A.C. MOTOR DRIVE FOR DIESEL-ELECTRIC LOCOMOTIVES

(57) Abstract: Alternator (6) converts mechanical energy supplied from diesel motor (1) shaft to electrical energy. Voltage regulator (7) calculates the difference between the alternator (6) output voltage and reference voltage value; and by changing the current in the single field winding it keeps output voltage of alternator constant. In this way, constant voltage with varying frequency is produced, thus at every shaft speed, power is kept constant. At alternator output (6) there are inductors and capacitors which are selected so as not to drive the circuit to the resonance and at the output there are inverters (11 and 12) which have LC filters for suppressing harmonics. Two individual inverters (11 and 12) drive fan and compressor motors (9 and 10) with three phase alternating current according to the commands produced by master control unit (13).
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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.
A.C MOTOR DRIVE FOR DIESEL-ELECTRIC
LOCOMOTIVES

This invention concerns the replacement of diesel-electric locomotives’ fan and compressor motors with asynchronous alternating current motors and is also about alternating current drives.

DE 11000 type diesel-electric locomotives are used for long-distance transportation and also for shunting.

DE 11000 locomotives’ diesel motor power is 785 kW, and there are 4 direct current motors for traction. Energy is provided by a diesel motor, and auxiliary system’s power is 59 kW. These locomotives have a maximum speed of 80 km/h.

In previous technique the auxiliary system was a hydro-mechanical system. Hydraulic pump is connected to the shaft of the diesel motor. Oil is circulated in closed circuit by means of hydraulic pump. By means of the oil pressure, two different shafts are rotated. One of these shafts is connected to the fan blade and the other to the compressor piston. By means of a proportional valve which is on the closed circuit, the fan is driven at two different speeds. According to the pressure of oil which runs through valve, the valve controls the flow of fluid in two states; totally open or half-open. In these locomotives, diesel motor’s cooling water fan and compressor are driven by hydraulic pump which is connected to the diesel motor’s shaft. Maintenance of the oil levels and filters of hydraulic pump, motors and also their mechanical parts results in locomotives which are frequently out of service.

The aim of this invention is to drive the fan and compressors of DE 11000 locomotives by alternating current drives.

Another aim of this invention is to keep the power constant at all speeds by producing constant voltage of varying frequency.
To realize the aim of this invention, the drive system produced is shown in the figures as,

Figure 1. The previous system’s block diagram
Figure 2. General drive block diagram
Figure 3. The block diagram of the A.C. drive which is the subject of this invention

All the parts are numbered one by one, and these correspond to:

1. Diesel Motor
2. Hydraulic pump
3. Hydraulic motor
4. Fan
5. Compressor
6. Alternator (Synchronous A.C. generator)
7. Voltage regulator
8. Protection units
9. Fan motor
10. Compressor motor
11. Fan inverter
12. Compressor inverter
13. Master control unit
14. Compressor pressure guard
15. Thermistor regulator card
16. Thermistor phase protection relay 1
17. Thermistor phase protection relay 2
18. Thermistor phase protection relay 3
19. Frequency relay
20. Voltage relay
21. Alternator cooling fan
22. Alternator cooling fan’s inverter
23. Thermic-magnetic circuit breaker
24. Contactor
25. Battery

The drive is composed of sub units which are alternator (6), voltage regulator (7), PWM controlled inverters (11 and 12), alternating current motors (9 and 10) and master control unit (13).

The alternator’s (6) rated power is 50 kVA, operating frequency is 25-60 Hz, output voltage is 3 phase 400 ± 5 Volts A.C, isolation class F with forced external cooling.

According to the temperature of the cooling water of diesel motor (1), the speed of fan motor (9) is changed. As the temperature of cooling water increases, the fan motor (9) is driven faster in order to enable sufficient cooling. To perform this task, an analogue output signal whose value varies between 0-10 V is produced; this signal is proportional to the on time of switching component. By applying this signal to the fan inverter’s (11) analogue input, temperature dependent speed control is realized.

By means of single field winding alternator (6) and its control and protection systems, diesel motor’s (1) mechanical shaft power is converted to the electrical power. Voltage regulator (7) calculates the difference of output voltage of alternator (6) and reference voltage. According to this difference, voltage regulator (7) increases or decreases the current of field winding to keep the output voltage of alternator (6) constant. In this way, by means of voltage regulator which controls the current of field winding, constant voltage with variable frequency is produced. Thus, the power is kept constant. Due to the varying frequency of alternator (6), inverters (11 and 12) are used at the output of alternator in order to provide both voltage and frequency control to the standard asynchronous motors (9 and 10) that are driven. Varying frequency of constant voltage, produced by alternator (6), is supplied to the inverters (11 and 12) as
input voltage. The values of inductor and capacitor in the inverters are chosen such that they do not drive the circuit into resonance. The harmonics are filtered by this LC circuit. According to the commands sent by master control unit (13), two different inverters (11 and 12) apply 3 phase alternating current to the fan and compressor motors (9 and 10). In inverters (11 and 12) there are protection circuits against short-circuit, over current, over voltage, low voltage, and over temperature condition. Fan inverter (11) drives the 15 kW fan motor (9); the compressor inverter (12) drives the 15 kW compressor motor (10). Energy is produced by 3 phase alternator that is connected to the shaft of diesel motor (1).

Due to the fact that diesel motor's speed may change between 750 rpm and 1800 rpm continuously, it is important to keep output voltage of alternator constant. This is achieved by voltage regulator (7) which controls the field winding. Inverters (11 and 12) drive compressor piston (5) which is a high torque load and the high inertia cooling fan (4), as desired. Compressor (5) is run between pressure levels 8-10 bar, fan motor (9) runs between cooling water temperatures 72-79 °C. Pressure signal is obtained from pressure guard (14). Temperature data is obtained from two thermistors (15) and by means of an electronic circuit it is converted to an electrical signal. Speed of fan motor (9) is controlled proportional to water temperature.

Alternator (6) voltage, current and frequency values are displayed on indicator panel. Alternator (6) is cooled by small alternating current motor which is driven by alternator cooling fan inverter (22).

Master control unit (13) starts and stops the system. It possesses half-automatic control, protection and monitoring functions. Master control unit processes frequency, loss of phase, over voltage, over current, alternator (6) temperature, motor (9 and 10) temperatures, over current in motors (9 and 10), motors' (9 and 10) speeds, diesel motor (1) cooling water temperature, compressor (5) pressure fault signal and sends these signals to monitor unit located on the driver's console. Master control unit uses square wave output signal coming from fan regulator card located on the locomotive. The square wave's pulse width changes according to on time of switching element and
according to temperature. On the other hand, this unit controls electro-pneumatic valve. This valve, according to fan motor’s state (i.e standstill or running), opens or closes hydraulic air grid located on locomotive.

Over and low voltage protection is provided by over and low voltage relay (20), over current protection by inverters (11 and 12), over temperature protection by both phase protection relay and inverters (11 and 12), loss of phase by phase protection relay, frequency protection by frequency relay (19).

A whole system, including hardware and software, has been developed, which collects data from different sensors and controls the processes, while not bringing any additional burden on the driver during operation. The control system, via panel, provides warning lamps about system condition. For technical service, measurement panel has been devised, and in order to minimize the down time of the system, the units, that make up the system are designed in a modular structure so that they can be used and replaced individually.
CLAIMS

1. Alternating Current motor drive, for diesel-electric locomotives, which is characterized by; system providing conversion of mechanical energy produced at diesel motor's shaft into electrical energy, supervision and protection systems that controls single field winding-alternator (6); voltage regulator (7) calculates the difference between alternator (6) output voltage and reference voltage at the same time, and also by increasing or decreasing current, flowing through field winding, it keeps output voltage of alternator (6) constant; voltage regulator (7) controls single field winding current, providing constant voltage of varying frequency; fan regulator card located on the locomotive, according to temperature, produces square wave output signal whose width changes according to on time of switching element during one period; system including master control card that controls electro-pneumatic valve and hence hydraulic air grid. It opens hydraulic air grid when fan motor runs and closes it when the motor is at standstill; master control unit, which has protection and monitoring function in semi-automatic character, evaluates frequency, phase loss, over voltage, over current alternator (6) temperature, motors' (9 and 10) temperatures, speed and overcurrent signals in motors (9 and 10), diesel motor's (1) cooling water temperature, compressor (5) pressure fault signal and then it sends them to monitoring unit; by system which includes inverters (11 and 12) filters harmonics and by LC filter circuit so chosen that it does not drive the circuit into resonance by a system applying three phase alternating current to the fan and compressor motors according to received commands.

2. Alternating current motor drive as mentioned in Claim 1 which is characterized by a system that converts mechanical energy at diesel motor's (1) shaft in to electrical energy; a system controlled by supervision and protection units; a system that produces variable frequency constant voltage
energy and a system that contains single field winding alternator (6) that provides constant rated power at every speed of diesel motor. (1)

3. Alternating current motor drive as mentioned in Claim 1 which is characterized by a system which contains voltage regulator (7) controlling field winding current of alternator (6) and by comparing the output voltage and reference voltage at the same time, it decreases or increases the current flowing through field winding.

4. Alternating current motor drive as mentioned in Claim 1 which is characterized by a system that contains protection against short circuit, over current, over voltage, low voltage and over temperature; system that provides standart asynchronous motors (9 and 10) to be driven; by a system that provides both voltage and frequency control of output voltage of alternator (6); by system that drives a load of compressor piston (5), having high torque and cooling fan, having high inertia, as desired.

5. Alternating current motor drive as mentioned in Claim 1 which is characterized by a system provides that fan motor’s (9) speed is adjusted according to temperature of cooling water and as temperature of cooling water goes up speed of fan motor is increased so that sufficient cooling is provided. By a system contains fan inverter (11) that provides speed control by means of signal that is varying between 0-10 V and produced at analogue card output, during one period this signal is produced as long as switching element is on.

6. Alternating current motor drive as mentioned in Claim 1 which is characterized by a fan motor (9), which runs when cooling water temperature is between 72-79 °C, and motor’s rotation speed is controlled proportionally to water temperature; by an electronic circuit which converts temperature values obtained from two thermistors into electrical signal.
7. Alternating current motor drive as mentioned in Claim 1 which is characterized by a alternator (6) which is cooled by a alternator cooling fan that is driven by alternator cooling fan inverter (22).

8. Alternating current motor drive as mentioned in Claim 1 which is characterized by a System which is made of alternator (6), voltage regulator (7), controlled PWM inverters (11 and 12), alternating current motors (9 and 10) and master control unit (13); by a system which is modular in structure.
**CLASSIFICATION OF SUBJECT MATTER**

**IPC**: B 60 L 1/00

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

**IPC**: B 60 L 1/00, 11/00; F 04 C 29/00; H 02 K 3/00, 3/22, 3/24

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

**WPI**

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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☐ Further documents are listed in the continuation of Box C.  ☒ See patent family annex.

**Date of the actual completion of the international search**


**Date of mailing of the international search report**

2 August 2000 (02.08.2000)

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