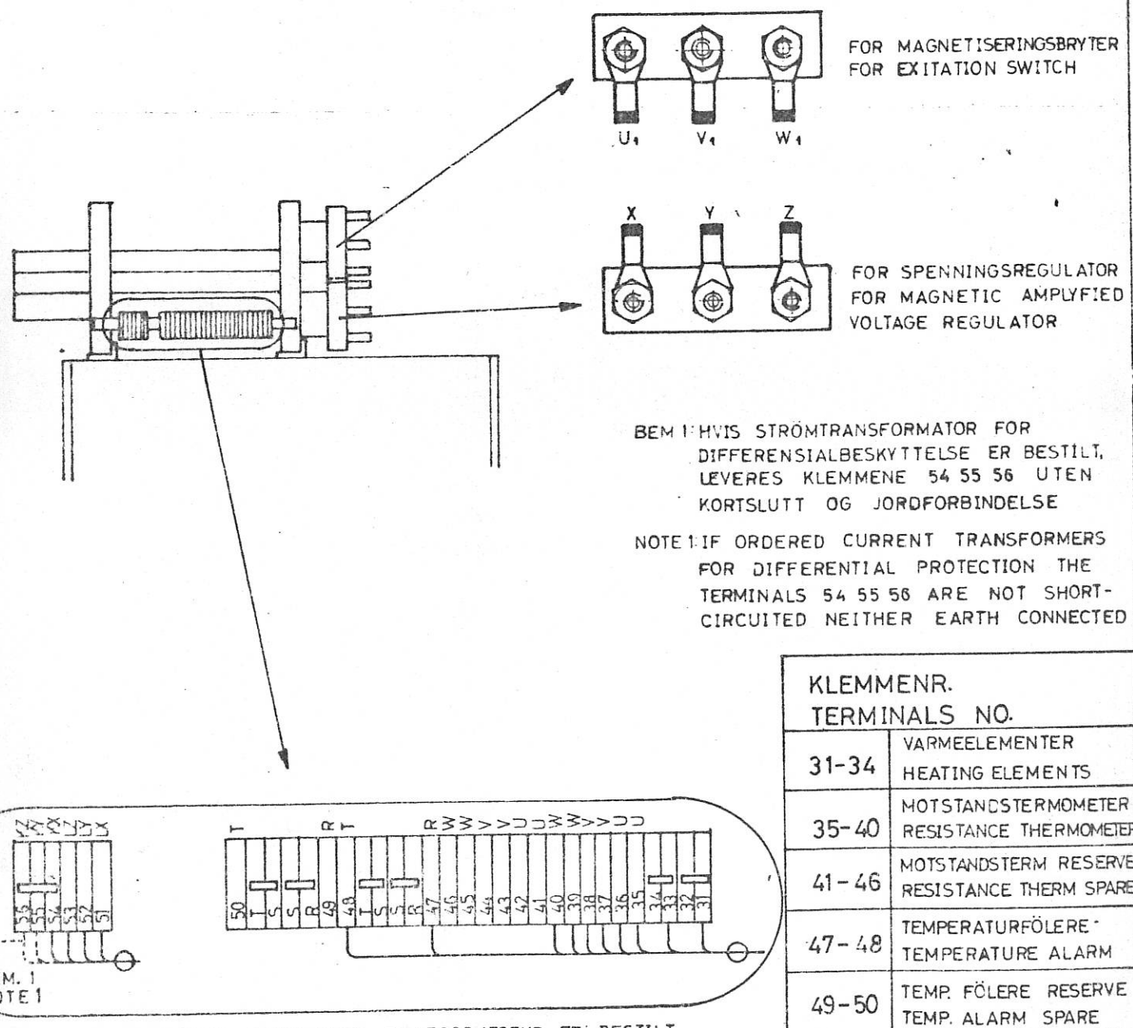
## PLASSERING AV HJELPEKLEMMER

## POSITIONS OF SECONDARY TERMINALS




| KLEMMENR. TERMINALS NO. | |
|---|---|
| 31-34 | VARMEELEMENTER HEATING ELEMENTS |
| 35-40 | MOTSTANDSTERMOMETER RESISTANCE THERMOMETER |
| 41-46 | MOTSTANDSTERM RESERVE RESISTANCE THERM SPARE |
| 47-48 | TEMPERATURFÖLERE TEMPERATURE ALARM |
| 49-50 | TEMP. FÖLERE RESERVE TEMP. ALARM SPARE |
| 51-56 | STRÖMTRANSFORMATORER CURRENT TRANSFORMERS |

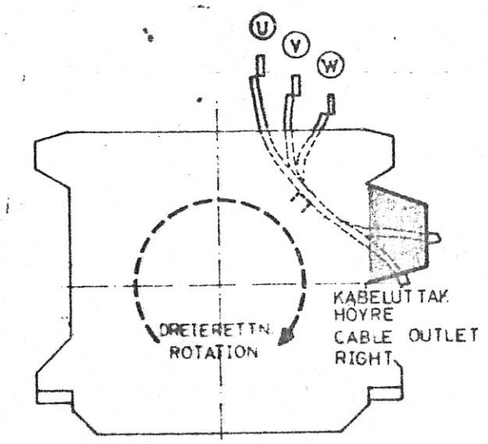
KLEMMER NR 35-56 LEVERES BARE HVIS TILLEGGSUTSTYR ER BESTILT

TERMINALS NO. 35-56 INCLUDED ONLY IF SUPLEMENTARY EQUIPMENT ORDERED

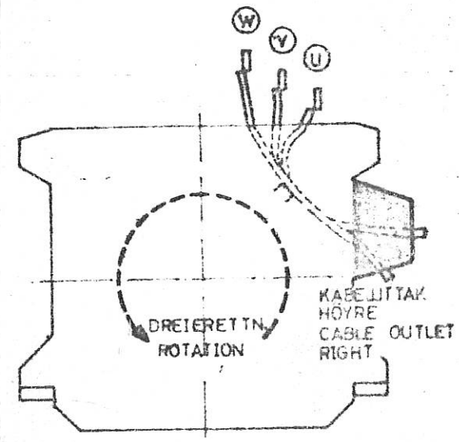
## PLASSERING AV HOVEDKLEMMER

## POSITIONS OF MAIN TERMINALS

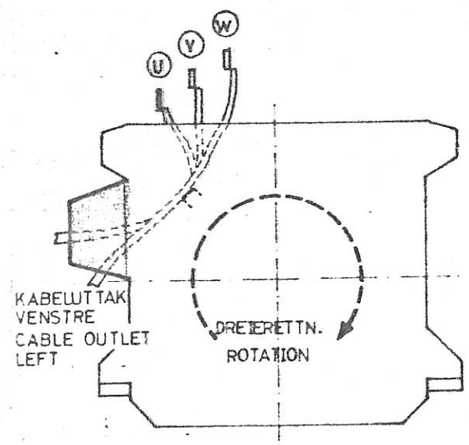
GENERATOR SETT FRA DIESEL / TURBIN
GENERATOR SEEN FROM DIESEL / TURBINE



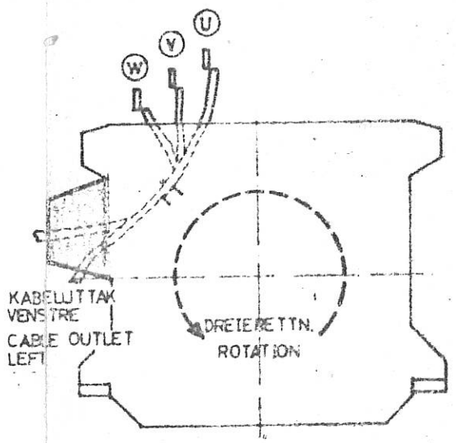

GENERATOR SETT FRA DIESEL / TURBIN
GENERATOR SEEN FROM DIESEL / TURBINE




GENERATOR SETT FRA DIESEL / TURBIN
GENERATOR SEEN FROM DIESEL / TURBINE




GENERATOR SETT FRA DIESEL / TURBIN
GENERATOR SEEN FROM DIESEL / TURBINE




STANDARDUTFÖRELSE MED PÅBYGD TRAFO OG DROSSEL

STANDARD DESIGN WITH NO-LOAD AND COMPOUNDING TRANSFORMER

GENERATORER TYPE WAB
PLASSERING AV KLEMMER I STATOR
GENERATORS TYPE WAB
TERMINALS POSITION IN STATOR

Erst. av:
Erst. for:
Beregn.:

| Måle-stokk | | | |
|---|---|---|---|
| | Tegnet | 13.7.72 | GWH sign. |
| | Kontroll | 14.7.72 | Ko |
| | Sett | | |

NEBB OSLO

NM303 306

Forandringer
Tegn omtegnet 24.6.75 SSA

Fotografert

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NEBB

MARINE DEPARTMENT

BERNT LEIRA

# PARALLEL OPERATION OF DIESEL GENERATORES

OFFPRINT FROM

NEBB

MARITIME NEWS

NO. 1 1969

BROWN BOVERI

NEBB

TELEGRAMADR. NEBB - TLF. (02) 55 70 90
POSTBOKS 429 SENTRUM OSLO 1

*BENT LEIRA:*

# Parallel operation of Diesel-generators

To obtain satisfactory parallel operation between AC generators, certain requirements concerning the diesel engine speed governor and the automatic voltage regulator must be met. It is also necessary for the operating staff to have a clear understanding of the meaning of the terms ACTIVE AND REACTIVE power as well as a knowledge of the devices which control the sharing of the corresponding loads between the alternators.

For many electricians — especially those who are new to the trade, or to those who have only served in vessels installed with DC power — these terms very often give quite some trouble, and this article is written in a hopeful attempt to throw some light on these problems.

The synchronizing itself, and connecting-up to the bus bars will normally give very little trouble, as long as the instruments, diesel governors and the associated electrical wiring are in working order.

However, if the diesel governor for example is functioning incorrectly thereby causing the frequency to fluctuate, it is not at all easy to synchronize the machine, although this must be attempted. Synchronizing under incorrect conditions, as many electricians have experienced, can cause blackout with all the unavoidable trouble following such an occurrence. When synchronizing under appreciable out-of-phase conditions, high voltages will be induced in the main field windings, which in certain conditions, may result in breakdown (by puncture) of the main rectifier.

*Sharing of active load (kW).*

When the alternators have been synchronized and connected to the bus bars they will have become electrically locked together. This means that the voltage and the speed (or frequency) are identical for all generators connected in parallel.

An increase of the fuel supply to one of the engines will therefore not cause an increase in the speed or frequency of the associated alternator in relation to the others. The result of an increased supply of fuel to one engine is to cause this to take over a greater part of the total active load, at the same time causing a slight increase of the frequency, as measured at the bus bars.

After parallelling the alternators the kW-load is shared between the machines by the appropriate operation of the engine governor control switch located on the main switchboard.

After having adjusted the load-sharing as described above any subsequent changes in load will be shared automatically between the alternators running in parallel, assuming a correct setting of the engine governors.

This automatic sharing of load is given by the sloping characteristic of the engine governor, which will decrease the speed by about 4 % between no load and full load. For instance if the frequency is 62 Hz, at no load, the frequency at full load should correspond to about 59.5 Hz.

If the no-load to full-load speed drop is equal for all engines the load will be equally shared between them after synchronizing and correct setting of controls. (See figure 1). If however, the speed drop is unequal for the different engines the load sharing will also be unequal. (Figure 2).

In order to find out if the speed drop is correct the following procedure can be employed: —

We assume that one alternator set is running and we will call this set No. 1. Further we assume that this set is running almost fully loaded and that the frequency is 61 Hz, we now wish to check the no-load to full-load speed drop on another engine set, No. 2, which is therefore started up, and synchronized with the busbars.

Synchronization has been carried out by the use of the engine speed governor on No. 2 set only so that the frequency at the busbars is still 61 Hz and the kW-meter for No. 2 engine is indicating near zero loading. The load from No. 1 is now transferred to No. 2 set by reducing the fuel supply to No. 1 engine. When the kW-meter for generator No. 1 shows zero, the load has been fully transferred to No. 2 set and now we check the frequency on the busbars. This should be about 58.5 Hz or about 4 % below the original value.

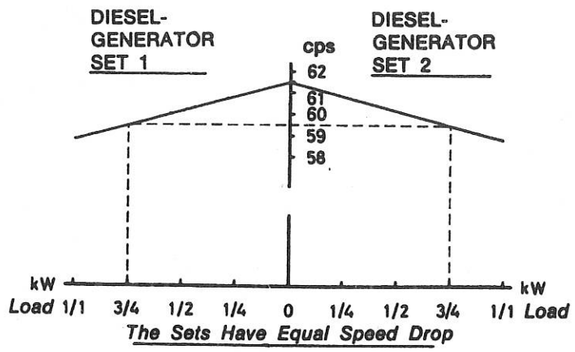


FIG. 1

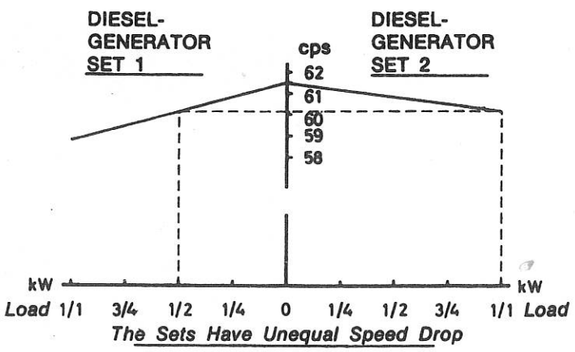


FIG. 2

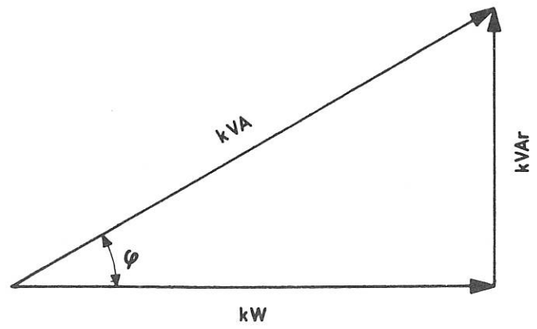


FIG. 3

In the same way the other diesel sets can be checked. If the speed drop is unequal between various engines the necessary adjustments on the speed governors must of course be carried out.

Another point worth mentioning in connection with the governor is the damping. If the damping is too weak, there is danger of hunting, due to governors over-regulating to correct for speed changes due to sudden and great load fluctuations.

Hunting i.e. instability of the governors, may finally lead to a black-out on the ship.

Backlash or dead motion and wear in governors and transfer mechanisms may lead to the same result.

*Load sharing of a reactive load (kVAr).*

It is well known that in AC mains supplies the load is not a pure (kW) load but a mixture of this and a reactive load (kVAr).

The active load — which is measured in kW is the power developed by the diesel engine and by being supplied to motors, heaters and lamps — is further converted into torque, heat and light.

The reactive load (often called watt-less), which is measured in kVAr, comprises the magnetizing forces in motors, transformers etc.

The magnitude of reactive power does not influence the active load, which means that the diesels are not aware of high or low magnitude of reactive power.

For the generator, however, this load is very significant, as the total load — as seen from the generator — is the vector sum of both active and reactive components. (fig. 3).

The total load is also named the apparent power and is measured in kVA. The reactive load must be shared about equally between the generators and this sharing is controlled by the automatic voltage regulator. How this is arranged will be made clear in the following: —

We know, that when the generators are operating singly, their voltages can be varied a little by

means of an adjusting rheostat on the control panel.

What actually happens is that the magnetizing current for the generator armature is increased or decreased, which causes a corresponding alteration in the generator voltage.

Any attempt to carry out the same procedure on generators running in parallel will cause no change in the associated generator voltage, since both machines are conected to a main busbar and, of course, should produce equal voltages. The only result of this attempt is to alter the power factor of the particular generator i.e. its share of the total reactive load, together with a minor increase or decrease in the bus-bar voltage.

Therefore, when the generators are running in parallel, the reactive load sharing can be adjusted by means of the trimmer rheostat which is part of the automatic voltage regulator equipment.

A subsequent increase in the reactive loading should now be automatically and equally shared between the generators. This is obtained by electric circuitry, which causes the generator voltage to decrease with an increase in the reactive loading.

It would take too long here to analyse in detail how this reduction is achieved, but we hope that a study of the instruction manuals and diagrams, which — we hope — are still available on board, will make this clear.

In the case of transductor-regulated generators, however, the operation is in the main as follows:

The magnetizing current to the main field winding is controlled by the regulator-circuit current; the higher the regulator current, the lower the magnetizing current. A stabilizing resistor is connected in series with the regulator circuit. A regulating current causes a voltage drop across this resistor. In one of the main phases is mounted a current transformer, the secondary of which is connected to the stabilizing resistor in such a way that an increase of reactive load on the generator reduces the voltage drop across the stabilizing resistor. A reduction of the voltage drop will increase the regulating current, which in turn, will decrease the magnetizing current to the generator main field, and in this way the desired end is achieved viz. a rise in the reactive loading is accompanied by a decrease in the generator voltage.
The stabilizing resistor is adjustable and by moving the sliding contact one way or the other, the stabilizing effect (or voltage drop) can be increased or decreased. The voltage drop (stabilization) necessary will vary from one installation to another, but for regulators fitted with Zener reference the voltage drop should amount to about 0.5—1 % from no-load operation to full-load operation at power factor (cos phi) = 0.8. For regulators with solenoid reference, a stabilization of 1—2 % is usual.

Regulators with solenoid reference are furthermore frequency-dependent, and this will cause a voltage decrease in proportion to the drop in engine speed, as active load is applied.

Generators with rotating exciters and fitted with Brown Boveri quick-acting automatic voltage regulators are also stabilized by reactive loading. The stabilizing principle is similar to that of the standard transductor regulators.

The importance attached to the characteristics of engine speed governors being identical, to achieve equal sharing of the active load, applies also to the falling characteristics of the automatic voltage regulators being similar, to ensure equal sharing of reactive loads.

The regulators will be correctly adjusted by our Service Engineer during installation, but later repairs etc. may involve alterations, which may necessitate readjustment of the equipment. ■