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OPERATION PARAMETER MONITORING AS A CONDITION TO CONTROLLING THE OPERATION OF THE MAIN POWER SYSTEM

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Abstrakt

This paper shows possibilities and effectiveness of application of a monitoring system to control an automatic regulation system and the main power system of a chosen ship. It presents an analysis of operation states where unstable operation of the shaft takes place and there are black-outs of shaft current generators from the ship power system due to faults. It has been indicated that the possibility to follow the changes of operation parameter values and their characteristics enables a current evaluation of power processes on-line, and in such a case installation of sophisticated diagnostic systems is not vital. An example of an operational decision taken on the basis of the presented control system has been presented.

Keywords: *monitoring, main power system, diesel engine, controlling, operation parameters*

1. Introduction

Destination of a ship power system is to transform energy supplied in the fuel into mechanical operation indispensable to make the vessel sail at a defined speed and to provide electricity and heat for technological and social purposes. A ship is an independent unit which cannot be backed-up during operation by external services. Therefore, the problem of correct functioning of the elements of the main power system at voyage is very important.

Contemporary ship power systems are equipped in control-monitoring systems which transform the measured physical values of the power system into electrical signals. It helps with the transformation of signals whose coupling with automatic regulation system and control processes is monitored for the diagnostics purposes.

This paper justifies the need to monitor operation parameters of the main power system in operational states manifesting non-designed operation of its element such as significant change of rotational speed of the propeller, and black-outs of the shaft current generator, in order to find their sources [6].

2. The structure of the system monitoring operational parameters of the ship main power system

Fulfilling the requirements of the automation class, a ship power system is customized to cooperate with the system monitoring operation parameters. Thus the system becomes a basic source of information for functional diagnosing and controlling the operation of the ship main power system [3, 5]

One of such tools is a system for remote control automatic regulation of the main engine, ABB-Remote Control System – ABB Marine Rotterdam, which together with a subsystem to monitor operational parameters, NORIS – German, and a system to control the operation of propeller and the FAMP III engine are installed on the container ship [1, 4]. It is an open system prepared to serve a one- or multi-engine power unit, the remote control of the propeller, the turbocompressor, a boiler run on thermal oil, a shaft current generator, and mechanisms cooperating with the main engines, such as: the main engine rotational speed regulator in a system coupled with the propeller, supplying air outlet valve, exhaust valve and the control of the temperature of supplying air.

In the described case the system was customized for a one-engine intermediate power system with an in-line diesel engine of the B&W MANN 8L56 type with the power of 3840 kW and rotational speed of the shaft – 750 rev/min, with a suspended shaft current generator equipped in an electronic rotational speed regulator [1, 2]. Nominal rotational speed of the propeller shaft is 147 rev/min.

Figure 1 presents a diagram of signal flow and transformation between rotational speed regulator of the main engine, the unit controlling the control pitch propeller (CCP) FAMP III and the NORIS monitoring system [1, 4]. The central control block of the automatic regulation sends the signals of the measured values to working subsystems NORIS. The system was programmed as a standard ABB Advant Controller unit to serve 110 processes. Constant monitoring of chosen parameters enables their graphic presentation as a time function with simultaneous recording of runs of the graphic parameters. Frequency of sampling and recording are set by the operator in the range from 1 to 1200 seconds, while the graphic runs can be edited in the time range from 5 minutes to 5 hours.

3. Detection of faults in the ship main power system

Figure 2 presents the runs of operation parameters of the main power system working with the turned-on shaft current generator recorded by NORIS within 2 hours. Disturbances in the main engine operation were manifested first of all as a short lasting change in rotational speed of the main engine shaft with black-outs of the shaft current generator from the rail of the main dashboard [5, 6]. The stated lack of rotational speed stability of the engine shaft was used for the analysis to find the causes of faulty operation of the ship main power system.

Current frequency disturbance accepted by classification societies for operation at constant rotational speed is (2 – 2.5)Hz. It is the condition allowing synchronization of the shaft current generator with the net and its coupling with the net. An alarming value for the shaft current generator, in regard to the frequencies generated for the net, is exceeding the 50Hz value by +/– (2.5 – 3/2)Hz. It corresponds with the rotational speed change by (5 – 6.4)% of the nominal rotational speed of the engine shaft. The limiting value at which the black-out of the shaft current generator from the main dashboard occurs at frequency fluctuations of +/– (3.5 – 3.8)Hz, which is equal to +/– (7 – 7.6)% corresponding to the change of rotational speed of (52.5 – 57.0) rev/min [4, 5]. These conditions are met by a faultlessly operating fuel supply system and the regulator of the rotational speed of the main engine at a technically usable power system.

Among the recorded runs the following showed changes in stability:1 – rotational speed of the engine shaft; 2 – fuel pressure and 3 – pressure of the supplying air. The remaining parameters did not show any significant changes. Time of disturbances was about 7 seconds. The decrease in the shaft rotational speed was so high (by 72 rev/min)that the recorded case was accompanied by shaft current generator black-out from the main dashboard. The immediate change of supplying fuel from the heavy one (International Fuel Oil 180 – IFO 180) to diesel oil (Marine Gas Oil _MGO) –

green line in figure 2 – brought about, for some time, stable operation of the power system with correct values of operational parameters.

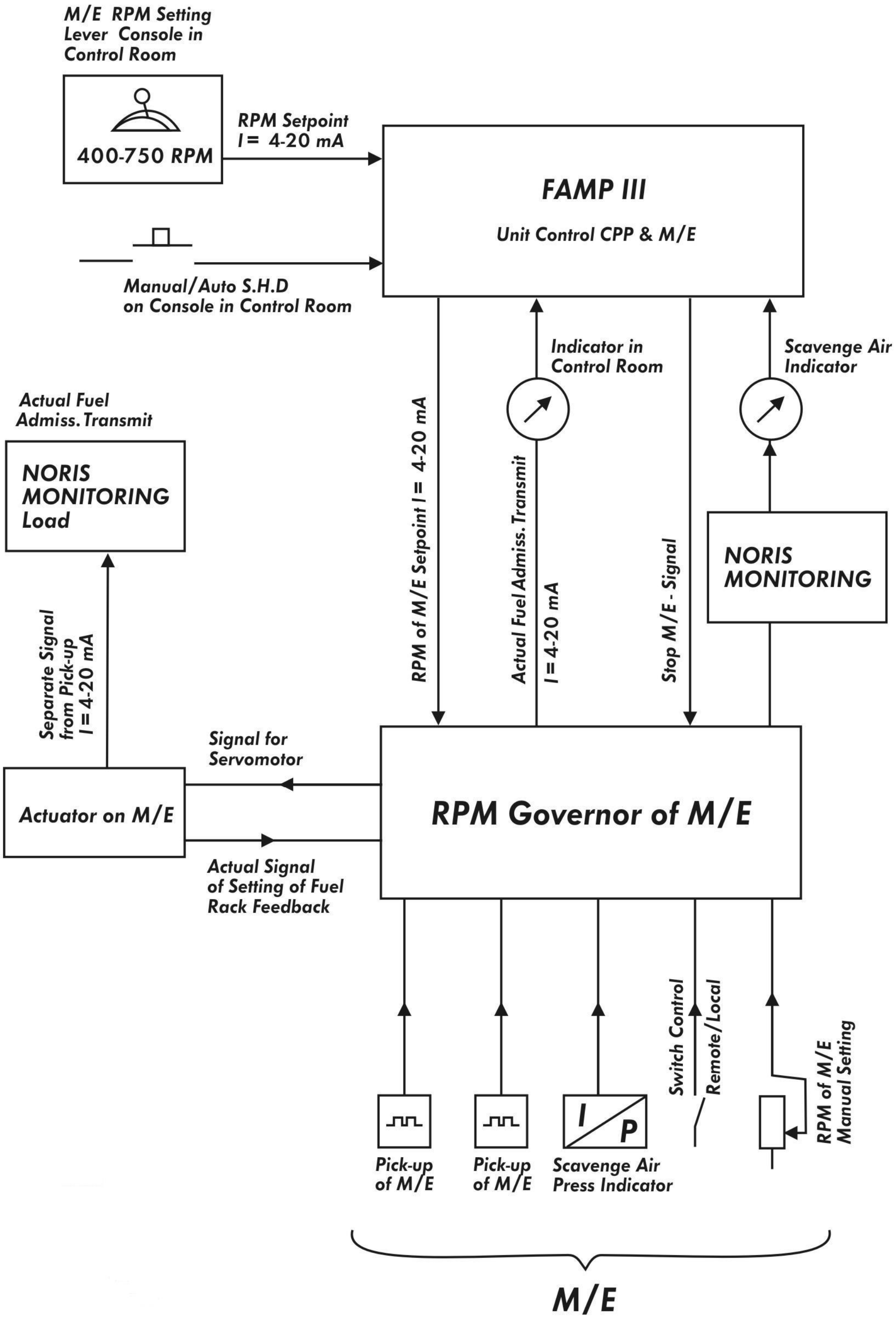

Fig. 1. A diagram of signal flow and transformation between rotational speed regulator of the main engine, the unit controlling the CCP propeller FAMP III and the NORIS monitoring system

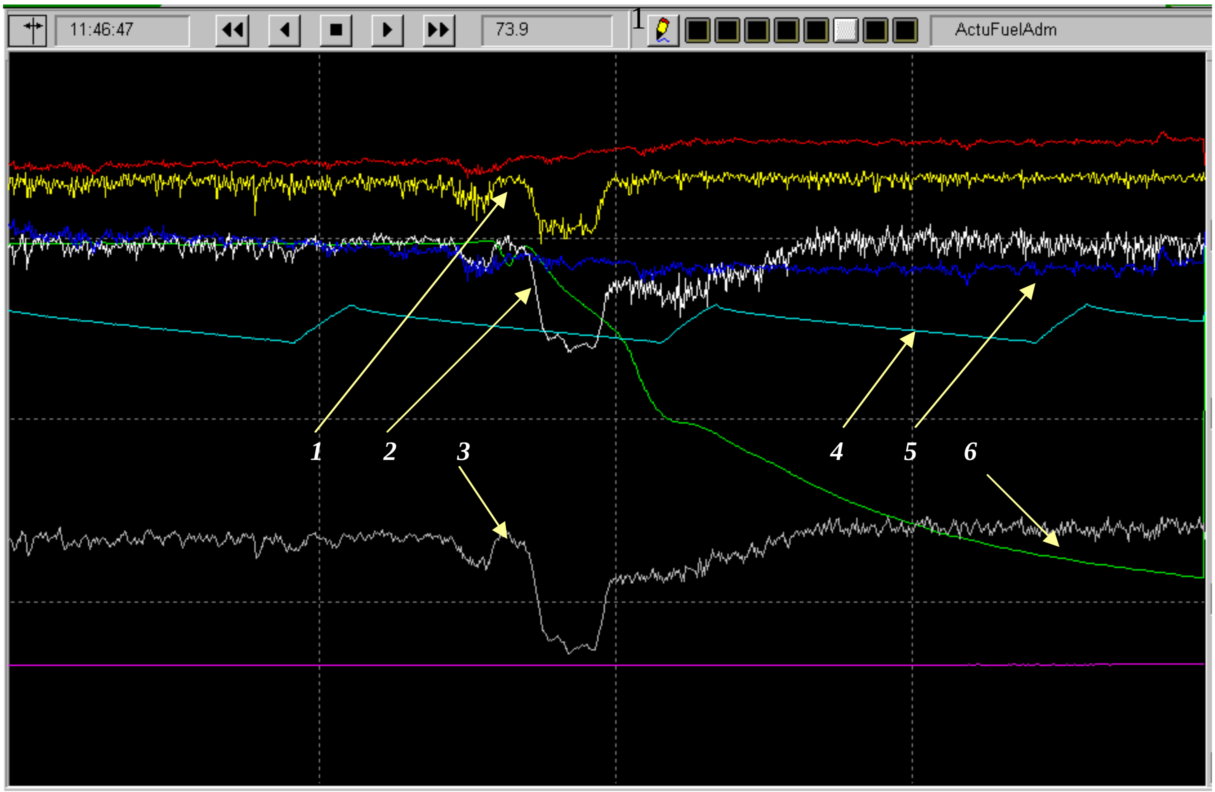

Fig. 2. Runs of operation parameters of the main power system recorded by NORIS
1 – rotational speed of main engine shaft; 2 – fuel board set-up; 3 – pressure of the supplying air;
4 – pressure of the controlling air; 5 – set up angle of the CCP propeller; 6 – temperature change of the fuel feeding the main engine at the change of fuel from the heavy one (IFO 180) to diesel oil (MGO)

As there were no external disturbances(e.g the weather, controlled load increase of the main engine) and there were no signals of internal disturbances (e.g faults in the fuel preparation unit) influencing the operation of the power unit, monitoring was directed towards operation quality of the electronic rotational speed control system (RPM Governor of ME), main engine overload controlled /monitored by NORIS MONITORING Load) block and connections between the CCP propeller control block and the main engine. (Unit Control CCP&ME, FAMP III).After stabilizing the operation of the main power system, again heavy fuel (IFO 180) was used whose temperature change can be seen in Fig 3 as green line 6 (with the two-hour edition time).

Stable operation of the ship main power unit lasted for a few days until another black-out of the shaft current generator from the main dashboard took place. In that case/situation control of signals from the CCP propeller control system and the FAMP III engine to the electronic rotational speed control system (RPM Governor of ME) was carried out, according to Fig. 1.

Their stability is guaranteed by stable operation of the system (constant rotational speed of engine shafts and shaft current generator and unchanged position of the CCP propeller of the main power system). Their values determine the response of the regulator- the change of set-up of the fuel board ensuring the required filling of the high pressure fuel pumps(Acctual Fuel Admiss. Transmit). In the studied operation state of the system monitoring of signals indicated correct values and runs of signals coming from the CCP propeller control system and the main engine (Unit Control CCP &ME, FAMP III).

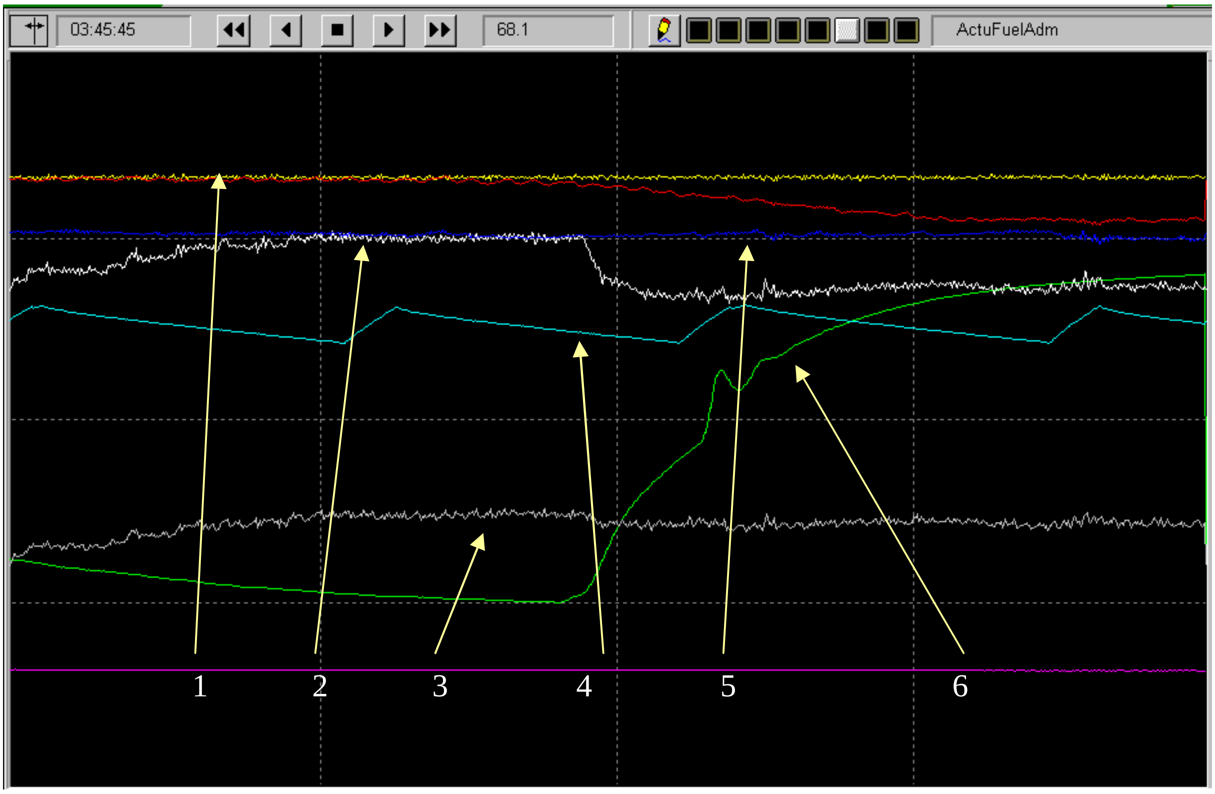

Fig. 3. Runs of operation parameters of the main power system recorded by NORIS at the come back to supplying with heavy fuel where: 1–2 as in Fig. 2.; 6 – the temperature change of the fuel supplying the main engine at switching on to heavy fuel

4. Analysis of causes of unstable operation of the main engine

The search for causes of the main engine unstable operation was carried out throughout a series of check-ups and preventive maintenance services. Detector positions for the control of rotational speed of the main engine shaft were corrected, the cooler of the supplying air was washed, the quality of operation of the hydraulic system of the CCP propeller of the ship main power system was check as well as the filling and venting of the thermo-fuel boiler. Regulation values of the set-up were checked and the time constant of the regulator was decreased. The run of parameters recorded within 2 hours was shown in Fig. 4. Although the picture was more dynamic, yet a relatively safe range of rotational speed of the main engine required for cooperation with the shaft current generator was maintained

Despite the undertaken means and switching-on to diesel fuel (MGO) when sailing at storm, the regulator worked too dynamically and its quick reactions caused instability of the rotational speed of the shaft and black-outs of the shaft current generator from the main dashboard still occurred. Such a condition and operation was unfavourable for the engine but directed the search for the cause of the lack of operational stability to the quality of functioning of the engine fuel unit. The causes of unstable operation of the main engine should be found in the faulty filling of fuel pumps or disturbances in the quality of fuel combustion in the engine.

The equipment for the high pressure fuel was checked. Faults in two precision pairs (shown in Fig. 5. and 6.) were found. Fig. 5. shows a defect on the on the working edge of the precision pair of the plunger.

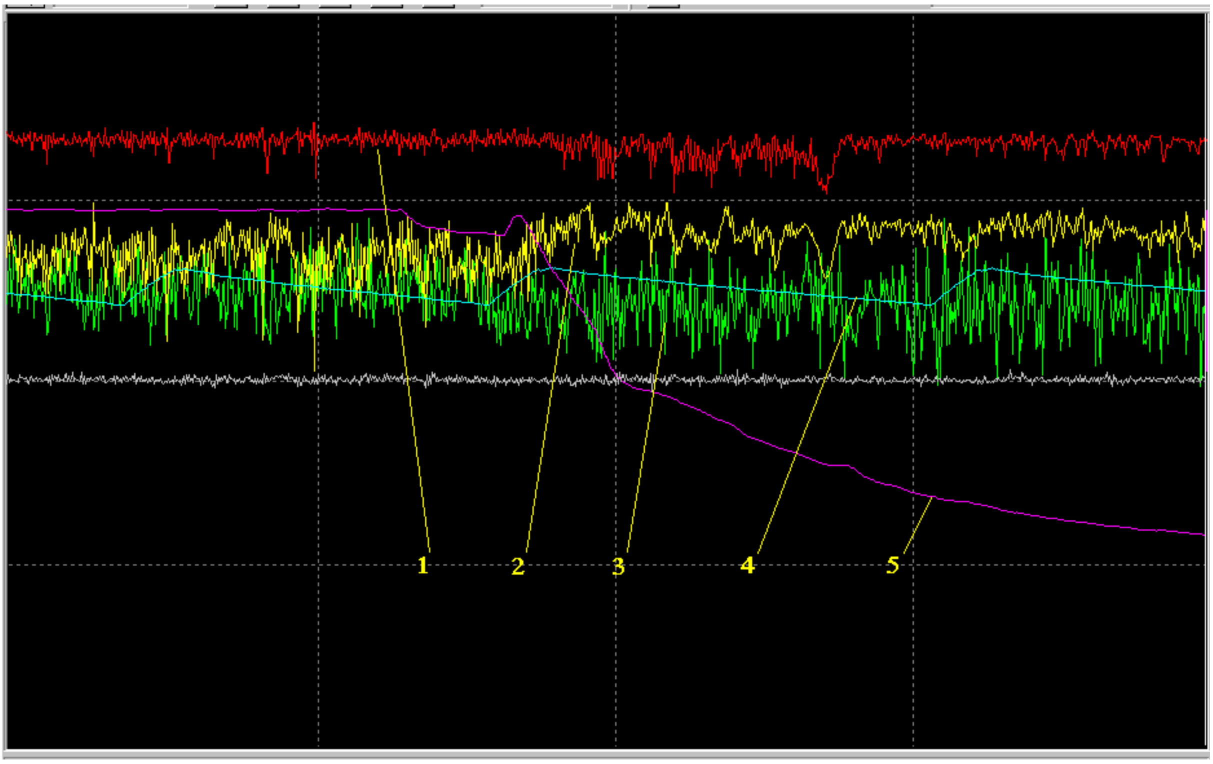

Fig. 4. Runs of operation parameters of the main power system recorded by NORIS after preventive maintenance services and corrections of set-ups:
1 – rotational speed of the main engine shaft; 2 – fuel board set-up; 3 – pressure of the fuel supplying the main engine; 4 – pressure of the controlling air; 5 – temperature of the fuel feeding the engine

Fig. 5. Defect on the working edge of the precision pair of the plunger of the fuel pump (point A)

Figure 6 shows discolouring of working surfaces of another precision pair_due to too high temperature as an effect of seizure. The faulty elements of the fuel pump were replaced with new ones. To check the effectiveness of maintenance services of the fuel equipment, resolution of edition of its recorded parameters was increased from the so-far 2 hours to 5 minutes. The picture of a screen test recording is shown in Fig 7 with the black-out and switching from heavy fuel (IFO 180) to diesel oil MGO.

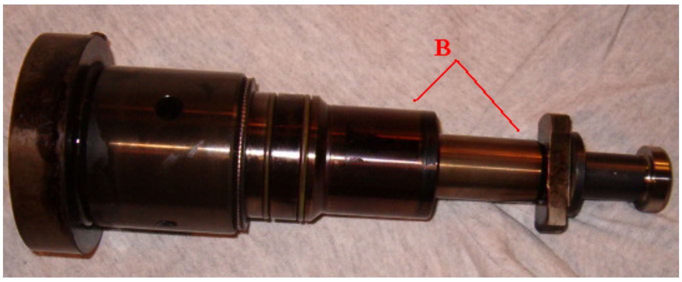

Fig 6 Discoloring of working surfaces of another precision pair due to too high temperature (surface B)

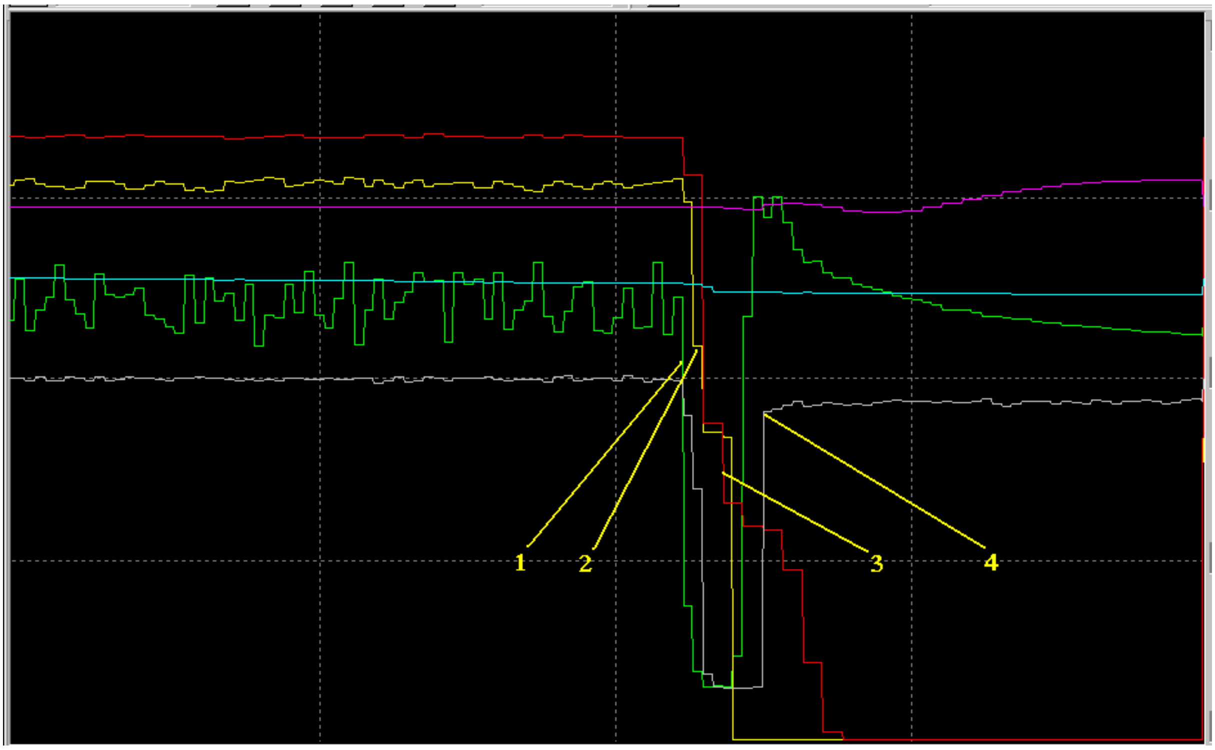

Fig. 7. Runs of operation parameters of the main power system recorded by NORIS at a black-out and with the heavy fuel (IFO 180) after servicing fuel equipment:
1 – pressure of supplying fuel; 2-fuel board set-up; 3-rotational speed of the main engine shaft; 4- pressure of the supplying air (time of edition of the recording on the monitor – 5min)

During the self- switch-off of the shaft current generator from the net, significant fluctuations of fuel pressure and decreases of pressure of the supplying air were observed. The system was unstable as if it had not responded to the programme of engine regulation n=idem (RPM constant) not taking account of the sets-up of the CCP propeller. The system searching for a new state of stable operation reduced the set-up of the fuel pump to the current load (pressure of the supplying air). In this case the runs of the following parameters were incorrect: pressure of the fuel feeding the engine, rotational speed of the engine shaft and the pressure of the supplying air. This result indicated that the unstable operation of the engine was due to the faulty operation of the engine fuel system.

With the checked-up fuel equipment, clean air and fuel filters and correct operation of the fuel preparation block, unstable operation of the main engine was still recorded. Thus its cause had to be the quality of the burnt fuel IFO 180. This assumption was supported by the fact that re-switching to MGO fuel resulted in a stable operation of the engine.

Summing up the results of fuel equipment servicing i.e. the recorded runs of operation parameters after exchanging IFO 180 fuel with MGO fuel, it can be stated that the burnt fuel did not meet the requirements of the engine manufacturer.

Fractional analysis of the applied heavy fuel IFO 180 showed its heterogeneity and tendencies to forming layers. After introducing “new” fuel, the described symptoms of unstable operation of the main power system disappeared. As a consequence sailing with a switched-on shaft generator even at stormy weather or with the waves from the stern was not a problem. The presented in Figure 8 runs of operation parameters recorded after exchanging the heavy fuel IFO 180 with the “new” one (edition time of runs on the screen –2 hours) are an evidence of removing the instability of operation of the main power system

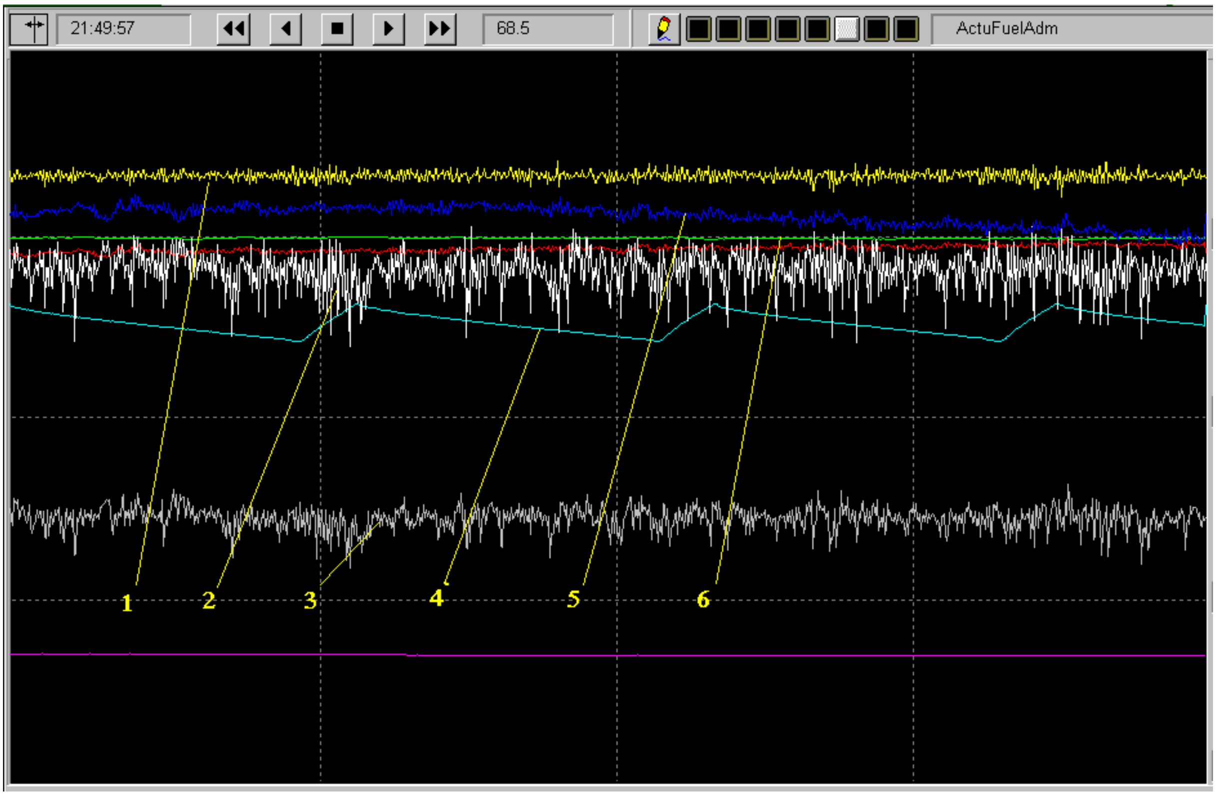

Fig. 8. Runs of operation parameters of the main power system recorded by NORIS:
1 – rotational speed of the main engine shaft; 2 – fuel boar set-up; 3 – pressure of the supplying air; 4 – pressure of the controlling air; 5 – set- up angle of the control pitch propeller; 6 - temperature change of the fuel supplying the main engine after using the “new” heavy fuel IFO 180 (“new” IFO 180)

Although the recorded run of the set up of the fuel board indicates a dynamic regulation of the main engine, stability of the rotational speed of the main engine shaft was unquestioned, met the requirements of the classification society and enabled further safe operation of the ship power system.

5. Summing up and final conclusions

The presented monitoring system of chosen operation parameters of the main power system enabled measurements, recording and evaluation of their runs/disturbances in the main engine fuel system – fuel pressure (Actul Fuel Admission Transmit) and changes of runs of parameter values which were the response of the automatic regulation system, in particular the pressure of supplying air, exhaust temperature, load of the main engine taking into account the controlled of the wings of the CCP propeller. Thanks to them it was possible not only to state the instability of the system but also to find its causes.

Constant monitoring of proper functioning of the ship main power system carried out by the on-board monitoring system enabled regulation of set-ups in the control system of the power unit and its instant diagnosis. This diagnosing supports making maintenance decisions preventing the occurrence of more significant faults and break-downs. Supplying information in successive procedures of diagnostic concluding, a monitoring system became a tool in operation process control justifying its utilitarian position on contemporary ships.

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