A&QT-R 2004 (THETA 14)
2004 IEEE-TTTC - International Conference on Automation, Quality and Testing, Robotics
May 13 – 15, 2004, Cluj-Napoca, Romania

ELECTRIC LOCOMOTIVE TAP-CHANGER DRIVE SYSTEM USING AN AC MOTOR

Răzvan Prejbeanu[1], Mihail Rădulescu[1], Constantin Pătraşcu[2], Jean Stăncioi[1]

[1]INDA S.R.L. Craiova, e-mail: main@inda.ro
[2]University of Craiova, e-mail: constantin.patrascu@comp-craiova.ro

Abstract: The driving system of the tap-changer uses an AC asynchronous motor, provided with short circuit rotor of industrial purpose, an incremental transducer and a control unit respectively. The information is processed by microcontroller. On this way the drums provided by cams and their contacts, the special DC motor, the relays of the tap-changer motor control, it's elastic clutch and both selsines of the control desks from the driver posts are eliminated.

Keywords: tap-changer, asynchronous motor, incremental transducer, microcontroller.

1. Introduction

The actual driving system of the selector-tap-changer assembly of the electric locomotive LE 5100 kW uses a special DC motor with a voltage supply of 110Vdc, drum provided with cams which acts the contacts through which the position of the graduator at a given moment can be determined (voltage step) so that the control of different sequences of scheme is depending on its position. The position of the tap-changer or the number of the voltage step (from 1^{st} to 40^{th}) is indicated in both control posts through a double selsine system [3].

2. Equipment description

According to the block schematic (fig. 1) the system consists of:

- AC asynchronous motor 0,37 kW/1500 rpm,
- Incremental transducer,
- Control and information processing unit
- Display provided with LED.

- The driving motor is a motor of industrial purpose provided with short circuit rotor with Pn=0,37 kW, n_N = 1500 rpm, Y/∇ - 380/220
- The incremental transducer is of optical type and generates a number in binary code depending on the position of the driving motor shaft.
- The display of the tap-changer step is using two digits

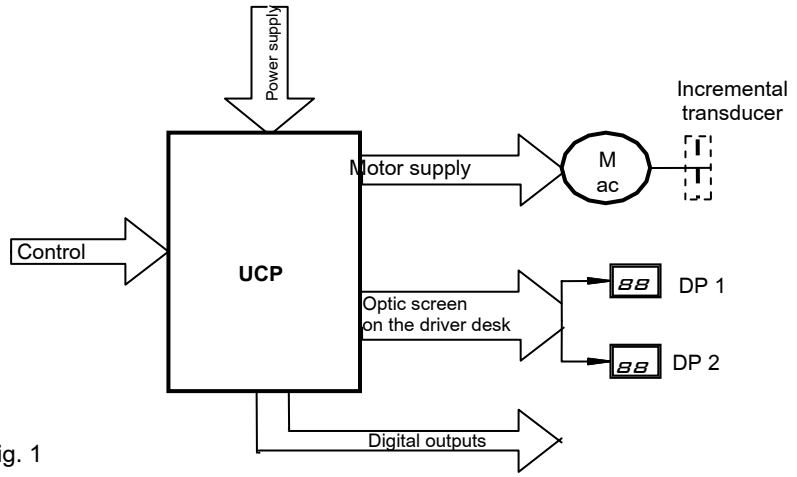

Fig. 1

The control and the information processing unit (UCP) is provided with microcontroller. It receives control signals for the tap-changer step on whose basis, with a programmable control, controls the electric driving motor and generates the numerical information for the displaying of the voltage step in the driving post (DP), respectively the output signals which assures the operation of the control schematics of the locomotive.

The block schematic of the UCP is that of the fig. 2 and consists of the following components[2]:

- switching power supply,
- static voltage and frequency converter,
- logical unit with μC,
- digital output interface (electromagnetic relays),
- control unit for digital screen (display).

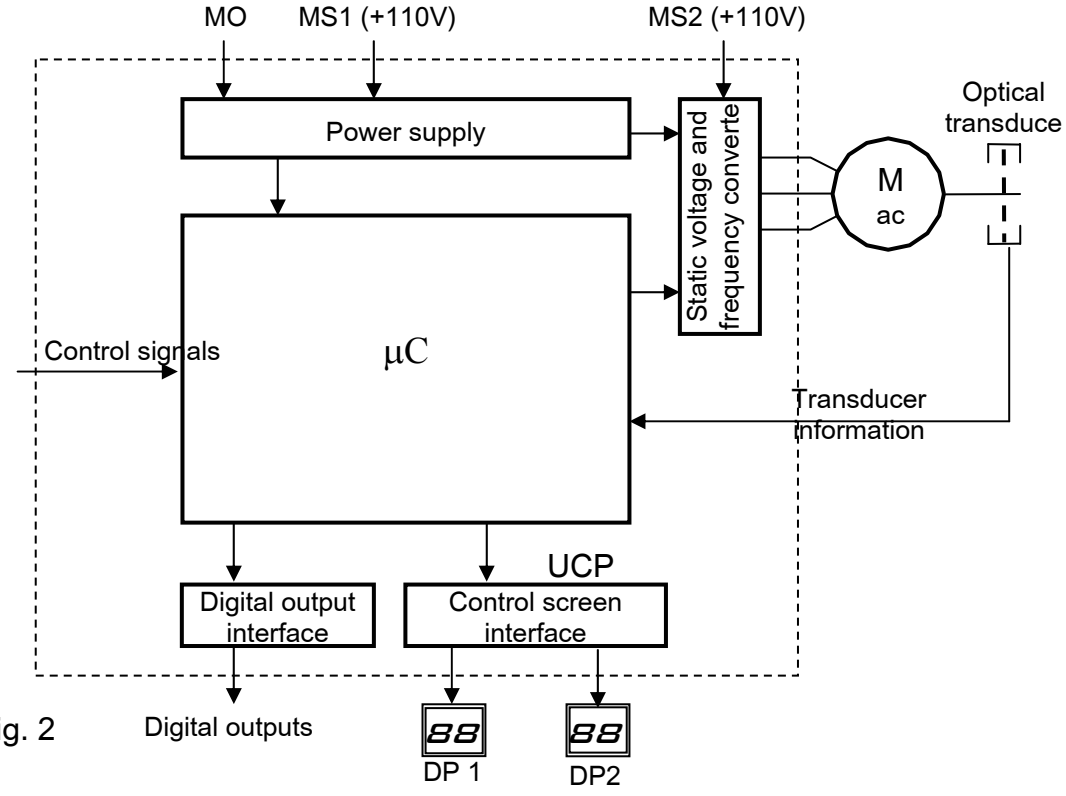

Fig. 2

The **output interface** is provided with relays, controlled according to a programmable routine, depending on the tap-changer position, respectively on the number of revolutions of the driving motor so that their contacts replace the cam contacts in order to perform the entire operation of the locomotive control schematics.
The **driving motor** is supplied through the frequency converter that generates symmetrical three-phase voltage -220 Vac- and performs an adaptive control that corresponds to a constant couple irrespective of the angular speed.
It's switching on **start** is performed free of mechanical shocks, under controlled current, under controlled programmable acceleration, by changing both the voltage and the frequency of the motor supply, respectively.
The switching off the tap-changer drive is possible by turning the asynchronous motor into the generator range, the **braking** deceleration of the system being controlled by appropriate software [4].

The voltage supply of the system is the control voltage of the locomotive 110Vdc +20 -30%

The failure of the system or the loss of the input voltage supply (110Vdc +20 -30%) produces the actuation of the emergency signal (y6) which disconnects the automatic circuit breaker by cutting off the voltage supply of it's maintaining winding.

The position on which the tap-changer is blocked due to the loss of the power supply is internally stored so that, when the power supply recovers, the system controls automatically the tap-changer to the 1st step of the traction voltage irrespective of the step it was positioned before.
The adjustment of the traction motor (TM) voltage supply is performed through a self-transformer T1.1. provided with 20 voltage plugs from 1250 to 1250 V, an additional coiling T1.2 with the voltage of 625 V and a selector-tap-changer assembly (T2.1, T2.2., T3.1), through which the voltage plugs of the self-transformer are selected according to fig. 3[3].

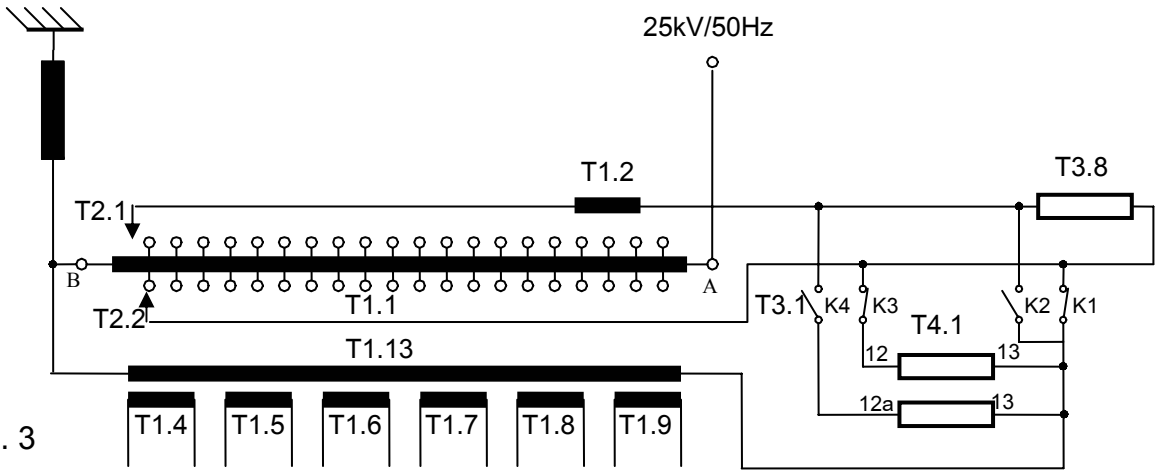

Fig. 3

The equipment shown above uses an AC motor coupled to a gear reducer provided with one input (hat for the motor) and three outputs (according to figure 4) as follows:

- The output 1 is represented by the main shaft T3.1 that perform a complete rotation when the selector pass from a voltage plug to another, over two steps of voltage (180^0 /step), respectively. The driving system of the load switches K1-K4 is mounted on this shaft, too.
- The output 2 actuates, through the helical gear reducer, the voltage collectors T2.1, T2.2 of the selector.
- The additional camshaft T3.3 represents the output 3 through which in the old system the cam contacts T3.3 a-v were actuated. Jointly with this shaft was coupled the shaft of the generating selsine in order to gradually send the position indication to the DP. This one rotates about 330^0 when the tap-changer moves from the 1st step of the traction motor voltage to step 40th of the traction motor voltage.

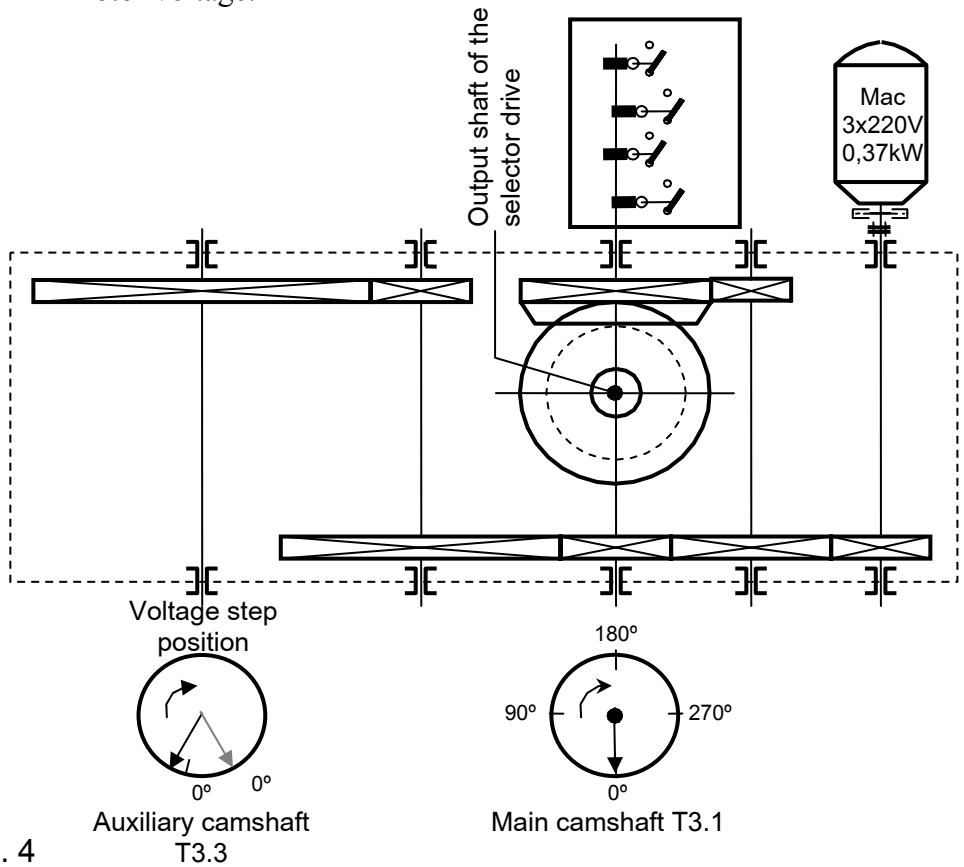

Fig. 4

The transmission ratio between the driving motor and main shaft T3.1 is of 1:24 and between the main shaft T3.1 and the auxiliary shaft the transmission ratio is of 1:21, 76 so that the main shaft rotates 180^O in order to increase the voltage by a voltage step of 625V, the shaft of the driving motor performs 12 complete rotations and the auxiliary shaft rotates by $8,25^O$ [3].

According to fig. 5 in order to increase or to decrease the voltage on the traction motors the control and processing unit (UCP) receives step signals of 110Vdc from the locomotive contacts F1.1:2 with the contact diagram shown bellow, as follows:

- ***Input x1*** actuated (pos. **"**1,D**"** of the traction controller) the system is initiated; the tap-changer selects the 1st step of the voltage
- ***Input x2*** actuated (pos. **"**2**"** of the traction controller) the voltage is increased up to the 3rd step of the voltage (first step of the locomotive acceleration)
- ***Input x3*** actuated (pos. **"**3**"**, M of the traction controller) the voltage is increased up to the 5th step of the voltage (the second step of the locomotive acceleration)
- ***Input x4*** actuated (pos. "F,A" of the traction controller) the voltage is increased up to the 40th step of the voltage. The deactivation of the input *x4* controls the maintaining of the tap-changer on any position above the 5th step of the voltage.

If the tap-changer is anywhere above the 5th step of the voltage (in motion or just stopped on whatever step) and any one of the inputs *x3, x2* or *x1* are actuated, the tap-changer returns to the controlled step 5th, 3rd or 1st.

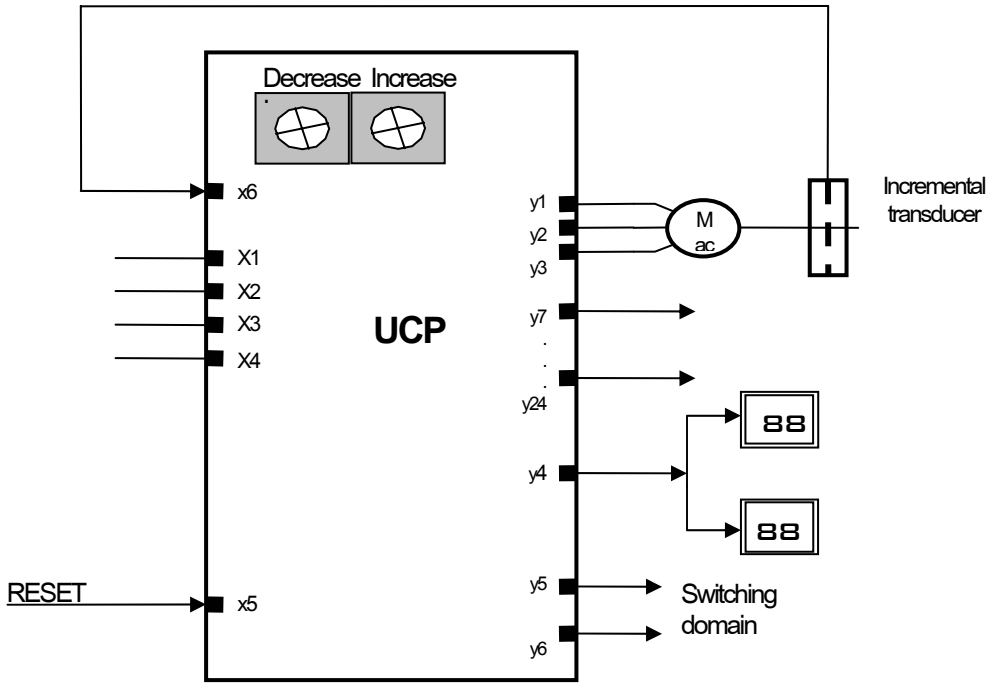

Fig. 5

The casual stop of the tap-changer on a main shaft angle of $21,5^{+0}_{-2}$ up to $158,5^{+2}_{-0}$, respectively $201,5^{+0}_{-1}$ up to $138,5^{+1}_{-0}$, due to the mechanical failure of the cinematic, lack of voltage supply or due to an inverter failure, leads to the disconnection of the automatic circuit breaker after no more then 2 seconds because of the system emergency signal (Y5) which disconnects the automatic circuit breaker.

The breaking of the tap-changer drive system is performed by switching the motor into the generator range and this braking take place either when the system

receives a stop command from outside (actuation of the inputs *x1 – x4*) or even internally by software on the steps 1^{st}, 3^{rd}, 5^{th}, 40^{th} of the traction voltage[2], [3].

The system breaking is done with a controlled breaking force upon a given characteristic, continuously, on the ground of information received from the incremental speed transducer (no. of pulses, their frequency). The system stopped in this way is blocked on the position by an easy breaking [5].

When the main shaft T3.1 has to move less than $17,5^{O}$ up to a certain step of the voltage (maintaining position) and receives a stop control, the system keeps moving and stops on the very next maintaining position (voltage step).

Because of both the behaviour and the high reliability of the asynchronous motor driven by static converter, switching between motoring and braking is faster then 400ms and allow quite unlimited no. of repeated changes in the level of the voltage at the traction motors all the time.

3. Conclusions

The implementation of the tap-changer drive by an asynchronous motor and static converter leads to:

- increase of mechanical performances by reducing the wear degree of the reducer teething by means of avoiding mechanical shocks within shafts and wedges as they appear in the positioning with special DC motor or step by step DC motor,
- increase of accuracy due to the use of the position incremental transducer [2],
- increase of the system reliability by introduction of the asynchronous motor driven by static converter,
- constant maintaining both during the switching time of a step (about 400ms) and passing through in increasing and decreasing direction of the 40 steps of selector irrespective of the variation of the supply voltage,
- elimination of the selsines replaced with a enhanced visibility system, with a reduced consumption of energy, irrespective of the presence of 25 kV voltage on the contact line,
- connection to a train main line and to a board computer able to perform both diagnosis and display,
- enhanced slip – slide control of the locomotive wheels due to the faster changes of the traction motor voltage controlled by the traction computer on a faster manner, close to those of the newer traction controlled rectifiers of the modern locomotives.

4. References

[1] Iwaji Y., Fukuda S., A Pulse Frequency Modulated PWM Inverter for Induction Motor Drives, IEE Transactionon Power Electronics, vol. 7, no. 2, April 1992, pag 404-410

[2] Koziol R., Sawicki J., Szklarski L., Digital Control of Electric Drives, 1992

[3] Marcu M.(1992), Schemele Electrice Şi Comenzile Locomotivelor, Editura Tehnică

[4] Năvrăpescu V., Mircea Covrig, Petru Todos(1998), Comanda Numerică A Maşinii Asincrone, Editura ICPE

[5] Whitaker Jerry C. (1996), The Electronics Handbook, IEE Press