

IN CONFIDENCE

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NATIONAL INSTITUTE FOR RESEARCH IN NUCLEAR SCIENCE

GENERAL PURPOSES COMMITTEE

7 GeV PROTON SYNCHROTRON
MAGNET POWER SUPPLY

The attached paper is being circulated before approval by the Project Committee. Any revision by them will be reported verbally to the General Purposes Committee.

7 GeV PROTON SYNCHROTRON.

Magnet Power Supply.

1. The Committee will recall that, after competitive tender to a detailed specification, a recommendation was made that the English Electric offer for the Rotary Machines for the Magnet Power Supply should be accepted. Accordingly the English Electric Company were given an instruction to proceed and approached the problem very vigorously, setting up a strong research and design team to work out the salient features of the machine design. After making a very detailed analysis of the complex torsional oscillation and stress problems, they concluded that it is not practical to evolve a satisfactory design for a 3000 r.p.m. motor-flywheel-alternator set. The fundamental difficulty is that the stresses in the shaft will exceed yield point if a line to line fault occurs. This criterion, although severe, is one which has to be satisfied for normal power supply plant, and is regarded as an essential one for the Magnet Power Supply.
2. In consequence of further research and design studies, the English Electric put forward two alternative propositions as follows:
 - 2.1 A single 120 Mva 3 phase 3000 r.p.m. turbo-alternator set driven by two induction motors, but having no flywheel.
 - 2.2 Two 3 phase 1000 r.p.m. motor-salient pole alternator-flywheel sets mechanically coupled with a phase displacement of $7\frac{1}{2}^\circ$ and driven by two induction motors.
3. Initially the proposition at 2.1 looked very attractive in that it was simpler, cheaper and could be manufactured to an existing design. A more detailed examination showed it was unsatisfactory for the following reasons:
 - 3.1 The system could not deliver the requisite energy to the magnet coil without a 10.5% speed drop.
 - 3.2 The above variation in speed would cause approximately 20% cyclic variation in centrifugal forces, in machine components already highly stressed.
 - 3.3 The system could provide no element of standby as achieved by two machines each of half the total capacity, as requested in our specification.
 - 3.4 The three phase output would necessitate a special transformer arrangement so as to achieve the 48 phase rectification specified.
 - 3.5 The frequency variation of the output of the alternator would introduce special problems for the manufacture of the converter equipment.
 - 3.6 It was found necessary to introduce hydrogen cooling and other modifications which, when added to the consequential costs on the Brown Boveri contract, materially reduced any financial benefit of the system. (See Appendix II).
4. In contrast to this the proposition 2.2, i.e. that of using 1000 r.p.m. machines, fulfills every detail of the initial specification. The fundamental advantage of the slow speed set over the 3000 r.p.m. set originally proposed is that it permits a much stiffer shaft to be used, and allows the rotor system to be designed so that its natural periods do not resonate with any of the periodic torques. Despite the technical superiority of the proposition, it was considered essential to examine in detail constructional points in regard to the salient pole alternator proposed, and Messrs. English Electric Company disclosed in detail much of their design practice to ensure that we should make a proper judgement of the two alternatives. Arising from these discussions it is proposed to manufacture the salient pole alternator with forged steel bodies integral with the shaft. The pole tips will be integral with the pole pieces which will be fastened to the body by means of dovetails, to which they are securely held by locked wedges. Ventilation will be by a closed air circuit and for reliability the fan blades are removed from the main shaft and externally driven. Both the English Electric Company and the Project Staff are confident that, with detail attention to locking and points of mechanical construction, a satisfactory machine can be produced.

5. The English Electric Company are now engaged in working out a detailed price for re-submission but have stated in a letter that the price will not exceed £490,000. Appendix II shows how this figure compares with the original cost of the English Electric 3000 r.p.m. proposal, to which must be added the essential extras and certain omissions in the original English Electric offer which were specified by us. It will be seen that the proposed scheme is £49,034 more than the sum provided by the Committee, but only £25,000 above the estimated final cost of the 3000 r.p.m. set originally offered. It should be borne in mind that the new machine will require much more drawing office work than the initial offer and this undoubtedly contributes materially to the increased cost.
6. A cost comparison has been made with that of the only other slow speed machine included in the original tenders. This machine was not offered separately, neither was its design satisfactory in some major respects. Using that machine, however, as a basis of comparison and allowing the figures shown in Appendix II to correct the unsatisfactory design features, it would appear that the English Electric offer is fair and reasonable.
7. Compatibility with the Brown Boveri Converter Plant.

We have discussed with Messrs. Brown Boveri the effect of the proposed change on the Converter equipment and we are assured that there is no incompatibility. It has, however, been necessary to hold up the design of the Rectifier Transformer and further hesitation may affect the delivery dates for the Converter gear.
8. Effect upon Delivery and Building Programme.

Messrs. English Electric, although forewarning us that delivery may be delayed by 3 months, have agreed to use every effort to meet the original date given, but forgings for the Rotor body are the deciding items and the completion dates will depend upon satisfactory procurement of these components.

The machine, being a new design, will involve extra design office work at Messrs. English Electric and in consequence there will be delay in the provision of the leading details required for the building programme. However, in collaboration with the New Works Group, Messrs. Merz and McLellan and Industrial Group, the programme has been recast so as to permit the building structure to go ahead and for the machine foundations to be completed later. There should, therefore, be no need to adjust the completion date for the Alternator House.
9. Building Dimensions.

A study has been made of the leading Dimensions of the Machine and English Electric have confirmed that the proposed plant can be accommodated in the building as designed and that no alteration is required to the structural steel work.
10. Crane Capacity.

The heaviest lift of the proposed plant will be the complete Alternator which weighs 130 tons. The hook height will remain unaltered. This lift is 10 tons heavier than the proposed crane capacity but there is no difficulty in amending the order and achieving the required delivery.
11. Financial Statement.

If the new proposal is approved the additional expenditure can still be met from the £1,100,000 estimated for the Power Supply Plant. The detailed expenditure on the two contracts placed is shown in Appendix II. There should be no accelerated expenditure if the new proposal is accepted.
12. Discussion.

Having reviewed all the relevant information and the programme relative to construction the Project Group are of the opinion that the English Electric offer is fair and reasonable, and that the effort directed to the complete study of the problem by English Electric has resulted in a more satisfactory solution of the problem. It is unlikely that anyone else could produce a more economical or more satisfactory solution; and to achieve the same result it would be necessary for any firm to expend some 4 - 6 months in making a

thorough design study of the problem. This delay would extend the final completion date of the machine as a whole by some 6 - 8 months since the alternators are the terminal items.

13. Approval is sought for:

1. The amendment of the English Electric contract so as to permit a financial expenditure not exceeding £490,000 for the 1000 r.p.m. set previously mentioned.
2. Acceptance of the English Electric offer knowing that there is some possibility of a 3 months delay in delivery.

A.E.R.E.
Building 412.
July, 1958.

P. Bowles.

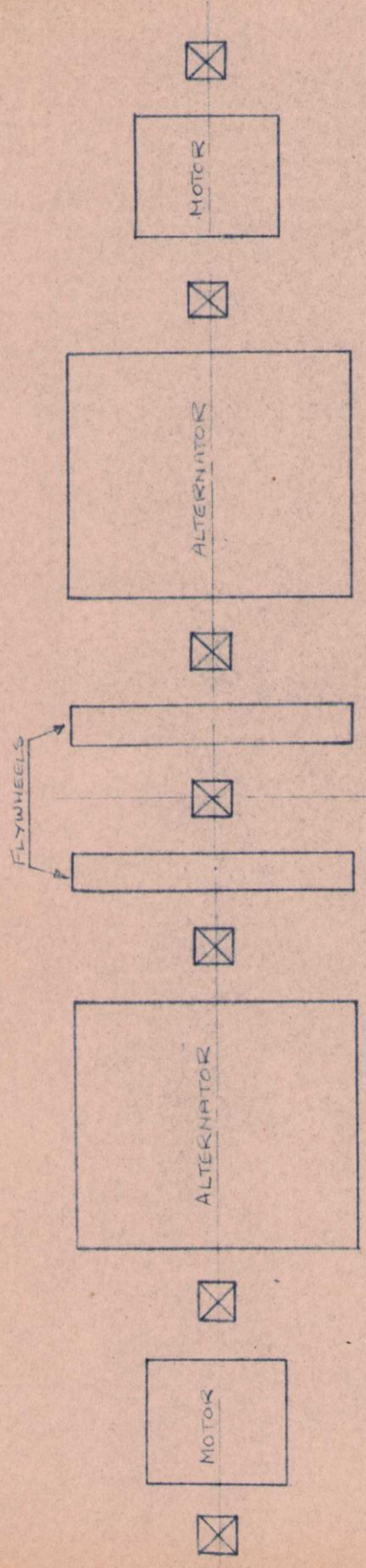


FIG 1 SCHEME FOR 1000 RPM SET

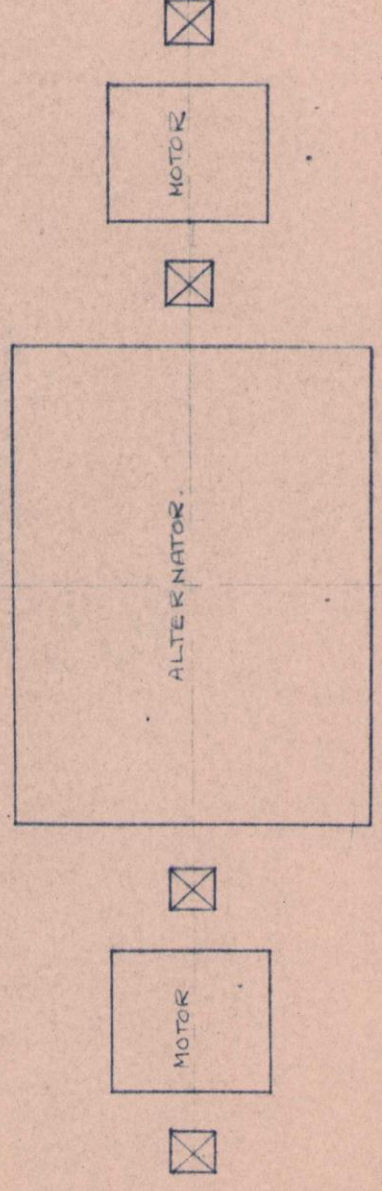


FIG 2 SCHEME FOR 3000 RPM SET

Financial Statement and Cost Comparison of Various Schemes.

GENERAL STATEMENT.

1.	Money included in Estimates for complete Magnet Power Supply	£1,100,000	
	<u>Estimated Expenditure.</u>		
	Converter Plant	British Brown Boveri Contract (including cables and installation)	£ 552,500
	Rotary Plant	English Electric Co. (new ceiling figure) (including installation)	490,000
		Concrete Foundation for Rotary Plant (approximate estimate)	15,000
		Cables and Busbars (Rotary Plant only)	20,000
			£1,075,500
		Transformer Base Rollers -- £1,600	} 24,500
		Cooling Water Pumps -- £3,000	
		Minor items awaiting final specification	
			£1,100,000

2. ROTARY PLANT QUOTATION INCLUDED IN BRITISH THOMSON-HOUSTON FULL TENDER.

2 - 1000 r.p.m.	Price	£459,000
salient pole-	This excluded: Part of supervisory equipment	4,000
alternator-	Apparatus for external cooling (est.)	4,000
motor sets		
with ancillary	<u>Allowance:</u> British Thomson-Houston cast steel rotor	
equipment	body English Electric forged steel	
	25 tons per sq. in. Y.P.	8,000
	Extra machining for forged rotor body	2,000
	Slow speed barring gear	2,000
		£179,000
	English Electric - Ceiling price includes	
	all above	£490,000

3. ROTARY PLANT QUOTATION RECEIVED INITIALLY FROM ENGLISH ELECTRIC CO. LTD.

2 - 3000 r.p.m.	English Electric quotation	£440,966
motor-turbo-	Supervisory equipment (excluded from tender)	9,900
alternator sets	Extra for Ni-Cr-Mo shafts (supplementary tender)	5,000
with flywheels		£455,866
and ancillaries		
	Anticipated Extras: Barring gear, flywheel	
	cooling	
	Total expected by English Electric to reach	£455,000

4. ALTERNATIVE SCHEME PROPOSED BY ENGLISH ELECTRIC CO. LTD.

3000 r.p.m.	Basic Price	£370,000
single set	Hydrogen cooling (extra to increase rating)	21,000
1 - 100 Mw	Externally driven fans	3,500
3000 r.p.m.	Consequential extras on Brown-Boveri Contract: (est)	
turbo-alternator	Transformer modification	} 8,000
set with two	Development work for large frequency range	
motors.	(rough estimate)	
No flywheel		£402,500
necessary.		

Spare Rotor for Standby if required £70,000
Spare 60 Mw set for Standby if required £136,000