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APPLICATION OF THYRISTORS IN THE MINING INDUSTRY

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I. INTRODUCTION

In the mining industry, the transport systems such as conveyors and winding plants are the most important and typical ones in the many methods of motor-application systems. In the last few years, the transport efficiency has been improved to minimize the personnel costs and almost all of this type of equipment is being automated. Especially, it has been requested that the complete automation and powering for the important mining machines used within the mine galleries are realized.

The environment in mine galleries is usually very bad due to high temperatures and humidity, dust, corrosive and explosive gases (mine gas), as well as a high degree of acidity and alkalinity in the cooling water and damages due to certain organisms such as iron bacteria. In the deeper area of the mine galleries, the power conditions become limited, heavy operation is necessary under strict voltage regulation and moreover good control characteristics are needed. It is often essential that operation remain stable even when the main power source is interrupted.

Because of these adverse conditions, Fuji Electric decided that thyristors would be appropriate for mine shaft equipment. This article will introduce vertical shaft elevators employing thyristor Leonard control, ac shaft winding equipment with thyristor dynamic braking control and electrical brake control of large conveyors by means of a thyristor chopper controller. It will give examples of practical applications which made possible the solution of certain problems, as well as equipment still in the planning stage.

II. APPLICATION TO MINE SHAFT ELEVATOR

" The mine shaft elevator " referred to in this case is the completely automatic mine shaft elevator system developed by Fuji Electric. It is for use in vertical mine shafts with a high lift and many levels (horizontal galleries). It provides fast, smooth transport of men and materials in accordance with recorded signals and requires no personnel. The aim of this equipment differs from that of main shaft winding where large scale repeated transport is necessary, This equipment has been planned to perform transport at irregular intervals in accordance with calls from one or other of the levels and is therfore used in auxiliary shafts, especially blind shafts.

The equipment delivered to the Kamaishi Mine of the Nittetsu Mining Co., Ltd. was installed in a blind shaft 210 m deep (310 m in the future) with 5 levels (7 in the future) at intervals of 50 m. It was intended especially for men riding. This shaft is always full of nitrous acid gas which arises due to excavation blasting and because of the high temperatures present, iron bacteria thrive. Therefore, ordinary electrical equipment would corrode quickly and soon break down. The possibility of any accidents in the men-riding elevator due to these bad conditions must be eliminated, maintenance must also be unnecessary, constant acceleration and deceleration must be possible using automatic rapid-response control no matter what the load, and passenger comfort must be maintained. In order to meet all these conditions, the drive system in this elevator employed a thyristor Leonard system constructed as follows.

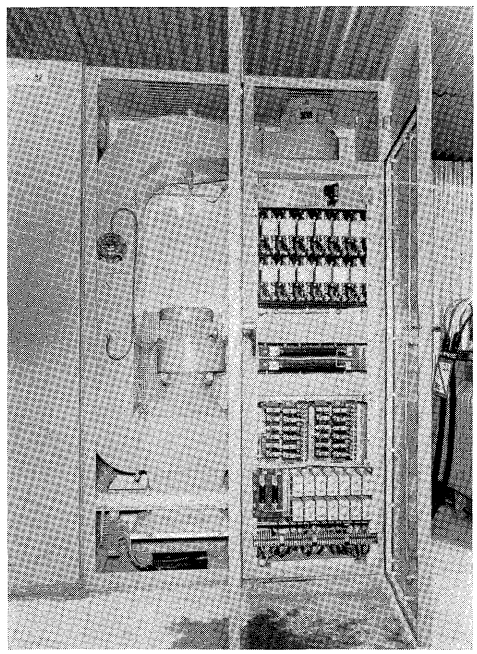


Fig. 1 Completely enclosed thyristor cubicle with air to air radiator

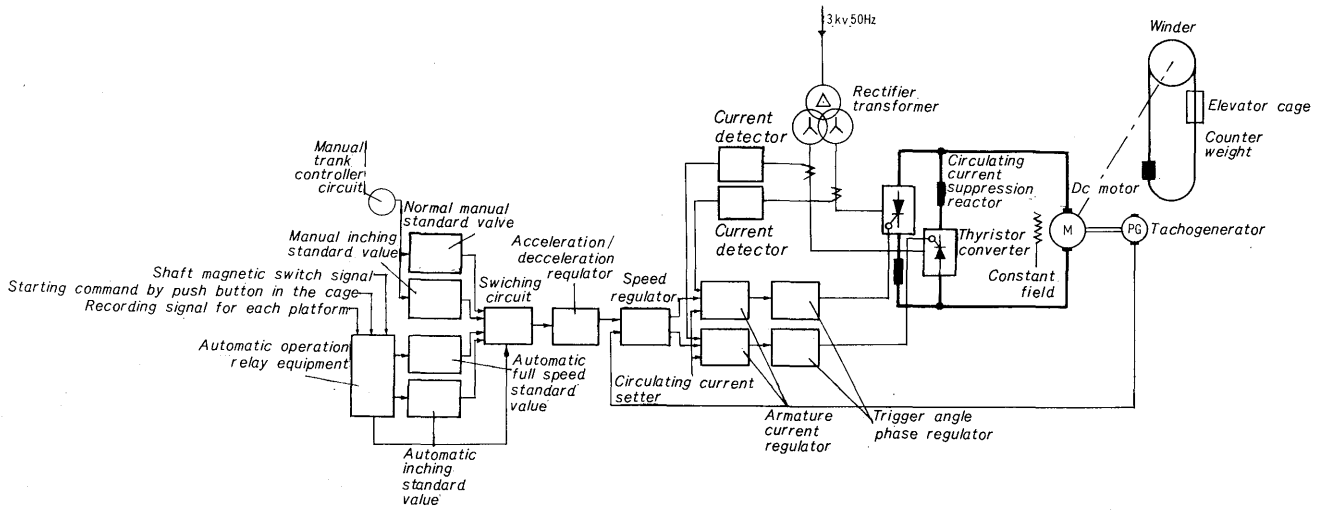


Fig. 2 **Block diagram of automatic control circuit**

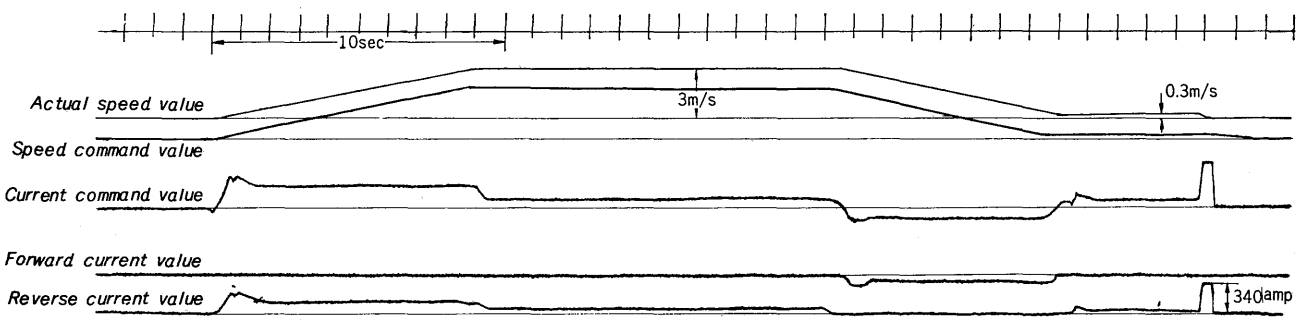


Fig. 3 **Oscillogram for automatic operation**

Winding motor : Drip-proof, self-ventilated separate-shunt dc motor with corrosion proofing
60 kw continuous rating, dc 220 v 750 rpm
Control source : completely-enclosed, inner circulation cooling-type thyristor converter cubicle
Connections : 3-phase bridge connection, cross connected double converter
Output dc 220 v 550 amp continuous rating

This thyristor converter is compactly installed in a completely enclosed cubicle and special internal air circulation piping provided so that the equipment is completely cut off from the outside air. This piping contains air-to-air cooling system made of corrosion resistant materials, and the inner air which is cooled by the external air (but completely isolated form it) is force circulated. Thus an indirect heat conversion system is used to cool the thyristor elements so that highly stable operation can be maintained with no adverse effects due to the bad atmospheric conditions. *Fig 1.* shows an internal view of this thyristor converter cubicle.

A block diagram of the automatic control circuit used in this thyristor Leonard system is shown in *Fig. 2.* After Fuji Electric standard armature current minor loop control, automatic speed control is performed. An oscillogram of automatic operation using this equipment is shown in *Fig. 3.*

III. APPLICATION TO AC VERTICAL SHAFT WINDER

In general, winding machines require stable inching operation and smooth acceleration/deceleration control no matter what the load. Dc winders can be greatly facilitated by employing the basic characteristics of Leonard control. However, in ac winders, the torque speed characteristics of induction motors are not normally encountered and therefore various control systems had to be considered. From these considerations, Fuji Electric have developed a low frequency control system of proven excellence on the basis of their wide experience in this field. This system is highly appropriate for automatic ac winding control and has operating characteristics which are just as good as those obtained with dc Leonard control. However, in the most recent blind shaft ac winding equipment completed by Fuji Electric for the Honbetsu Mine of the Sumitomo Mining Co., Ltd., all of the equipment had to be of explosion-proof construction but pressure-resistant explosion proofing of the ac commutator type low frequency generator as the low frequency power source was considered to be both impractical and uneconomical due to problems of commutator maintenance and the adverse effects of carbon dust. Therefore various investigations were carried out and dc dynamic braking

control containing thyristors was employed for the following reasons.

1) The dynamic braking source is required only operation at the rectifier zone, but not at the inverter zone, so that the control equipment is very simplified and thus more economical.

2) In the dynamic braking dc source, the output voltage is generally low and therefore the equipment can be of comparatively low capacity. For this reason, standard self-cooled thyristors with continuous ratings which are most suitable for explosion-proof construction can be appricable.

3) Not only can the same basic system as with the low frequency control be used, but smoother braking control is also possible because of the stepless rapid-response thyristor characteristics.

The specifications of this recently completed winder with dynamic braking dc source is as follows.

Winding motor :

Safety-increased explosion-proof construction, drip-proof self-ventilation type, wound-rotor induction motor.

500 kw continuous, 3000 v 50 Hz 8 P 750 rpm

Braking source : Pressure-resisting explosion-proof self-cooled thyristor converter

Connection : 3-phase bridge connection

Input : ac 3ϕ 90 v 50 Hz

Output : dc 120 v 250 amp continuous rating

The thyristor converter is arranged in the pressure-resisting explosion-proof box in such a way as to achieve optimum self cooling. *Fig. 4* is an external and internal view of this type of pressure resisting explosion-proof thyristor converter box.

A block diagram of the thyristor-DB controlled ac winder is shown in *Fig. 5*. This system employs

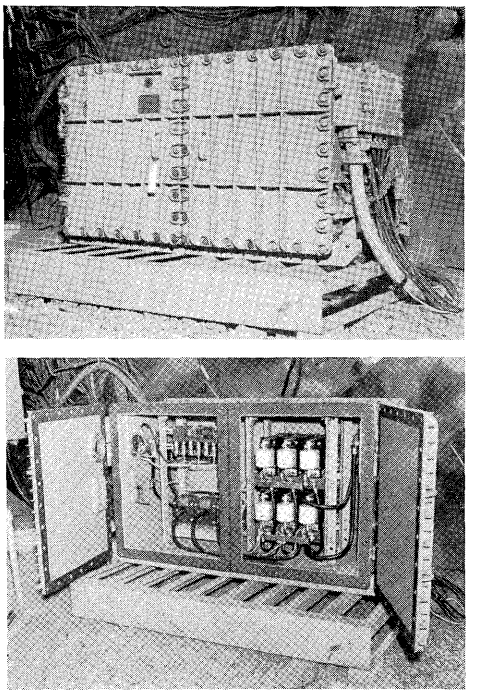


Fig. 4 Pressure resisting explosion-proof thyristor converter box

the same principles as used in the analog-type low frequency control system also developed by Fuji Electric, but the load capacities differ for men and materials winding. For men winding, braking operation during deceleration is essential and control with a view to passenger comfort is effected by a deceleralion speed prescribed by means of stepless thyristor speed adjustment in the braking control zone. For materials winding, constant braking current control with several steps is performed in accordance with

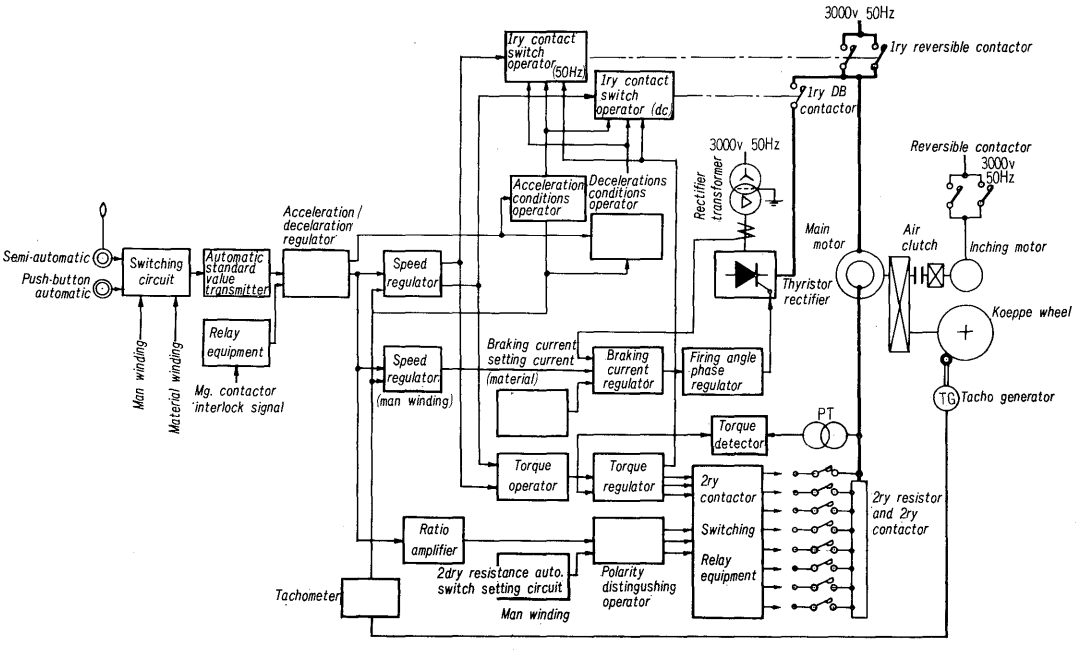


Fig. 5 Block diagram of thyristor-DB controlled ac winder

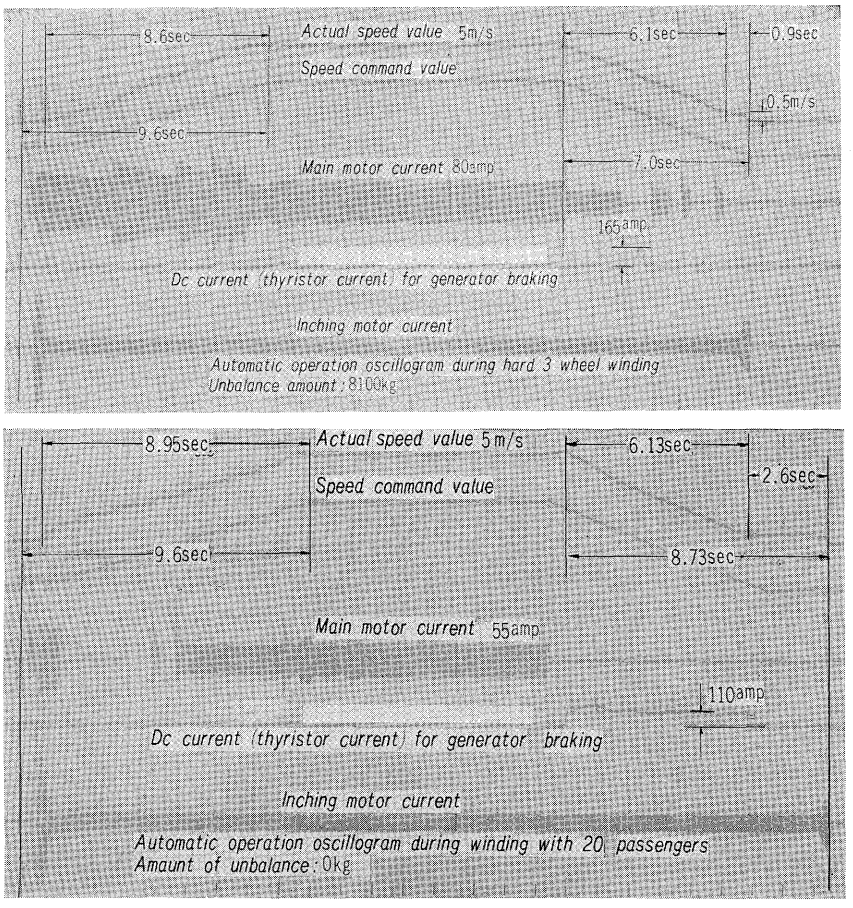
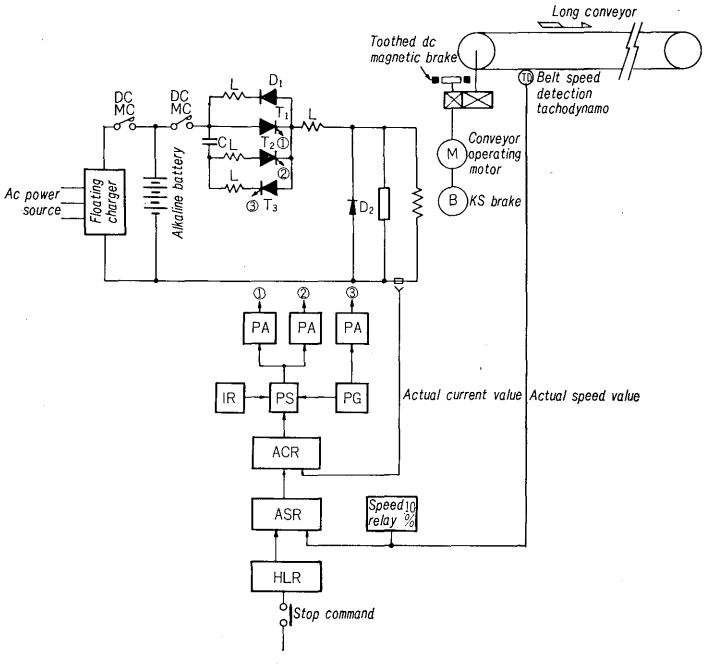


Fig. 6 **Oscillogram for man winding (upper) and materials winding (lower)**

the winder speed by the thyristor converter acting as a semi-stationary rectifier in respect to the load capacity conditions over a wide range of motoring and braking. The speed control is primarily switched by an analog operator essentially the same as that used in the low frequency control system. Smooth automatic acceleration/deceleration control covering the whole range can be achieved by secondary contact switching using the torque control line. *Fig. 6* shows oscillograms of automatic operation using this system.



T_1: Main thyristor
T_2: Turn-off thyristor
T_3: Aux. thyristor
D_1: Aux. diode
D_2: Commutation diode
PA: Pulse amplifier
PS: Phase regulator
PG: Pulse generator
IR: Initial reset
ACR: Current regulator
ASR: Speed regulator
HLR: Deceleration signal generator
L: Reactor
C: Capacitor

Fig. 7 **Block diagram of conveyor brake control by thyristor chopper**

IV. APPLICATION IN MINING BELT CONVEYORS

In recent years, mine belt conveyors have become faster and longer, and their control and protection equipment has also come to differ from that used for ordinary conveyors.

Fuji Electric recently received an order from the Nittetsu Mining Co. for electrical equipment to be used in a long conveyor for its Torigatayama mine. This equipment is to consist of 8 conveyors connected to make a total distance of 24 km. This will be the largest of its kind in Japan with a maximum conveying capacity of 1800 t/hr and a belt speed of 260 m/min.

The length and arrangements of these 8 conveyors differ a great deal due to the lay of the land, so that the stoppage time during power interruptions vary and the chute pile ups which occurred with the previous brake system at the conveyor connection points can not be avoided. Usually, this pile-up is absorbed by placing hoppers in the shutes, but this equipment has such a high speed that hoppers can not be used since they require uneconomical feeders below them. Therefore the pile-up problem must be solved by means of electrical control. To do this a brake with automatic control is required which stops the conveyor for a constant period during power interruptions or emergency stoppages no matter what the load. In order to make control possible during power interruption, the system must be such that it can be maintain brake control energy for a while once the interruption begins.

Because of these requirements, a KS brake (marketed by Fuji Electric as an " eddy current brake ") with a short-time rated alkaline battery as control source and thyristor chopper control is planned. The short-time discharge characteristics of this alkaline battery are excellent, no corrosive gases arise, it is compact and maintenance is easy. It can also be included in a dust-proof totolly enclosed cubicle along with a floating type battery charger. The capacity is sufficient for supply short time KS brake exciting current for braking and a transistor regulator, or the exciting current of a toothed magnetic brake, and these capacities need not be large. *Fig. 7* is a block diagram of the conveyor brake control using a thyristor chopper controlled KS brake.

During conveyor operation, the thyristor chopper does not operate, the floating charger charges the battery and supplies dc current to the magnetic brake and control equipment. The thyristor chopper control equipment is composed completely of TRANSIDYN regulators. The control line consist of a speed control line with a main current loop. Control of the KS brake exciting current is carried out in such a way that the deceleration signal voltage generated by the unit integrator (HLR in the diagram) and the actual speed voltage value from the conveyor belt speed detection tachometer dynamo are compared and made equal.

The inherent braking function of the KS brake is lost when the speed drops to about 10% of the total or less. Therefore speed drops to 10% are detected by a speed relay, and once such a drop is detected the conveyor is stopped completely and maintained in that condition by toothed brake force exerted by the magnetic brake after the chopper and dc magnetic brake excitation are switched to OFF.

One of the main features of this equipment is that the brake control equipment is completely static so that there is almost no wear and maintenance is easy. It is also lightweight and compact which makes it easy to transport and install. It is particularly appropriate for mines where the space is limited and there are many restrictions on maintenance and installation sites.

V. CONCLUSION

This article has given a typical example of this type of equipment for use in mines. Besides this equipment, contactless thyristor switches can be used for general control of coal/ore selection equipment, and there are many examples of partial thyristor application in thyristor chopper speed control equipment for mine battery local and floating battery charging equipment, etc. From now on, the range of application is inspected to increase rapidly. Electrical equipment for mines requires many special characteristics including high accuracy, good withstand properties, easy maintenance and adaptability to special constructions.

Fuji Electric will continue in the future to find new ways to employ thyristors in all fields and also to meet user's demands for more practical equipment.