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APPLICATION OF THYRISTORS IN THE PAPER INDUSTRY

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I. INTRODUCTION

Dc motors are employed in paper mills for paper machines and finishing machines. The paper machine operates for 24 hours a day so that drive equipment which is both highly accurate and efficient as well as easy to maintain is essential. Static Leonard systems are used for this purpose. Formerly they contained mercury rectifiers but at present the majority employ thyristors. The finishing machines formerly employed M-G Leonard systems, but these are gradually being replaced by thyristors.

II. APPLICATIONS OF PAPER MACHINE DRIVE EQUIPMENT

There are two types of paper machine drive systems : the line shaft drive system (single motor system) and the sectional drive system (many-motor system). The line shaft system contains one main conductor shaft (known as the line shaft) and this is driven by a single motor. All parts are driven from this shaft via a mechanical continuous speed change gear and a clutch (refer to *Fig. 1*). A list of this type of equipment supplied by Fuji Electric is shown in *Table 1*. A skeleton diagram for typical large

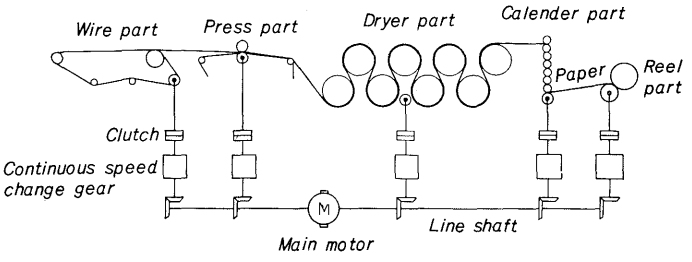

Fig. 1 Line shaft drive

Table 1 **Supply List of Thyristor Leonard Sets for Paper Machine Line Shaft Drive**

No.	Delivery Date	Customer	Machine		Use	Thyristor Rated Output (kw)	Rated Voltage (v)	Control
			Wire width (mm)	Speed (m/min)				
1	Nov. 1966	Jujo Paper Mfg. Co. (Yatsushiro)	2740	360	Line shaft	380	600	Speed control
					Wire helper	43	220	Current control
					Press helper	88	220	Current control
					Size press helper	4	110	Voltage control
2	Nov. 1966	Jujo Paper Mfg. Co. (Yatsushiro)	2740	300	Line shaft	380	600	Speed control
					Wire helper	43	220	Current control
					Press helper	88	220	Current control
					Size press helper	4	110	Voltage control
3	July 1967	Kasuga Seishi Kogyo Co.			Line shaft	94	260	Speed control
4	July 1969	Chuetsu Pulp Industry Co. (Fushiki)			Wire helper	35	220	Current control
5	May 1969	Chuetsu Pulp Industry Co. (Sendai)			Line shaft	495	440	Speed control
					Wire helper	69	220	Current control
					Press helper	24	220	Current control
6	June 1969	Chuetsu Pulp Industry Co. (Sendai)			Line shaft helper	155	440	Current control
					Wire helper	53	220	Current control
7	June 1969	Kasuga Seishi Kogyo Co.			Line shaft	100	260	Speed control
8	July 1969	Kasuga Seishi Kogyo Co.			Line shaft	94	260	Speed control

Table 2 **Supply List of Thyritor Leonard Set for Paper Machine Sectional Drive**

No.	Delivery Date	Customer	Machine			Use	Thyristor Rated Output (kw)	Rated Voltage (v)
			Wire width (mm)	Speed (m/min)	Kind of paper			
1	July 1968	Tonami Paper Mfg. Co. (Futatsuka)	3710	760	Newspaper	Wire	326	440
						No. 1 press	313	440
						No. 3 press	137	440
						No. 1 dryer	110	440
						No. 2 dryer	163	440
						No. 3 dryer	163	440
						Breaker stack	59	440
						No. 4 dryer	110	440
						Calender	137	440
						Reel	56	440
2	Dec. 1968	Kitanihon Seishi Co. (Ebetsu)	3780	550	Various kinds	Wire	272	440
						No. 1 press	272	440
						No. 3 press	153	440
						No. 1 dryer	62	440
						No. 2 dryer	62	440
						No. 3 dryer	113	440
						Size press	55	440
						No. 4 dryer	100	440
						No. 1 Calender	134	440
						No. 2 Calender	134	440
						Reel	40	440
3	1969	Jujo Paper Mfg. Co. (Ishinomaki)	6000	650	Middle & low class	Wire	527	440
						No. 1 press	425	440
						No. 3 press	243	440
						No. 1 dryer	89	440
						No. 2 dryer	133	440
						No. 3 dryers	133	440
						Breaker stack	75	440
						No. 4 dryer	133	440
						No. 1 Calender	240	440
						No. 2 Calender	240	440
						Reel	93	440
4	1969	Jujo Paper Mfg. Co. (Nakoso)	3800	450	Special	Wire	272	440
						No. 1 press	131	440
						No. 2 press	87	440
						No. 1 dryer	44	440
						No. 2 dryer	44	440
						No. 3 dryer	44	440
						No. 4 dryer	44	440
						Pre calender	87	440
						Coater	138	440
						Coater helper	25	440
						Coater helper	25	440
						No. 5 dryer	92	440
						Calender	133	440
						Reel	27	440

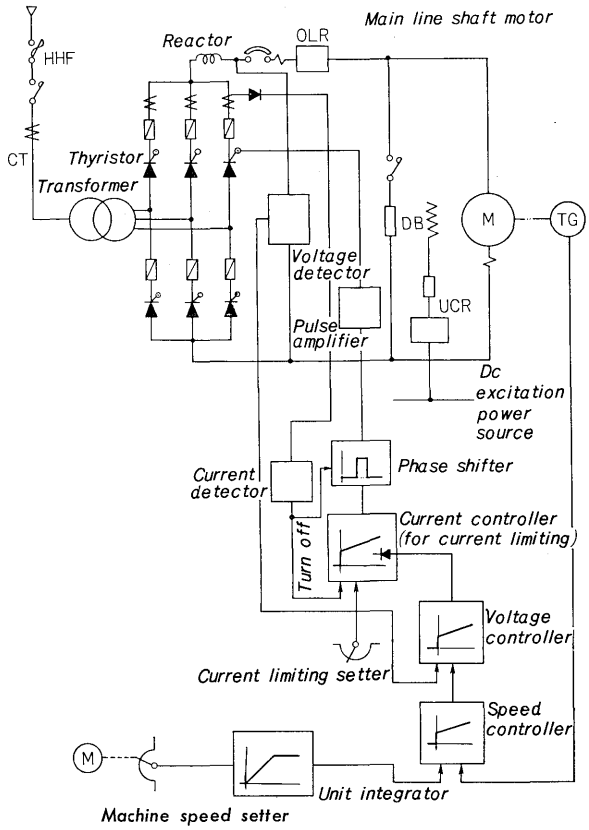

Fig. 2 Skeleton diagram of line shaft drive

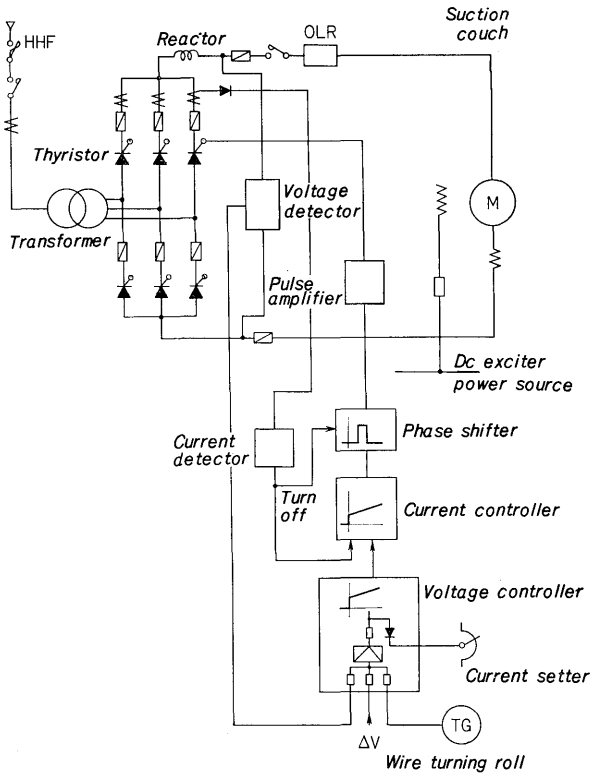

Fig. 3 Skeleton diagram of wire part helper motor

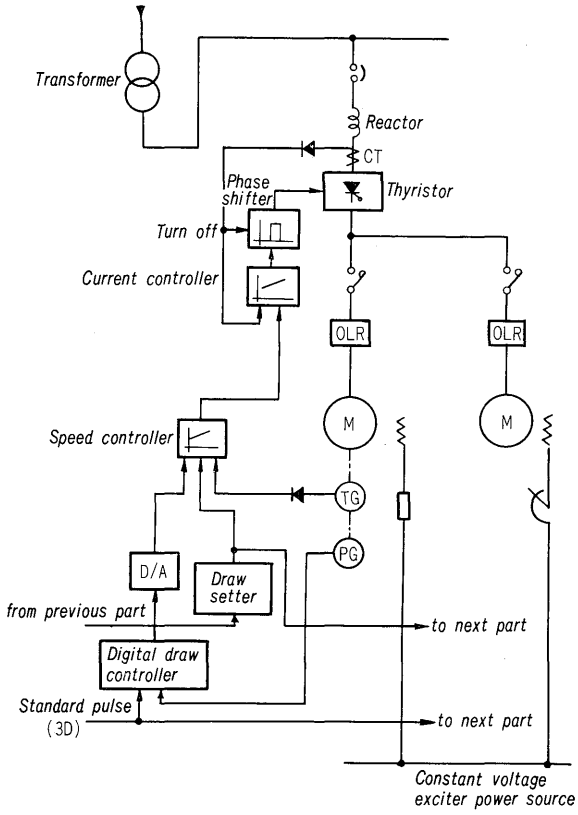

Fig. 4 Skeleton diagram of sectional drive

capacity equipment is shown in *Fig. 2*. The motor load is mainly the friction torque of the machine and since no rapid speed reductions are required, the thyristors can be in the forward direction. Automatic speed control is performed by means of cascade control and a voltage regulation loop is arranged in the speed control loop. In line shaft equipment, once the line shaft speed has been increased to the operating speed, the clutch in each part is closed. For this reason, current limit circuits are provided. In addition to the main motor for line shaft drive, a helper motor is often provided. *Fig. 3* is a skeleton diagram of a wire part helper motor. By controlling the armature current at a constant value, a contstant torque is produced. Even when the motor load torque falls below the set value due to roll slippage, the motor will not exceed its specified speed and when the motor load is decreased, there is automatic switching from the current control line to the voltage control line.

For paper machines with higher speeds, sectional drive is used. The sectional drive equipment produced by Fuji Electric is listed in *Table 2*. A skeleton diagram for one part of the sectional drive system is shown in *Fig. 4*. Thyristors can be employed in the sequence. A thyristor converter is provided for each part and the speed of each part is controlled by the Leonard system. The rectifier and transformer are in a single unit and ac reactors to prevent mutual interference are provided in all parts. The specified speed is controlled by an analog system and when very high accuracy is required, a digital type draw controller (scanning type) is provided. For analog speed control, a current control loop is provided in the main speed control loop. Because of the drooping

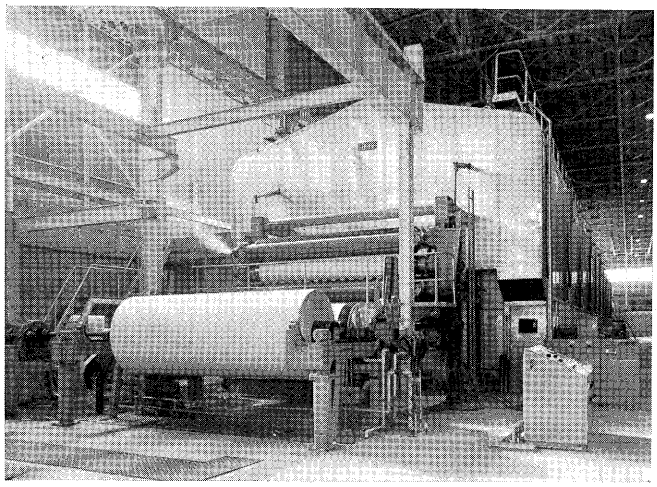

Fig. 5 General view of paper machine

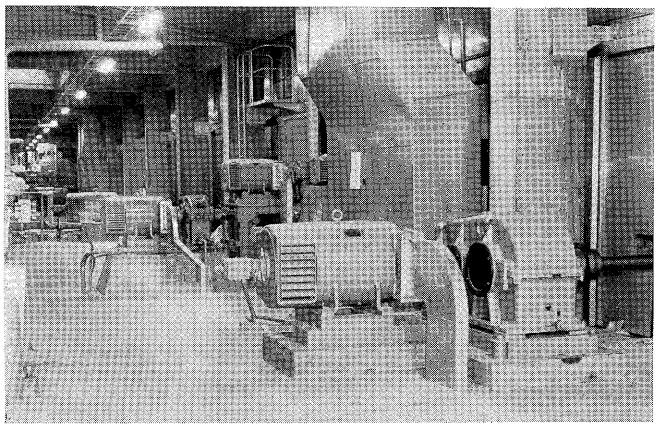

Fig. 6 View of dc section motors

characteristics in the helper motor, it is connected to the same dc source as that of the main motor of the part in question. *Fig. 5* shows a general view of the paper machine and *Fig. 6* shows a group of dc section motors.

III. APPLICATIONS OF FINISHING MACHINERY DRIVE EQUIPMENT

A dc motor is provided in the rewinder used for rewinding when the slit operates and in the super calender used for glossing the paper manufactured by the paper machine. As was mentioned previously, the M-G Leonard system is still used in most cases for reasons of economy, but it is now technically possible to change to the thyristor-Leonard system and this system will probably replace the M-G type in the near future.

The super calender is as shown in *Fig. 7*. In many cases, the drive equipment drives both the main unit and the winding section with a single motor, but in large capacity equipment, individual motors are usually provided. The motor output in large scale main units is around 300～500 kw while that of the winding motor is about 30～50 kw. Speed control is employed for the main unit and the winding section

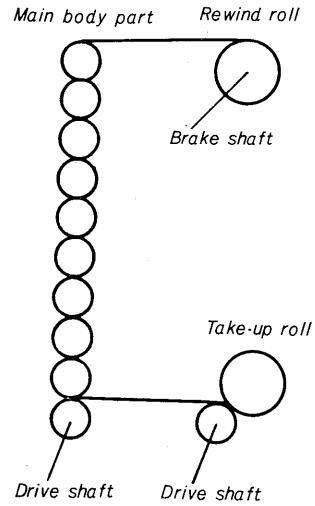

Fig. 7 Supper calendar

requires speed control in the case of surface drive or current control in the case of center drive. The super calender differs from the paper machine in that it is essential to reduce the load torque. Starting, stopping and speed changes also occur very often and high speed stopping is required when the paper is broken. The load of the main unit drive equipment decreases considerably since pressure to the roll is cut off when the paper is broken and it is necessary that rapid stops be executed within 6～8 seconds. In many cases, dynamic braking is not sufficient since the braking torque decreases in proportion to the motor speed. It is also often impossible to employ machanical brakes due to space limitations. In such cases, it is necessary to perform rapid stopping by means of regenerative braking. When the thyristor Leonard system is used, regenerative braking can be carried out in three ways: (1) using an inverter, (2) performing armature switching or (3) performing field switching. In the super calender main part, either (2) or (3) can be

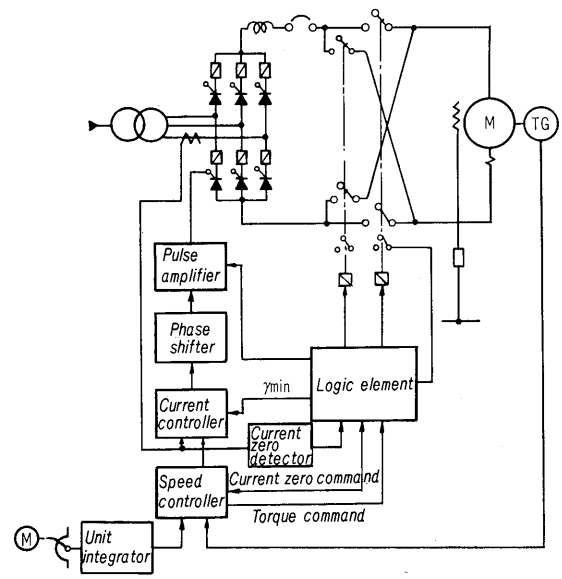

Fig. 8 Skeleton diagram of super calender main part

Table 3 **Supply List of Thyristor Leonard Sets for Finishing Machine**

No.	Delivery Date	Customer	Machine		Use	Thyristot Rated Output (kw)	Rated Voltage (v)	Cotrol
			Roll width (mm)	Speed (m/min)				
1	June 1968	Honshu Paper Mfg. Co. (Iwabuchi)	3360	1000	Rewinder	51	220	Speed control
2	Sep. 1968	Fuji Photo Film Co. (Odawara)	1200	180	Super calender	73	200	Speed control
3	Nov. 1968	Honshu Paper Mfg. Co. (Nakatsu)	1400	250	Super calender	165	440	Speed control
4	Dec. 1968	Mori Shigyo Co. (Hirakata)		150	Corrugate Machine	26	220	Voltage control
						40	220	Voltagel control
						67	220	Voltage control
5	1970	Honshu Paper Mfg. Co. (Fuji)	3350	1800	Rewinder	125 (Anti-parallel)	440	Voltage control (Circulating current-free)

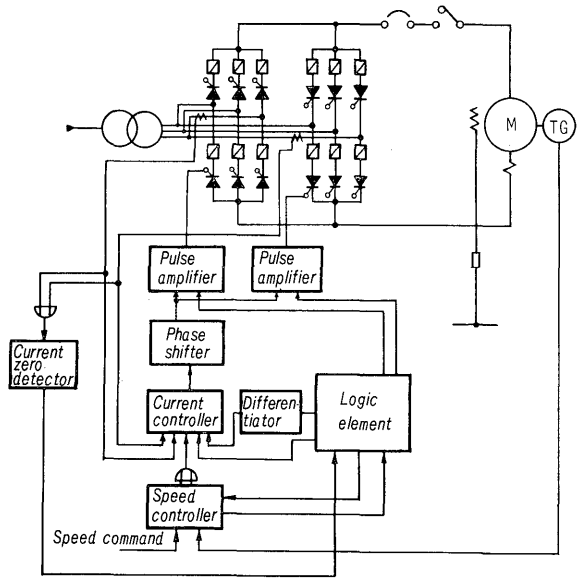

Fig. 9 Skeleton diagram of super calender winding part

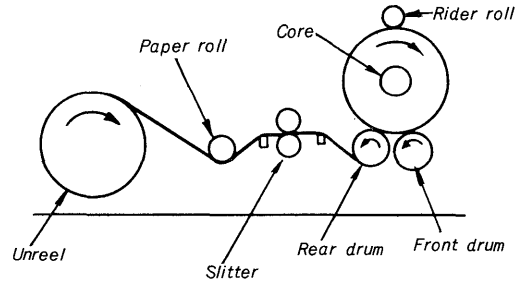

Fig. 10 Rewinder

used. *Fig. 8* is a skeleton diagram of a super calender using (2). In the winding section drive equipment, the motor load current decreases when the tension on the paper is low. Under such conditions, it is necessary that the armature current flow in the reverse direction even when usual speed reduction (speed reduction time : 40～50 sec.) is performed. With ordinary speed reduction, the paper is connected between the winding section and the main unit. It is therefore essential that current direction switching must be smooth, which means that method (1) must be used. The system used is anti-parallel circulating current-free control. *Fig. 9* is a skeleton diagram of this part.

In all the large capacity equipment delivered up to the present, M-G Leonard systems have been used for reasons of economy. Medium and small capacity equipment have used thyristor Leonard systems as can be seen from *Table 3*, but in all these systems, dynamic breaking was employed for rapid stops.

The rewinder is as shown in *Fig. 10*. The two rolling drums are driven by either one or two motors. The rewinder must undergo even more frequent startings, stoppages and speed changes than the super calender. In many cases, it is necessary to provide an inverter in the thyristor unit for use during usual speed reductions. Most of the equipment delivered up to now employs the M-G Leonard system. The first equipment in *Table 3* does not contain an inverter. The current is kept flowing during usual speed reduction by means of a parallel resistor (slow-down resistor). In the fifth equipment in *Table 3* an inverter is used and control is effected by the anti-parallel circulating current-free system.

The drive equipment in corrugating machines used for making corrugated cardboard has the same load characteristics as those of the paper machine and therefore the thyristor Leonard system can be used throughout.

IV. CONCLUSION

This article has described the application of thyristors in paper machinery. In order to expand the use of thyristor Leonard systems in super calender and rewinder equipment where regenerative power is essential, it is necessary to produce thyristors and their control equipment much more cheaply. Considerable work is being done on this problem at present.