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

THREE-PHASE DRIVING SYSTEM FOR TRAMWAYS

Florea Burdubuș[1], Mihail Rădulescu[1], Răzvan Prejbeanu[1],

[1]*INDA S.R.L. Craiova, e-mail: main@inda.ro*

Abstract: At this time is under development a large modernizing activity concerning the existing tramway fleets of many roumanian cities. This paper describes the electric traction system intended for modernizition of the a. m. tramway-fleets.

The propulsion system mainly consists of two IGBT direct pulse inverters that are directly fed from the overhead line and two fully sprung, completely sealed and self ventilated maintenance-free asynchronous traction motors, controlled and monitored by a INDA micro-computer system. Among these must be mentioned the use of the high-performance PC-based INDA diagnosis software with detailed service data recording and fault analysis

The concept of the driving equipment features: the reduction the energy, maintenance and purchase costs; high reliability of the system; high efficiency and good performance; and very important for passengers, a high traveling comfort.

The installation of the electrical equipment can be realized on local content.

Keywords: static converter, asynchronous motor, tramways

1. Introduction

Manufacturers of electric vehicles have a large number of technical demands for the development of the drive equipment: first, and most importantly, is the reduction the energy, maintenance and purchase costs; second, is high reliability of the system; third, most critical for the development engineer, is high efficiency and good performance; and forth, very important for passengers, a high traveling comfort. The a.m.features of the equipments (high passenger comfort, high technical parameters, high reliability and low costs - purchase, energy and maintenance), request a sophisticated design for the entire propulsion system, auxiliary power supply and control and diagnosis with a advance software ensuring detailed service data recording and fault analysis. One can say, that the design of the vehicle is governed as much as by the manufacturer and passengers' needs as by the requirements of the operators and the maintenance personnel.

In this project, INDA is responsible for the design, delivery and commissioning of the entire electrical driving system of the vehicle, including the auxiliary power supply.

2. Block Diagram and Main Circuits Diagram

The block diagram of the electrical driving system and the main circuits diagram are presented in fig.1 and respectivelly fig.2. The key components of the tramway driving system are: Inverter Container A; Inverter Container B; Braking resistor RFA; Braking resistor RFB; Master Controler; Main Control Unit (UC 2); Inverters Control Units (UC 1); Tramway Bus; Signaling and Diagnosis Unit (EPS TR); Traction Motors and Auxiliary power supply (non reprezented in these figures).

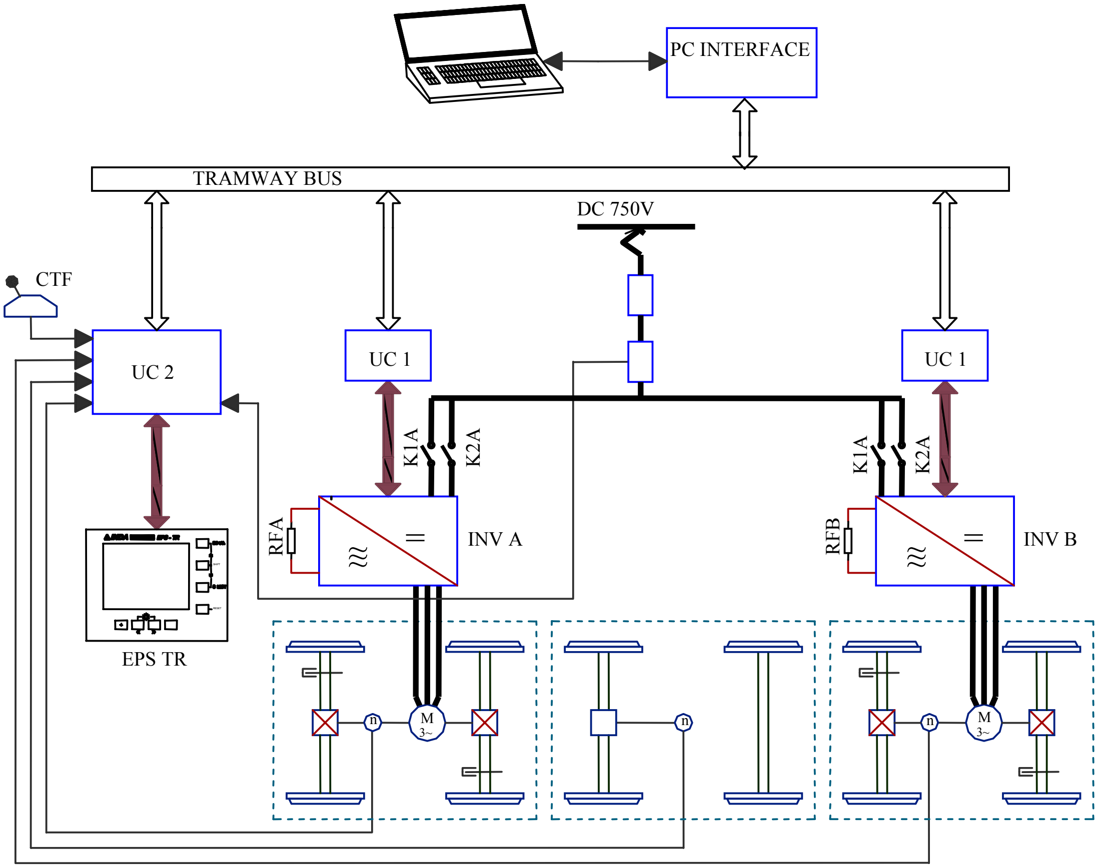

Fig.1. Driving system - Block Diagram

The achievement of the main conditions mentioned above, has imposed as each of the two traction motors to be operated by a separate traction converter with individual control.

Each of the two propulsion units, consists of a micro-processor controlled IGBT direct pulse traction inverter, directly fed from the overhead line, with individual drive control, its braking resistor and fully sprung, completely sealed and self ventilated maintenance-free asynchronous traction motor.

This concept offers high vehicle availability as special interest was focused on optimum system redundancy.

All system is governed by microprocessor

A high traveling comfort is achieved by a digital drive/brake control enabling jerk-free starting and braking.

The recuperated energy by regenerative braking can be fed back to the line which positively influences the energy consumption.

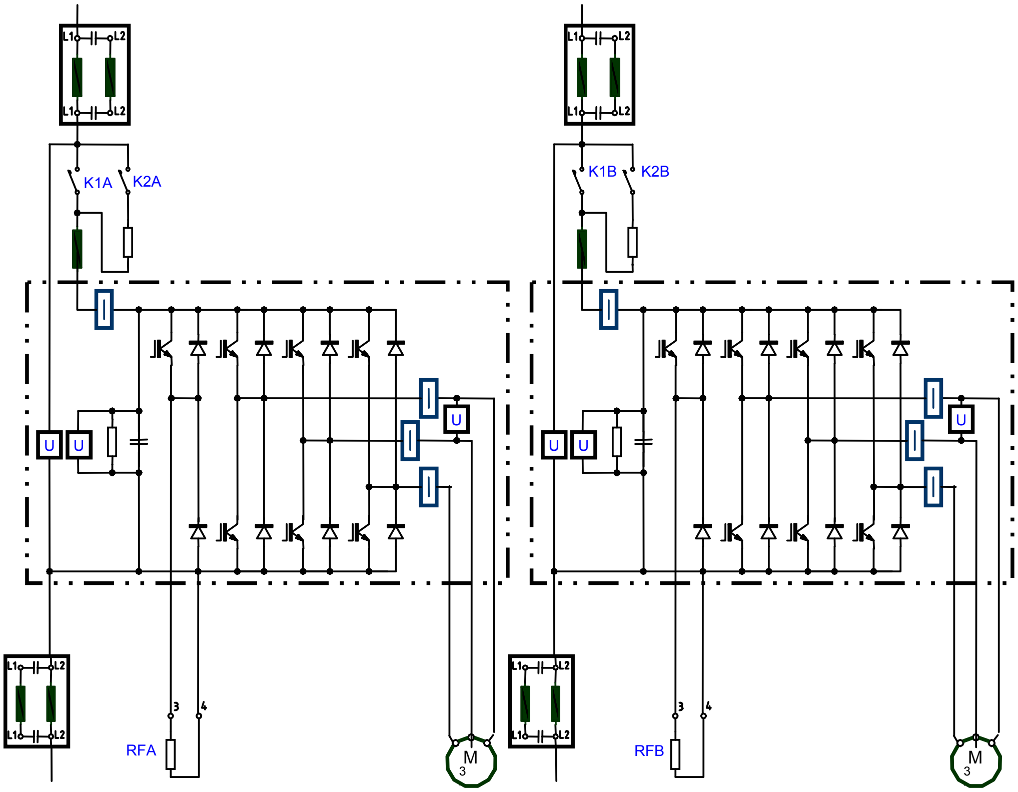

Fig.2. Main Circuits Diagram

The microprocessor control with its embedded spin/slide correction system allows a jerk-free acceleration and deceleration of the vehicle.

The master controller group is equipped with a cruisecontrol setting, which allows the vehicle to cruise at a given speed.

All system controls use a data bus that operates according to the internationally standardized protocol.

The independent auxiliary static converters using state-of-the art IGBT technology are also equipped with a diagnosis and monitoring system.

3. Equipment description

Traction inverters: 2 IGBT direct pulse inverters directly operated on the mains, input voltage DC 750 V (+25 %, -30 %); output power 400 kVA; forced air cooling.

Main characteristics of the traction inverter: IGBT technology; control of the drive units via fiber optics, pulse patternscomputed by assigned converter control unit; jerk-free starting and braking; dynamic braking up to standstill of the vehicle; combined regenerative/rheostatic brake; contactor-less changeover between motoring/breaking mode and forward/reverse

Traction control: Traction control system consists of inverter drives control units (UC 1) and system control units (UC 2)

Characteristics of the traction control system: operating process control based on microprocessor technology, wheel spin/slide protection, mains current limitation, regenerative brake with continuous supervision of the mains receptivity, event/fault storage, service data recording, diagnostics/fault analysis via PC

Traction motors: 2 longitudinal, fully suspended, self-ventilated, AC asynchronous motors, MAB T 10 type: rated power 240 kW; rated voltage 500 V; rated current 349 A; rated frequency 50 Hz; rated rotational speed 1485 min-1, motor mass 900 kg.

Auxiliary power supply: IGBT auxiliary static converter; input voltage DC 750 V (+25 %, -30 %); DC output 24 V, 200 A; final charging voltage 24 V to 28.8 V; AC output 3 AC 400/230 V, 20 A.

4. Main data of the vehicle and the location of the equipments.

As an application example, is considered the V3A-93-AS tramway.

Line voltage: DC 750 V (+20 %, -30 %)

Constructive characteristics: V3A-93-AS, 8-axle articulated tramway for unidirectional operation type: rail gauge 1,435 mm; maximum speed 55 km/h operationaly and 65 km/h constructive; wheel arrangement Bo’ + 2’ + 2’ + Bo’; wheel diameter (new/worn) 686 mm/616 mm; gear ratio 5.66 : 1; mass empty ca. 35 t; mass loaded ca. 55 t .

Traction requirments: acceleration/ deceleration (half load),1.05 ms-2

General Layout of the equipment. INDA driving equipment is placed on the V3A old structure during the modernization of the existing fleet, according to fig. 3.

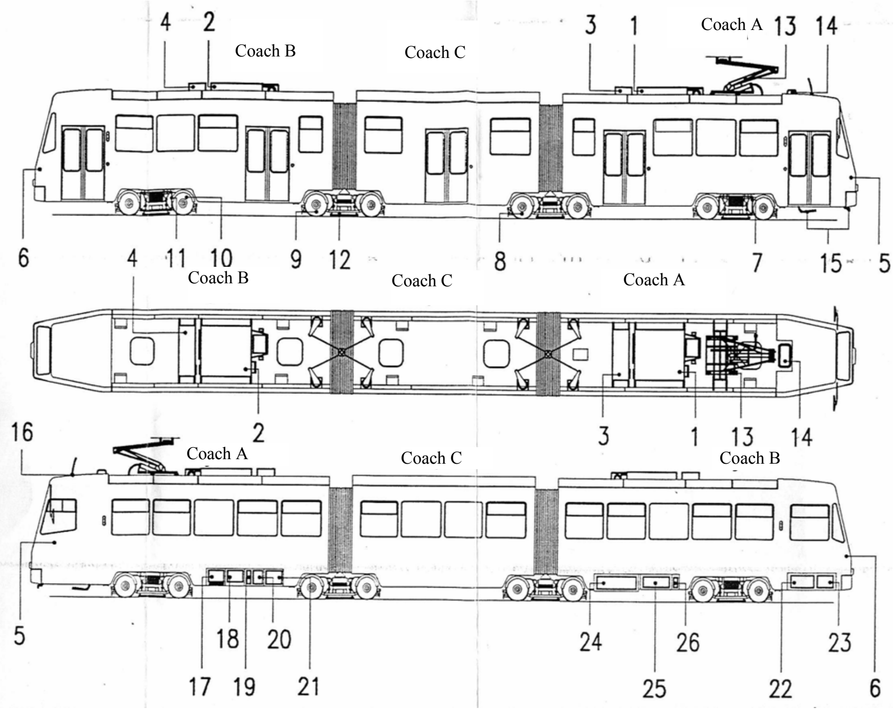

Fig.3.General Layout of the example vehicle

The main components of the tramway driving system, the two INDA inverter containers (position numbers 1 and number 2) are located over both motor bogies on the roof. Each of the two roof containers contains, one complete traction inverter and braking chopper, including inverter and chopper control module (UC 2) as well as further functional units. The roof containers are supplied to the car builder completed wired and functiontested.

The braking resistore are placed also on the roof (see pos.2 and 4).

Traction motors (position 11) are places on the motor bogies of the tramway.

5. Performences (Traction/Braking effort and Running Diagrams)

Traction/Braking effort and Running Diagrams are presented in fig. 4 and fig. 5.

Tractive effort curve is settled for the nominal parameters of the tractions motors with the constant tractive effort up to 0,5 of maximum constructive speed and constant power for the rest. The braking effort curve follow the same pattern with constant deceleration up to 40 km/h and constant braking power between 40 km/h and the maximun constructive speed.

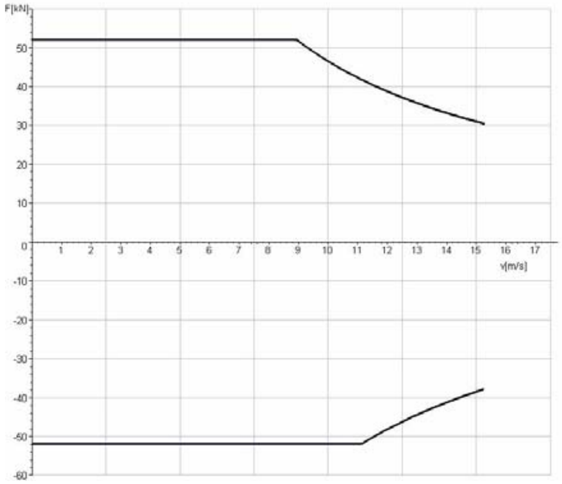

Fig.4. Tractive/Braking effort curve.

Running diagram (fig.5) is calculated for the shortest running time and space with four intervals: constant acceleration and variable power up to base speed, acceleration limited by the power up to maximum speed, braking deceleration limited by the set braking power, constant braking deceleration with decreasing braking power.

The rezult: the accelerating and decelerating time of 31.980 s and a total space of 260.746 m. Taking into account 20 s of station time, rezults a commercial speed of 5.0162 m/s that means ca.18 km/h, which are satisfactorily for the operation. For the other conditions with bigger stations intervals, using either maximum speed or coasting regime the commercial speed will increase.

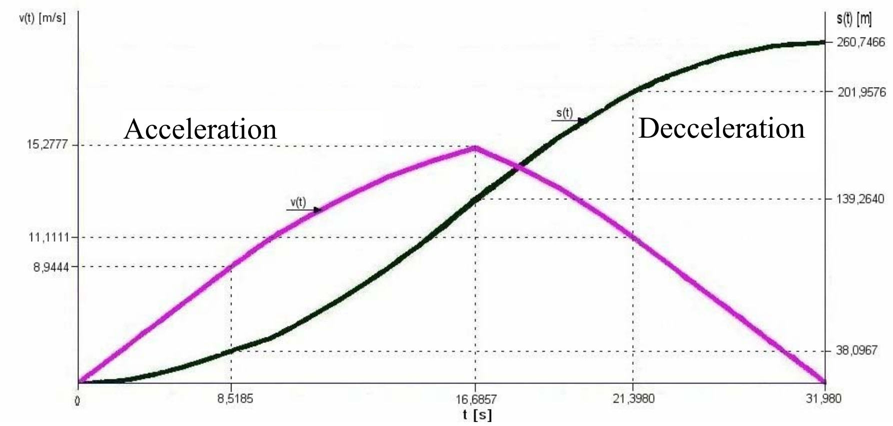

Fig.5 Running diagram for halfloaded vehicle

6. Conclusions

The proposed driving system with a good technical characteristics will satisfy the operational needs through increasing commercial speed, reduced energy and maintenance costs, and also very important a high traveling comfort for the passengers.

References

[1] Weigel, W.-D.: Eine neue Generation van elektronischen Triebfahrzeug-Steuerungen mit Mikrocomputer. ZEV-Glas. Ann. 107 (1983). Nr. 819. S. 305-312.
[2] Urbanke, C.: Moderne Steuer- und lnformationstechnik auf Bahnfahrzeugen. ZEV-Glas. Ann. 110 (1986). Nr. 6/7. S. 223.231.
[3] Bayer, K.H.:TRANSVEKTOR-Regelung-Ein Regelprinzip für Drehstromantriebe. ZEV-Glas. Ann. 104 (1980). Nr. 8/S, S. 291.298.
[4] S. Ogasawara, H. Akagi, and A. Nabae, “A novel PWM scheme of voltage source inverters based on space vector theory,” in *European Power Electronics Conf. Rec.*, 1989, pp. 1197-1202.
[5] Wagner, R.: Advances in the Development of the Three-Phase AC Drive, Translation of an article from “ZEV Glasers Annalen” No.11/12, 1987, pp.418-427
[6] Depenbrock, M.;Steimel, A.: High Power Traction Drive and Converters.Proc.Electrical Drives Symposium ’90, Capri, S.I 1-9
[7] Depenbrock, M.: Direct Self-Control (DSC) of Inverter-Fed Induction Machine. IEEE transaction on Power Electronics 1988, H.4,S. 420-429
[8] Steimel, A.: Stator-flux-oriented high performance in traction. Tutorial H-4, 35th Annual Meeting IEEE IAS Industry Application Society, Rom 2000
[9] Bakran, M.; Eckel, H.G.: The Evolution of IGBT Converters in Mass Transit Ampplication. IEEE IAS Annual Meeting 2000, Rom, CD-Rom
[10] Weschta, A.: Power Converter with IGBTs for the new Light Rail Vehicle for the City of Frankfurt, 5th Europ. Conf. on Power Electronics, Brighton 1993, S. 229-234.
[11] Steimel, A.: Electric Railway Traction in Europe. IEEE IAS Industry Application Magazine, Vol.2, H.6, Nov./Dec. 1966, S.6-17
[12] Steimel, A.: Control of induction machine in traction.Electrische Bahnen 96 (1998) H.12, S.361-369.