Adaptive Software Oriented Automation for Industrial Elevator

MONICA LEBA, EMIL POP, ALIN BADEA
System Control, Applied Informatics and Computer Engineering Department
University of Petrosani
Str.Universitatii, nr.20, 332006, Petrosani
ROMANIA
monicaleba@upet.ro, emilpop@upet.ro

Abstract: - In this paper the complex automation of an industrial elevator is considered. The elevator is used to transport tens of tons of material loaded in two skips moving upwards and downwards from underground to the surface or reversed. The elevator has an induction electric drive controlled in voltage and frequency by the principle of constant U/f. The movement must be done according to a specific speed profile (tahogram), in order to allow the start, acceleration, maximum speed working, deceleration and precision stop for material unloading. For this reason, it is used an adaptive controller having a plant parameters estimator. Using these parameters a new gain value is determined and supplied to the controller. A second controller is used for logic control signals, like drive start/stop, brakes and decision making at plant fault detection. The solution for automation is software oriented using a graphic user interface (GUI) for the operator dialog. There are implemented a lot of other facilities, like on-line maintenance, on-screen virtual measurements, real-time state and tahogram display, on-line events database update. The software was tested on a laboratory model of the mining elevator with good results.

Key-Words: - software, adaptive control, mining elevator, graphic user interface

1 Introduction

For a class of industrial elevators and transport systems there are characteristic the big starting torque and variable unknown transport load. These lead to the necessity that the drive should be controlled according to a certain speed profile which has the following parts: load and start, accelerate, maximum speed working, decelerate, unload and precise stop.

In fig.1 is presented the speed profile form, called tahogram, which is symmetrical and has the above five periods.

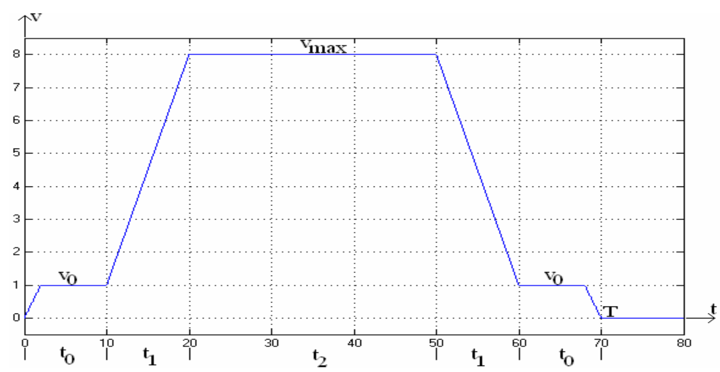


Fig.1. Imposed five periods tahogram

In fig.1 there were used the following notations:

- t_0 is the load and start period that is the same with the unload and stop period;
- t_1 is the acceleration period to the maximum speed v_{max} that is the same with the deceleration period to the reduced speed v_0;
- t_2 is the v_{max} working period.

The period t_0 is about 5..10% of the entire period T and the other two periods are determined according to the maximum space H, the maximum acceleration a_{max} and the maximum speed v_{max}.

The precise achievement of the above requirements depends on the unknown load Q_u and therefore the period T must be determined for each transport cycle.

Because the load Q_u cannot be weighted, it is necessary to identify some parameters from which it can be estimated. This is the reason why there is used an estimator and an adaptive controller so that there can be ensured a tahogram as close as possible to a previously imposed profile. This strategy also achieves the minimum period T, which ensures maximum productivity of the plant.

The logic controller achieves the following main operations: the integrity test for all the plant equipments; automat/manual control; precise speed profile control according to the imposed tahogram; emergency stop at fault detection; maintenance control according to the principle diagram etc.

This solution was implemented by two software components: the first for logic control and the second for estimation and adaptive control.

2 Problem Formulation

Industrial elevator automation will be achieved using a logic controller and an adaptive controller together with a classical feed-back regulator. The block diagram is presented in fig.2, where can be seen the main parts of the system, as follows: electrical drive; elevator wheel and gear; two skips for mass transport; brake with its servo and local controller; plant speed transducers for speed measurement. The plant also has an inverter to control the speed using scalar U_x/f_x method, a main switch for the on/off inverter power supply. In order to detect any out of order state in the main switch are embedded electric sensors, which send fault signals.

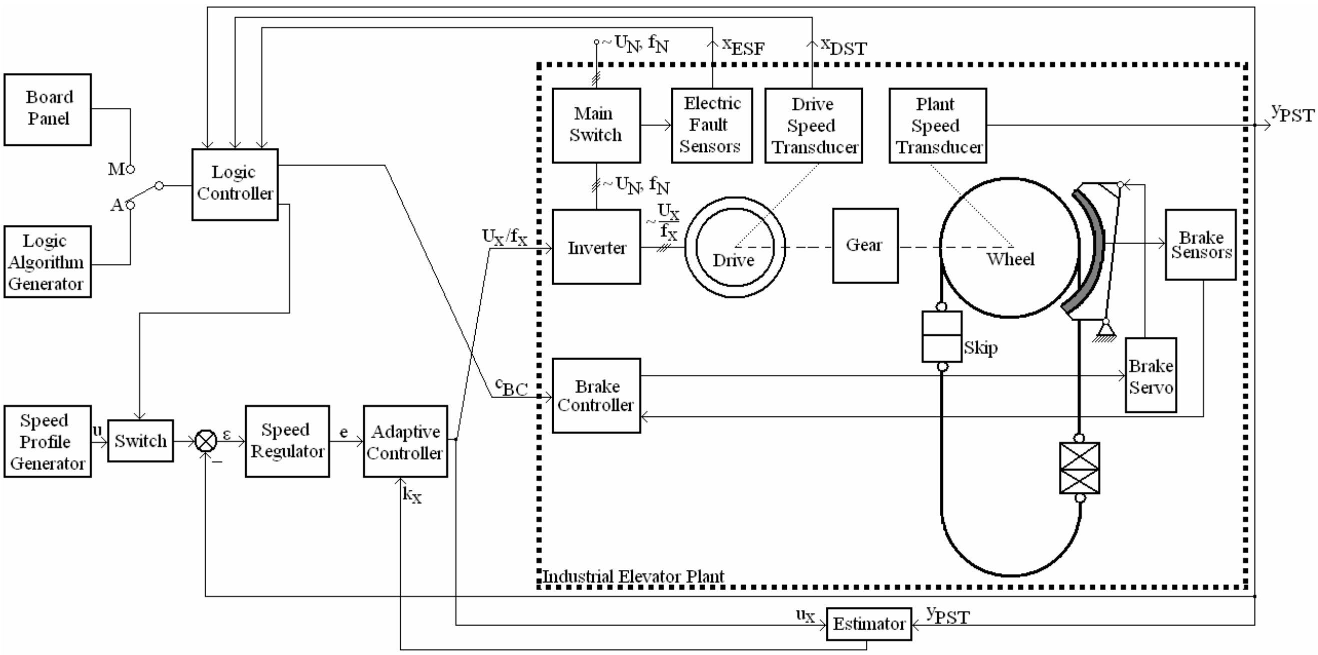


Fig.2. Plant block diagram

The plant had three inputs for control: on/off for main switch, U_x/f_x for inverter and c_{BC} for brake controller. The plant also has three outputs for feedback control: x_{ESF} from electric fault sensor, x_{DST} from drive speed transducer and y_{PST} from plant speed transducer that represents the real plant speed.

The logic controller ensures automat (A) and manual (M) control by means of a two positions switch. For the M position the operator uses the manual switches board and for the A position the systems runs automatically based on the logic algorithm. The controller also starts the adaptive part, connecting the speed profile generator to the system.

The analogical part consists of two closed loops, the first to stabilize the plant speed using a classical speed regulator with a negative feedback and the second with an adaptive controller using a plant parameters estimator. The estimator generates the new gain k_x for the adaptive controller in order to maintain the tahogram very closed to the imposed speed profile.

The algorithm is presented in fig.3.

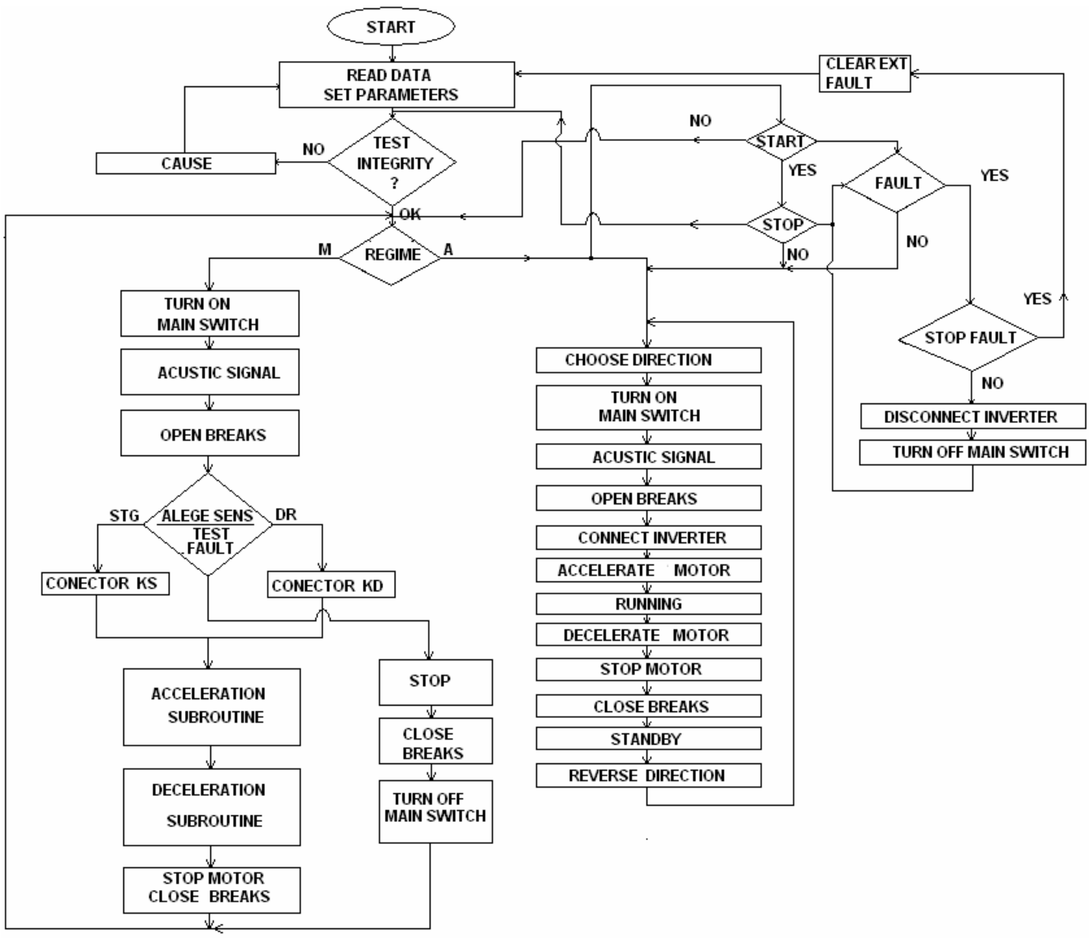


Fig.3. Algorithm diagram

Next, is presented the model and simulation of this plant. The mathematical model was developed based on the paper "Maximum Productivity Adaptive Control of a Mining Elevator".

On this plant model we connect the logic controller and speed profile generator as shown in fig.4.a. In fig.4.b are presented the simulation results.

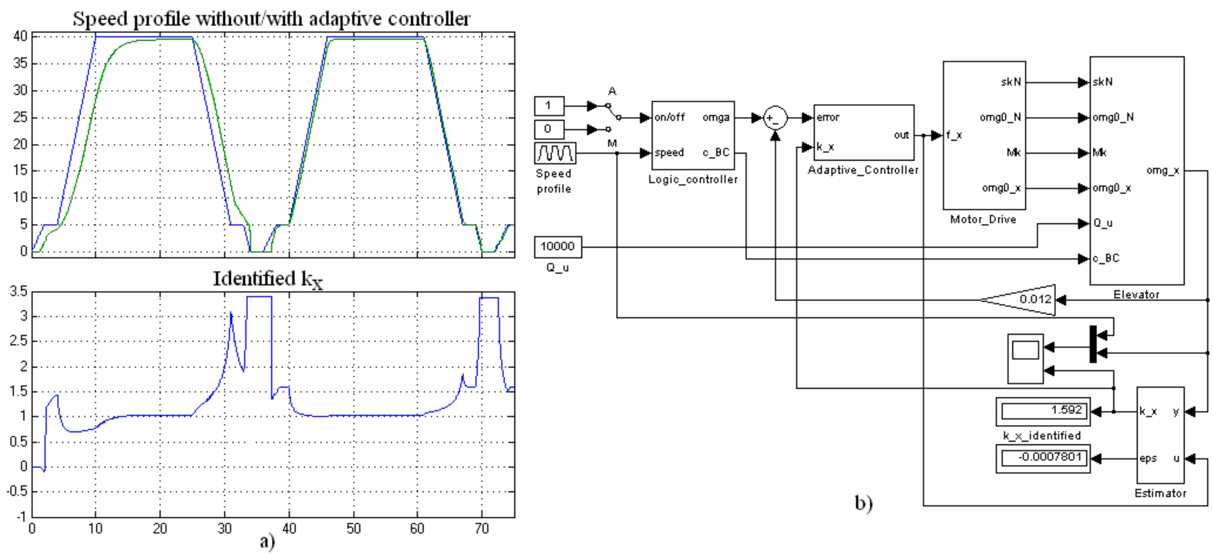


Fig.4. Adaptive controller system: a) model; b) simulation results

3 Problem Solution

In order to design software oriented adaptive controller for the industrial elevator, we use the model and simulation results presented above.

3.1 Graphic user interface

The software was written in Visual Basic and has a friendly graphical user interface, as presented in fig.5.

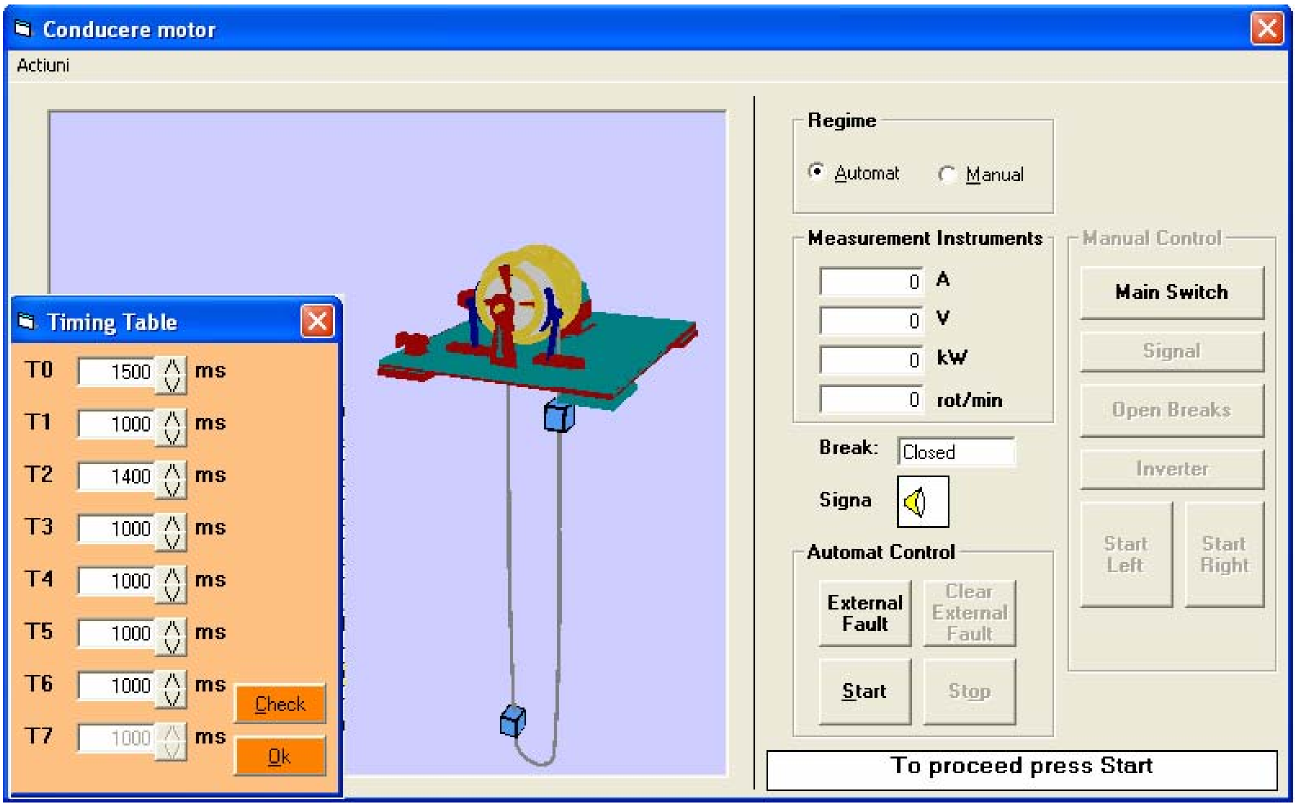


Fig.5. GUI control panel

The GUI has two sections. The left section consists of a window showing a real-time animation of the elevator according to the speed profile imposed by the timings table. Also in this section are presented several relevant states, like brakes open/close, speed and rotation direction. The right section represents the automatic and manual control board. For automatic control it is necessary to select the “Automat” option button and consequently the “Automatic control” frame becomes active. Note that in the pause regime the electric drive is stopped, the brakes are closed and in order to start the system it is necessary to push the “Start” button.

In automat regime there takes place the following events sequence: inverter on; acoustic signal on; brakes opened and drive running. The drive speed increases in eight steps from v_0 to v_7. The last speed v_7 is the maximum speed, which is the steady state speed.

At the end of the steady state period the drive decelerates in reversed order of speed, from v_7 to v_0. Then, the drive stops and the brakes close. After that follows a pause period necessary to load/unload the skips.

The manual control M automatically deactivates the automat control A. This command is achieved by the operator step by step using the panel buttons, except the drive acceleration, deceleration and adaptive control that still run in automat regime. The speed profile is achieved based on the timings table form from fig.5.

3.2 Option forms

A first option is the principle diagram activation, which is useful for monitoring and maintenance. This diagram is real time automatic updated synchronous with the plant working regime (fig.6).

Another option is the tahogram display, according to fig.7.

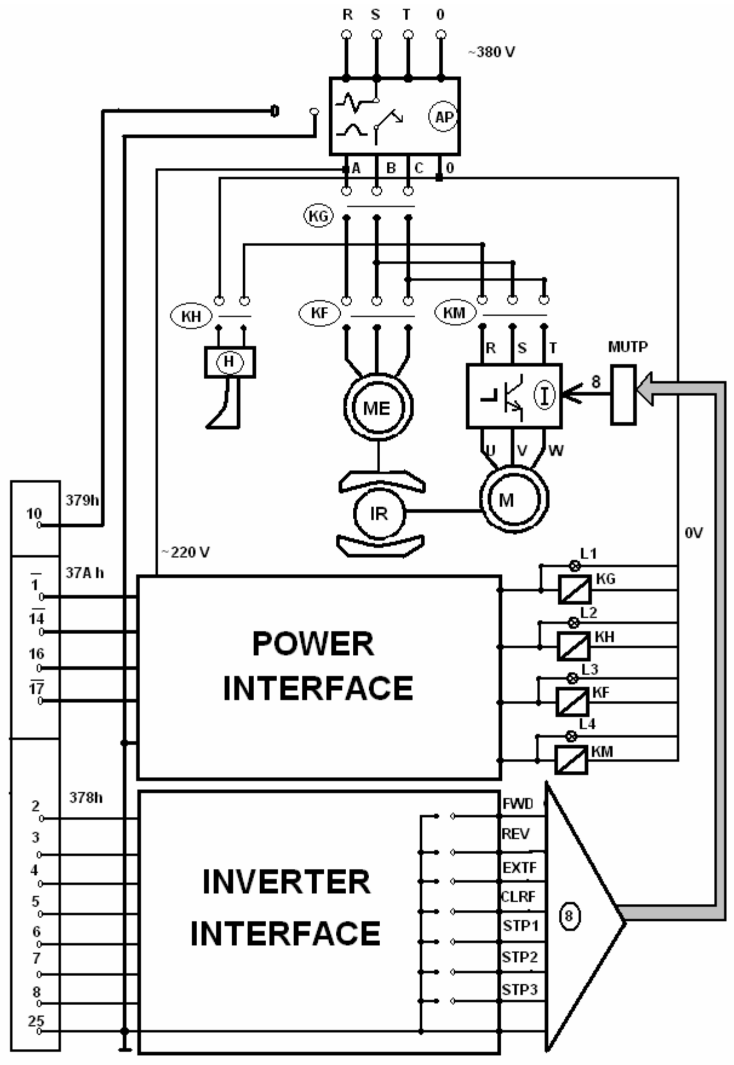


Fig.6. Principle diagram

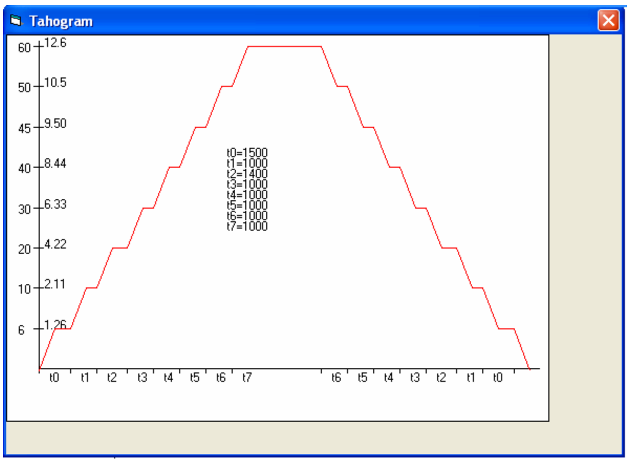
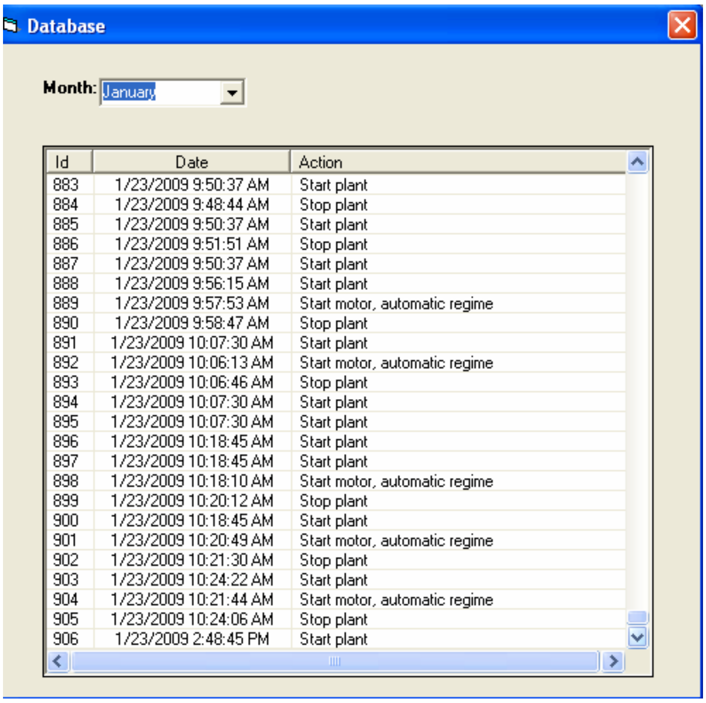


Fig.7. Tahogram

This tahogram is updated according to the plant adaptive strategy.

The last option is the use of a database that stores all the important information regarding the plant events on a month period (fig.8).



Id	Date	Action
883	1/23/2009 9:50:37 AM	Start plant
884	1/23/2009 9:48:44 AM	Stop plant
885	1/23/2009 9:50:37 AM	Start plant
886	1/23/2009 9:51:51 AM	Stop plant
887	1/23/2009 9:50:37 AM	Start plant
888	1/23/2009 9:56:15 AM	Start plant
889	1/23/2009 9:57:53 AM	Start motor, automatic regime
890	1/23/2009 9:58:47 AM	Stop plant
891	1/23/2009 10:07:30 AM	Start plant
892	1/23/2009 10:06:13 AM	Start motor, automatic regime
893	1/23/2009 10:06:46 AM	Stop plant
894	1/23/2009 10:07:30 AM	Start plant
895	1/23/2009 10:07:30 AM	Start plant
896	1/23/2009 10:18:45 AM	Start plant
897	1/23/2009 10:18:45 AM	Start plant
898	1/23/2009 10:18:10 AM	Start motor, automatic regime
899	1/23/2009 10:20:12 AM	Stop plant
900	1/23/2009 10:18:45 AM	Start plant
901	1/23/2009 10:20:49 AM	Start motor, automatic regime
902	1/23/2009 10:21:30 AM	Stop plant
903	1/23/2009 10:24:22 AM	Start plant
904	1/23/2009 10:21:44 AM	Start motor, automatic regime
905	1/23/2009 10:24:06 AM	Stop plant
906	1/23/2009 2:48:45 PM	Start plant

Fig.8. Database events for January

4 Conclusions

In this paper the complex automation for industrial elevator is considered. The elevator is used for material transportation loaded in two skips, moving in ascendant and descendent directions as is the case of underground to surface transport.

The elevator has an asynchronous electric drive supplied by a voltage and frequency regulator based on constant U/f method.

The movement of the skips must be according to specific speed diagram (tahogram) in order to allow start, acceleration, maximum speed moving, deceleration and precise stop for material unloading. This needs a special speed profile, which must be achieved with a good precision level. For this reason, it is used an adaptive controller having an estimator of the plant parameters and from these the gain k_x is determined and supplied to the adaptive controller.

A second controller is used for logic control to start/stop the drive, open/close the brakes and decision making at fault events at plant level.

The solution for automation is software oriented using a GUI to dialog with the operator. There are a lot of other facilities, like: on-line maintenance, integrity test, real-time tahogram and dynamic state display, monthly events history database storage etc.

The program is very flexible, friendly and is based on sustainable development principle.

References

[1] T.Gang, *Adaptive Control Design and Analysis*, Wiley&Sons, 2003.

[2] K.J.Astrom, B.Wittenmark, *Adaptive Control*, Add. Wesley, 1994.

[3] P.Ioannou, J.Sun, *Robust Adaptive Control*, Prentice Hall, 1995.

[4] S.Sastry, M.Bodson, *Adaptive Control. Stability, Convergence and Robustness*, Prentice Hall, USA, 1989.

[5] E.Pop, *Automatizări în industria minieră*, Editura Didactică şi Pedagogică, Bucureşti, 1983.

[6] E.Pop, M.Leba, *Microcontrollere şi automate programabile*, Editura Didactică şi Pedagogică, Bucureşti, 2003.

[7] F.Neghina, E.Pop, M.Leba, *Adaptive Control Strategy For Motor Drive Systems*, CSCS16, Bucuresti, 2006.