NEW PARTIAL MODERNIZATION FOR D.C. GEAR-LESS HIGH-SPEED ELEVATORS

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ABSTRACT

Mitsubishi Electric Corporation has developed a new drive-control system for partial modernization of D.C. gear-less high-speed elevators. The new drive-control system with the following characteristics consists of the chopper circuit and its technology is based on the technology of the inverter circuit which has been widely applied for the high-speed elevators.
Characteristics;

- Reduced harmonic current in comparison with the Thyristor Leonard system
- Reduced energy consumption of 40% in comparison with the Ward Leonard system.
- Superior performances (ride comfort, landing accuracy etc.) as our latest elevators
- Many optional features are available

Current applicable D.C. gear-less high-speed elevators are those with speeds of 120～240m/min and capacities below 1,600kg, and they are going to be widely applied. This article introduces a new drive-control system with a chopper circuit.

1. INTRODUCTION

Due to a short construction period and lower price, the partial modernization, which changes a control system and remains the traction machine, is becoming popular in the modernization of elevators.

The Thyristor Leonard system has been applied to the D.C. elevator control, but its harmonic current is higher than that of the existing Ward Leonard system. It sometimes affects a sound facility of the building and the harmonic problem can be serious, so the power system of the building had to be separated in advance to newly install elevators when constructing a building. However, it is not possible when an elevator is modernized partially. We needed to the harmonic current of the latest inverter-controlled high-speed elevators.

Moreover, the inverter system has generally been adopted in the industrial use, and a control device IGBT which is high voltage and high current, and is capable of fast switching, and a high performance microprocessor have been supplied economically. By applying these devices and the P.W.M. control technology cultivated from the inverter technology, we have developed a new drive-control system for the modernization that attained our high-speed elevator performances, and solved the harmonic problem.

2. MAIN CIRCUIT

2.1 THE CONFIGURATION OF THE CONVERTER AND CHOPPER CIRCUIT

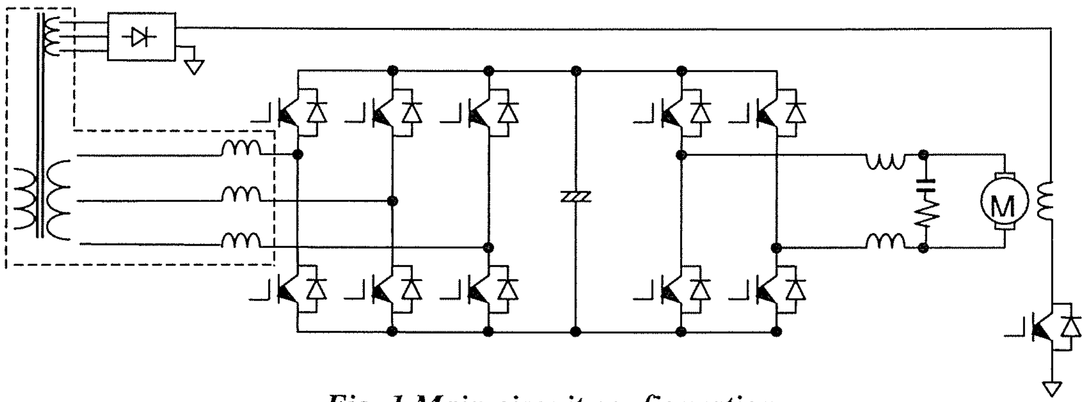

Fig. 1 Main circuit configuration

Fig. 1 shows the basic configuration of the main circuit. The main circuit consists of the P.W.M. converter and the chopper circuit. Three-phase A.C. power supplied to the system is stepped down by the insulated transformer and then converted to a D.C. constant-voltage by the P.W.M. converter. The chopper circuit converts this constant-voltage to variable-voltage to feed the D.C. motor through the filter circuit. The high-speed, high voltage and high current 1,200V 600A IGBT module is used to perform the power switching.

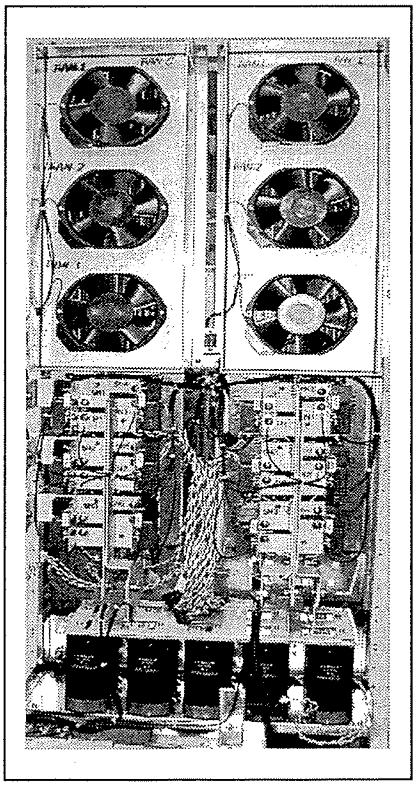

Fig. 2 Converter and chopper

The chopper circuit is a configuration of the H shape. It can drive the D.C. motor clockwise and counterclockwise, and also can drive it with the motoring power and the regenerative power. The chopper circuit's elements consist of many parallel-connected IGBT modules, the same as the converter. The large amount of heat in the IGBT modules is carried away by the compact heat sinks using heat-pipe technology.

Fig. 2 shows the external appearance of the P.W.M. converter and chopper circuit. The left is the converter unit and the right is the chopper unit. The smoothing capacitors are mounted beneath them. In order to suppress the surge voltage generated in the switching of IGBT, these modules are parallel connected with oppositely placed P and N laminated bus-bars. The forced wind cooling system is applied to the cooling section of the upper heat pipe to further downsize.

2.2 REDUCED HARMONIC CURRENT

The P.W.M. converter is the circuit that has achievements at our inverter control applied high-speed elevator. The relative harmonic components included in the A.C. power source current can be reduced because it is quickly controlled to be sin waveform on the input side.

Fig. 3 shows comparison of the A.C. power source current's waveforms of the Thyristor Leonard system and P.W.M. converter. The current waveform of the Thyristor Leonard system is similar to a square wave, and includes approx. 20% of the harmonic components of current.

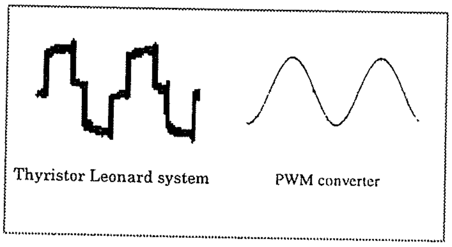

Fig. 3 Waveform of power source current

On the other hand, the current waveform of the P.W.M. converter system is similar to a sin waveform and includes only below 5% of the harmonic components of the current by the measurement. Consequently, it is unnecessary to take a countermeasure for the harmonic current on the power equipment side of a building.

Also, the P.W.M. converter controls the power factor ($\cos\Phi$) of the current on the input side to $\cos\Phi \fallingdotseq 1$ during the motoring power and $\cos\Phi \fallingdotseq -1$ during the regenerative power. As the power factor is controlled to $\cos\Phi \fallingdotseq 1$, the power equipment capacity has been succeeded in reducing approx. 20 to 30 % than that of the Thyristor Leonard system.

2.3 REDUCED THE ELECTROMAGNETIC NOISE

With the Thyristor Leonard system, the armature current includes six times as much ripple components as the frequency of power source (300～360 Hz), generating the electromagnetic noise from the D.C. motor. In the chopper circuit, the frequency of P.W.M. set at 5kHz and the new drive-control system modulating all H-shaped 4 arms of the chopper circuit simultaneously has turned the ripple current components of frequency of flowing into the D.C. motor to doubled, 10KHz, the modulation frequency. The electromagnetic noise generated from the D.C. motor is not audible.

2.4 EMI

When the P.W.M. converter is applied, a noise voltage due to the switching surge becomes higher than the Ward Leonard system; however, setting a filter circuit to the input keeps the noise voltage lower. Fig. 4 shows the measurement result of the circuit with or without a filter circuit, and prEN12015.

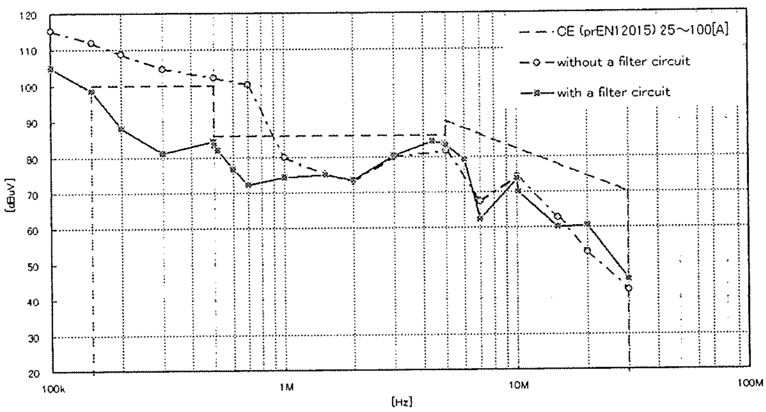

Fig. 4 Characteristics of EMI

2.5 THE COUNTERMEASURE FOR THE LEAKAGE CURRENT

In the chopper circuit using the P.W.M. control, the leakage current, generated from the D.C. motor, is increased because it is switching at a high frequency. Since the leakage current induces the noise voltage to the earth line, it may affect any sound equipment connected to the same power system. The insulated transformer connected to the P.W.M. converter input reduces the leakage current. Therefore, it protects the other equipment in the building from the damage by leakage currents generating in the elevator.

3. THE COUNTERMEASURE FOR THE SURGE VOLTAGE

When the surge voltage impressed between terminals of the D.C. motor exceed its maximum rated voltage, it causes the insulating break down. As the switching time of IGBT is less than 0.1 microsecond, the serge voltage is led to be higher, reaching approx. twice as much as the D.C. line voltage.

As the D.C motors in the modernization declines in the tolerance of insulation, attention is especially required to this type of damage. This time a countermeasure is taken to prevent generation of the surge voltage.

As a surge voltage generation mechanism, the output voltage from the chopper circuit resonates electrically between the output cable and armature windings of the D.C. motor due to its short rise and fall time. This resonance generates the surge voltage, and it is impressed on the input terminal of the armature windings.

Since the rise time of this surge voltage is very short, potential is concentrated between first turns of the armature windings. The surge voltage can break down the insulation between those turns consequently. The LCR filter circuit is connected to the chopper circuit output to limit this danger by lengthening the rise time (more than 1 microseconds) and lowering the peak value of the surge voltage.

3.1 THE SIMULATION OF THE SURGE VOLTAGE

A computer simulation to search the relation between a parameter of the filter circuit and the surge voltage has been carried out using a distributed-parameter circuit as a model and SABER as a simulator.

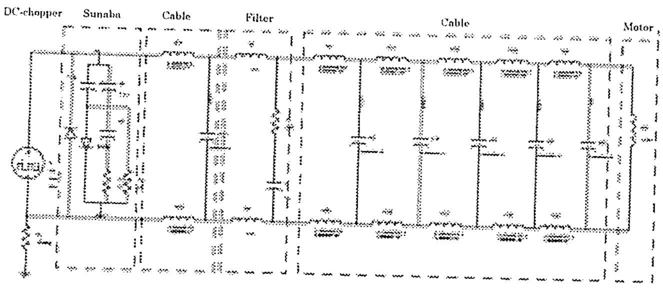

Fig. 5 Circuit model

Configuration of model circuit：

- Filter constant :
  L=1mH,R=500Ω,C=0.1μF
- Motor constant:
  L=6.75mH,R=0.0972Ω
- Cable length：30m
- Pulse is used for input signal.
  Switching frequency：10KHz ,
  Switching on voltage：350V

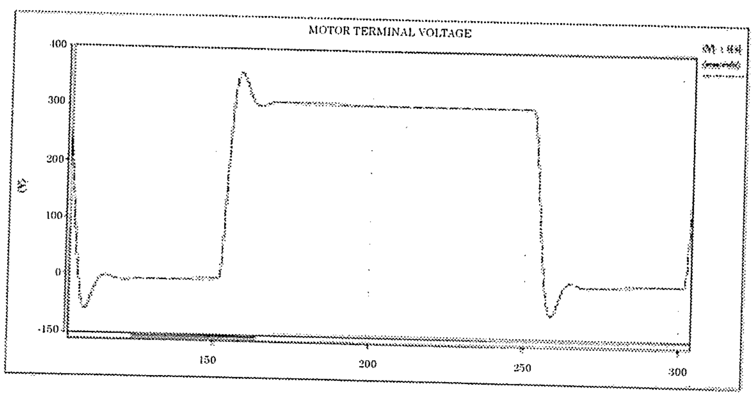

Fig. 6 Simulation waveform

The most appropriate parameter of the filter has been determined according to this result.

3.2 A MEASUREMENT OF THE SURGE VOLTAGE

Fig. 7 shows the waveform of the generated surge voltage between the input terminals of the armature windings when the IGBT is turned on in case of a long cable.

The rise time of the surge voltage is approx. 8 microsecond, and its peak voltage is increased only approx. 5% over the D.C. line voltage (350V). Moreover, since the rise time is long, it is unlikely that the potential will be concentrated between turns of the input terminals of the armature windings and the over-voltage will be impressed.

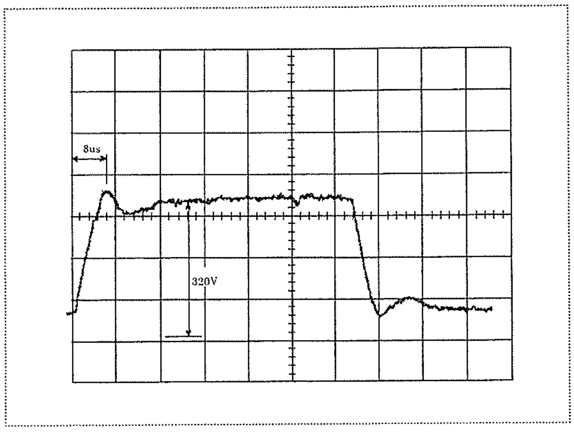

Fig. 7 Surge waveform

4. A NEW DRIVE-CONTROL SYSTEM

Fig. 8 shows the configuration of the new drive-control system, which consists of the converter control circuit, the chopper control circuit and the field current control circuit. As the rated voltage of the field coil is lower than the main circuit voltage, the power source has been separated and the P.W.M. control has been applied for the circuit. The control circuit has adopted a large system LSI that the high performance microprocessor, same as the latest inverter-controlled high-speed elevators, is built in to miniaturize.

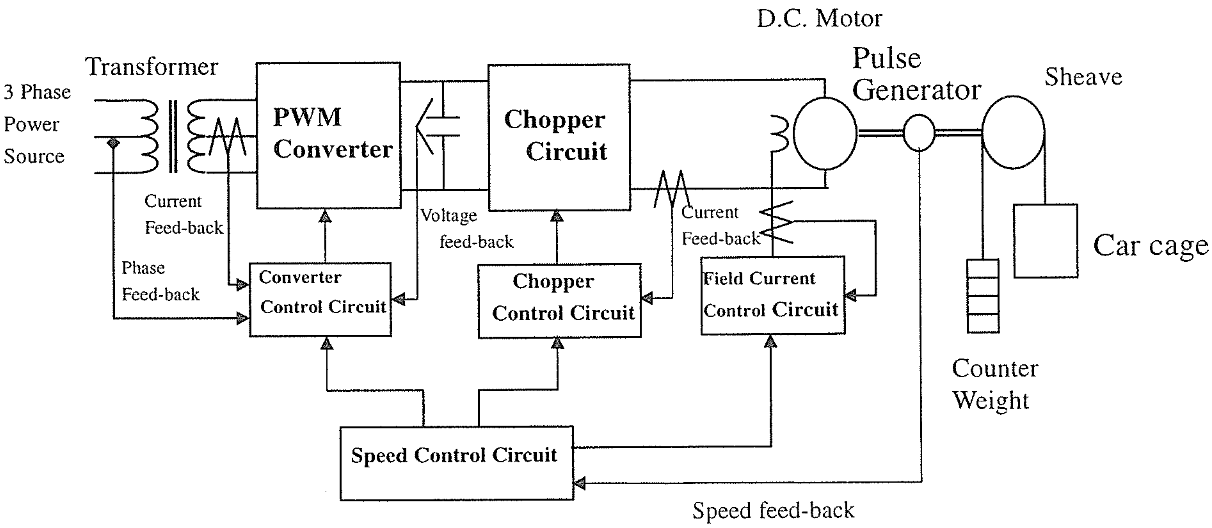

Fig. 8 New drive control system

4.1 ELEVATOR SPEED CONTROL

A main feedback loop constitutes the speed control by detecting rotational speed of the D.C motor by the pulse generator installed at the shaft of the D.C motor. Also a minor feedback loop constitutes it by detecting the armature current of the D.C motor by the current detector to achieve extremely accurate speed control. In the control method of software, application of a Reference Model Following Control has achieved a quick response and the use of the vibration control arithmetic operation together has created smooth riding comfort.

4.2 FIELD CURRENT COTROL

We have applied a variable current control to change the field current of the D.C. motor according to the operating conditions, acceleration, constant speed and deceleration, and load of the car. This variable field current control can decrease the heat of the field coil, and wears of the brush and commutator. The heat of the field coil can be decreased 10 to 15 K more than the old control.

Output torque (Tm) of the D.C. motor is shown as the following formula.

$$Tm = pMIf \cdot Ia$$

Where; M: Motor mutual inductance
If: Field current
Ia: Armature current

When the field current is varied during the car running, the output torque of the D.C. motor changes and the elevator ride comfort is influenced. Therefore, the control circuit is consisted to be controlled by the same microprocessor for the field current control and the armature current control. The control constant value calculating the armature current instruction value is changed according to the field current value. As a result, the output torque of the D.C. motor is kept constant even when the elevator changes the field current during running, and a stable ride comfort is achieved.

5. RUNNING PERFORMANCE

Fig. 9 and 10 show running performances of the Ward Leonard system and the chopper circuit system measured. Both figures show waveforms when the elevator runs at no load at our test tower. The same smooth acceleration waveform is achieved as the latest inverter-controlled high-speed elevators, and the ride comfort is considerably improved than the existing Ward Leonard system. Detecting the car position before landing with below 0.5mm accuracy by the pulse generator installed at the governor and compensating the speed pattern has largely improved the landing accuracy.

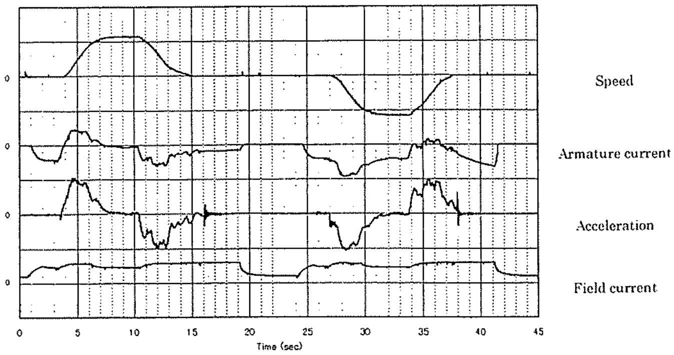

Fig. 9 Ward Leonard system

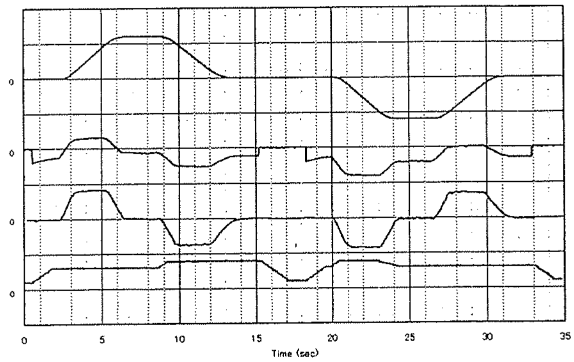

Fig.10 Chopper circuit system

6. CONCLUSION

The new control system with the newly developed D.C. chopper has been developed as an exclusive model for modernization of DC-GL high-speed elevators. Besides the features listed above, the control panel is divided into two, top and bottom, to carry it in the machine room easily.

There are large numbers of 20 to 30 year-old DC-GL high-speed elevators operating in the world. We will apply this new control system to those buildings in order to present a comfortable living environment to people and we are convinced for it to becomes a main current in a partial modernization.

Biographical notes;

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