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A new concept of ship electric power plant with the so-called floating frequency

SUMMARY

This paper presents a method of reducing electric energy consumption in ships which consists in application of the variable frequency in ship's electric installation, dependent on main engine loading.

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INTRODUCTION

Possibilities to improve energy economy in ships by perfecting further the main propulsion plant based on the contemporary low-speed diesel engine have been developed almost completely. Potential improvements in effective electric energy production, especially when applying shaft generators, are even more scarce. In this situation it is worthwhile to direct efforts also to more rational usage of the available electric energy by designing and operating ship's power plant in such a way as to decrease electric energy consumption.

An analysis of electric energy balance of merchant ships (refrigerated ships excluded) shows that the electric motors which drive pumps, fans and other mechanisms of main engine service installations consume 40 ÷ 60% of electric energy produced during ship's voyage at sea, dependent on her type and size [1]. This is confirmed by the electric energy balance of B545 bulk carriers fitted with 6RTA58 main engine, built by Szczecin Shipyard Co in the end of 1980s (seeTab.).

Electric power demanded by different consumers of B545 ship during voyage at sea

No	Consumer group	Active power demand (voyage at sea)* [kW]	Share in the total active power demand[%]
I	Main engine service pumps, engine room fans, engine room auxiliary mechanisms	308,3	49,5
II	Workshop equipment	13,6	2,2
III	Deck equipment	16,2	2,5
IV	Domestic equipment	49,7	7,8
V	Ventilation and air conditioning	194,2	31,2
VI	Lighting	36,4	5,7
VII	Radio and navigation equipment	7,4	1,1
	Sum total (network loss exluded)	622,8	100

*) Coincidence factor equal to 0,8 was assumed to account for demand coincidence of consumers of the II ÷ VII groups and some of the I group

Ship power plants are designed, according to the classsification societies' requirements, for the least advantageous working conditions. It means that most of the equipment appear over-powered for average service conditions and climatic zones, and in addition, in the frequent cases when they are used at a reduced ship's speed. It concerns, first of all, coolers and pumps as well as ventilators.

Decreasing capacity of pumps or fans, to a level which results from the actual main engine load, causes in consequence a decreasing demand for electric energy.

Two methods, which consist in matching the number of revolutions of pumps or fans with actual demand, can be used here; both of them are characterized by low losses and serve to lower mass flow in installations:

- matching revolutions of each pump or fan individually by using frequency converters or electric motors with reconnectable number of poles
- revolution matching common for all electric motors by decreasing frequency of current in ship electric network [2].

PROFITS FROM DECREASING CURRENT FREQUENCY IN ELECTRIC NETWORK

The decreasing of current frequency in electric network which results in the lowering of electric motors' revolutions is a specially advatageous concept in comparison with other concepts mitigating working medium flow, because it is not connected at all, or to some extent only, with additional investment expenditures, provided a ship electric plant in question is fitted with shaft generator. In such situation during voyage at sea, electric network is supplied with current of the frequency proportional to propeller's number of revolutions, if no frequency control is provided. In this way the coupling of electric motor revolutions with main engine revolutions is obtained. It means that electric motors behave as being driven by the main engine. This state is called „work with floating frequency". An approximate, cubic relationship between the number of revolutions and power, $P \sim n^3$, is valid for most of pumps and fans; it means that substantial electric energy savings can be achieved owing to the reduced number of propeller's revolutions and in consequence a lowered current frequency in electric installations.

The determination of an allowable variation range of current frequency is an important issue when working with floating frequency. Classification societies require any electric energy consumer to be fail-safe against minor variations of current frequency and voltage, by establishing allowable deviations from their nominal values [3].

Eventual approval of a power plant working with floating frequency is connected with some departures from the actual requirements ; it means that development of new, safe operation criteria for ship power plants is necessary.

The measurements carried out on many ships of different type and size showed that the lowering of frequency in the allowable range of 5% resulted in 10÷15% average savings of electric energy consumption [1], [2]. Positive experience gained from ships operating with the lowered current frequency within present limitations was an incentive to build or rebuild ship electric installation in such a way as to make its operation with the frequency floating within 80÷100% of the nominal value possible.

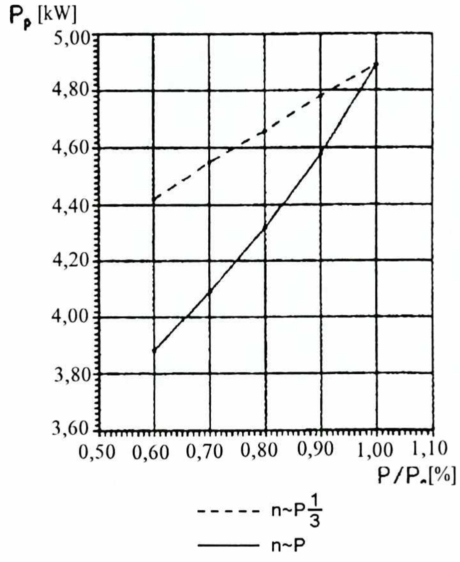
The first two ships, designed specially to operate with floating frequency, are the HEINRICH ESSBERGER and the EBERHARD ESSBERGER built for J.T. Essberger by Sietas shipyard in Hamburg-Neuenfelde [1]. A characteristic feature of the electric instalation on these ships is the separation of the constant frequency network from that with the floating frequency (proportional to main engine speed).

Development of the new requirements, permitting to operate electric installations within broader limits of frequency variation, was preceded by many tests on ships. One of them was that on the motor ship, BLUMENTAHL [4]. The tests were carried out with the frequency variation between 52 and 62 Hz. The temperatures, not to be exceeded in cooling and lubricating installations, were kept within limits all the time. It means that the coolers were specified with appropriately large margins. No working medium pressure deviations outside the permissible limits were measured in machinery installations.

In the case of the periodically switched-on equipment, e.g. air compressors, somewhat longer filling time of tanks was observed at the decreased current frequency. The frequency decreasing did not cause either any lowering of separation effectiveness of centrifugal seperators or changes in their separation cycles. However, some influence of current frequency on separators' output, which changes proportionally to the change of revolutions or current frequency, was observed. This fact should be taken into account while regulating separators. During the tests the temperature of electric motor windings was also measured. In no case any exceedance of the maximum allowable temperature of winding was reported at a lowered current frequency. The results indicate that electric energy savings up to 20% can be expected when working at 90% of nominal frequency and voltage lowered by 5÷7%.

It is assessed that current frequency floating within 66÷100% of its nominal value can be used on ships fitted with shaft generators and solid propellers [2]. Appropriate guidelines have been already prepared by Germanischer Lloyd. However, no such installation has been built till now. One of the unanswered questions is, a.o., a thorough assessment of the influence of pump revolutions on the main engine cooling quality. The problem was broadly presented in [2], where conditions for approval of power plant operation with floating frequency were formulated. This author also analysed the conditions on the basis of his own calculations simulating work of the cylinder block cooling installation of 6L50MCE (MAN-B&W) engine, carried out with the use of CADES software [5],[6].

Figure presents relationship between power consumption of 63Wa20M54 service pump and main engine relative load when working with the floating frequency, assumed in the simulating calculations.



Power consumption of 63Wa20M54 service pump versus main engine relative load during work with floating frequency [5]

CONCLUSIONS

Results of many experimental and theoretical investigations indicate that application of the concept of electric plant operation with floating frequency is rational because it makes substantial energy savings possible.

Container carriers of B186 series being built for German owner in Szczecin Shipyard Co, were expected to be among the first ships where such design, based on GL rules, was to be applied.

In the original design floating frequency within 50÷60 Hz range was assumed, of the electric current supplied by 1250 kVA shaft generator. Unfortunately the shipowner withdrew his approval of that design at the last moment, and a traditonal installation with thyristor control of current frequency was applied.

Nevertheless such design concepts which can bear substantial, economic profits should be promoted to overcome the conservatism of many shipowners.

BIBLIOGRAPHY

1. Droste W., Hochhaus K.H.: „ Reduzierung des elektrischen Energiebedarfs auf Handelsschiffen ". Hansa 124, 1987, Nr 21/22
2. Juchniewicz L.: „ Dynamisches Verhalten der Kühlkreise von Dieselmotoren bei Gleitfrequenz und bei Einsatz drehzahlgeregelter Pumpen ". VDI Fortschrittberichte Reihe 12, Düsseldorf, 1992, Nr 177
3. Morawetz R., Paduch W.: „Anforderungen der Klassifikationsgesellschaften an die Anlagen von Schiffen bei Gleitfrequenzbetrieb (GFB)". Hansa, 122, 1985, Nr 20
4. Meier-Peter M.: „ Untersuchung des Einflusses von Gleitfrequenzbetrieb auf das Verhalten der Schiffsbetriebstechnischen Systeme am Beispiel BLUMENTAHL ". Hansa, 122, 1985, Nr 20
5. Zeńczak W.: „ Możliwości poprawy gospodarki energetycznej statku dzięki eksploatacji sieci elektrycznej ze zmienną częstotliwością ". XV International Symposium on Ship Power Plants, Gdynia, 1993 r.
6. Michalski R., Zeńczak W.: „ Pakiet programów komputerowych CADES wspomagających proces projektowania instalacji okrętowych siłowni motorowych ". Budownictwo Okrętowe i Gospodarka Morska, 1991 r., Nr 10

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