IEEE Transactions on Nuclear Science, Vol. NS-28, No. 3, June 1981

PERFORMANCE OF THE MEA SOLID-STATE HIGH DUTY FACTOR MODULATOR

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Summary

The MEA 500 MeV electron linac is powered by 12 solid-state 10% duty factor line type modulators. Repetition rates up to 2000 Hz, pulse widths of 50 microsec. and RF peak power up to 4 M.W. at 2856 MHz have been obtained. Some of the modulators have been used for several thousands of hours, performance will be presented. Special attention will be given to the freon cooling system.

Introduction

November 1972 a 100 kW RF (av.power) prototype solidstate modulator became operational as a test facility.[1] On the basis of the testdata a new set of specifications and operating levels was written for the construction of the final series of 13 modulators (12 accelerator units and 1 test and repair facility). The first accelerator unit became operational late 1975. The basic concept[1] has not changed and consists of a high duty factor modulator constructed with a number of low duty factor modules. For economical reasons however the total number of modules, each consisting of two pulse forming networks (PFN), has been reduced from 24 to 20. For this reason only three RF peak power output levels are available regulated on a pulse to pulse basis with a 3% fine tuning. The details are listed in table 1.

Table 1: Modulator operating levels

Frequency	2856			MHz
RF peak power	1	2	4	MW
pulse width	50	50	50	µsec.
Cathode voltage	80	102	130	kV
Cathode current	44	63	91	A
Klystron imp.	1818	1619	1428	Ohm
Repetition rate	2000	1000	500	Hz
Duty-factor	10	5	2.5	%
Video peak power	3,5	6,4	11.8	MW
Transformer ratio	1:11	1:8	1:11	
Number of modules	9	16	15	
PFN units per mod.	1	1	2	
PFN line voltage	1828	1845	1842	V
Prim. pulse curr.	484	504	1001	A
PFN imp.	2.08	2.08	2.08	Ohm
PFN rep.rate av.	512	426	398	Hz
PFN rep.rate max.	625	625	625	Hz
Flat top ripple	0.1	0.1	0.1	%
Droop of flat top	+0.5	0	-0.5	%

Number of PFN units per modulator 40

Cooling : klystron : water, transformer: oil, PFN'S : freon } in combination with air coolers

Controls : A programmable special purpose processor in combination with a minicomputer.

Power supp: Two unregulated 1000V/3000A DC power supplies.

Circuit description

Each modulator consists of 20 modules, each containing 2 PFN units (fig. 1 and 2).

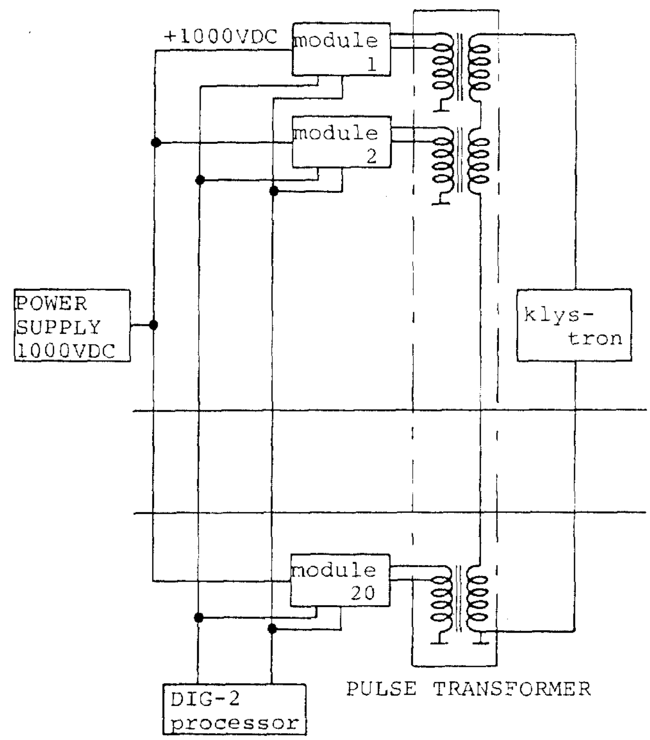

FIG. 1. MODULATOR SCHEMATIC DIAGRAM.

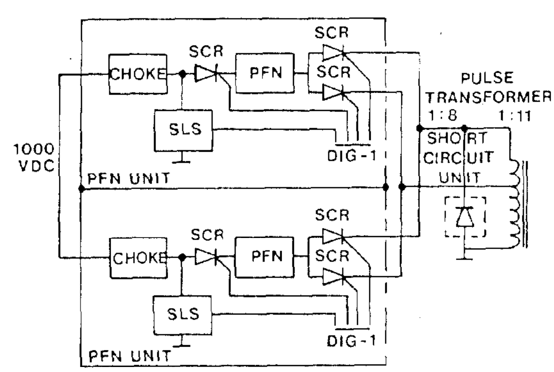

FIG. 2. MODULE DIAGRAM

Each module feeds a primary winding of a special summing pulse transformer. By seclection of the number of modules, the number of PFN units per module and the transformer step up ratio, the video power output can be varied according to the requirements as listed in table 1. Optimum use of all the available PFN units is made by a cyclic pulsing scheme. Two spare modules have been incorporated in the design. Considerable redundancy has been obtained in this manner, since the loss of one or more PFN-units implies at most the

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the reduction of the duty cycle and not the klystron RF peak power (table 2).

Table 2: Redundancy of PFN's per modulator

klystron RF output peak power MW		1	2	4
Repetiton rate (max)		2500	1250	625
PFN's required		9	16	30
Number of redundant modules at:				
rep.rate (50 μsec. pulse length)				
625	d.f. 3.1%	31	24	10
1250	d.f. 6.2%	22	8	*
1875	d.f. 9.3%	13	*	*
2500	d.f. 12.5%	4	*	*

* not applicable, exceeds max. allowed rep. rate.

The recovery time of the switching devices limits the repetition rate of line type pulsers. High modulator repetition rate (2000 p.p.s.) is obtained by sequentially switching low (625 p.p.s.) repetition rate PFN units. The schematic diagram of a PFN unit is given in fig. 3.

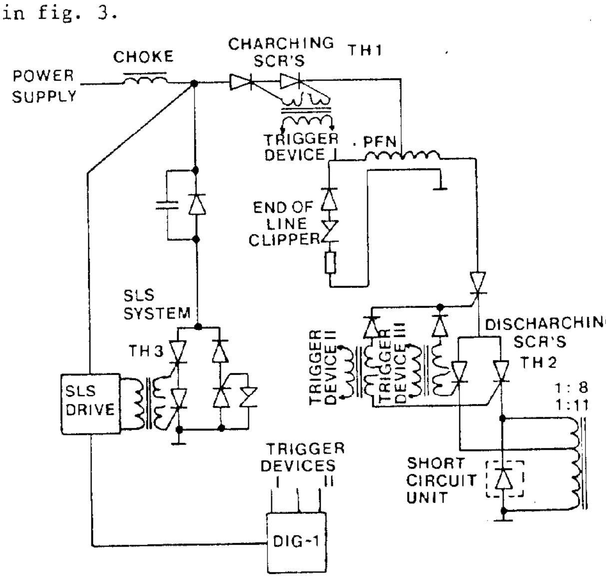

FIG. 3. PFN-UNIT CIRCUIT DIAGRAM.

A pulse forming network is charged to appros. 2000V by means of a charging circuit from the external 1000 V unregulated DC power supply. Triggering the discharge SCR's discharges the line with a 1000V 500A pulse into the pulse transformer.

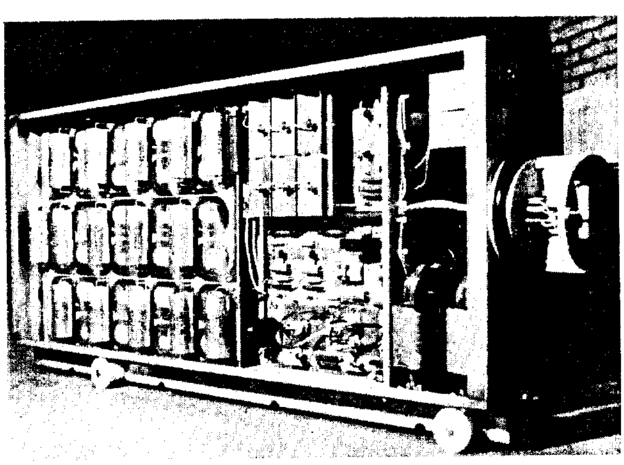

fig.4 The actual PFN unit

Performance

In July 1980 the construction of the thirteen modulators had been completed. At this moment eight modulators are in continuous operation. Another five will become operational during 1981. The performance will be presented in table 3.

Table 3: Modulator performance

		design	obtained	
RF pulse width		50	50	μsec
0.1% flat top pulse width		50	45*	μsec
1% flat top pulse width		50	50	μsec
Pulse to pulse basis stab.		0.1	0.1	%
Long term stability		0.1	0.1	%
Repetition rate at:				
1 MW RF(peak power)	df 10%	2000	2000	Hz
2 MW "	df 5%	1000	1000	Hz
4 MW "	df 2.5%	500	300	Hz

*Due to unexpected behaviour of the pulse transformer. It will be necessary to retune the PFN units and to compensate the pulse transformer with a special network.

Freon cooling

System description. High duty factor modulators require complex cooling systems. With the high power solid state components employed, conventional air or oil cooling systems are difficult to realize. Therefore an insulating cooling liquid, Freon 113, has been used, where the Freon is directly sprayed on the electronic components. Boiling heat transfer limits hot spot temperatures to approximately 45 degrees Centigrade. Temperature regulation of the pulse forming networks is now easily obtained.
Fig. 5 represents a block diagram of the freon system.

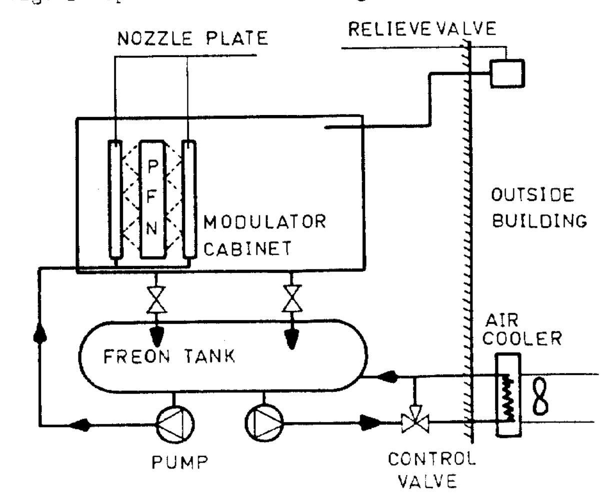

FIG. 5 BLOCK DIAGRAM OF FREON COOLING

The PFN units have been located in two stainless steel cabinets per modulator. (only one cabinet is shown in the block diagram) These cabinets support maximum over and underpressure of $3x10^4$Pa. Relief valves are set to approximately $6x10^3$Pa. Underneath each cabinet a storage tank has been installed which containes approximately 500 l of freon. From these tanks the liquid is pumped into the PFN cabinets and is sprayed on the PFN units by special nozzles. After transferring the heat, the liquid flows back to the storage tanks. A second pump transfers the freon through a forced air cooler. By means of control valves, heaters and control of the airflow the average freon temperature in the cabinets is stabilised to approximately 37°C.

System performance. The system operates very well. Experience obtained untill now has resulted in cooling capacities up to $13W/cm^2$. Contrary to manufactures specifications many components were not freon resistant Freon resistance is very important because freon is not consequently intert. Great care had to be taken to the choice of components related to the appliance of elastomers because freon 113 dissolves the softeners of these materials and changes in this way the structure. Relating to the electric and electronic components, we have been succesfull to obtain a set of resistant components. On the mechanical side however, the seals wtill cause freon leakage. More research will have to be done on the application of materials.

Acknowledgement

We gratefully acknowledge the valuable contributions of the members of the various departments. The work described in this paper is part of the research program of the National Institute for Nuclear and High Energy Physics, section Nuclear Physics (NIKHEF-K), made possible by financial support from the Foundation for Fundamental Research on Matter F.O.M.) and the Netherlands Organization for the Advancement of Pure Research (Z.W.O.).

References

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An all solid-state line-type modulator for 10% duty factor.