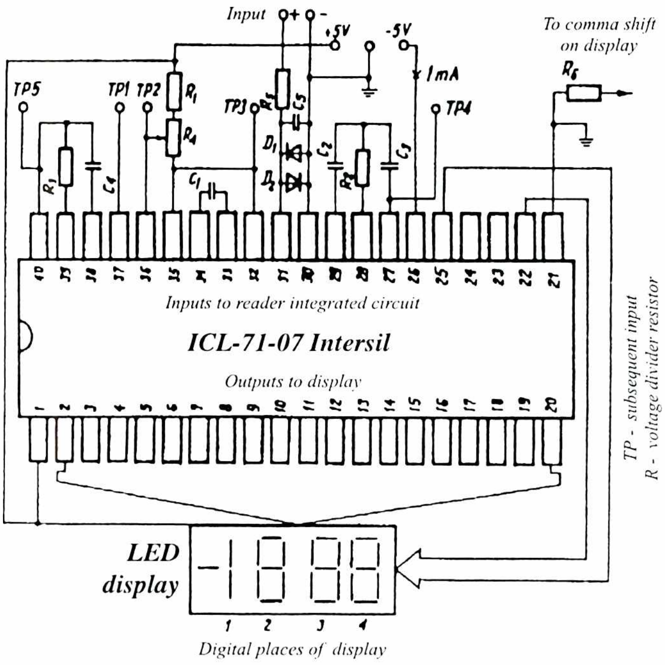


***Fig.4.*** *Scheme of the digital voltmeter of the electric power meter based on ICL-71-07 integrated unit*

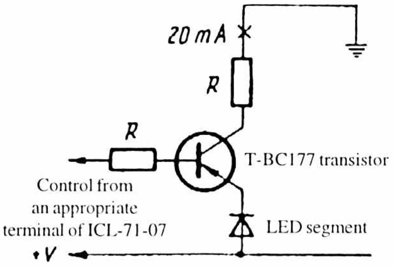


***Fig.5.*** *Scheme of LED diode control of the digital display (common anode system)*

Its measurement range is contained between 0 and 1.999 V, input current is normally of 1 pA order, but in an unfavourable case it may reach even 10 pA. The permissible ambient temperature range is from 0 to 70°C, thus it complies with the standard environmental conditions for ship power plants. The voltmeter output signal is sent to the display or also to the measurement record printer (in dependence on programator's setting). The allowable measurement frequency is 3 per second. The integrated circuit of the voltmeter comprises also an analog-to-digital converter (of dual slope) made in MOS.LSI technique. More details can be found in [8]. The generally available, integrated and discrete elements were used to its realization.

### Electronic programmable controller

In Fig.6. a central control system is demonstrated, for all important operations connected with sea-going ship's exploitation. The presented electronic power meter provides measurement information to the main station of steering, supervision and control of continuous processes. Programs to be introduced to S5-100U controller can be written in AWL, FUP, KOP machine languages or in accordance with [10]. The controller realizes AND/OR functions, information storage, counting, timing, storing, transferring, summing and substracting, as well as the functions which are contained in the programs stored in its memory.

Main particulars of the controller are as follows : RAM EPROM memory of a capacity up to 20 x $2^{10}$ bites, rate of 1.6 ms/100 binary instructions.

The maximum number of digital inputs and outputs is 256, and the analogue ones - 32. Besides the controller is of 2048 markers, 128 time settings and 128 counters.

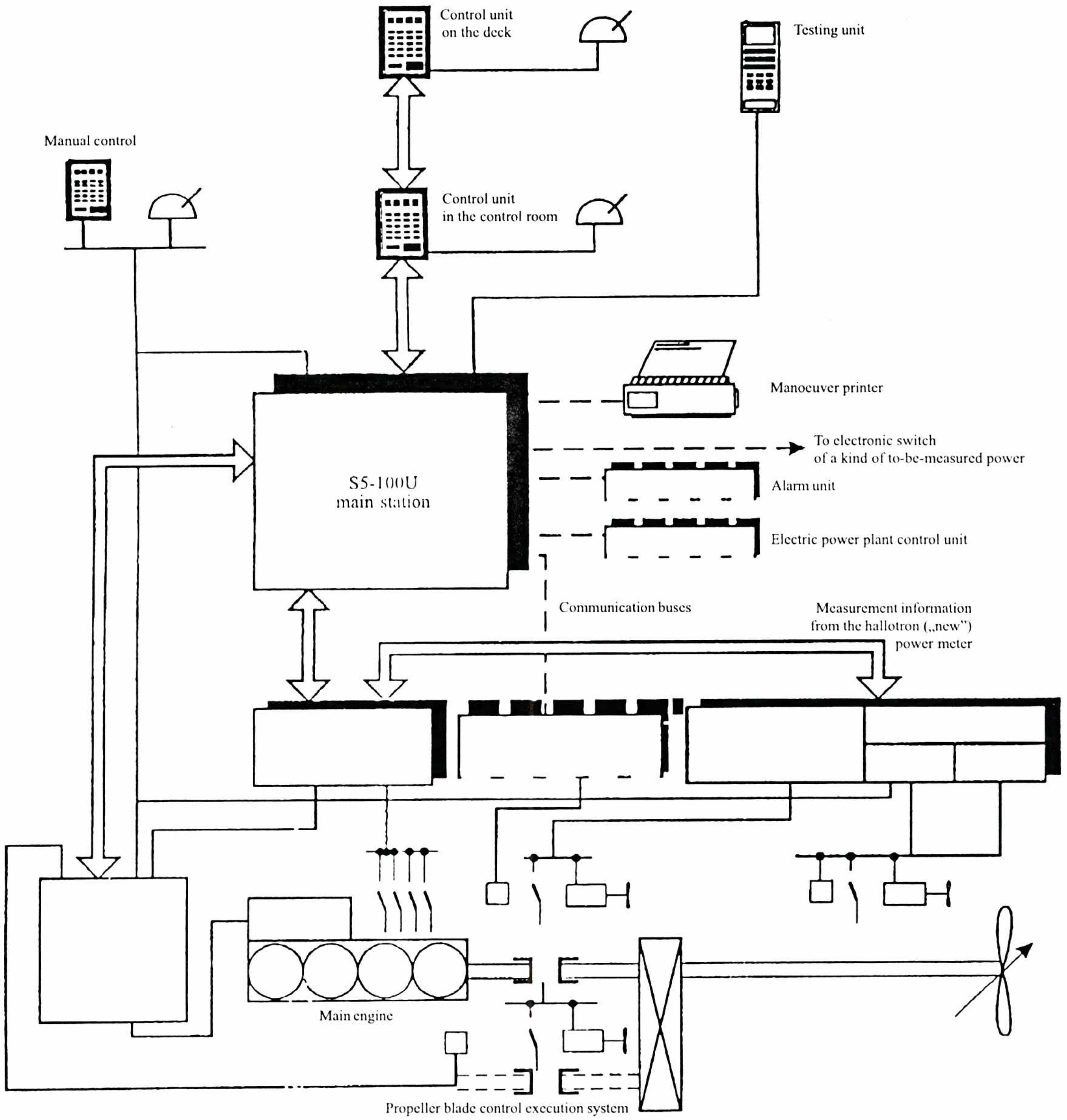


*Fig.6. An example of common scheme of electric power measurement and ship electric power plant control with application of the integrated automation system*

## SENSITIVITY AND ERRORS OF THE HALLOTRON POWER METERS

Specific questions of measuring the electric power in ship installations are described in [6,7].

The basic factor which influences quality of the meter is the hallotron itself whose efficency usually is not greater than 1%. The efficiency can be best utilized by applying the integrated technique (especially LSI technique), and in result, the obtained characteristics are comparable with those of conventional devices.

### Sensitivity

The following magnitude is usually assumed to be the numerical measure of hallotron wattmeter sensitivity :

$$K_S = \frac{U_{yH}}{UI\cos\varphi} = \frac{U_{yH}}{P} \qquad (15)$$

The current which flows through hallotron is a part of that received from the current transformer, therefore it can be expressed in respect to the current I in the investigated circuit, as follows :

$$i_x = K_i I \qquad (16)$$

The line-to-line voltage of the investigated circuit, at constant value of ship network frequency, is connected with the magnetic induction B which affects the hallotron, in accordance with the following relationship :

$$B = K_u U \qquad (17)$$

The following relationship can be written if the symbol „y" is assigned to the phase shift between the current I' and induction B :

$$U_{yH} = \frac{R_H}{d} i_x \cdot B\cos\psi \qquad (18)$$

By substituting the relationships (16), (17) and (18) to the definition (15) the expression (19) is obtained :

$$K_S = \frac{R_H}{d} K_i K_u \frac{\cos\psi}{\cos\varphi} \qquad (19)$$

where:

$R_H$ - Hall constant
d - plate thickness

It is necessary to elaborate the hallotron system which fulfils the equation: cosψ = cosφ. It can be obtained if the currents $i_x$ and I are in phase as well as the induction B complies in phase with the voltage U. However special solutions are required in designing the magnetic core and magnetizing coil. Application of the hallotron output signal amplifier provides an important sensivity correction.

The current constant $K_i$ results from application of the typical current transformers of the nominal secondary current equal to 5 A or 1 A. The values are too high for the usual hallotrons therefore distribution of the secondary current is applied by means of the shunt of the resistance $R_{fb}$.

The current extension coefficient $K_i$ is defined as follows :

$$K_i = \frac{R_{fb}}{R_{fb} - \rho h} \tag{20}$$

where :

ρh - hallotron resistance at current terminal.

The coefficient $K_i$ can be corrected by increasing the shunt resistance. However care should be taken not to exceed the permissible value which is limited by the nominal power of selected transformer. The difficulty can be overcome by applying an additional unit which transforms the secondary current of the transformer. Such solution will be applied to a new version of the meter.

## Basic errors

Basic errors mainly result from the properties of the applied multiplying element, i.e. of the hallotron. First of all the non-linearity error of voltage output should be specified in relation to the control current $I_x$ at the unchanged induction B generated by the voltage applied to the magnetizing coil.

It can be expressed as follows :

$$U_{yH} = f_1(i_x) \quad at \quad U = const \tag{21}$$

The next source of non-linearity is an influence of the pulsation ω of the voltage which generates the induction B at the unchanged control current $i_x$ of the hallotron, which can be written as follows :

$$U_{yH} = f_2(\omega) \quad at \quad i_x = const \tag{22}$$

Each of the non-linearities leads to the non-linearity of measurement characteristics of the hallotron, i.e, the element which reacts to the investigated active power P; it can be expressed as follows :

$$U_{yH} = f(P) \tag{23}$$

The factors change the sensitivity $K_S$, that leads to an error of the measured power value P.

Seperate factors affecting the real sensitivity (thus also the errors) are: the hallotron resistance in the magnetic field and Joule heat resulted from the control current as well as also shape, size and location of the hallotron within the gap of the ferromagnetic core. Some of the problems are highlighted in [6,7,11].

Electronic units affect not only sensitivity but also accuracy of the meter. The operation amplifiers, active phase shifter and rectifier-filter block should be taken into consideration. However more detail discussion of errors caused by electronic units is outside the scope of the paper.

Sensitivity of the meter can be described by the following relationship [9] :

$$K_S = K_u \frac{R_H(20)(1+\alpha_\beta \Delta T)(1+\alpha_{\rho h}\Delta T)}{R_{fb}(20)(1+\alpha_{RK}\Delta T)} \tag{24}$$

where :

$K_S$ - sensitivity of the meter
$K_u$ - voltage constant
$R_H(20)$ - Hall constant at 20°C
$R_{fb}(20)$ - shunt resistance at 20°C
$\Delta T$ - temperature increment of the nominal value, assumed during designing and scaling
$\alpha_\beta$ - resistance temperature coefficient
$\alpha_{\rho h}$ - temperature coefficient of the hallotron resistance $\rho_h$
$\alpha_{RK}$ - temperature coefficient of meter resistance

The following expression for the temperature error $\delta_T$ yields from the above given relationship :

$$\delta_T = \frac{K_S(T) - K_S(20)}{K_S(20)} = \frac{(1+\alpha_{Rf}\Delta T)(1+\alpha_{\rho h}\Delta T)}{1+\alpha_{\rho h}\Delta T} - 1 \tag{25}$$

ρh - hallotron resistance characterized by the temperature coefficient $\alpha_{\rho h}$. The shunt temperature coefficient is determined as the average from two relevant measurements.

Influence of the frequency transient changes should be also accounted for during measurements in the ship network. The influence does not exceed 1.9% [7].

Voltage assymmetry may cause another measurement error as follows:

$$\delta_T = arc\ tg \frac{N}{\sqrt{3}} \tag{26}$$

where:

N - voltage assymmetry degree; N ≅ 0.8% results from the measurements [7].

The value of the average temperature coefficient of the current shunt system can be determined from:

$$\bar{\alpha}_{Rf} = \frac{1}{2}(\alpha'_{Rf} + \alpha''_{Rf}) \tag{27}$$

One value of the temperature coefficients is calculated from the lowest temperature increment Δt (e.g -29°C), the other from the highest increment (e.g. +20°C), at constant reference temperature.

The value of the coefficient $\alpha_{Rf}$ is determined from the relationship (28) :

$$\alpha_{Rf} = \frac{1}{\Delta T} \cdot \frac{1+\alpha_{\rho h}\Delta T}{1-\alpha_\beta \Delta T} \tag{28}$$

Thermal compensation is designed on the basis of the value obtained from (27).

## FINAL REMARKS

- The presented meter is suitable for continuous measurements of active, reactive and apparent power in ship electric networks. Controlling the electric energy production can be executed by including the meter into the control loop which is shown in Fig.7. Second version of the meter shown in Fig.3 co-operates with S5-100U programmable controller, which is presented in Fig.6. The electronic programmable controller can co-operate also with the first version of the meter, however this has not been tested yet.

- The presented meter is applicable also for the land-based electric networks. In the case of a seperated network it can co-operate with an appropriate programmable controller.

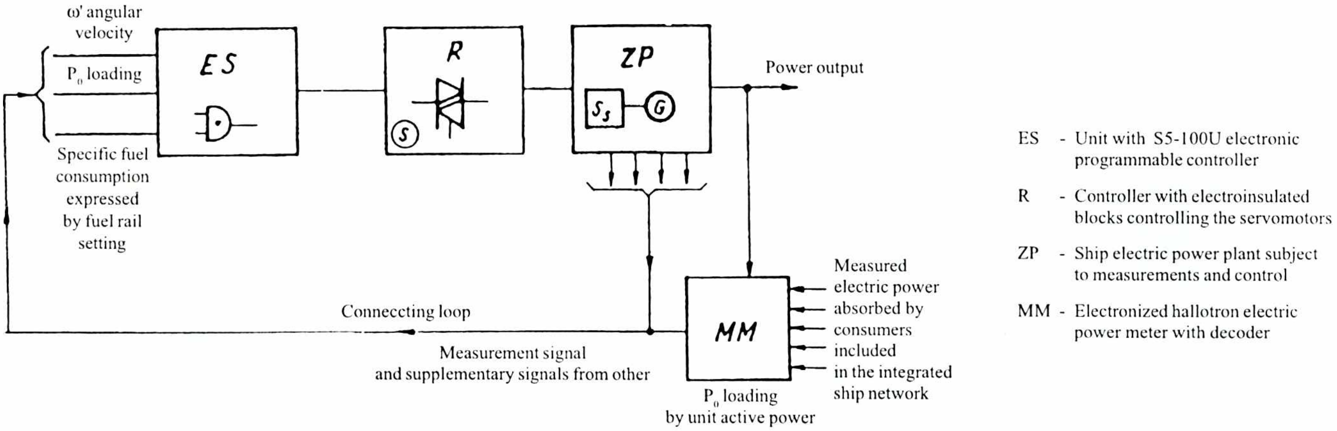


***Fig. 7.*** *Block diagram of two-parameter control system of electric power produced by ship electric power plant, with the hallotron power meter and controller*

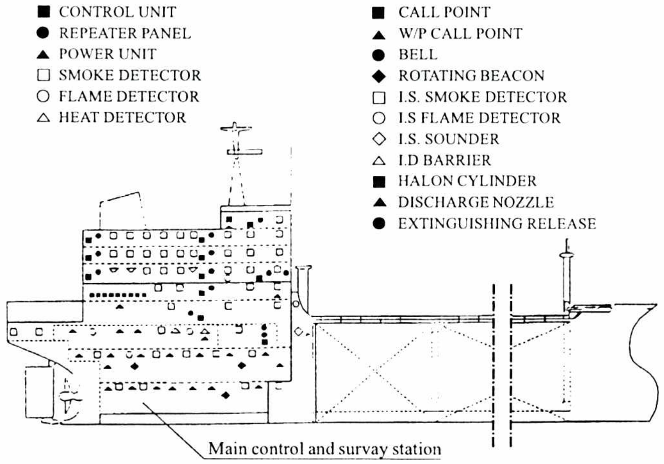


***Fig. 8.*** *Layout of telemetric fire-alarm transducers and measurement points of temperature and other physical parameters, applied to a computerized, integrated ship automation system based on light-pipe technique*

- Works on a more thorough error analysis of the elaborated versions of the meter are continued and provided premises for further development of the designs. The works are aimed at perfecting the meter as to make it suitable also for deformation power measurements.

- The problems are even more important in view of the application of light-pipe telemetric control networks for ships, which include all physical magnitudes of importance for ship operation and safety. A layout of such system is exemplified in Fig.8 [12,14].

## NOMENCLATURE

d - plate thickness
$i_x$ - hallotron current
k - output current terminal
l - output current terminal
r - voltage divider ( r', r" - its components)
t - time
$u_{yH}$ - instantaneous value of Hall voltage
B - alternate magnetic induction
C - separating condenser
$C_r$ - shifter condenser
$C_3$ - filter unit separating condenser
D - diode
I - current in an investigated circuitry
$I_{max}$ - peak current value in an investigated circuitry
K - main circuitry current terminal
$K_i$ - current constant
$K_S$ - sensivity of hallotron wattmeter (as digital meter)
$K_u$ - voltage constant
L - main circuitry current terminal
N - degree of voltage assymetry
$N_u$ - voltage terminal
P - active power
Q - reactive power
$R_h$ - current transformer shunt
$R_{fh}$ - shunt resistance
$R_H$ - Hall constant
$R_r$ - shifter resistor
$R_T$ - controllable termistor
$R_1$ - operating amplifier resistor
$R_3$ - resistor
$R_3$ - current limiting resistor
S - apparent power
T - temperature
U - line-to-line voltage of an investigated circuitry
$U_{max}$ - peak voltage value in an investigated circuitry
$U_{RO}$, $U_{SO}$, $U_{TO}$ - phase voltages
$U_w$ - phase-to-phase voltage
$U_{wy}$ - switch-set voltage
$U_y$ - output voltage of meter
$U_{yH}$ - output Hall voltage
W - switch
$\alpha_{Rf}$ - temperature coefficient of shunt resistance
$\bar{\alpha}_{Rf}$ - mean value of shunt resistance temperature coefficient
$\alpha_{RK}$ - temperature coefficient of meter resistance
$\alpha_{\beta}$ - resistance temperature coefficient
$\alpha_{\rho h}$ - temperature coefficient of hallotron resistance
$\rho_h$ - hallotron resistance
$\varphi$ - phase shift angle
$\omega$ - pulsation
$\Phi$ - magnetic flux
$\Psi$ - phase shift angle between the current $i_x$ an induction B

## BIBLIOGRAPHY

1. Wieland J.: „Hallotronowy miernik mocy pozornej z prostownikiem szczytowym". Przegląd Elektrotechniczny. Warszawa, 1974, nr 1
2. Wieland J., Markowski E.: „Podstawy teoretyczne pomiaru mocy pozornej ustrojem elektrodynamicznym". Archiwum Elektrotechniki. Warszawa, 1972, zeszyt nr 4
3. Sawicki J., Wieland J.: „Sposób pomiaru mocy i energii biernej oraz urządzenie do stosowania tego sposobu". Patent PRL nr 63530. Warszawa, 1971
4. Sawicki J., Wieland J.: „Przetwornik mocy pozornej na wartość prądu stałego". Patent PRL nr 54184. Warszawa, 1974
5. Wieland J., Bartosinski E.: „Układ do pomiaru mocy czynnej, biernej i pozornej". Patent PRL nr 116369. Warszawa, 1983
6. Wieland J., Bohdanowicz J.: „Pomiary mocy w sieciach okrętowych". Biblioteka Elektryka Okrętowego WSM Gdynia, 1978, zeszyt nr 5
7. Wieland J., Bohdanowicz J.: „Analiza czułości i uchybów pomiaru mocy w sieciach okrętowych z zastosowaniem przetworników hallotronowych". Biblioteka Elektryka Okrętowego WSM Gdynia, 1974, zeszyt nr 2
8. Nawrocki J., Sułek R.: „Pomiary mocy elektrycznych w aspekcie zintegrowanej automatyki okrętowej z propozycją nowego miernika". Praca magisterska pod kierunkiem J. Wielanda. WSM Gdynia, 1992
9. Wieland J., Kiwit L.: „Niektóre aktualne systemy zintegrowanej automatyki okrętowej". Budownictwo Okrętowe i Gospodarka Morska. Gdańsk, 1992, nr 1
10. Wieland J.: „Propozycje elektronicznych sterowników programowalnych dla okrętownictwa". (to be published in Budownictwo Okrętowe i Gospodarka Morska)
11. Zawicki J.: „Hallotronowy przetwornik mocy prądu przemiennego o wysokiej czułości". Pomiary - Automatyka - Kontrola. Warszawa, 1973, nr 8
12. Krzeszczyk W.: „Elektroniczny sterownik programowalny w rozwiązaniach metrologicznych z uwzględnieniem ochrony przeciwpożarowej statków morskich". Praca magisterska pod kierunkiem J. Wielanda. WSM Gdynia, 1993
13. Gąszczak J., Wieland J.:„ Nowe rozwiązania w pomiarach mocy elektrycznych z uwzględnieniem sieci okrętowych". XI Konferencja „Przetwarzanie i przesylanie energii i informacji". Poznań, 18÷19.05.1995
14. Wieland J., Bachta M., Burzyński A.: „Światłowody w okrętownictwie". Budownictwo Okrętowe i Gospodarka Morska. Gdańsk, 1996, nr 11

***Appraised by Jerzy Sawicki, Prof.,D.Sc.,E.E.***