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POWER-GENERATING EQUIPMENT

INTRODUCTION

ALTHOUGH GHANA has a large electricity-generating capacity from the Volta Dam Scheme, distribution is not yet nation-wide. Areas of industrial development are those which are being first served and as the sound broadcasting transmitter station at Ejura and the television transmitting stations at Adjankote, Jamasi and Kissi lie outside these areas, provision has had to be made for diesel generators to serve these stations. The television stations are each provided with triple 40-kW automatic changeover diesel alternator sets. The microwave link stations at Ejuanema and Koforidua, which are also not within reach of the public supply, have dual diesel alternator sets, and Kumasi has an automatic standby diesel alternator, in case of public supply failure. These installations are all comparatively straightforward. The site at Ejura, however, presents a much more complex problem and this article concentrates on the design considerations and solutions at this comprehensive power station.

CHOICE OF ENGINE SIZES

One of the main difficulties in planning a diesel power station is the selection of engine types and powers to cater for a wide range of loads over different periods.

The two large 250-kW transmitters each require an average power of 680 kW, whilst the six (future eight) 10-kW transmitters each require an average power of 25-kW.

After discussion with Ghana Broadcasting Corporation it was considered that a typical day might result in the following station loading:

5.00 to 8.00 hr:
Four 10-kW transmitters = 100 kW

8.00 to 10.00 hr:
Six 10-kW transmitters = 150 kW

10.00 to 12.00 hr:
Off = 0 kW

12.00 to 14.00 hr:
Six 10-kW transmitters = 150 kW

14.00 to 23.00 hr:
Six 10-kW and two 250-kW transmitters = 1510 kW

Allowance had also to be made for power-house auxiliaries and station load. This meant a total load of between 150 and 1,585 kW. With the addition of two future 10-kW transmitters the final load would be in the region of 1,635 kW assuming all transmitters on a maximum continuous level of modulation.

Apart from inefficient use, very much increased maintenance is needed if diesel engines are run at below one-third full load. It was therefore decided to adopt three different engine sizes to ensure good operating conditions throughout the twenty-four hours and at the same time allow great flexibility in equipment in use.

Two 50-kW Dorman/English Electric 5LB engines running at 1,500 rev/min were chosen as house sets to be used when all transmitters were shut down. These supply not only essential requirements for the

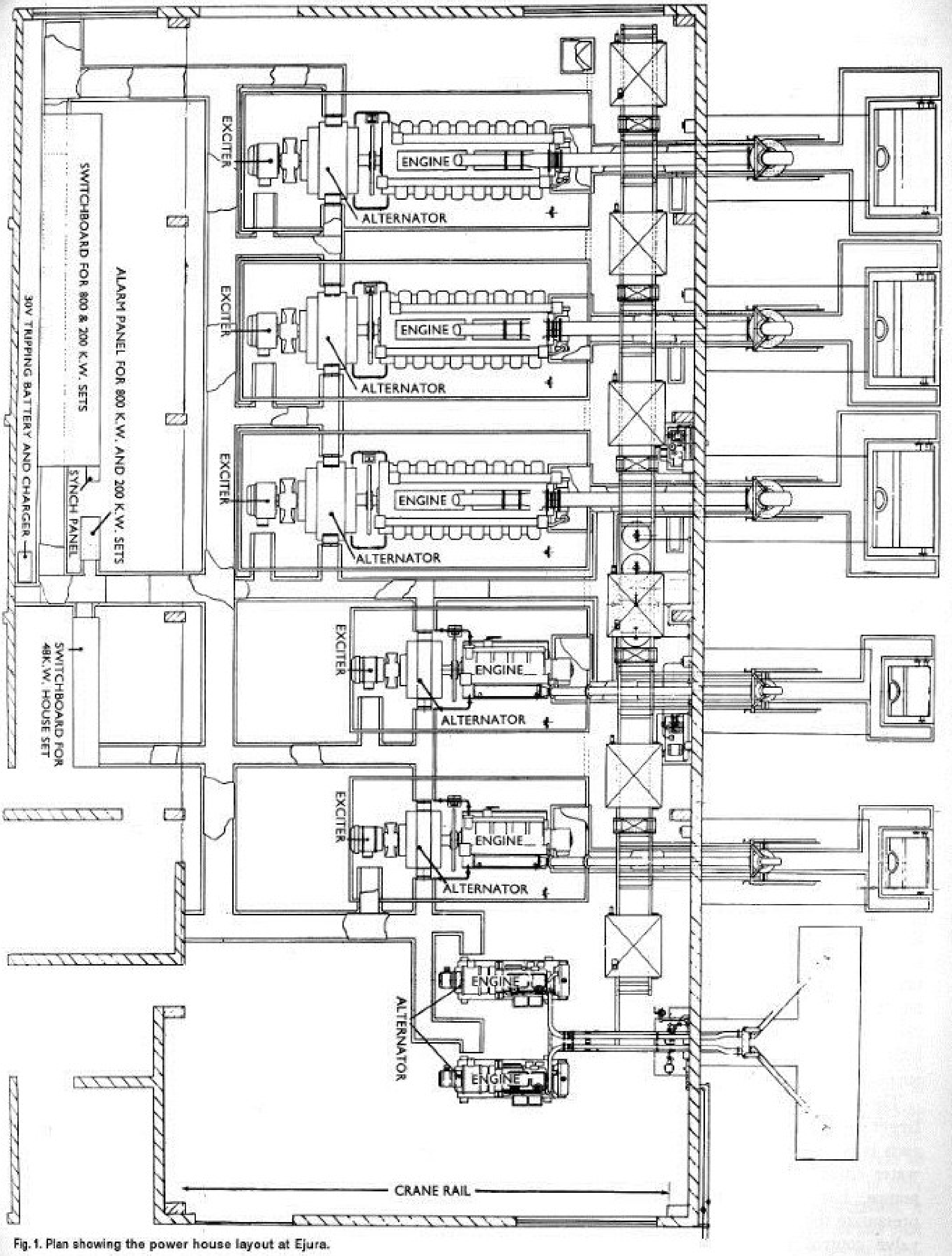

Fig. 1. Plan showing the power house layout at Ejura.

transmitting station, e.g. mast lights, link equipment, etc., but also power for the domestic site.

These function as automatically starting sets, either to the main generators or to each other, and a set therefore automatically starts immediately the house set bus-bar becomes dead. This ensures continuity of domestic supplies as well as mast lighting, link equipment, etc.

Two 200-kW English Electric 4RK engines running at 750 rev/min are provided for the 10-kW transmitters. Each of these can handle between two and six 10-kW transmitters and the station load, and when one of these sets comes into operation the house set is shut down. When the two future 10-kW transmitters are added, one 200-kW engine will be able to take all eight transmitters, and a house set take the station and domestic load, or the two 200-kW sets will be paralleled to share the total load.

On-load synchronizing with an automatic 'check' relay to prevent out-of-phase paralleling is provided.

Three 800-kW English Electric 16-V engines running at 750 rev/min are provided for the two 250-kW transmitters. Basically two engines in parallel supply the large transmitters and, via a section breaker, can supply a number of 10-kW transmitters and the station load.

This arrangement leaves adequate standby capacity for maintenance. As any of the sets are required only for a portion of the day much routine and minor maintenance can be carried out in off-duty periods; but, nevertheless, adequate capacity is available at all load levels for major overhauls.

All engines and electrics are rated for continuous full load under maximum site temperatures and conditions, and are suitable for 10% overload for one hour in twelve hours.

POWER HOUSE ANCILLARIES

Each engine is provided with a fuel service tank, except the two small sets which share. These service tanks are replenished from two bulk storage tanks mounted outside by duplicated electrically driven float switch-controlled transfer pumps. Tanks can be isolated for maintenance and cleaning purposes and are supported at high level from the power-house floor.

The engine water- and oil-cooling radiators for the larger sets are mounted outside the power house and each is cooled by an electric-driven fan, the oil and water circulation being by means of engine-driven pumps. Each engine has a water header tank to pressurize the system and allow for expansion. Ball-valve control is provided at each tank which is supplied from rain water collected from the roof and pumped to a high-level tank. The house-set radiators are mounted on the sets themselves with belt-driven fans. They are not ducted to the outside of the power house as there is adequate air volume to dissipate the heat. Also it has the advantage of preventing too humid conditions during the night.

Duplicate air compressors are provided, one electrically driven and the other diesel driven as a standby. The electrically driven compressor is automatically controlled by a pressure switch to maintain the compressed-air cylinders at the correct pressure for engine starting, this system being used for all engines except the house sets which are electrically started from 24-V batteries. The chances of not being able to start the station through lack of starting systems are therefore remote.

STRUCTURAL CONSIDERATIONS

All the engine silencers are outside the power house and are supported by a structure independent of the building which tends to reduce noise. As mentioned earlier, fuel and water tanks are mounted on a self-supporting structure from the floor of the building, thus avoiding the building becoming complicated through incorporating brackets and fixtures for the engine ancillaries.

The crane which spans the power house and traverses its length is suitable for the heaviest lift required during maintenance. Its rails are, however, supported from the building structure as the height of the rail supports were readily ascertainable in the early stages of the design. The rail-support beams were thus made into useful structural members.

The house sets are mounted on fabricated bed-plates with anti-vibration mountings resting on the concrete floor of the power house. The 200- and 800-kW sets are mounted on concrete foundation blocks, which are carried by anti-vibration matting on a reinforced concrete raft extending under all the sets at a depth of approximately 6 ft and which is independent of the building foundations. This ensures the minimum of transference of vibration both between sets and to the buildings and in particular to the transmitter building. The alternators for the larger sets have single-pedestal sleeve bearings, the exciter armatures being overhung. The drive end of the alternators are solidly coupled to the engines. In the case of the house sets the alternators are flexibly coupled to the alternators which are equipped with ball/roller bearings, which are satisfactorily isolated

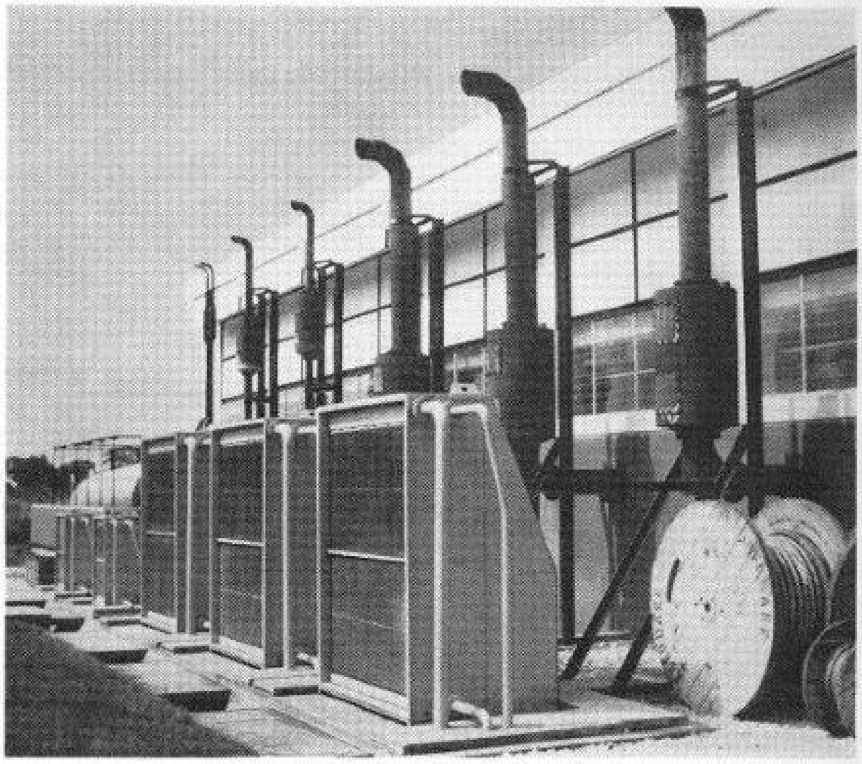

Fig. 2. The exhausts and cooling radiators for the two 200-kW and the three 800-kW sets at Ejura. The supporting structures are independent of the main building to simplify construction.

from excessive vibration by the resilient mount of the sets and the flexible coupling to the engine.

ELECTRICAL SYSTEM

The choice of generator voltage was carefully assessed to give the best economical and technical compromise.

The Ghana Broadcasting Corporation on a previous mains-fed station preferred a distribution voltage of 400.[1] The house sets would certainly have to be 400 V and the highest practical voltage for the 200-kW sets would have been 3·3 kV which would have involved stepping down to 400 V as required by the 10-kW transmitters. In a compact site layout and at 200 kW it was preferable to make these sets generate 400 V. This also simplified switchgear. The 800-kW sets could be 11 kV, 3·3 kV or 400 V. If mains came to the site, 3·3 kV is not now a standard voltage, and after detailed costing a satisfactory technical performance was found to be possible at 400 V. A worth-while saving of over 11 kV was effected, bearing in mind the ease of interconnecting the various sizes of sets which would result and the simplified operation. Although this involved heavier cables than a higher voltage system, these still remained manageable by using single-core cables between the alternators and switchboard and two 3-core cables in parallel for the main h.t rectifier, which in any case conveniently takes two feeds.

No very special characteristics were required from the house sets and these were fitted with conventional rotating-field salient pole alternators, exciters and magnetic amplifier regulators, having a steady state accuracy of $\pm 2\frac{1}{2}\%$. Frequency tolerances, as determined by the engine governors, were $\pm 2\%$ under steady-state conditions.

The 200-kW generating sets used for the 10-kW transmitters were specified on the assumption that all transmitters could at times take a common programme, and therefore their mains load swings would coincide and produce relatively large fluctuations. Also, as a 250-kW transmitter constituted a large proportion of load on the 800-kW generating sets, the same general specification also applied. Briefly, in order to maintain the transmitters within acceptable performance, the voltage of the mains has to be maintained within a certain tolerance and, as the rate of change of load reflected back on the mains is only slightly less than the rate of change of modulation, it can be extremely rapid at times; so rapid in fact that no regulating system applied to machines of these sizes can completely follow it. Therefore, the inherent characteristics of the alternator must be chosen to limit the instantaneous voltage change sufficiently for the voltage regulating system to hold sustained changes within the requirements of the transmitter. In this connection consideration also has to be given to the voltage tolerance allowable on all valve filaments and the magnitude and duration permissible for momentary deviations. The sub-transient reactance of the alternator, which is one of the main parameters involved in transient performance, affects not only the transient but also the long-term regulation of any rectifier systems. In the case of the 800-kW generator sets a lower limit could not be exceeded for the sub-transient reactance, as this characteristic also determines the initial fault current produced by the machine. It seemed desirable, therefore, to keep the total fault current of the system within the fault-handling capacity of the available switchgear, without limiting the number of alternators which could be paralleled onto the bus-bars by an interlocking system.

It was found possible to choose a value of sub-transient reactance for the alternators with sufficient allowance for design and manufacturing tolerances to meet all requirements.

Following a rapid load change (due, for instance, to modulation), although the instantaneous system voltage change is determined as mentioned earlier by the sub-transient reactance, within a very short time 'secondary' effects take place and the voltage deviates still further if the changed loading conditions are maintained. If an automatic voltage-regulating system were not employed, this deviation could be considerable and, depending upon the alternator design and the nature and magnitude of the load, would level out in about 1 sec following approximately an exponential curve. It is therefore advantageous to initiate automatic correction as rapidly as possible and further improvement can be made by field (excitation) forcing.

On these particular alternators a number of established techniques were employed to minimize voltage changes. The alternators have laminated poles; the exciters have completely laminated fields; and time constants were reduced as much as practicable by increasing the R to L ratio. The exciters were designed to have a ceiling voltage of twice that of normal full load, and a fast-acting electronic automatic voltage regulator, capable of taking the exciter to the full ceiling voltage, was employed. The overall accuracy of the regulating system is better than $\pm 1\%$, and for 1% deviation outside these limits it is capable of giving full field forcing corresponding to exciter full ceiling voltage. The automatic regulator works as a

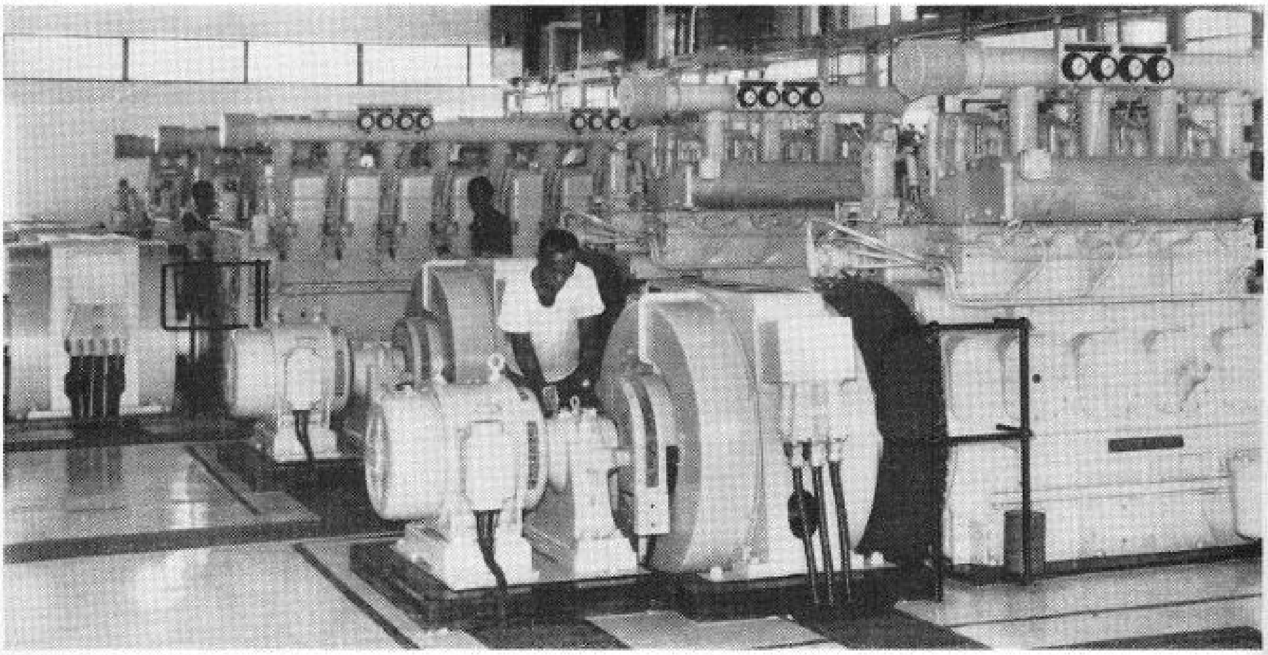

Fig. 3. The two 200-kW and the three 800-kW sets at Ejura. The two house sets are just out of the picture on the right. The header tanks, on independent supports, can be seen above the engines.

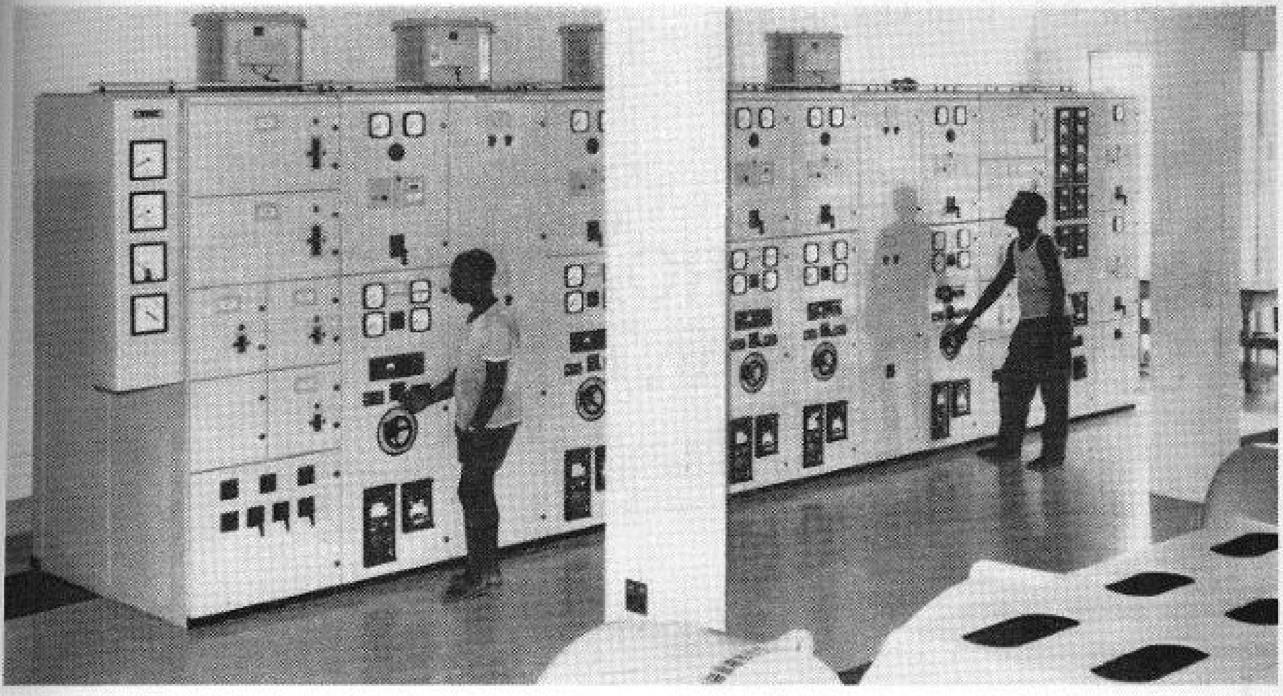

Fig. 4. The control board for the larger sets at Ejura.

closed-loop system, with rate of change feedback from the alternator field. In order to reduce the system voltage rapidly on rejection of load, the exciters are fitted with negative fields.

For the size and type of alternators it is thought that this must be amongst the fastest of systems of this type in service. This enabled higher reactance and hence smaller alternators to be employed than hitherto and still achieve close regulation under rapidly varying load conditions.

In connection with the modulation load it will be appreciated that this can produce difficulties in engine-governor stability. High-performance centrifugal sensing with a hydraulic servo-work output system is employed. The governor characteristics can be readily matched for parallel operation. It is also essential that the correct flywheel energy must be available in the system.

It is generally thought desirable during parallel operation of alternators to earth solidly the neutral of one only. This means additional switching operations and also the exercise of care to ensure that during single operation, or operation with the bus section open, a machine is earthed or that both systems are earthed. Apart from the safety aspect of earthing, from protection and domestic supply considerations, there is an additional danger should a breakdown occur between say the h.v rectifier system and the 400-V system (e.g. a rectifier transformer fault).

In this installation, however, by suitable design of the alternators to reduce triple harmonics to a very low order, it has been possible to parallel permanently all alternator neutrals via the neutral bus-bar in the switchboard, and this is earthed to the power system earth at one point only. Circulating currents between machines and through earth connections have been to all intents and purposes eliminated.

A comprehensive system of both electrical and engine protection is included giving audible and visible warning of abnormal conditions and where necessary initiating shut-down.

CONCLUSION

Great care is necessary in specifying generating equipment for high-quality broadcasting transmitters to ensure that their performance is not adversely affected when compared with operation from a substantial public supply; but when all reasonable measures have been taken, it is difficult to detect any significant deterioration.

REFERENCE

1 F. J. Sidebotham: Some Aspects in the Planning and Construction of a Large Short-wave Broadcasting Station; *Sound and Vision broadcasting*, Vol. 4, No. 1, Spring 1963.