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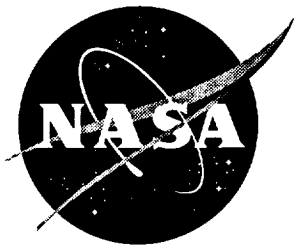
NASA Contractor Report 198250



Performance Validation of Version 152.0 ANSER Control Laws for the F-18 HARV

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Hampton, Virginia 23681-0001

Overview

The Actuated Nose Strakes for Enhanced Rolling (ANSER) control laws were modified as a result of Phase III F/A-18 High Alpha Research Vehicle (HARV) flight testing (Reference 1). Four control system modifications and a new load of 30 On-Board Excitation System (OBES) maneuvers make up a new software release for use in the Research Flight Control System (RFCS) flight control computer. The new software release is version 152.0.

Testing Performed

A brief description of the changes to the control laws follows:

1. Longitudinal gain sets 0 and 1 were swapped in the Dial-A-Gain setup.

2. The symmetric strake deployment schedule was modified to begin deployment at 20 degrees angle of attack (AOA) instead of 30 degrees AOA. Maximum symmetric deployment of 30 degrees AOA is reached at 50 degrees AOA instead of 60 degrees AOA.

3. A lateral stick filter was added to the lateral command path to filter the 20 Hz update rate associated with signal balancing that occurs in the lateral stick signal selection logic.

4. A longitudinal stick multiplier to account for signal selection logic effects encountered in the flight system was applied to forward longitudinal stick deflections. A longitudinal stick multiplier already existed in version 150.0 for aft longitudinal stick deflections.

All checkcases were run by using the Dryden batch simulation with FORTRAN coded RFCS version 152.0 ANSER control laws, and compared with the Hardware-In-the-Loop (HIL) simulator by using the Ada flight code. A subset of the ANSER performance validation checkcases documented in Reference 2 were run to test version 152.0. Thirteen checkcases were used to test the four control system modifications listed above. These checkcases are listed in Table 1.

Table 1
Closed-Loop Checkcases for V152.0 Performance Validation

Check case	RFCS Mode	Altitude (ft)	Mach Number	AOA (deg)	Load Factor (g's)	Thrust	Inputs
1	TV	25000	0.35	trim	1.0	trim	+3/-2.5 in. ramped long. stick doublet.
4	TV	35000	trim	30.0	1.0	trim	+3/-2.5 in. ramped long. stick doublet.
7	TV	16000	trim	50.0	trim	MAX A/B	+3/-2.5 in. ramped long. stick doublet.
20	S	25000	0.35	trim	1.0	trim	2 in. ramped lateral stick doublet.
22	S	35000	trim	30.0	1.0	trim	+3/-2.5 in. ramped long. stick doublet.
23	S	35000	trim	30.0	1.0	trim	2 in. ramped lateral stick doublet.
26	S	16000	trim	50.0	trim	MAX A/B	2 in. ramped lateral stick doublet.
30	S	40000	0.68	trim	1.0	trim	PLA ramped input to MAX and IDLE. +5 in. (aft) ramped longitudinal stick pulse. +1.5 in. (rt) ramped lateral stick pulse. -50 lb (lt) ramped pedal pulse.
33	S	25000	0.3	trim	1.0	trim	PLA ramped input to MAX and IDLE. +5 in. (aft) ramped longitudinal stick pulse. -3 in. (lt) ramped lateral stick pulse. 50 lb (rt) ramped pedal pulse.
41	1	25000	0.35	trim	1.0	trim	2 in. ramped long. stick doublet.
42	1	35000	trim	30.0	1.0	trim	2 in. ramped long. stick doublet.
43	1	16000	trim	50.0	1.0	trim	2 in. ramped long. stick doublet.
51	TV	35000	trim	30.0	1.0	trim	+3/-2.0 in. ramped long. stick doublet.

Checkcases 1, 4, 7, 41, 42, and 43 were used to test the Dial-A-Gain option swap modification. Checkcases 20, 22, 23 and 26 were used to test the new symmetric strake deployment. Checkcases 30, and 33 were used to test the lateral stick filter modification. Checkcase 51 is a new checkcase that was added to test the multiplier on the pitch stick.

Discussion of Results

Dial-A-Gain Option Changes

Figure 1 shows three parameters per page for checkcases 1 and 41, versions 150.0 and 152.0. The parameter GAINSEL corresponds to the pilot selectable Dial-A-Gain option, with zero being the default setting and 1 corresponding to Dial-A-Gain option 1. Two additional longitudinal parameters labeled GTILY1 and GTILY2 are included. These parameters correspond to longitudinal proportional feedback gains for angle of attack and pitch rate respectively. By referencing all three parameters, it can be noted that GAINSEL = 0 for version 150.0 now corresponds to GAINSEL = 1 for V152.0. Likewise, GAINSEL = 1 for version 150.0 now corresponds to GAINSEL = 0 for version 152.0.

Differences between batch and HIL can be attributed to the differences discussed in References 2 and 3. The primary reason for the gain differences in Figure 1 is the differences in impact pressure between the batch and HIL simulations. The differences between the batch simulation runs in version 150.0 and 152.0 are due to the longitudinal stick multiplier, which was turned ON for version 152.0 runs.

New Symmetric Strake Schedule

Figure 3 contains three plots for checkcase 22 that was run with RFCS version 152.0. The internal RFCS AOA is shown on plot one, and the left and right strake positions are show on plots two and three respectively. It can be observed that at 30 degrees AOA the strakes are symmetric deployed at 10°, and at 50° AOA the full symmetric deployment of 30° is reached. These strake deflections follow the new symmetric deployment that was added to RFCS version 152.0.

Lateral Stick Filter

Figure 2 contains four plots for checkcase 23 that was run with RFCS version 150.0. The lateral stick input into RFCS (LAT_STICK_IN) is shown on the first plot, LATST_CMD, which is the lateral stick command rescaled and filtered, is shown on plot two. This same parameter is shown again on plot three with an expanded y scale between 1 and 4 seconds. A 20 Hz oscillation can easily be observed on the HIL data, and is due to the signal balancing that occurs in the

lateral stick selected signal from the 701E control system. The signal selection logic is not implemented in the batch simulation. Plot four contains the left strake command, which shows that the 20 Hz oscillation appears in the surface commands.

A notch filter was added to the lateral stick command path for RFCS version 152.0 to reduce the impact of the 20 Hz oscillation. Page 2 of Figure 2 contains the same parameters and plot scaling to show that the filter performs as expected.

Longitudinal Stick Multiplier

Figure 4 contains batch versus HIL comparisons for the longitudinal stick. The data on Figure 4 correspond to checkcase 51, which had a longitudinal stick doublet of +3/-2 inches from trim. Plot 1 shows the longitudinal stick (DEP) with the generated doublet input. Plot 2 shows the longitudinal stick input into RFCS (PITCH_STICK) against the internal longitudinal stick signal (PSGTOT) which is the total stick command after OBES and pitch trim. The same comparisons are shown on plot 3 for the HIL run (PSTICK_1 versus PSGTOT_1). An expanded scale is shown on plot 4 for the negative portion of the longitudinal stick run. A magnitude of roughly -1.27 inches is shown for PSTICK_1. Multiplying by 1.1 which is the longitudinal stick multiplier, and accounting for the 0.06 inch deadband in the longitudinal stick path, results in the total longitudinal stick command of -1.34 inches shown on plot 4.

OBES Maneuvers

All OBES maneuvers were run in the batch simulation only, using flight Ada code to check the OBES generated input signals against the OBES specification (References 4 and 5). Closed loop dynamics were checked to ensure desired aircraft response characteristics in order to achieve acceptable research data. All OBES maneuvers coded in this software release matched their specification and are acceptable for flight test.

Summary and Conclusions

The Ada implementation of the ANSER control laws was tested in the HIL simulation and compared with the FORTRAN control law implementation in batch simulation. There are differences between the HIL and batch simulation results, but the significant differences can be accounted for by known differences in the simulations. When these differences are taken into account, the time-history results between simulations compare relatively well. The Ada modifications to the ANSER Control Laws perform satisfactorily and are ready for Phase III flight test.

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2. Messina, M. D.: *Performance Validation of the ANSER Control Laws for the F-18 HARV,* NASA Contractor Report 198196, August 1995.

3. *Performance Validation of the NASA-1A Control Laws for the F/A-18 HARV Final Report.* Internal High-Alpha Technology Program Document, 21 March 1994.

4. Morelli, E. A.;: *F-18 High Alpha Research Vehicle (HARV) Parameter Identification Flight Test Maneuvers for Optimal Input Design Validation and Lateral Control Effectiveness.* NASA Contractor Report 198248, December 1995.

5. Morelli, E. A.;: *F-18 High Alpha Research Vehicle (HARV) Parameter Identification Flight Test Maneuvers for Closed Loop Modeling.* NASA Contractor Report 198269, March 1996.

Figure 1 - Performance Validation Version 150.0
CASE_1__TV_Mode__.35-25k_trim_AOA_3_-2.5_in_ramp_dep

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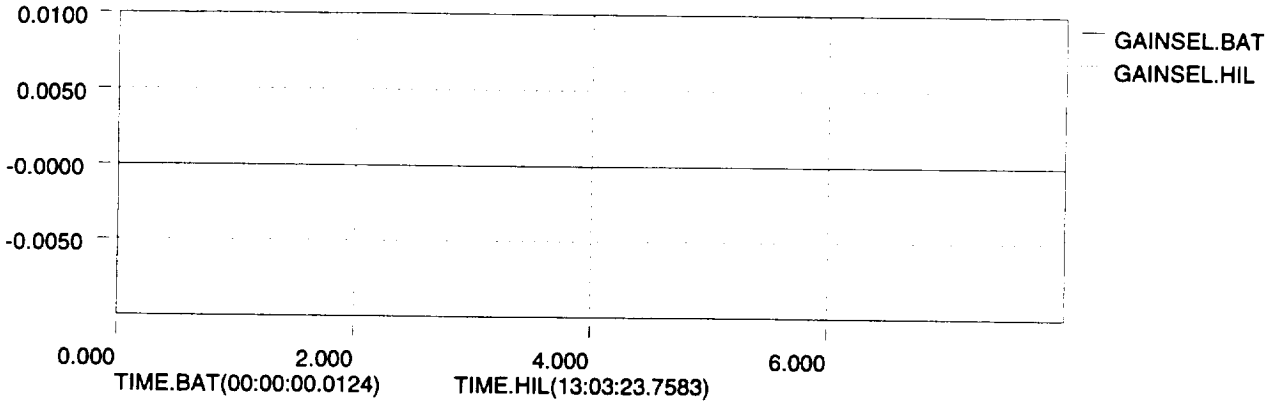

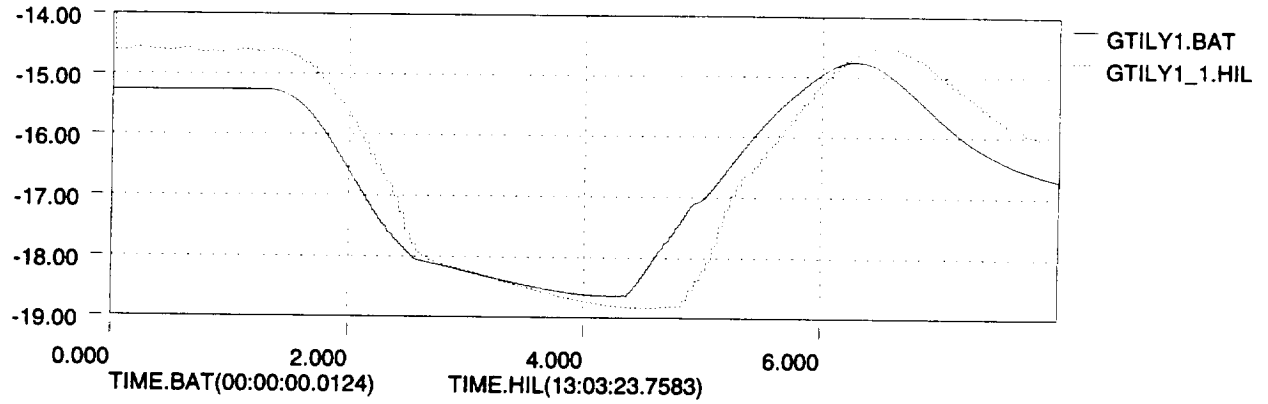

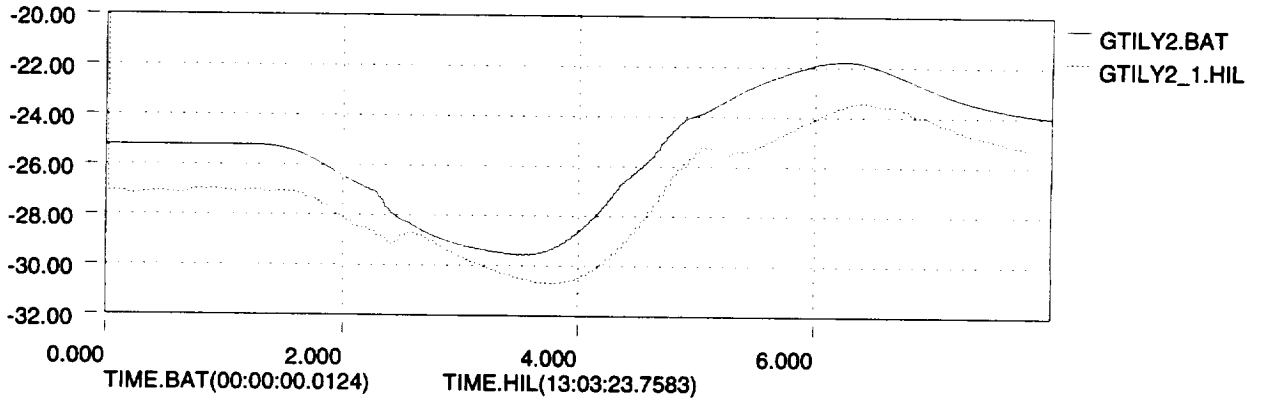

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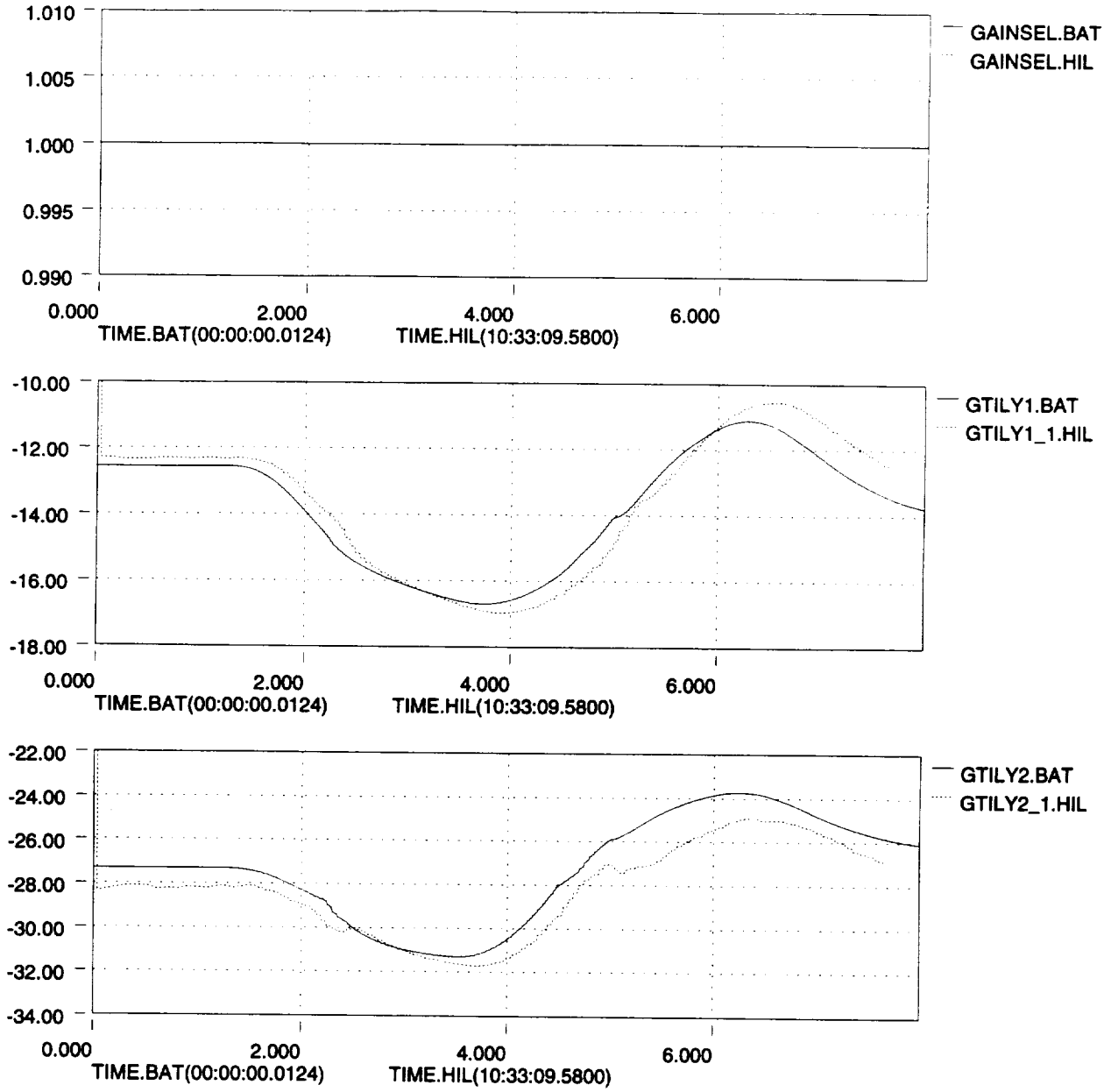

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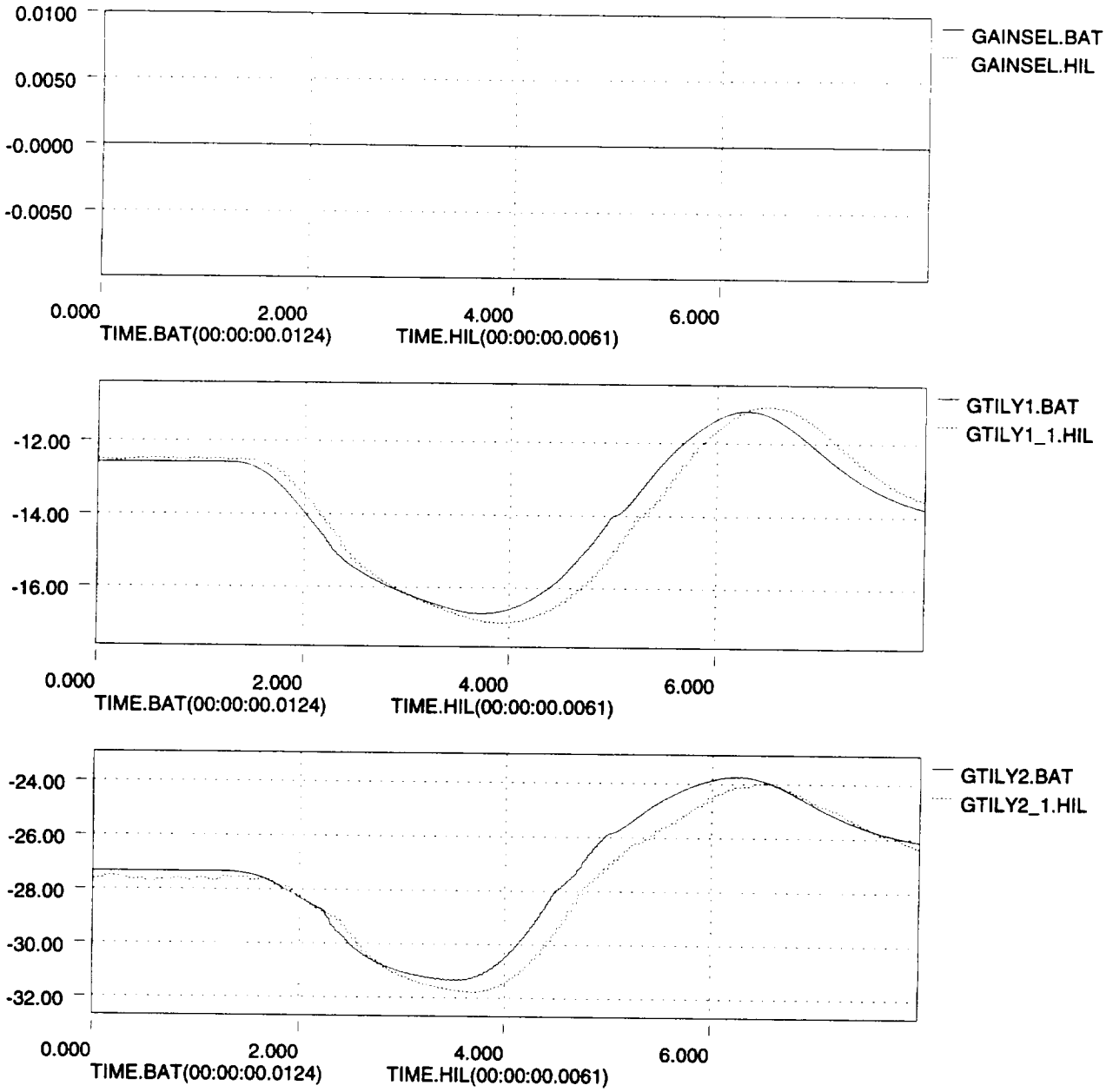

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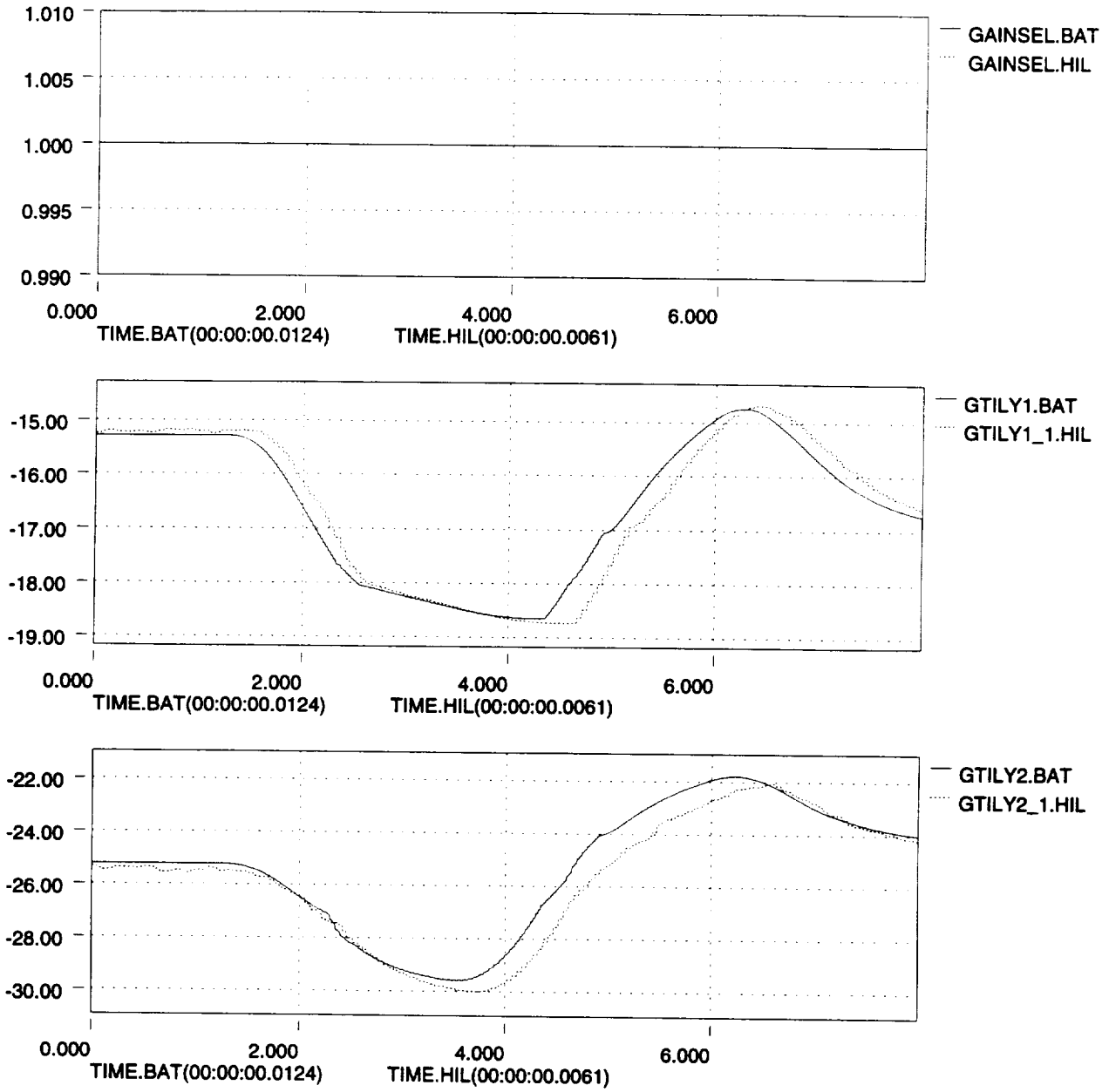

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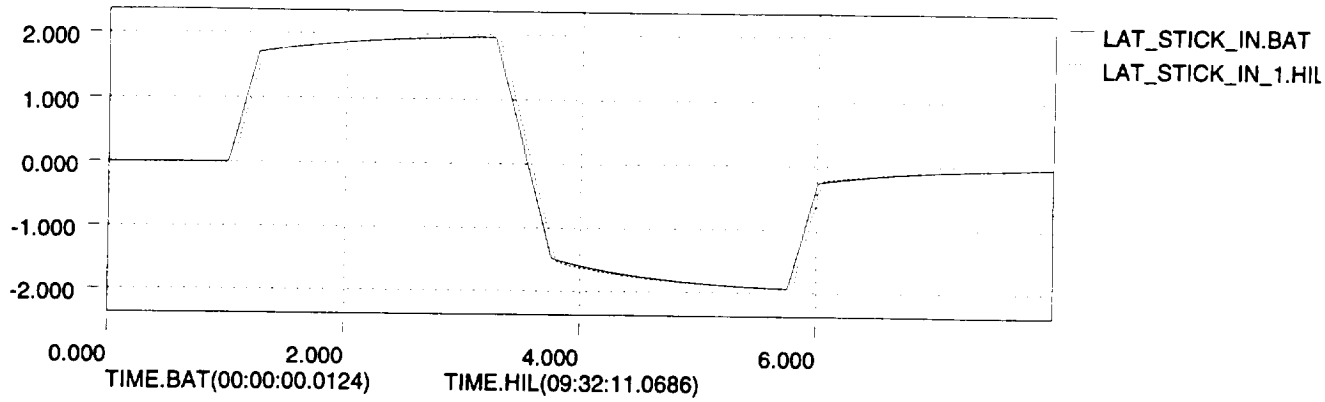

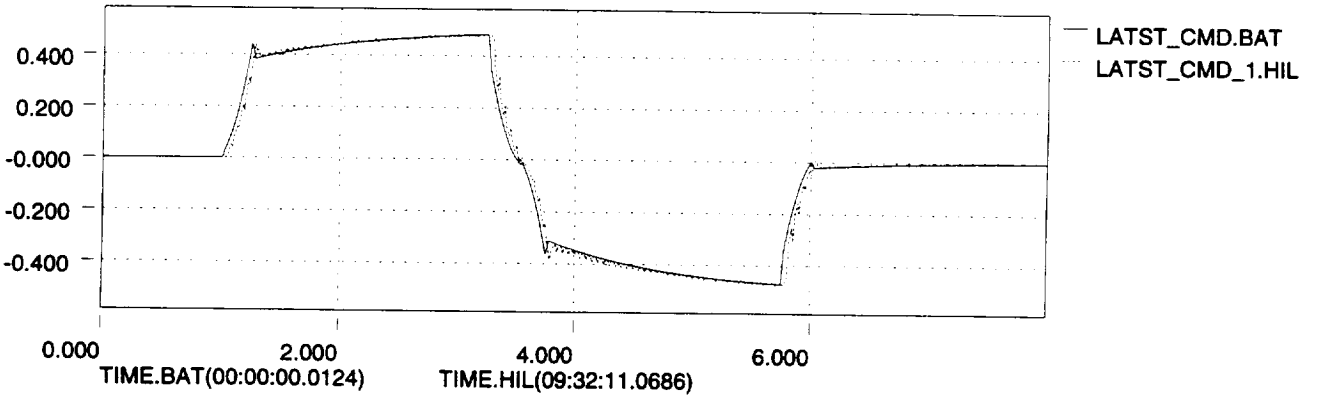

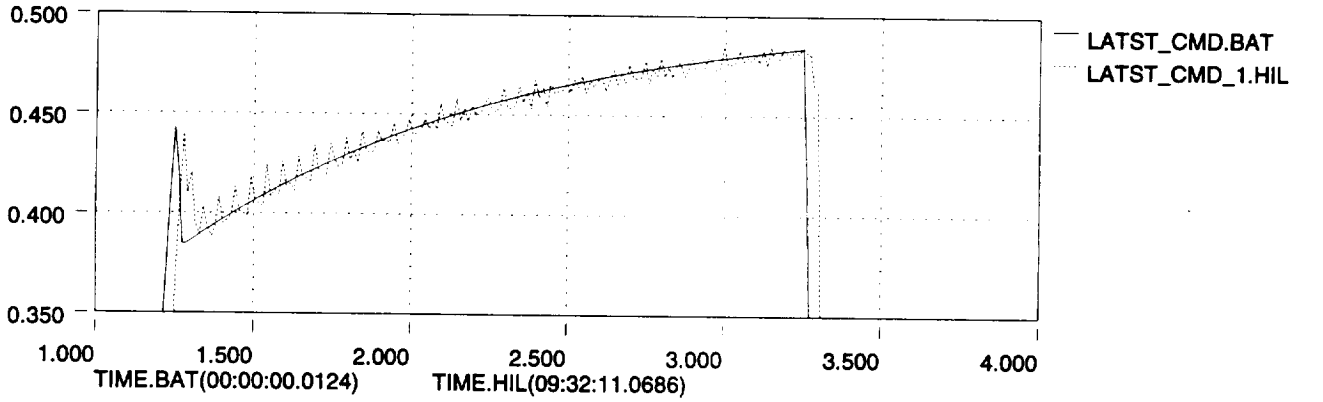

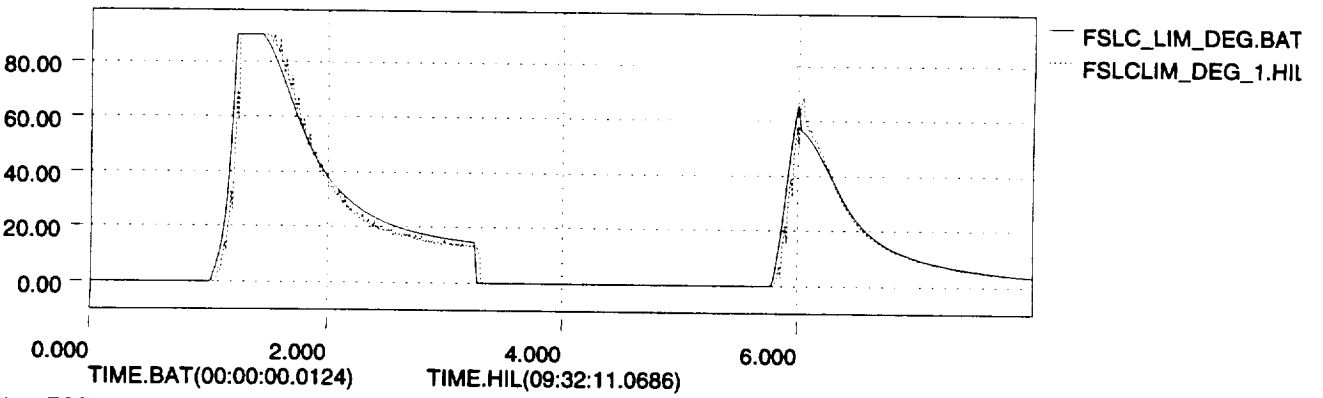

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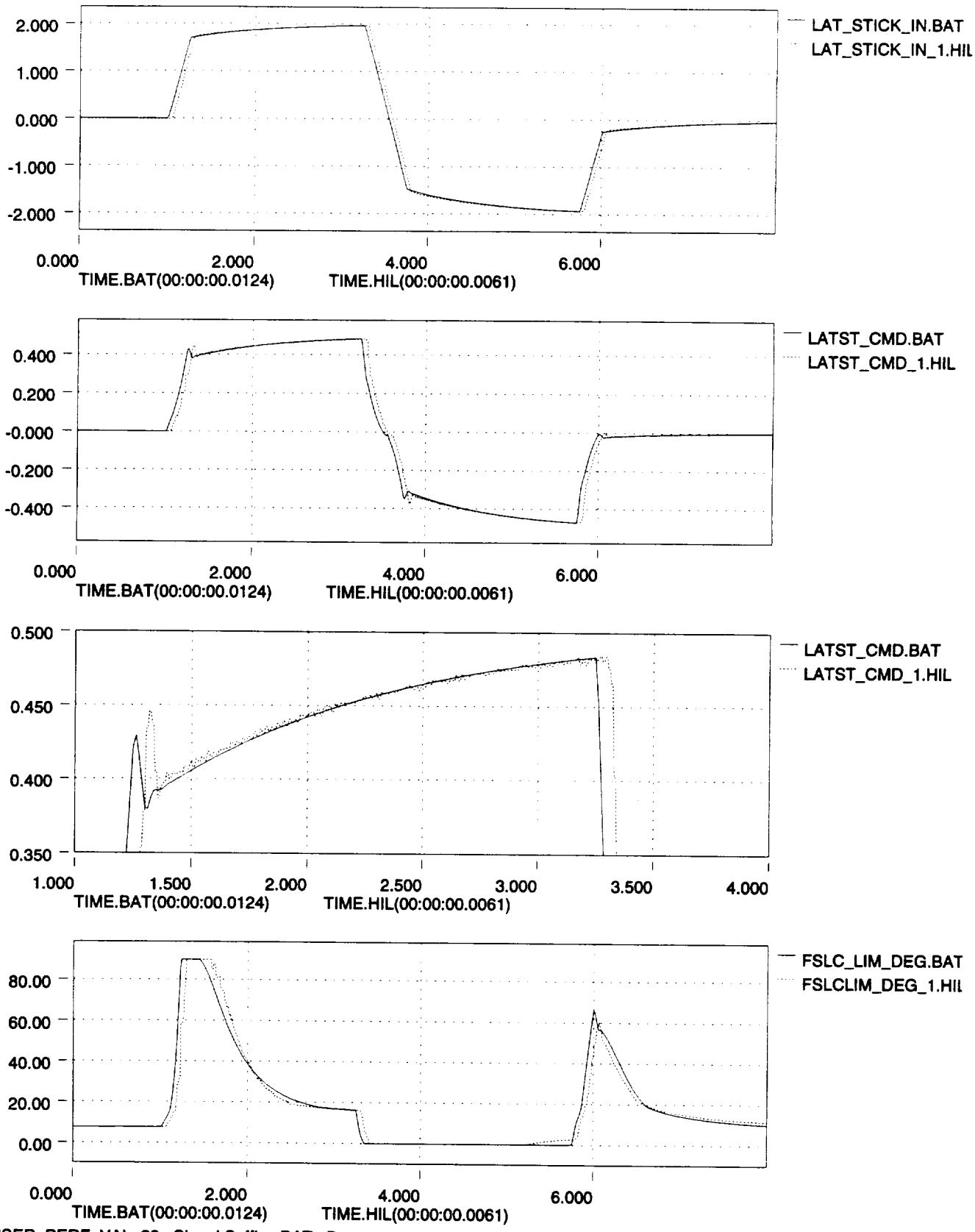

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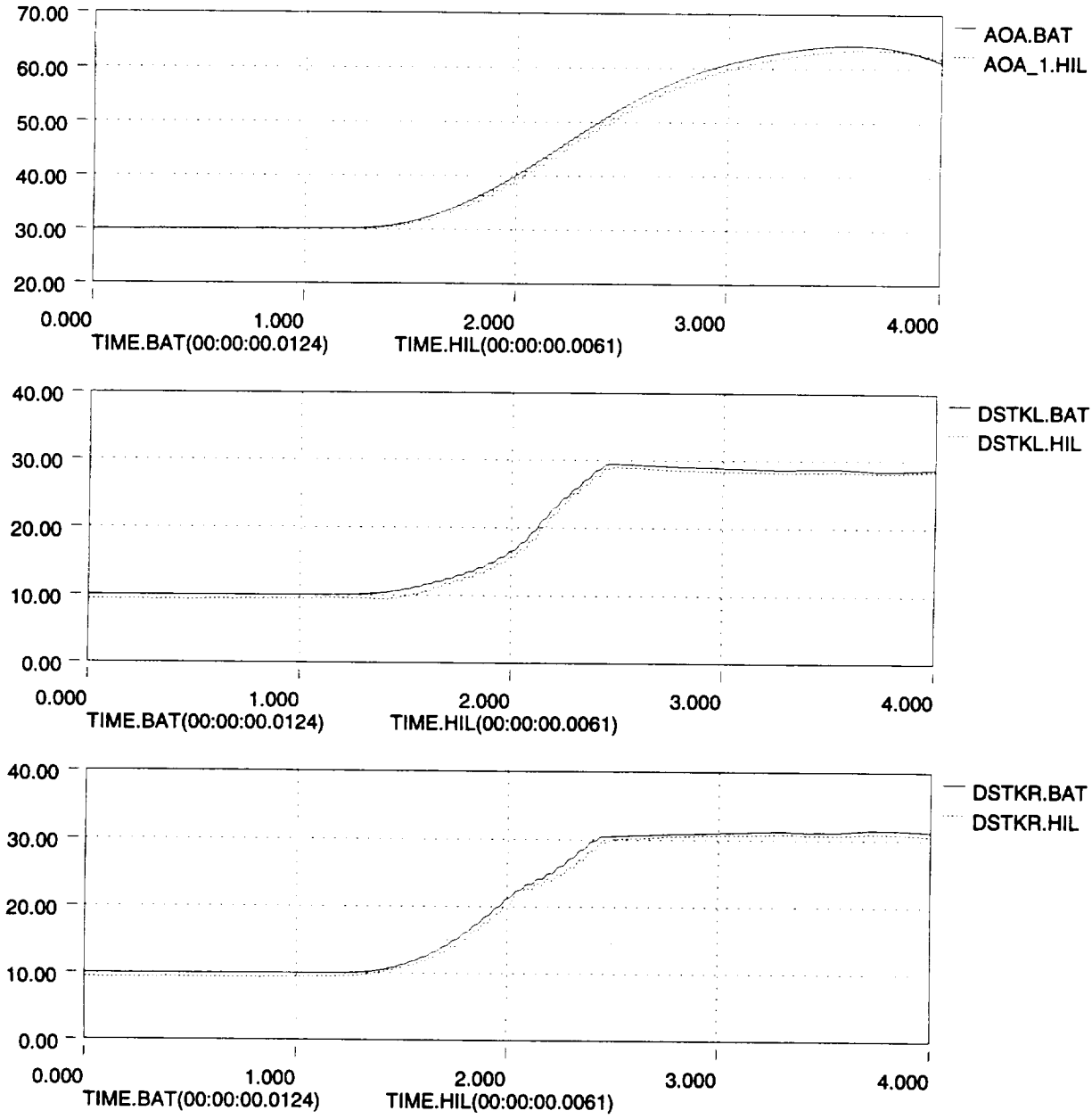

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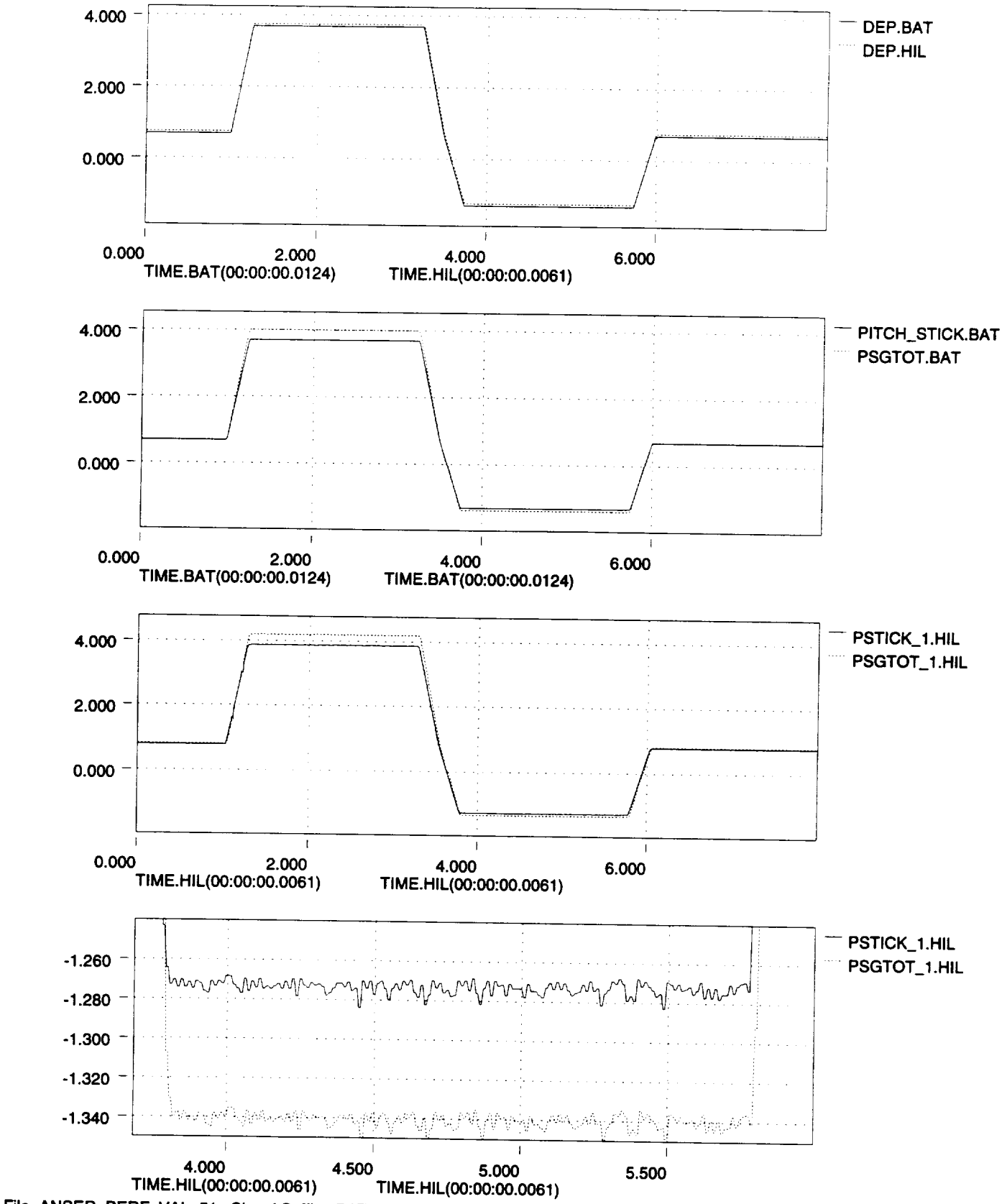

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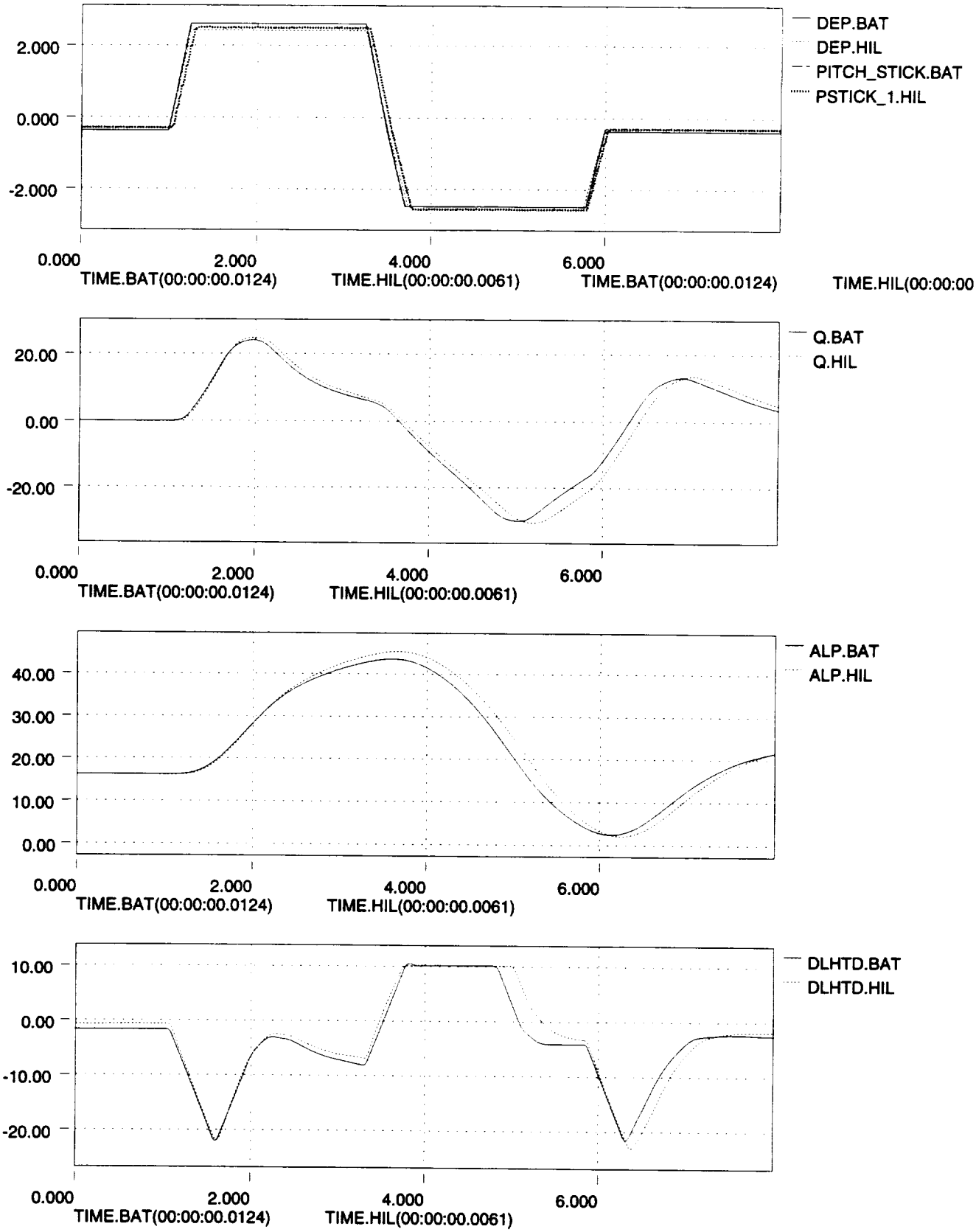
APPENDIX A

Batch versus Hardware-In-the-Loop Time Histories



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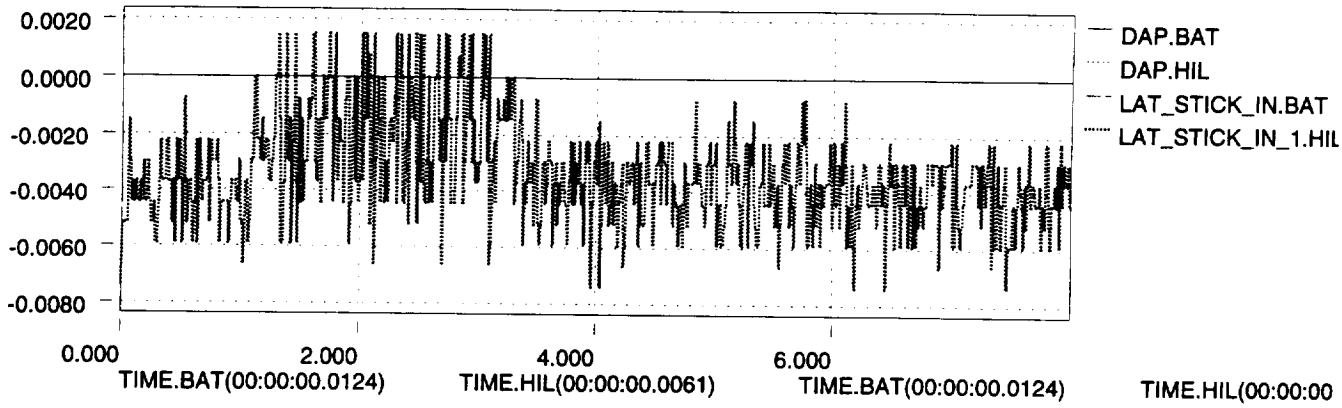

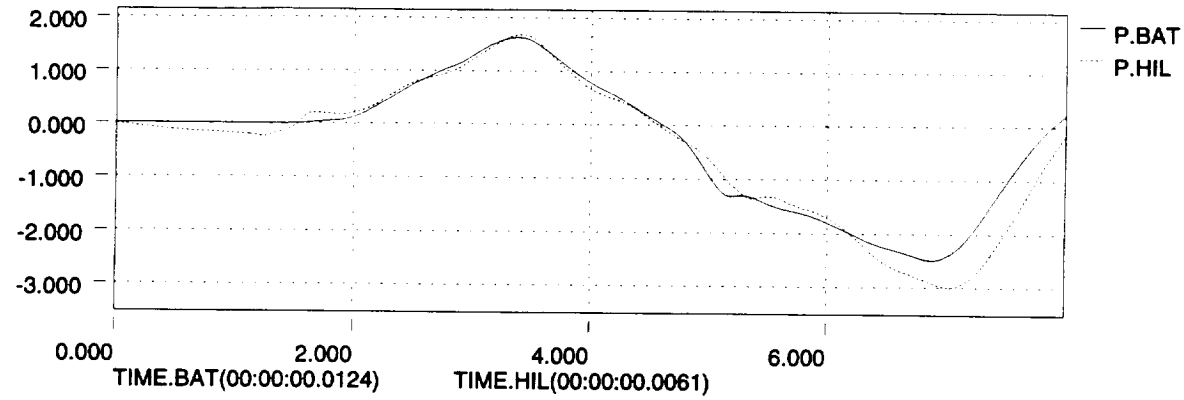

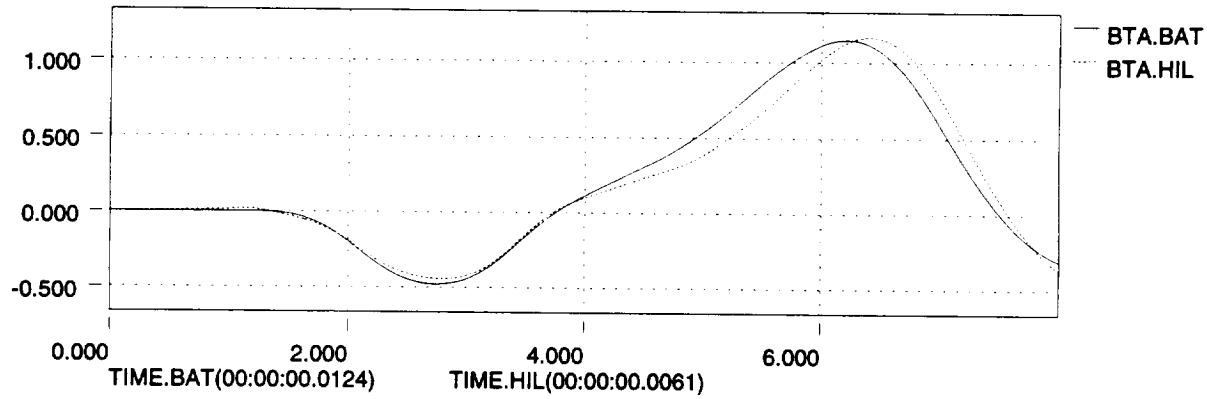

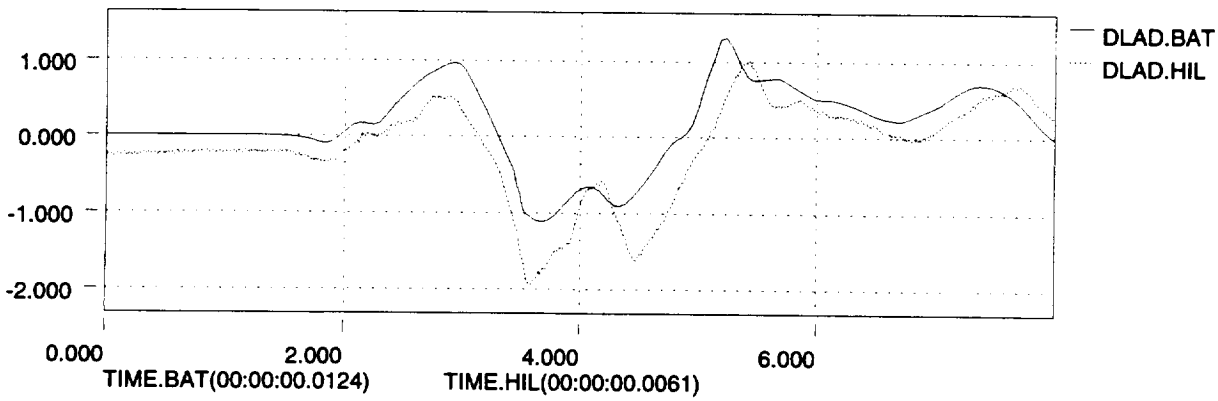

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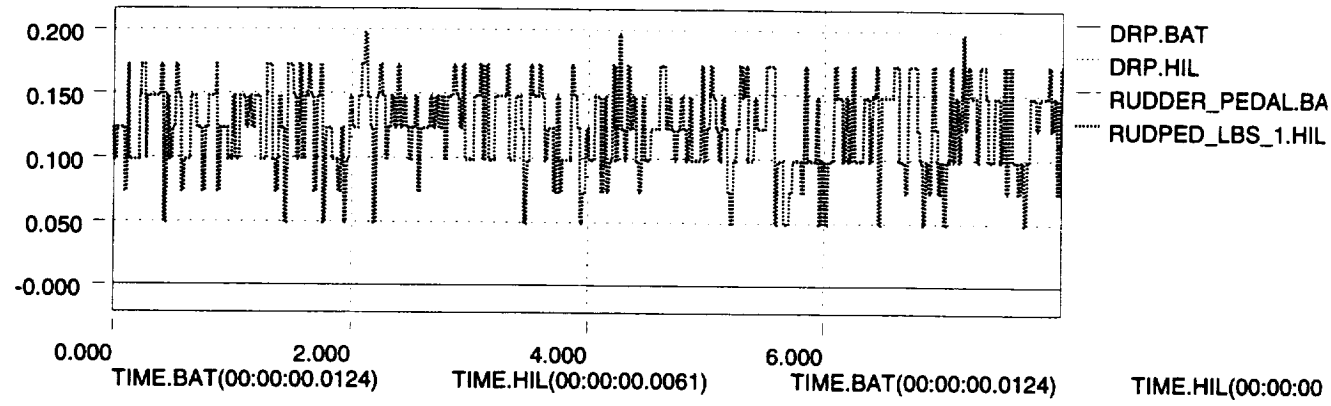

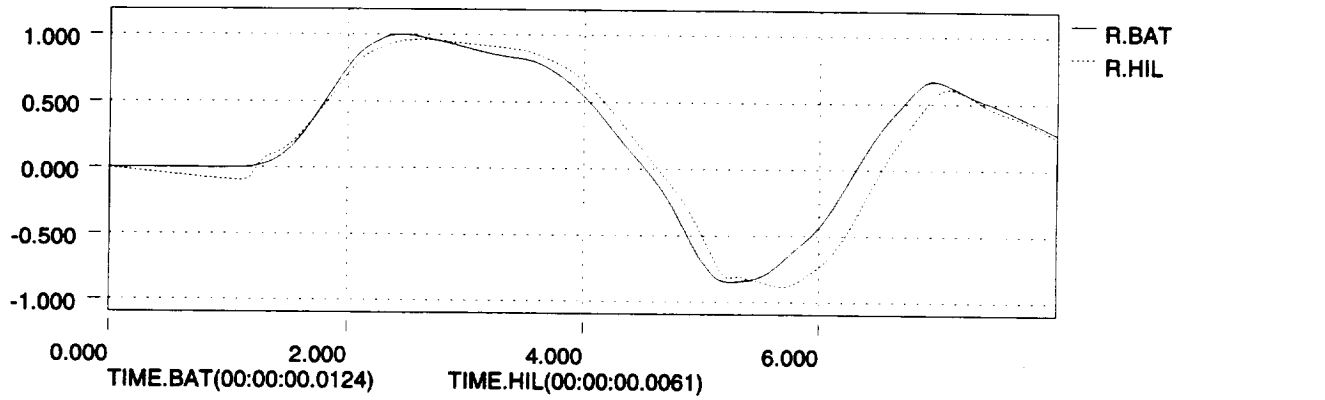

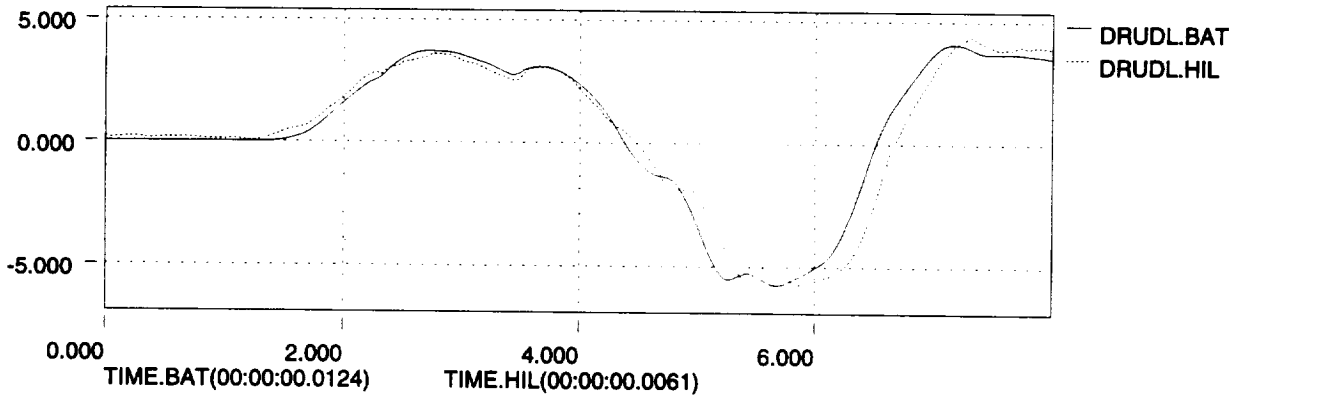

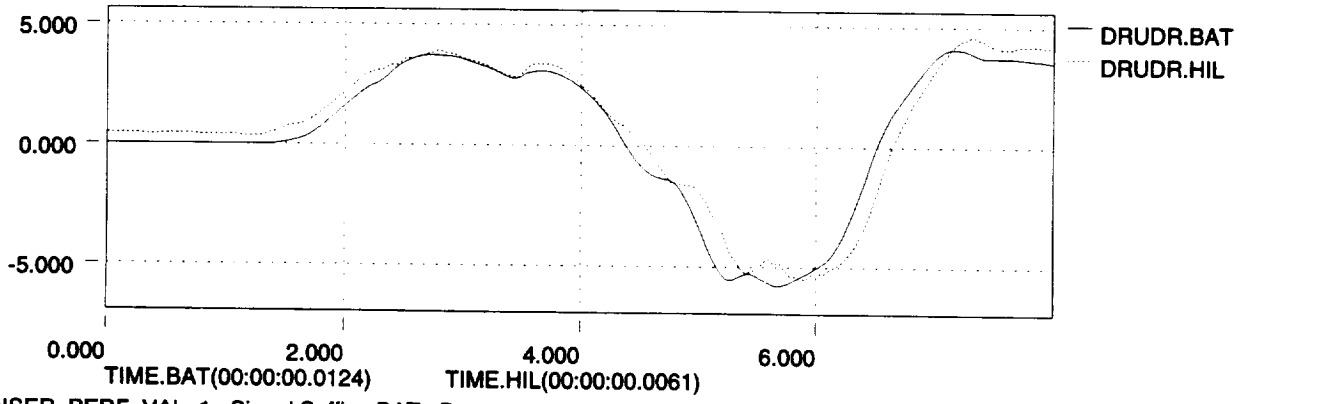

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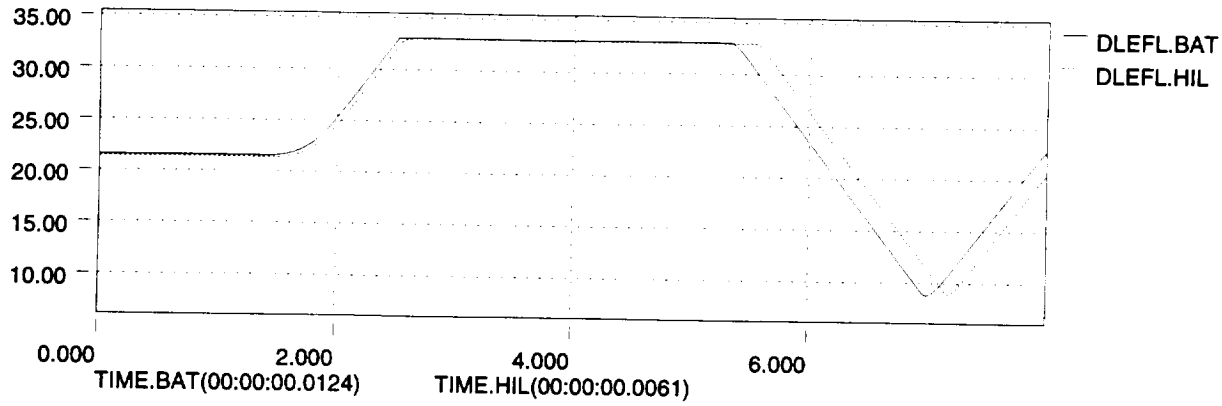

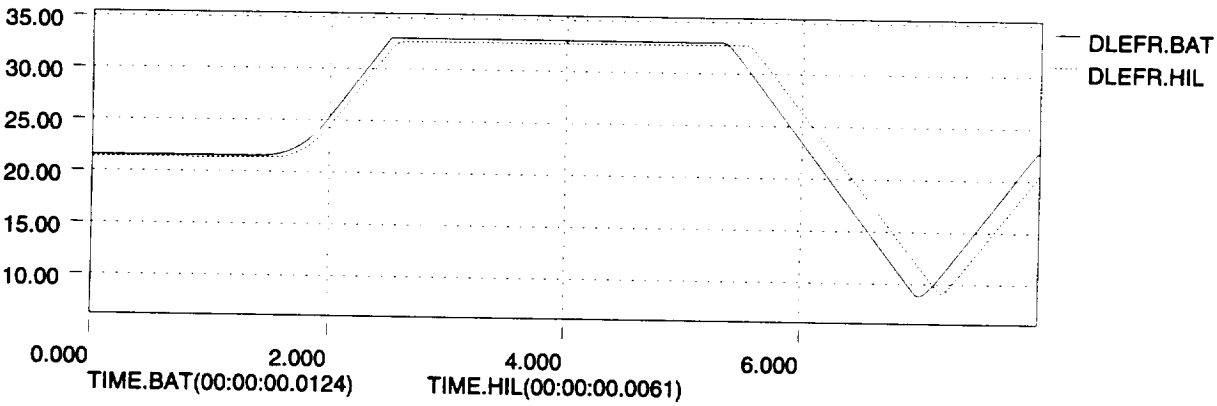

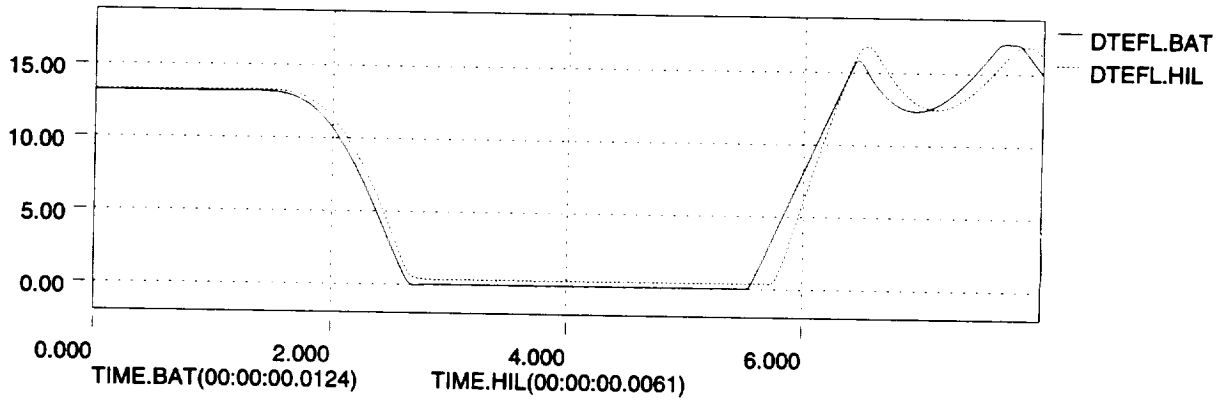

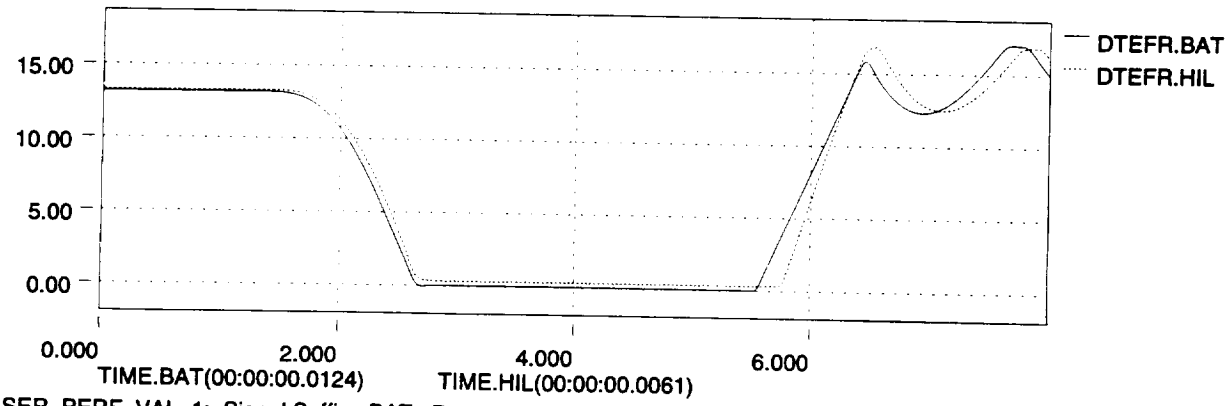

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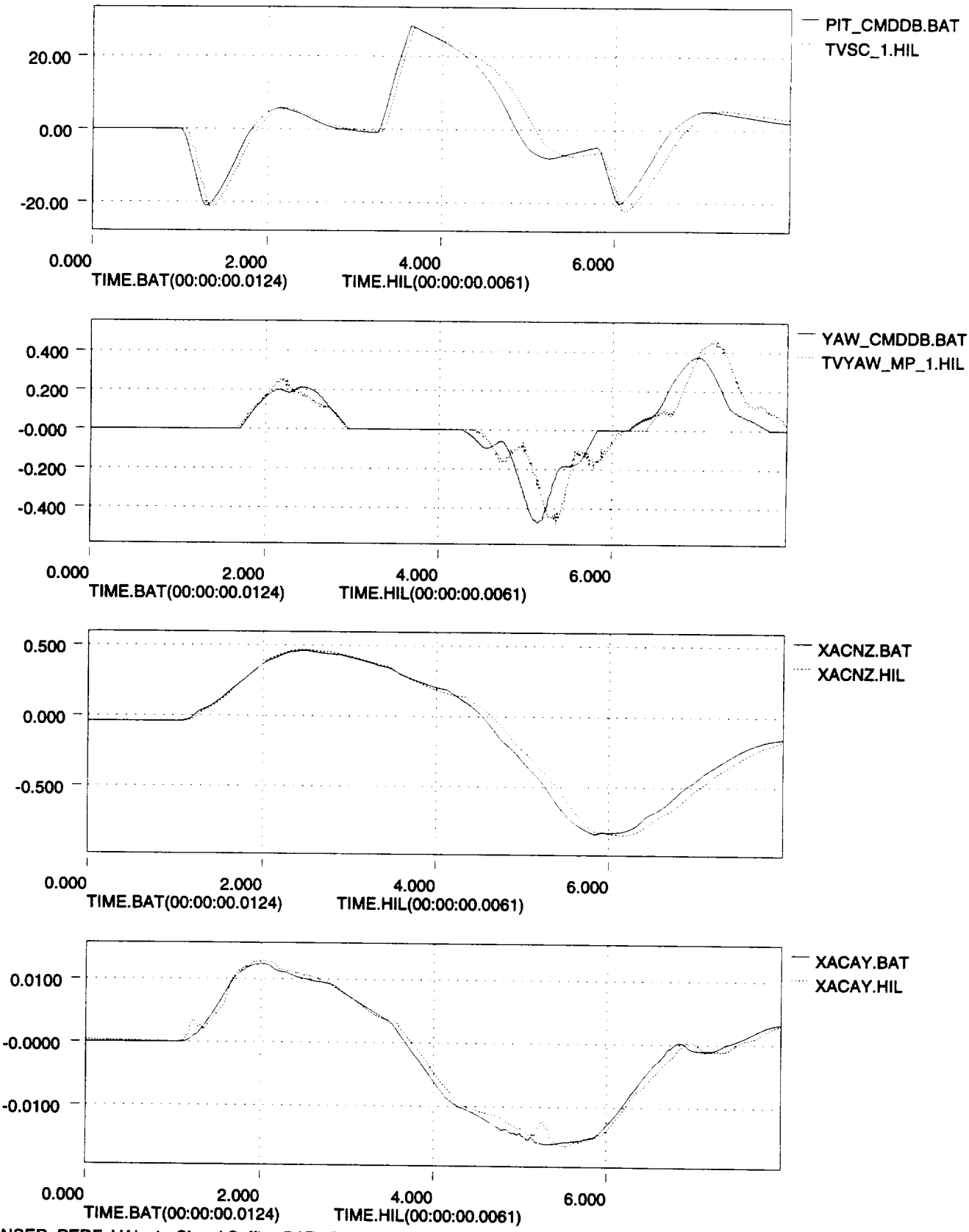

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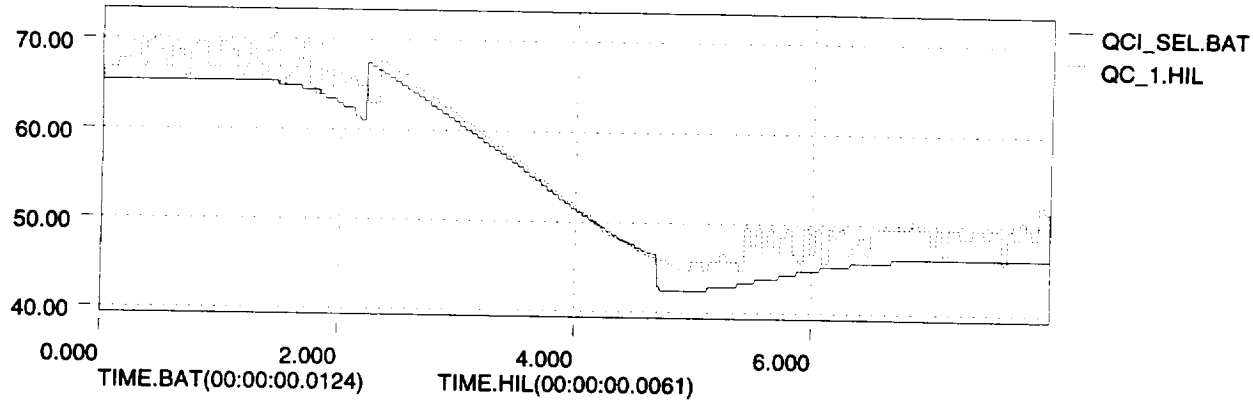

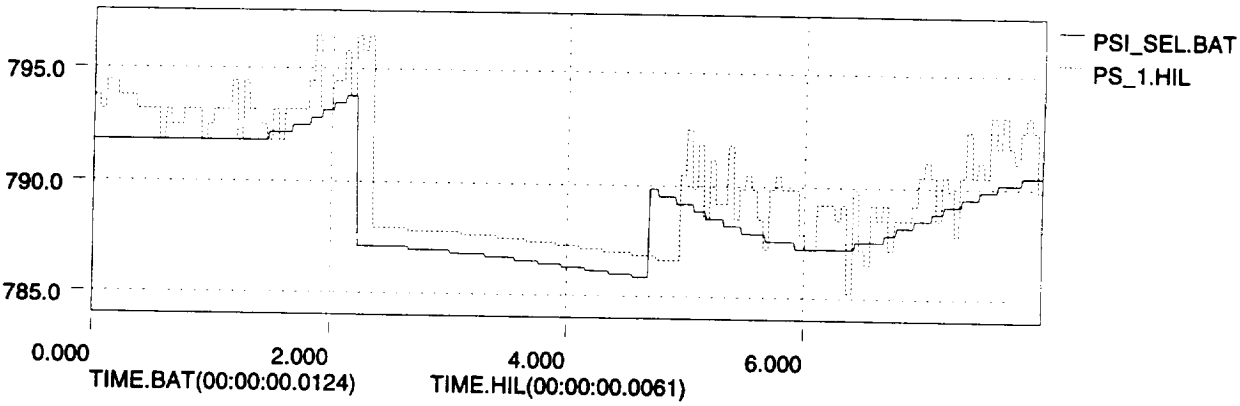

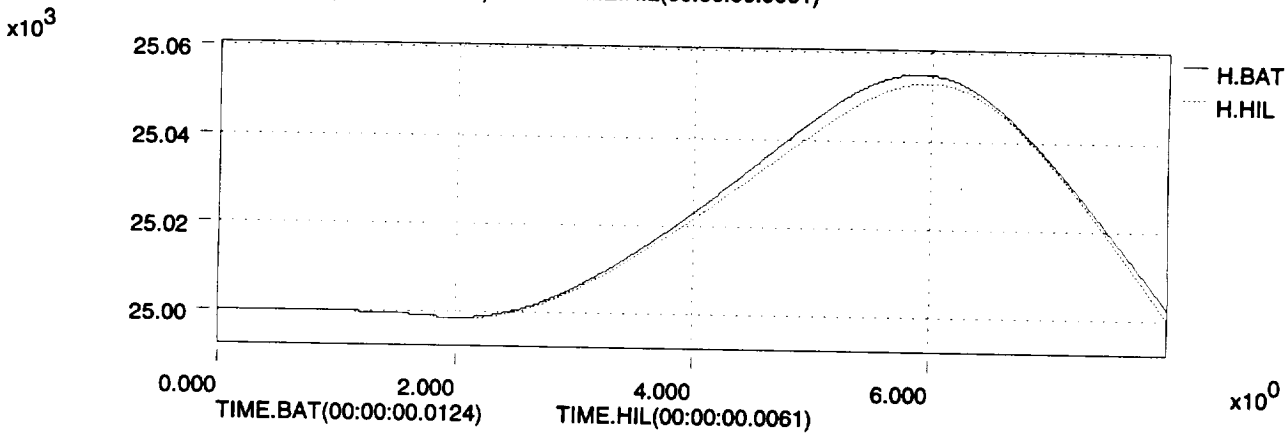

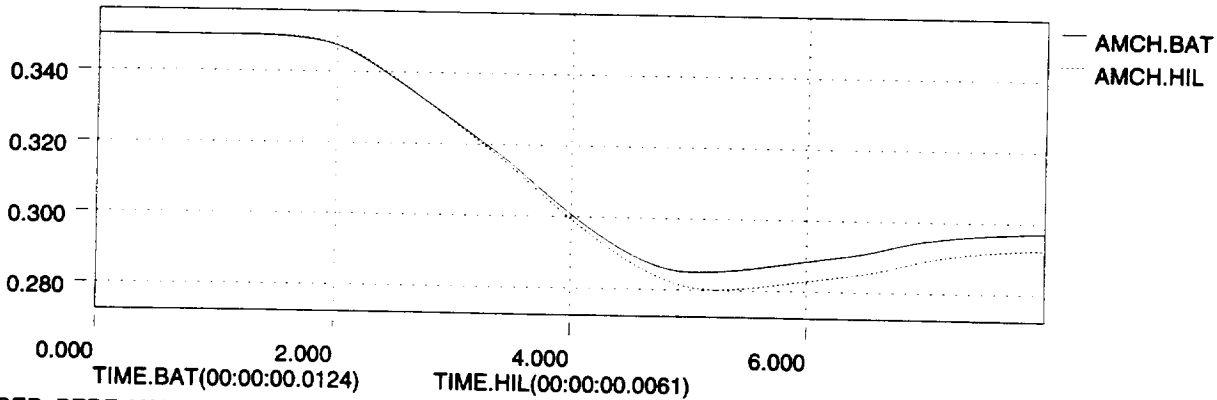

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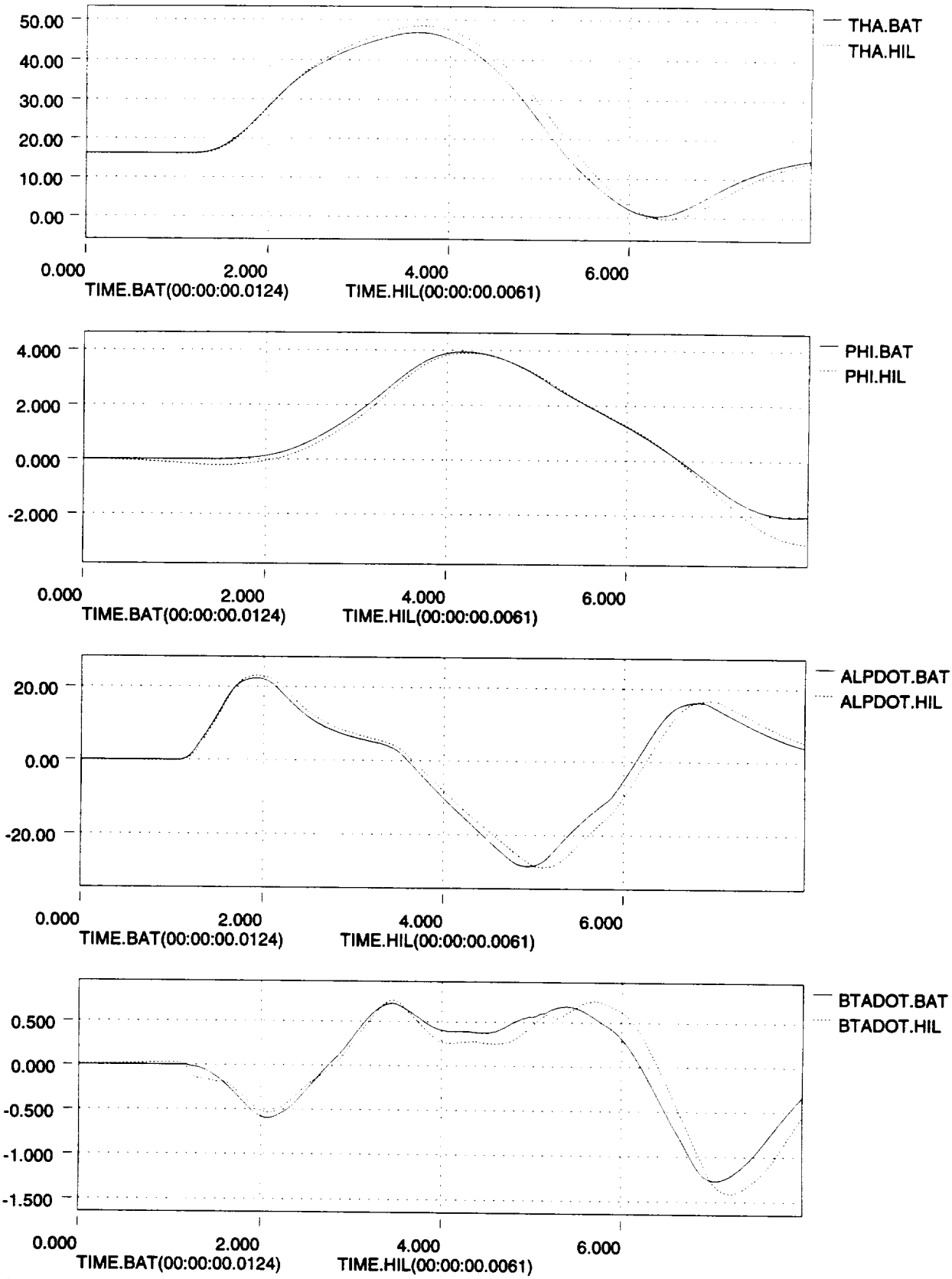

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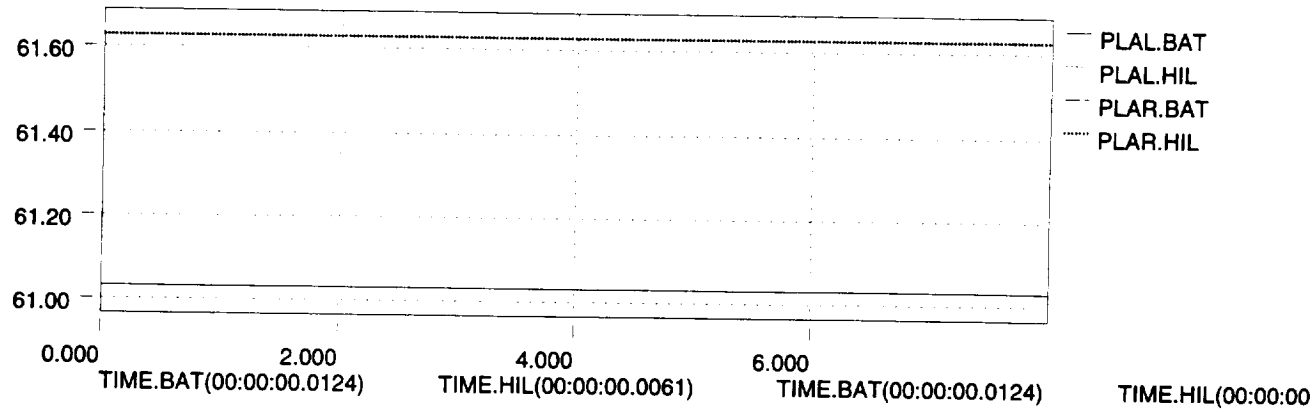

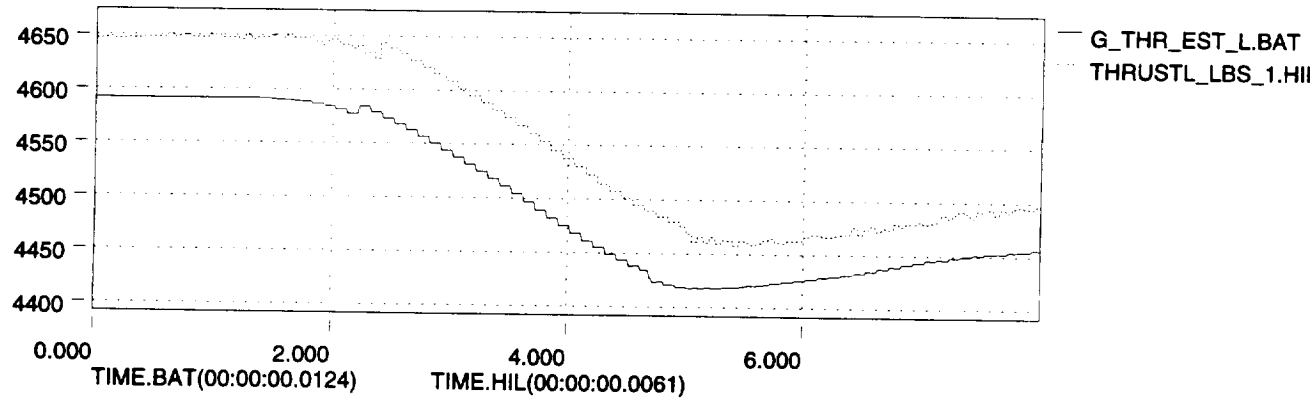

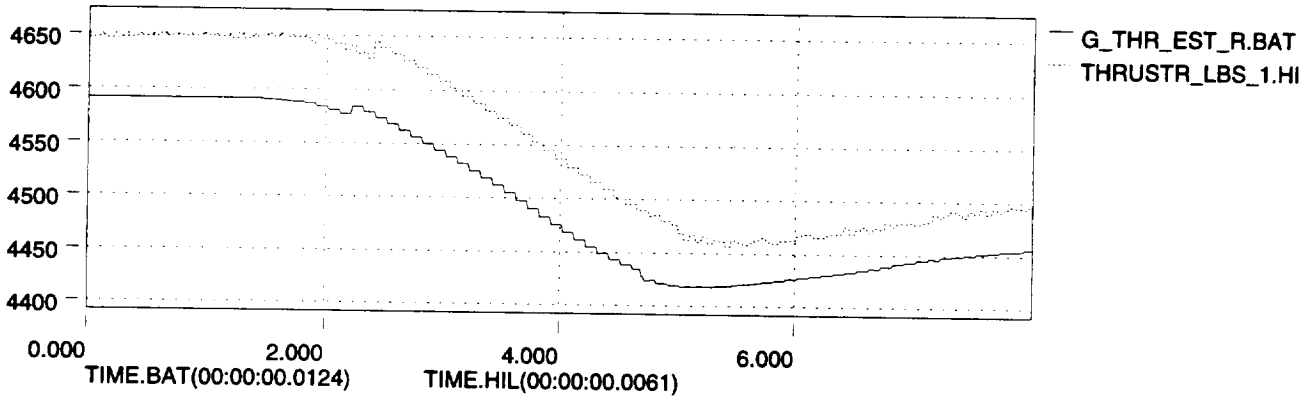

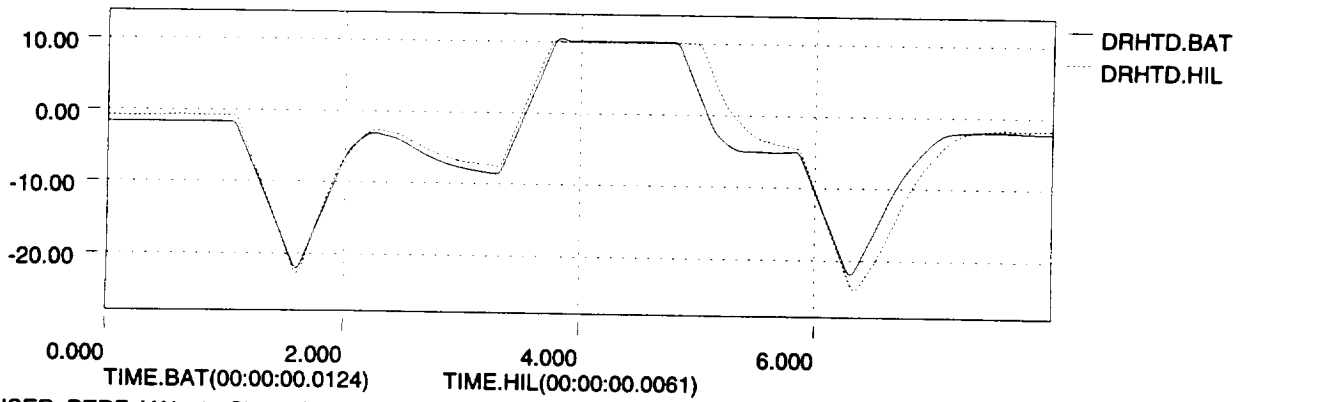

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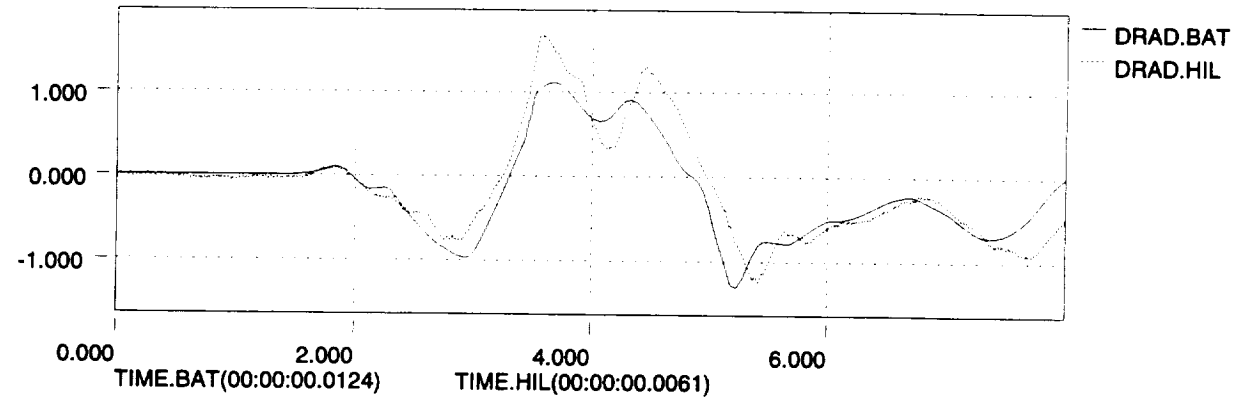

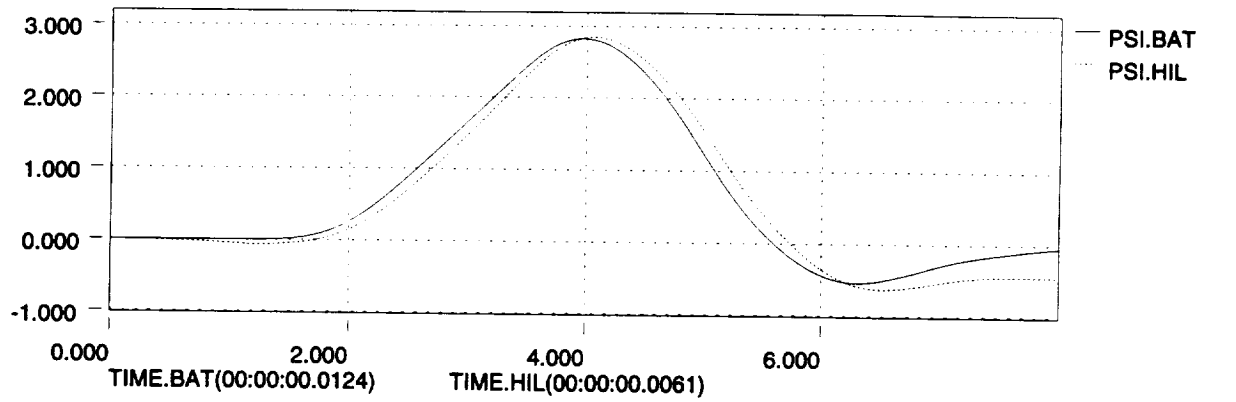

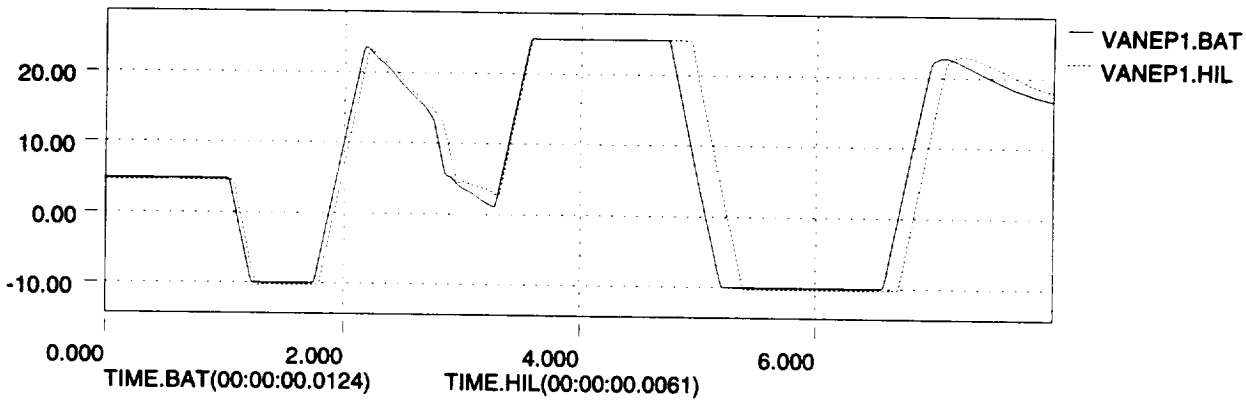

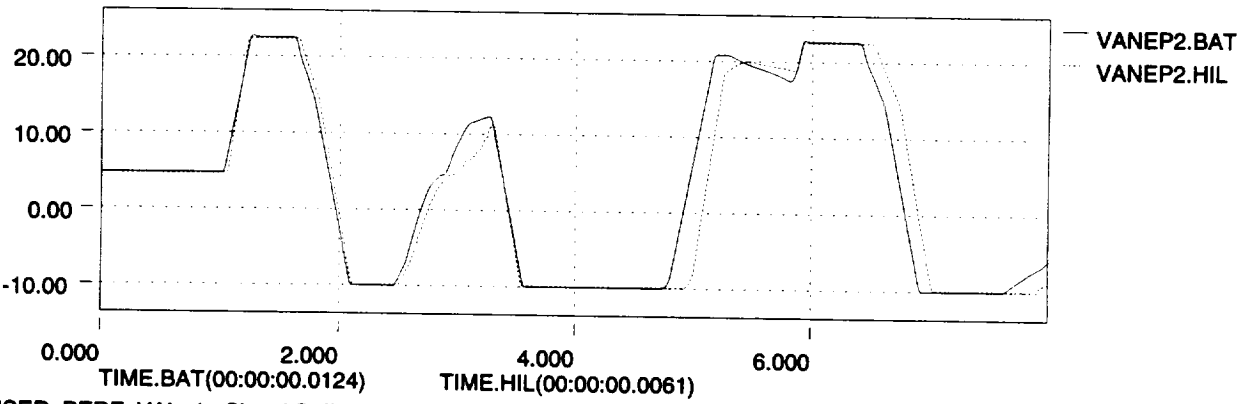

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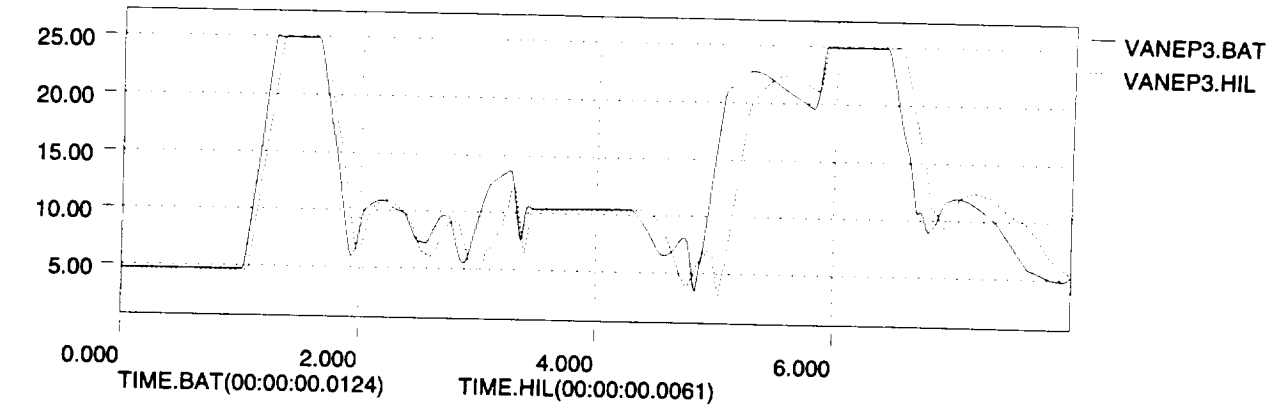

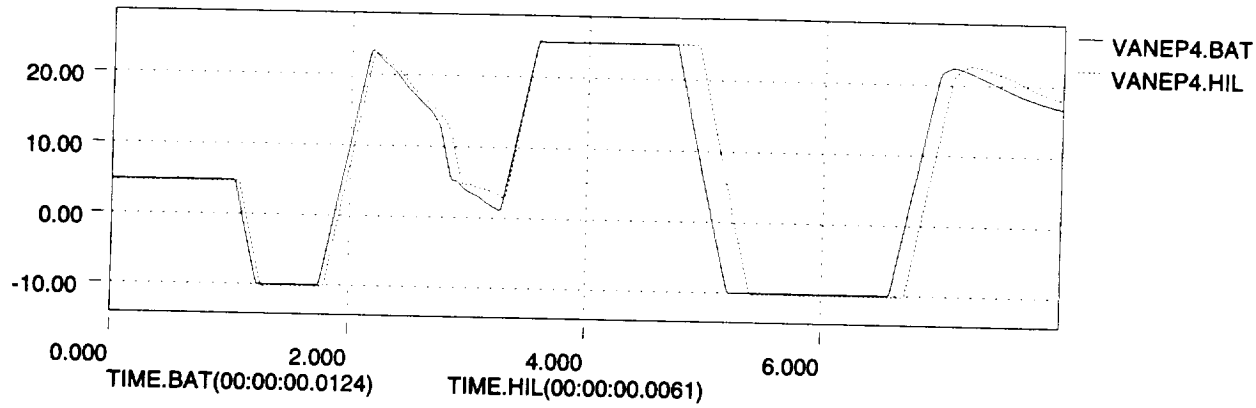

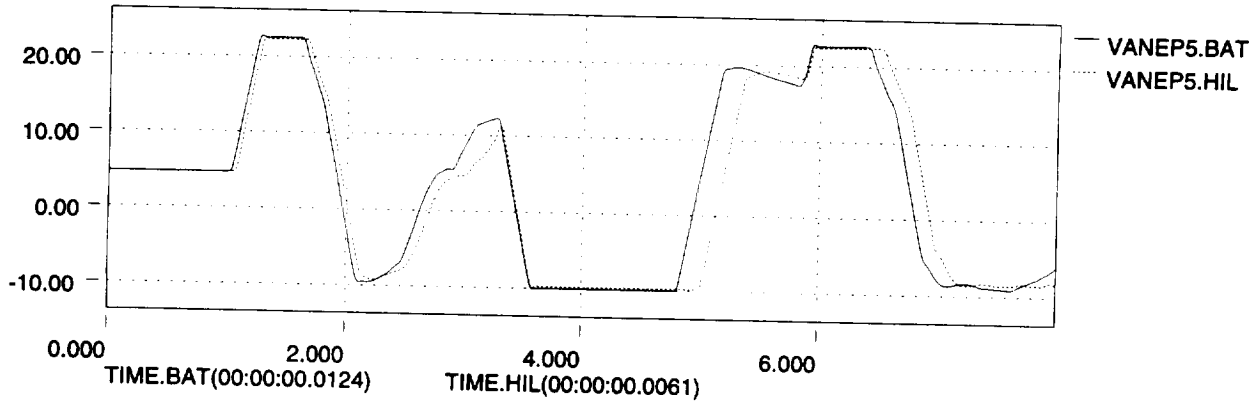

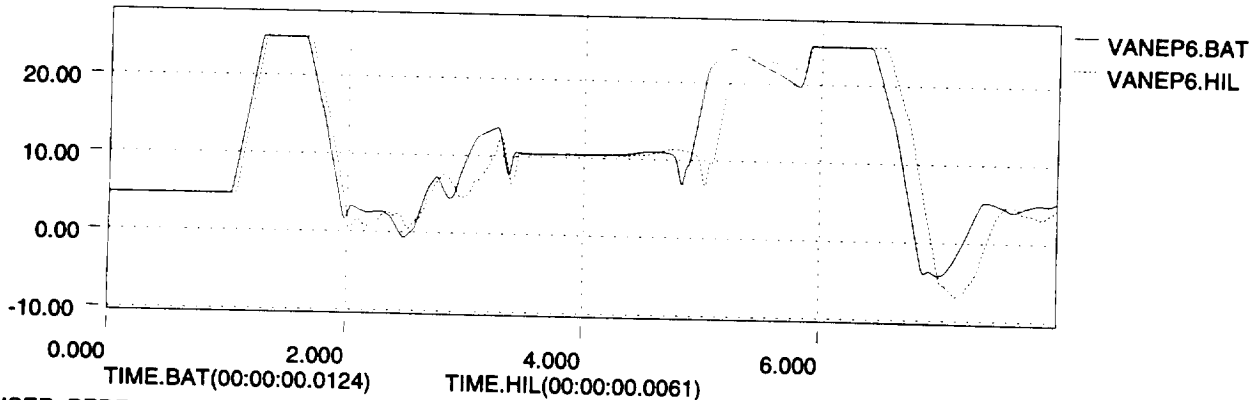

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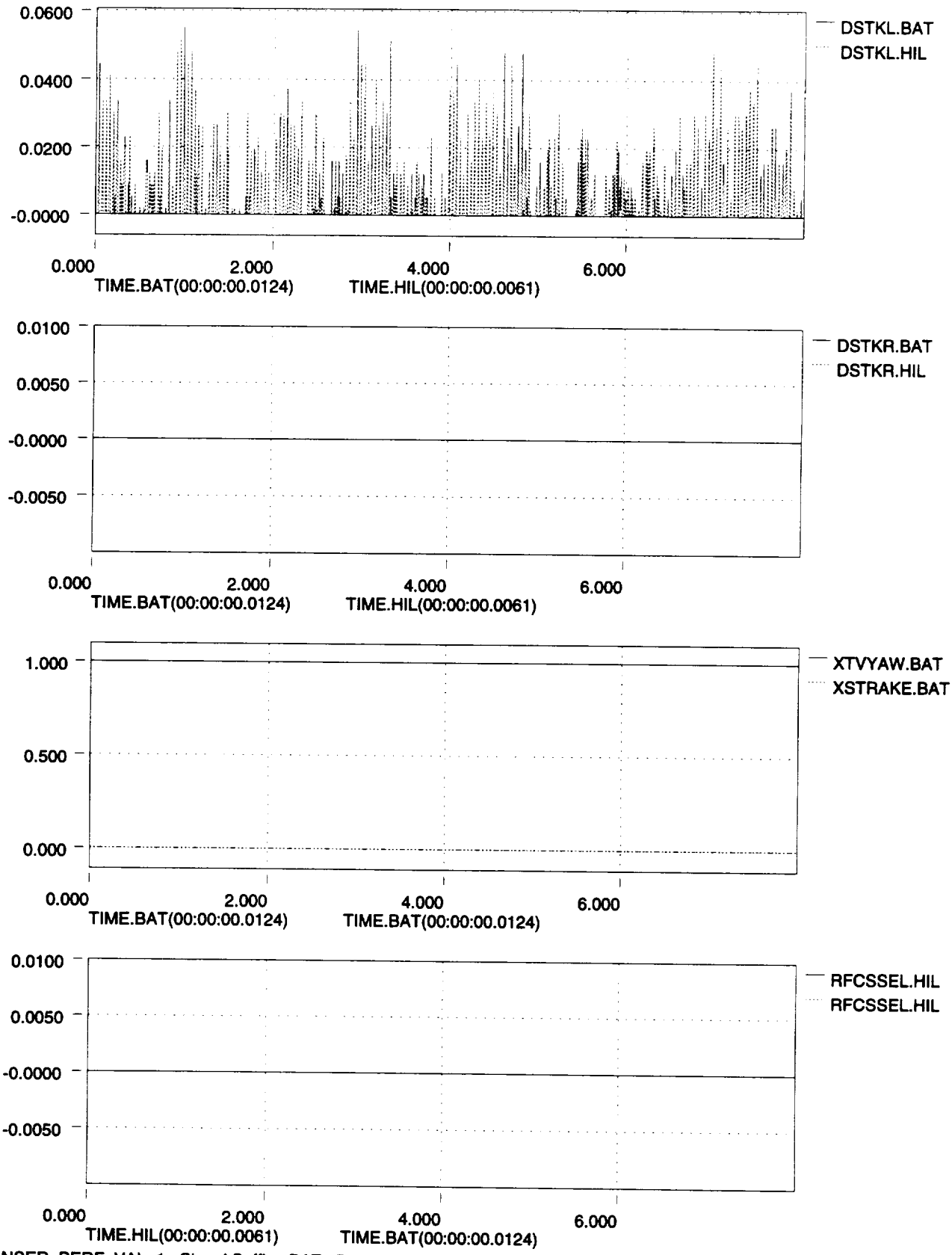

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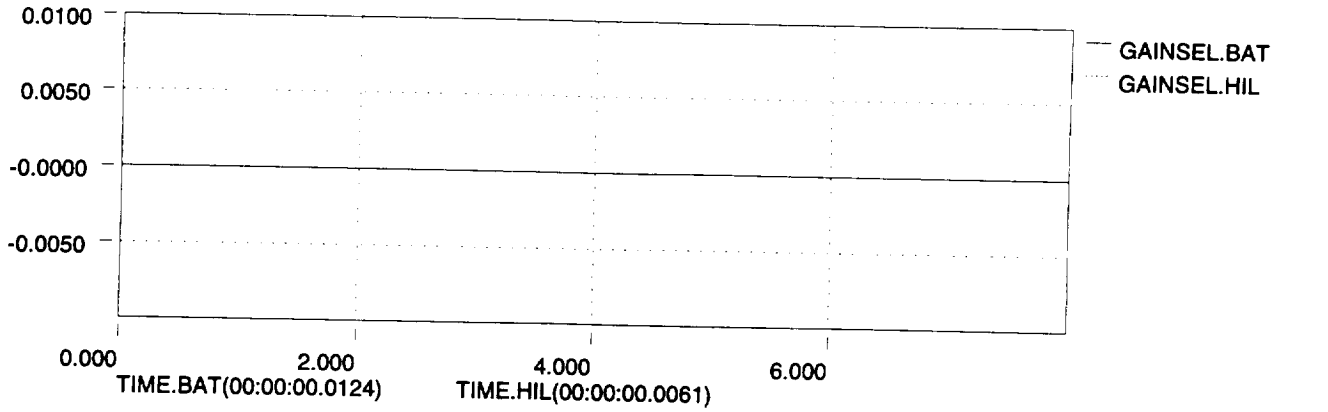

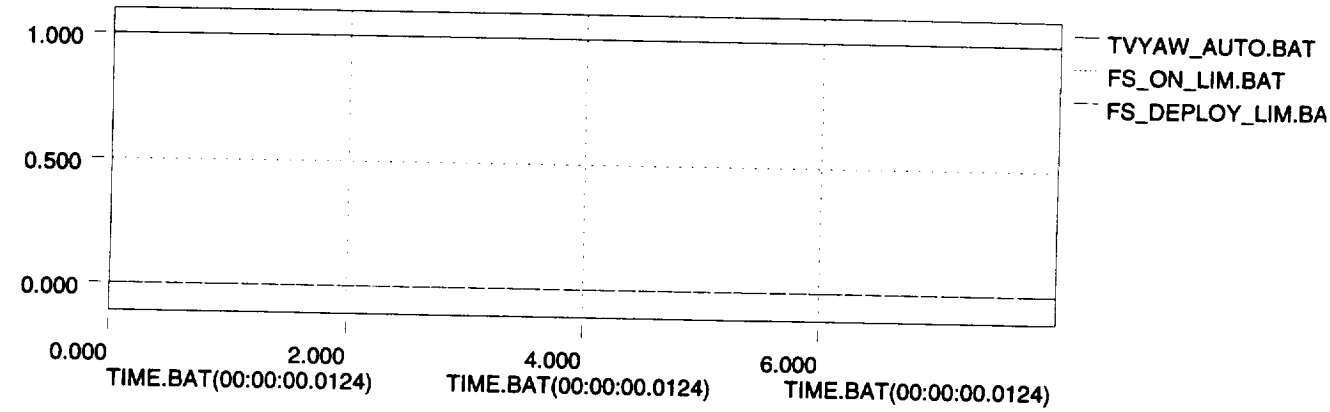

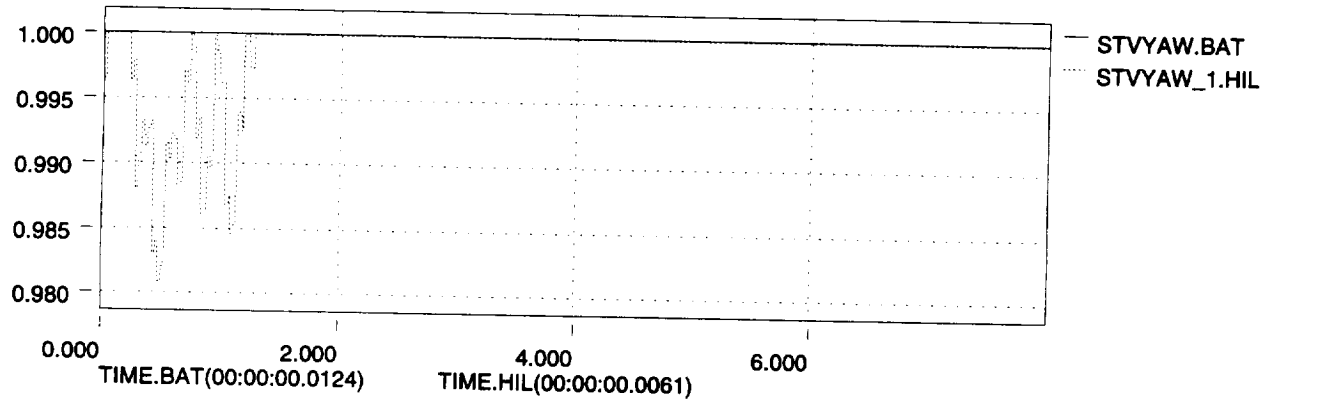

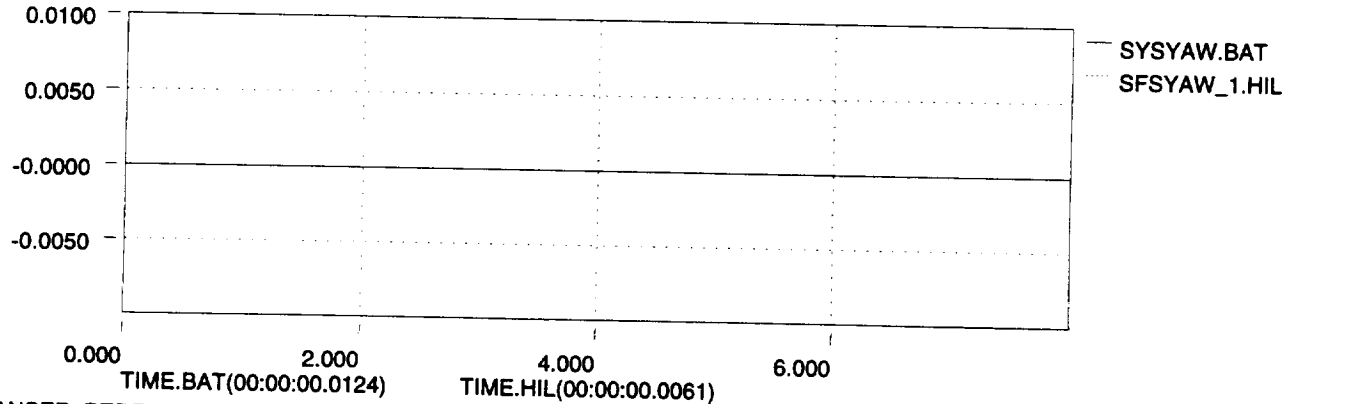

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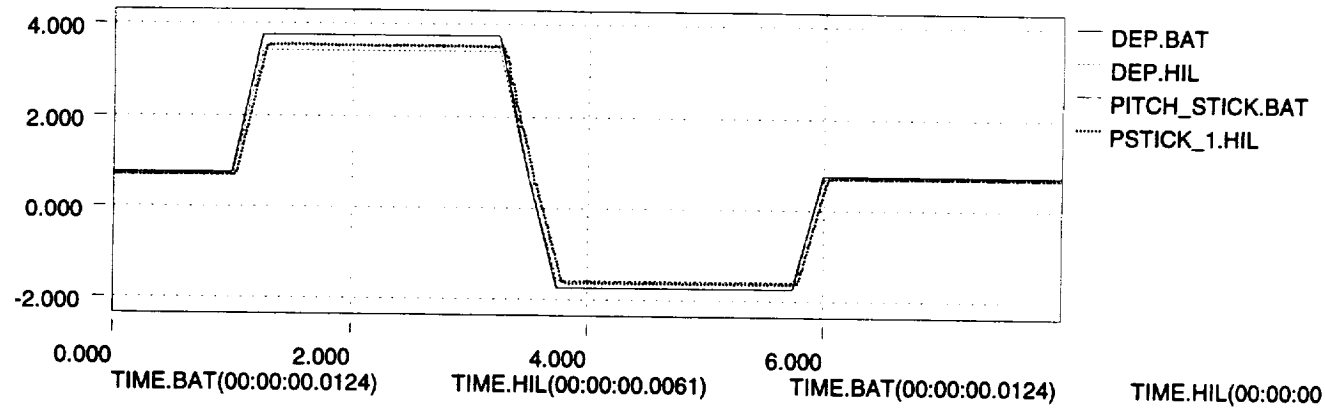

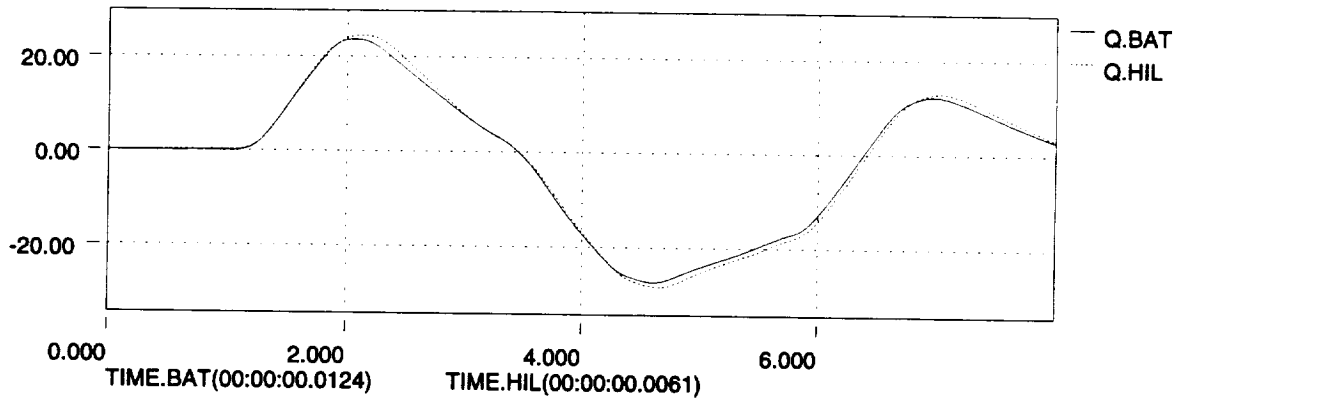

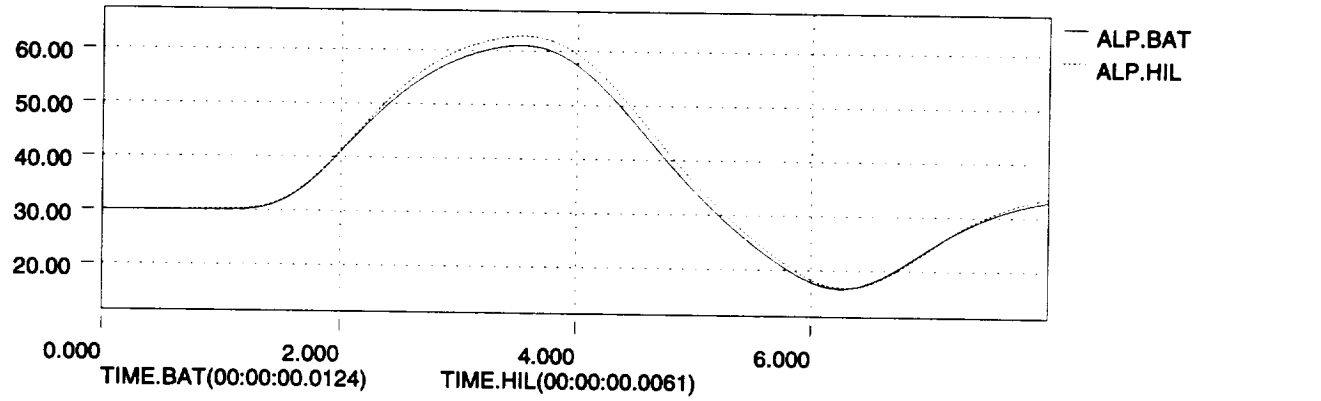

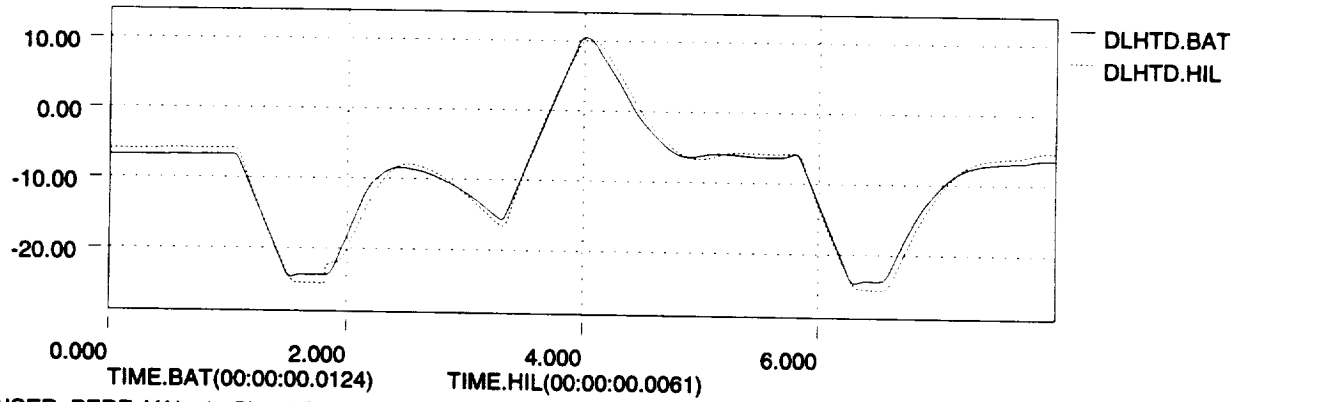

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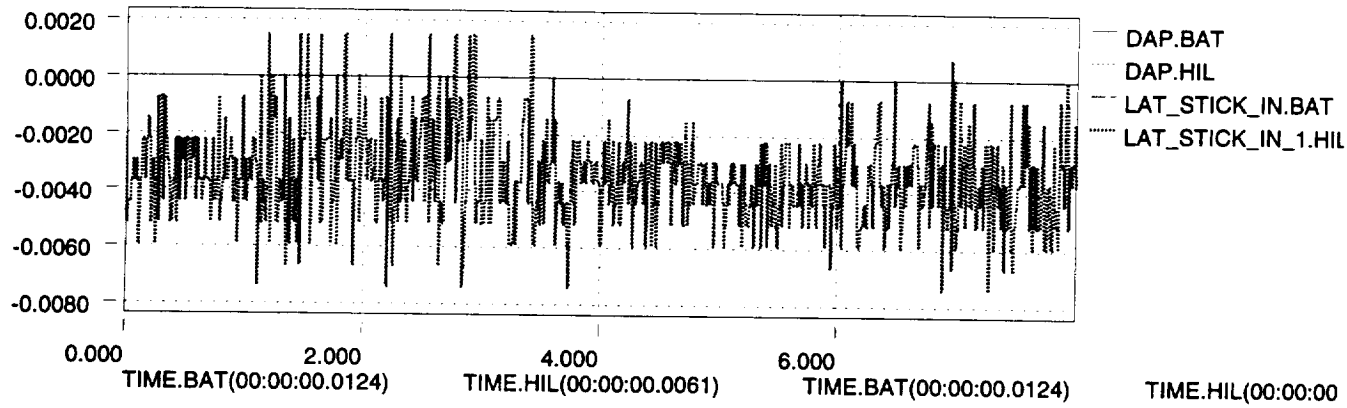

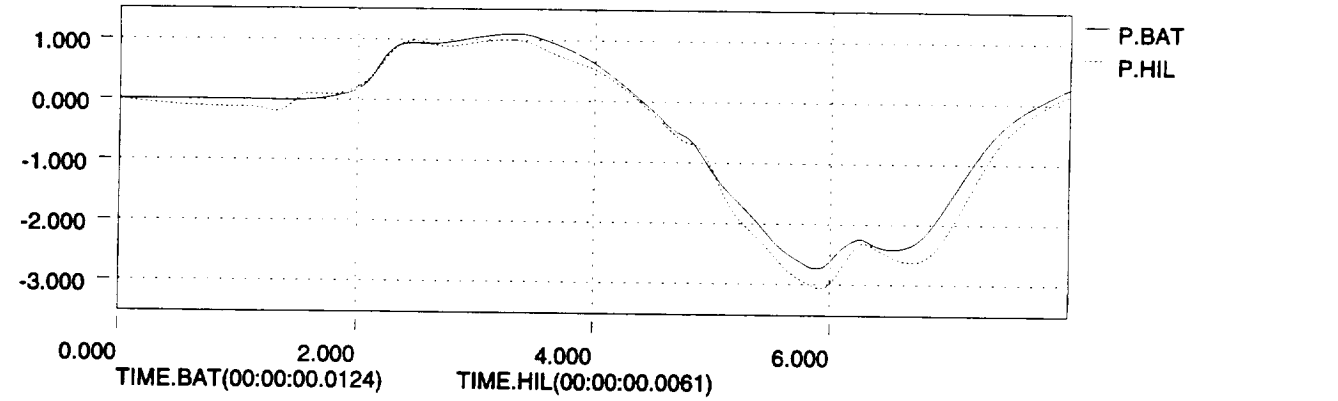

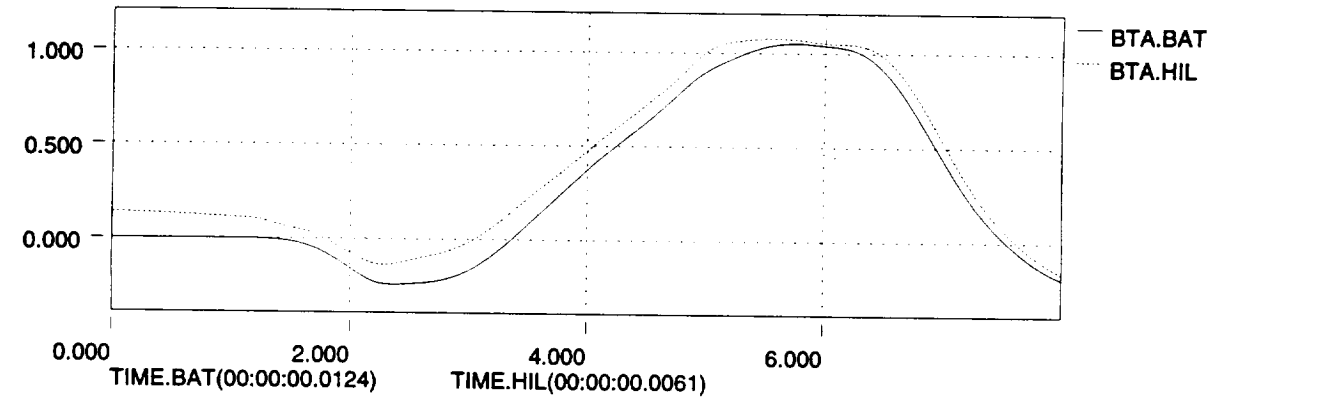

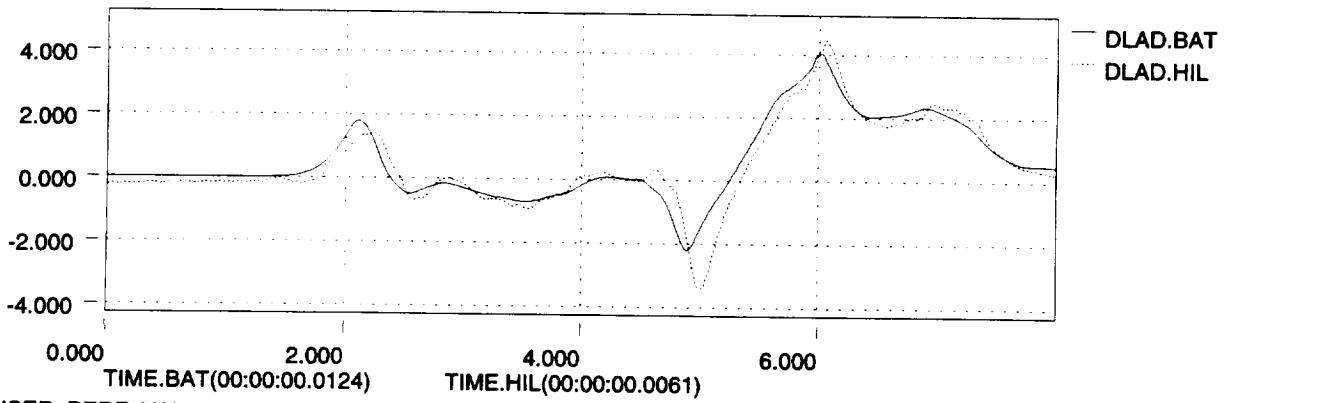

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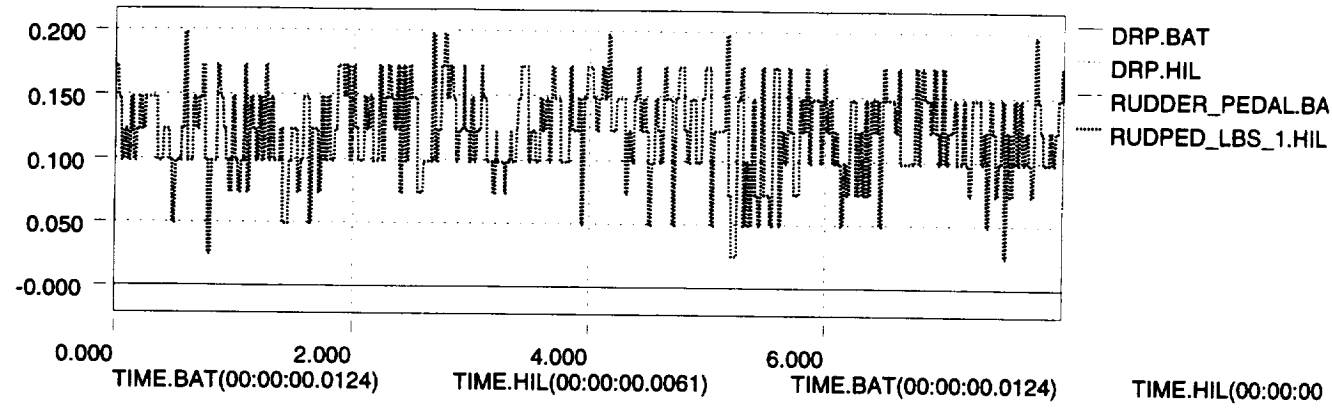

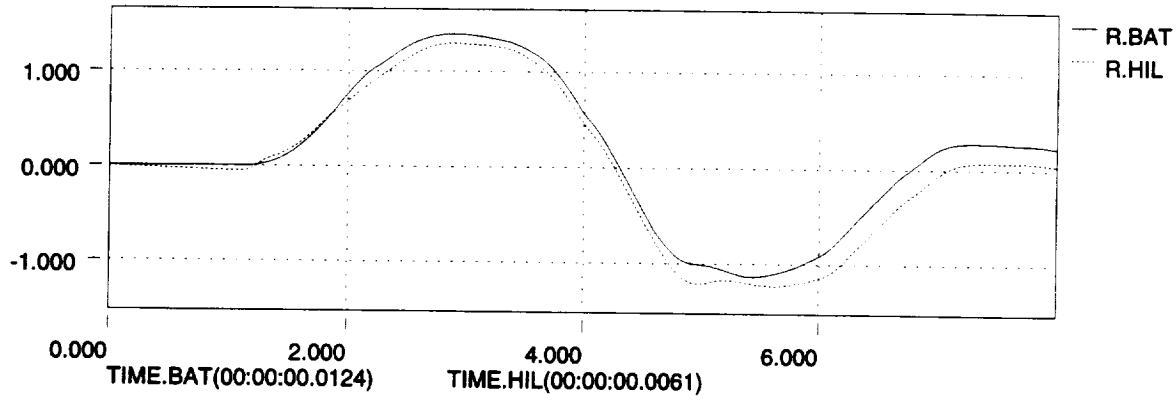

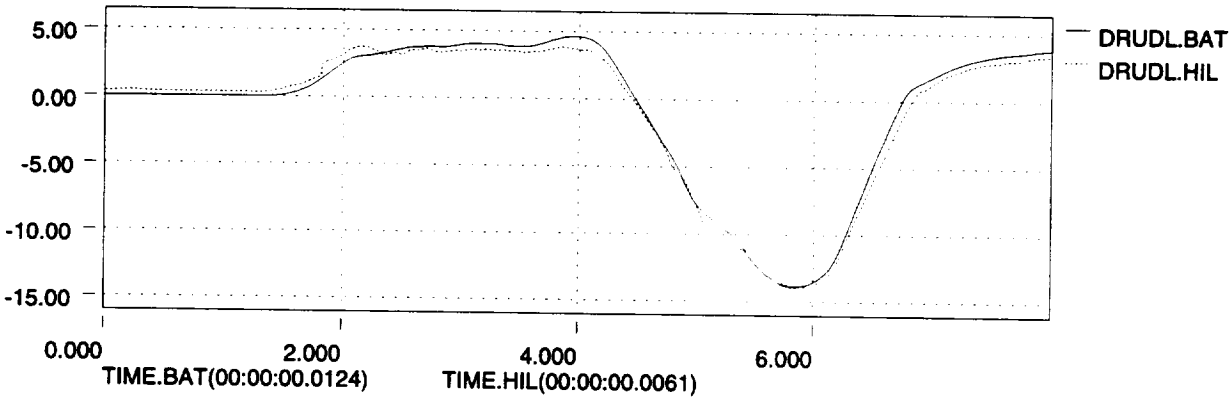

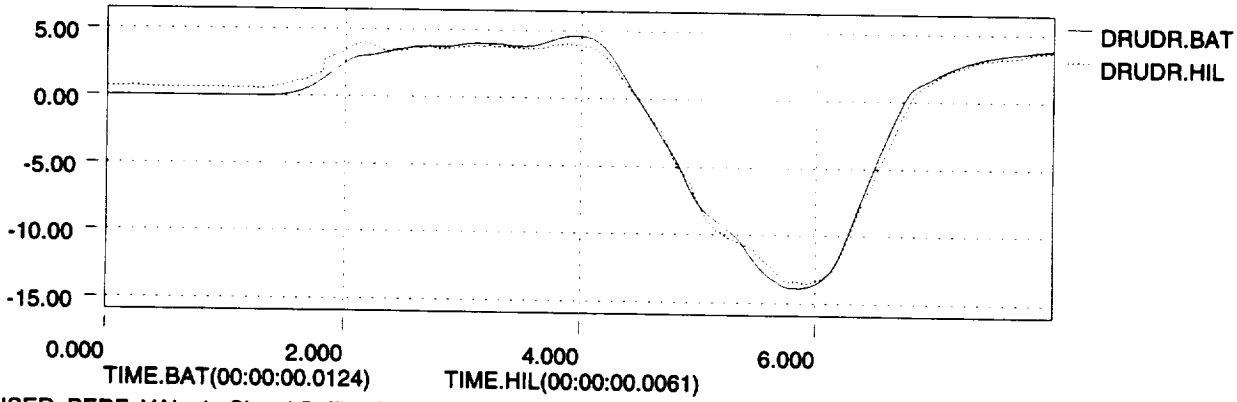

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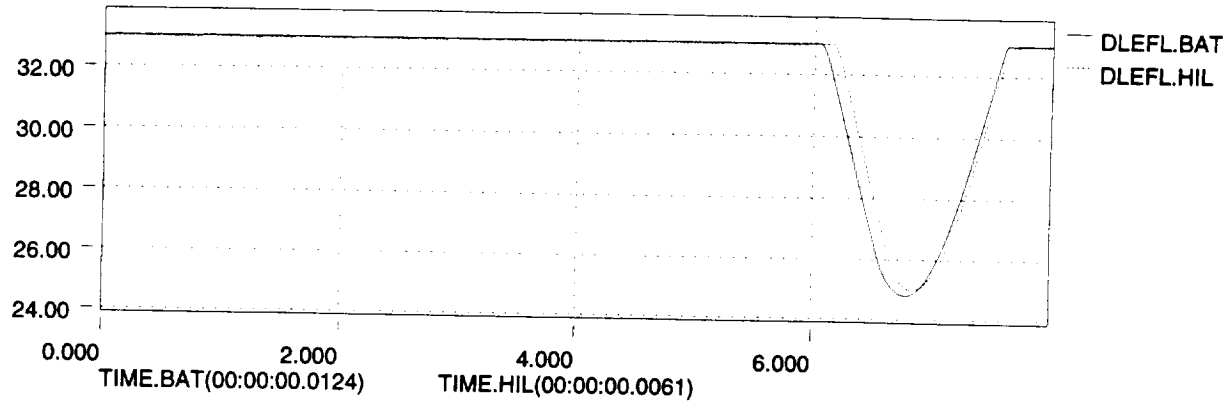

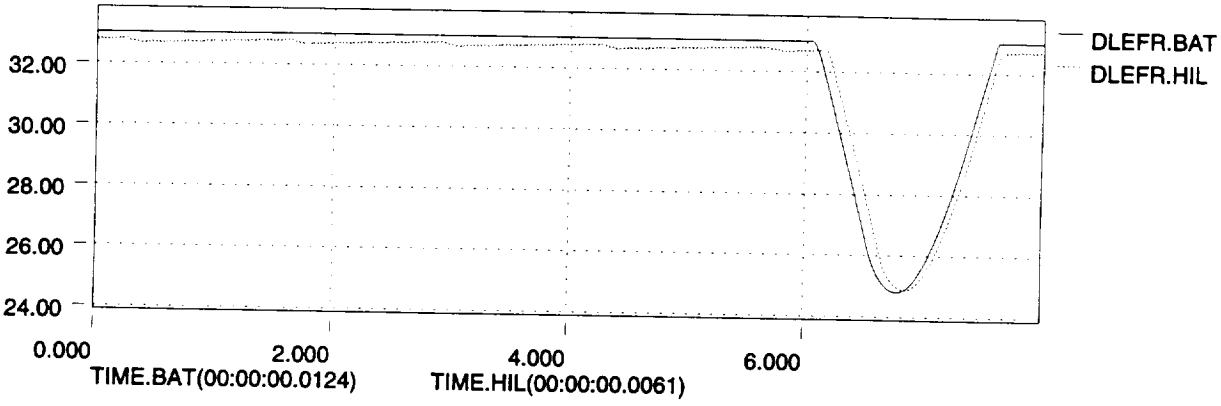

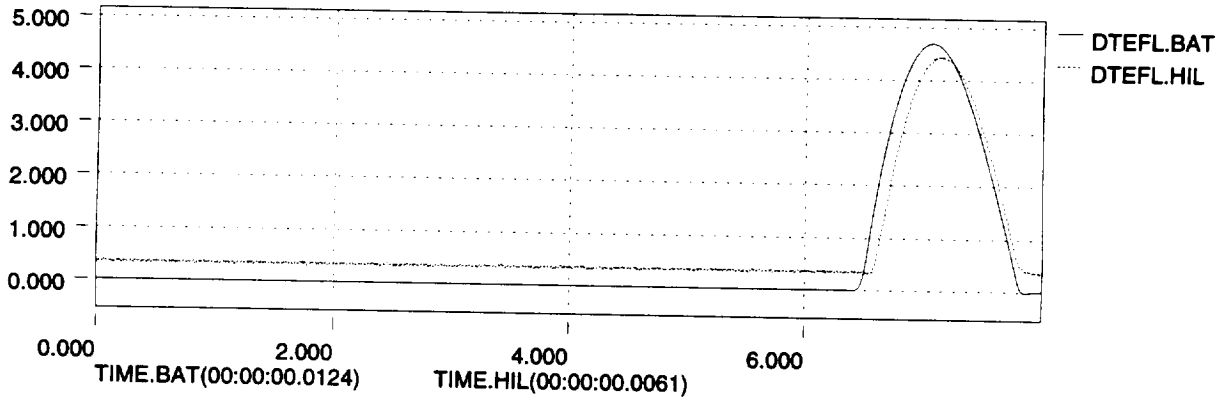

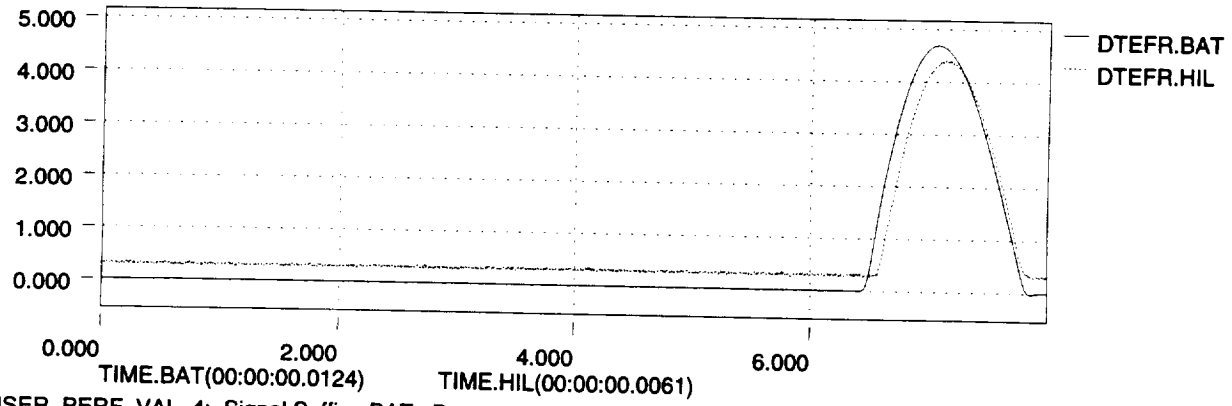

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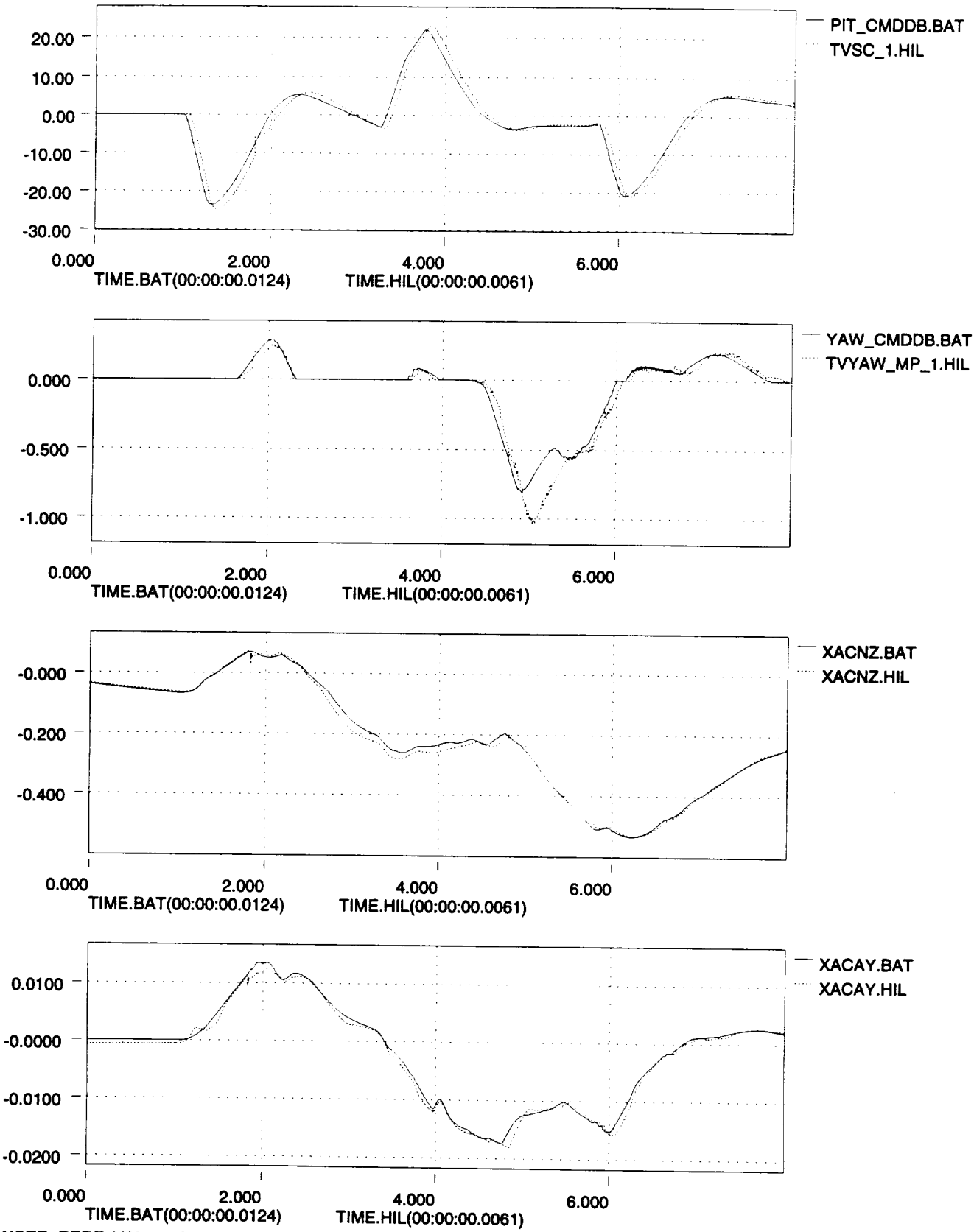

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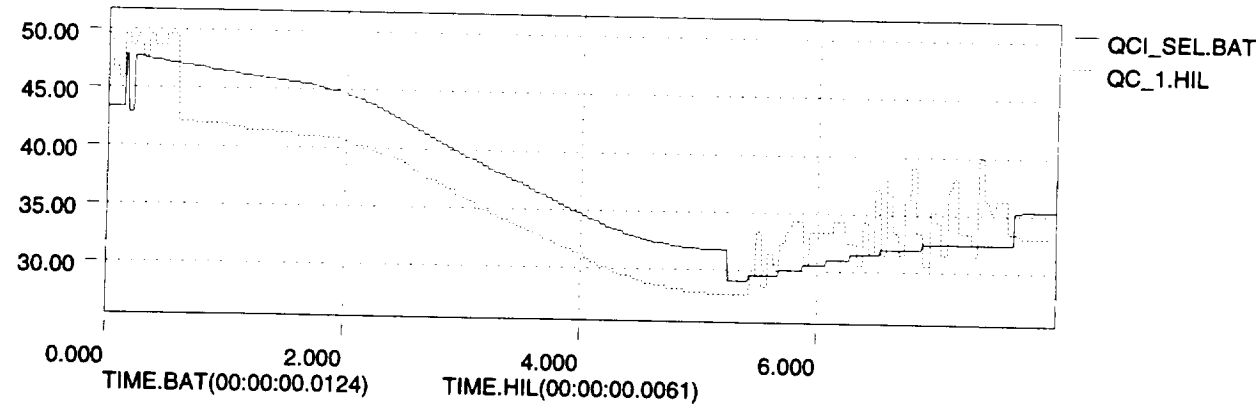

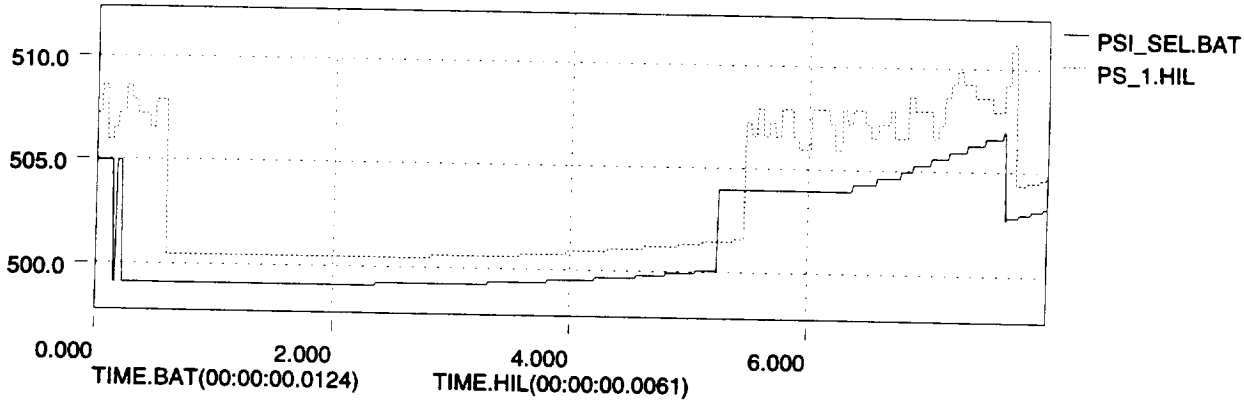

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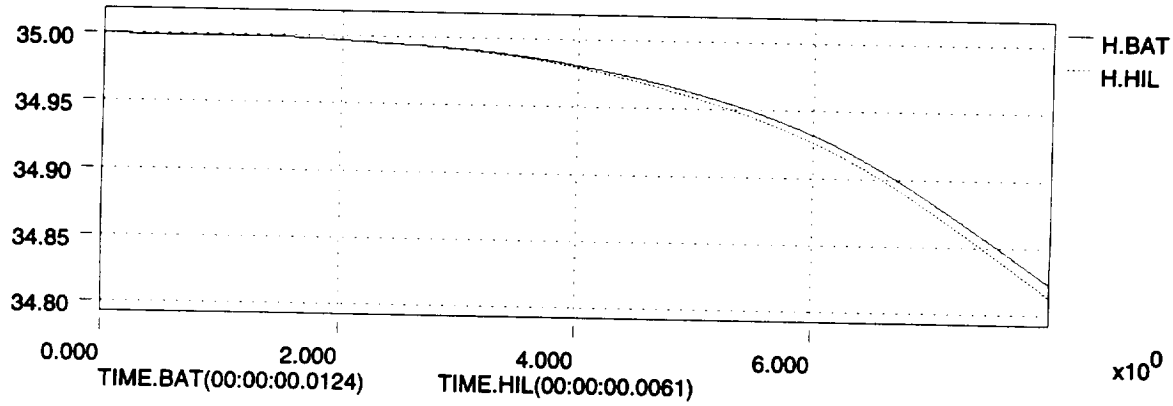

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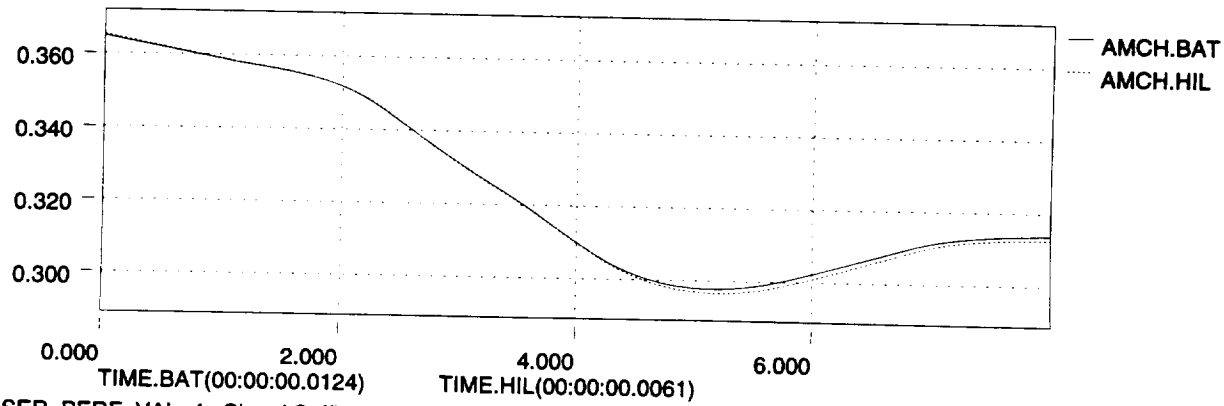

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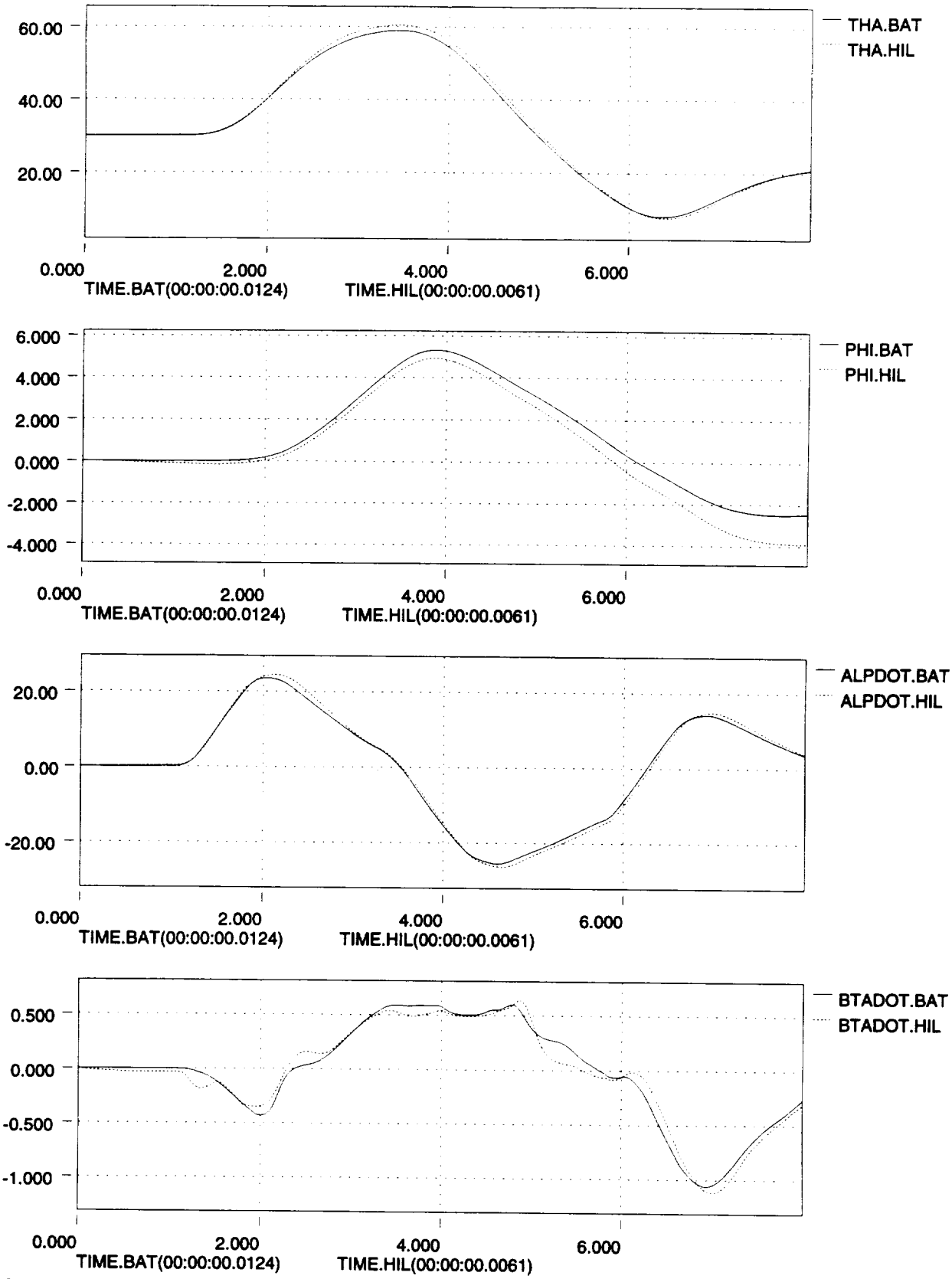

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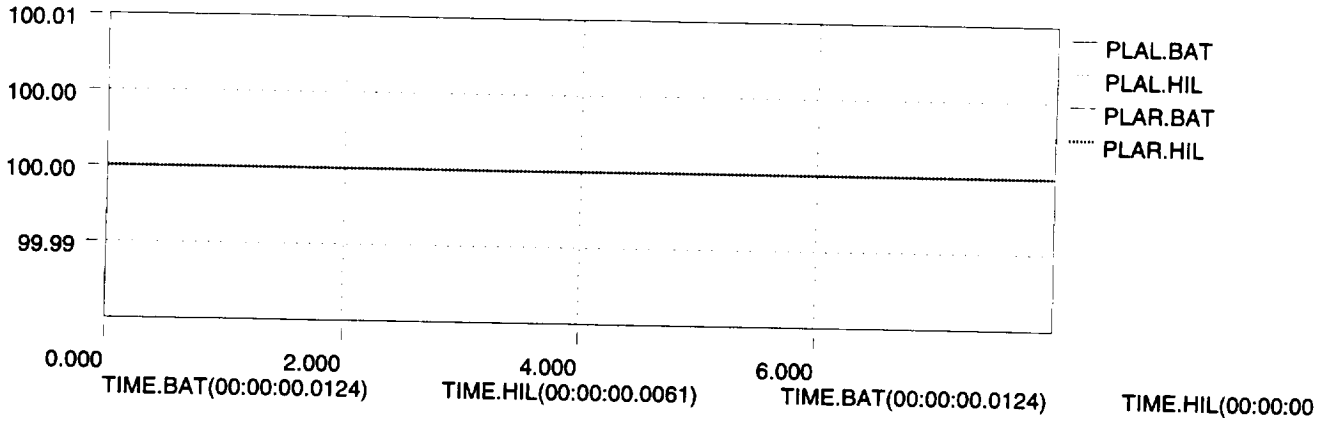

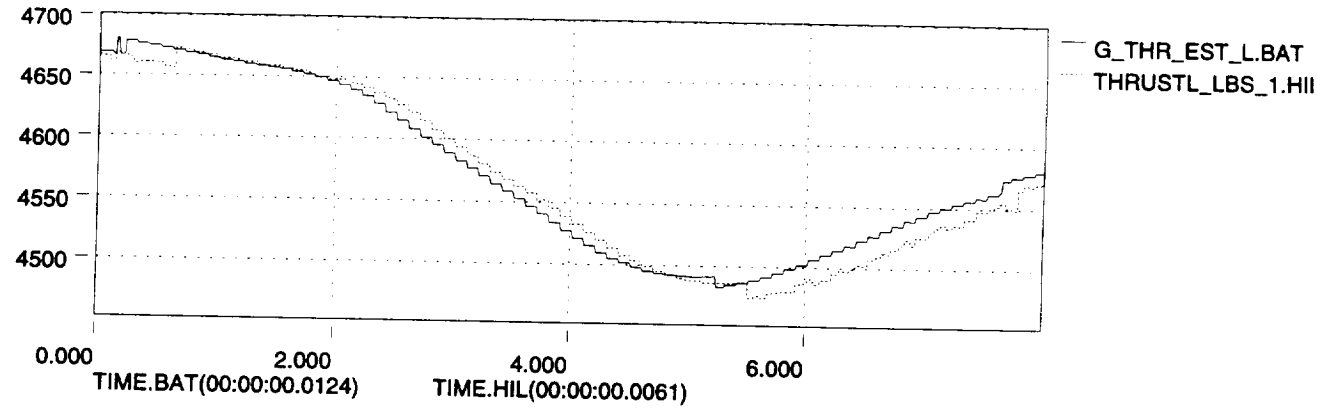

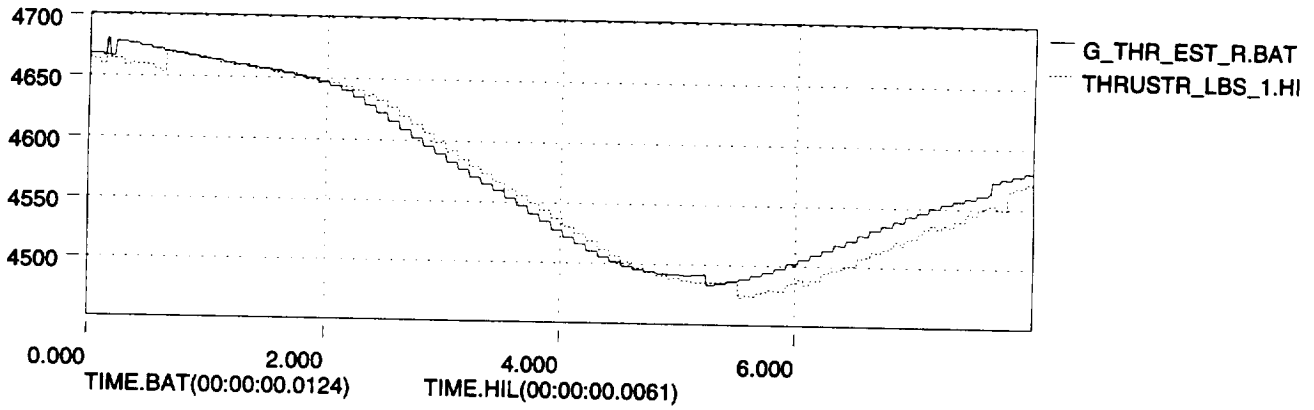

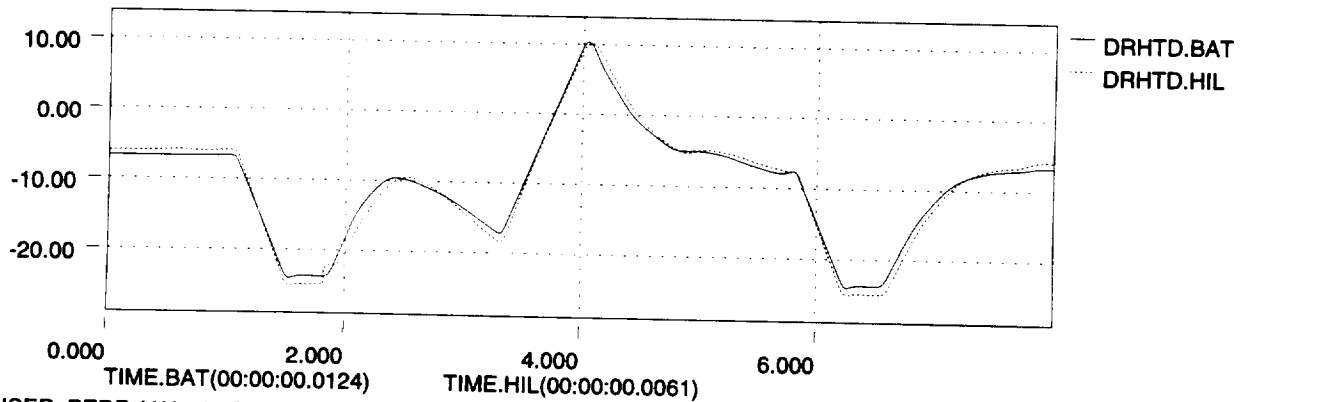

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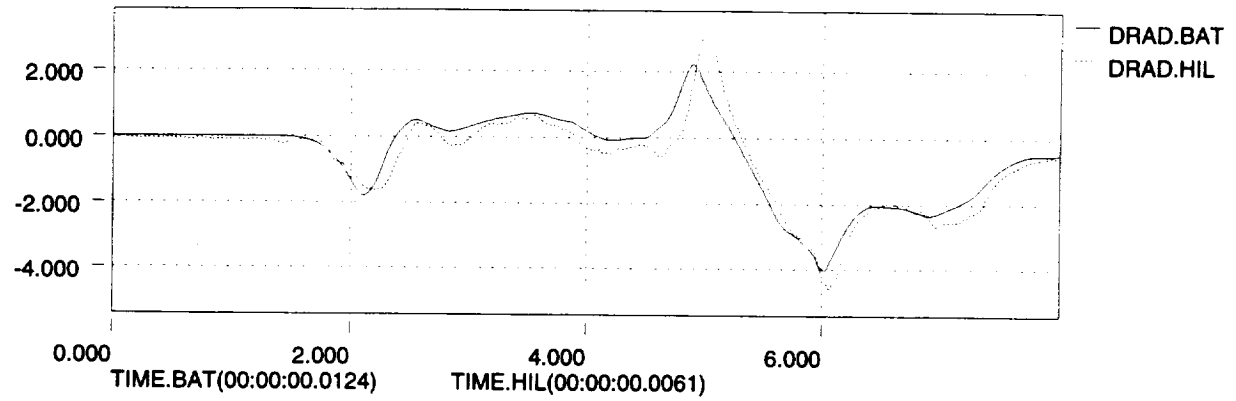

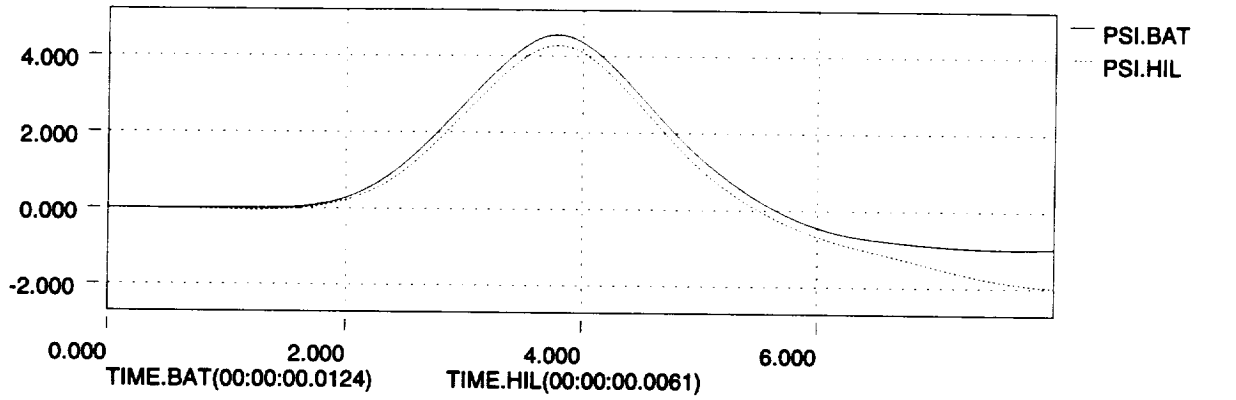

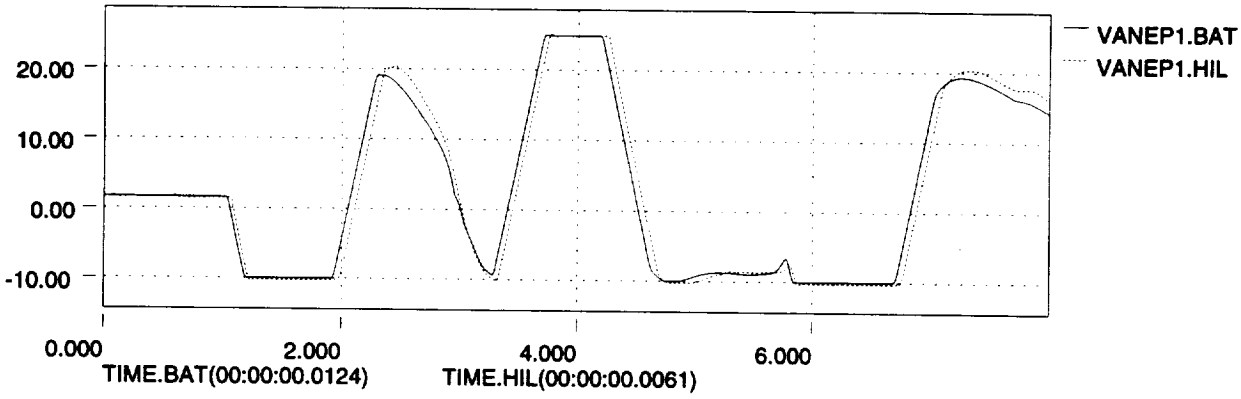

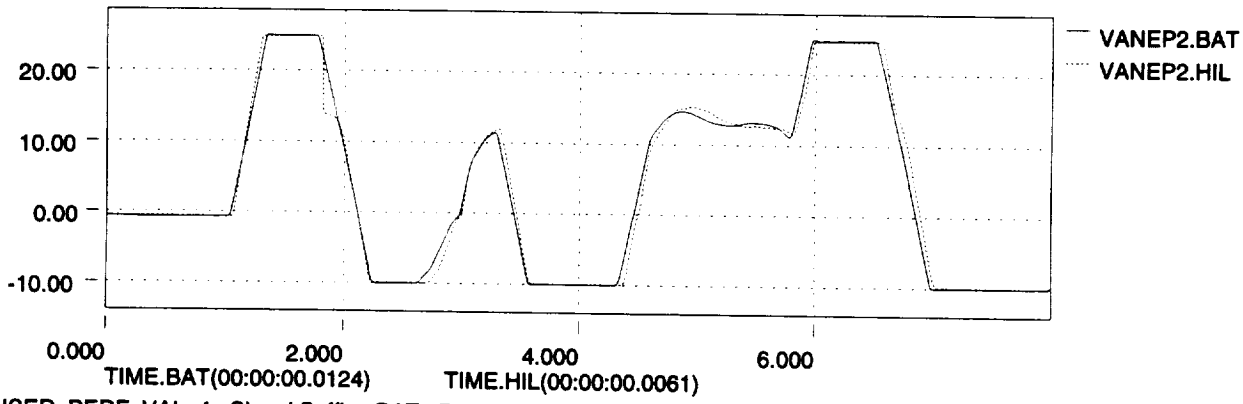

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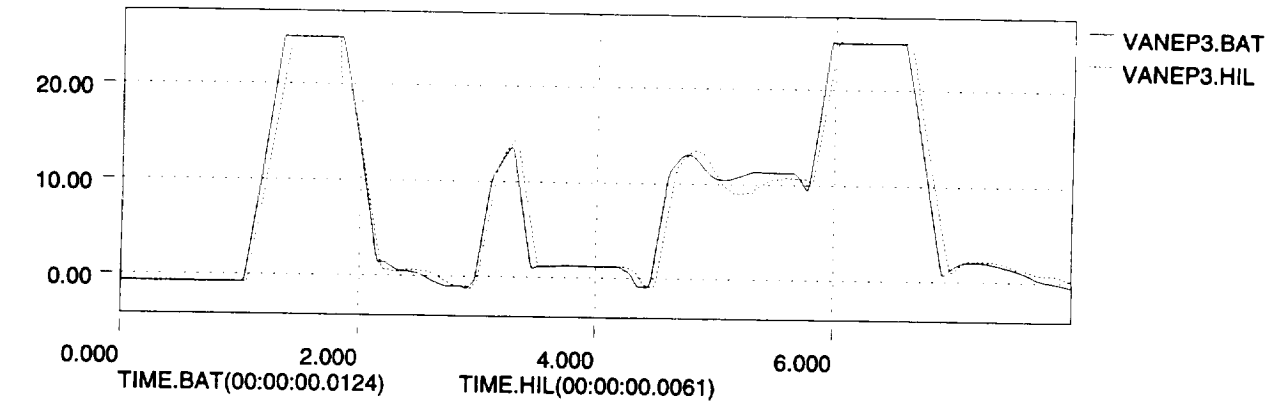

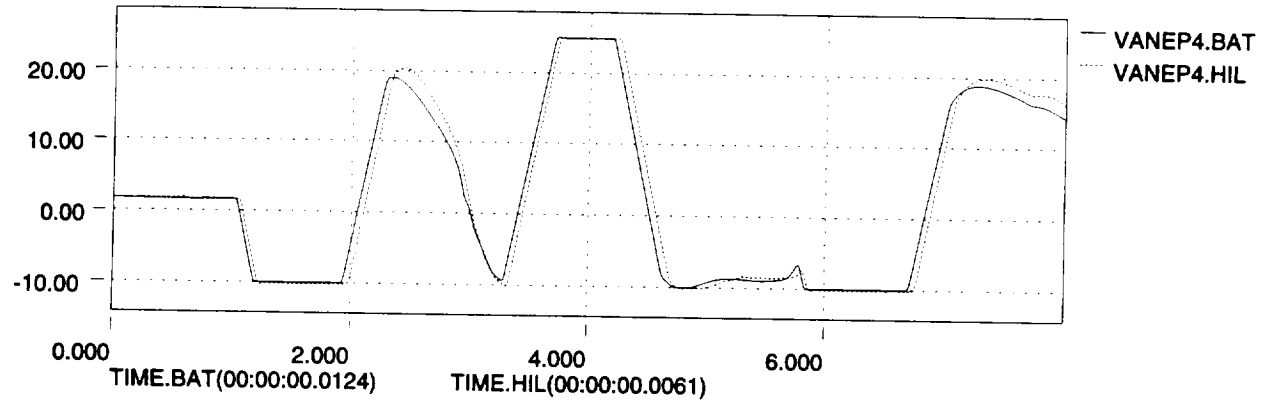

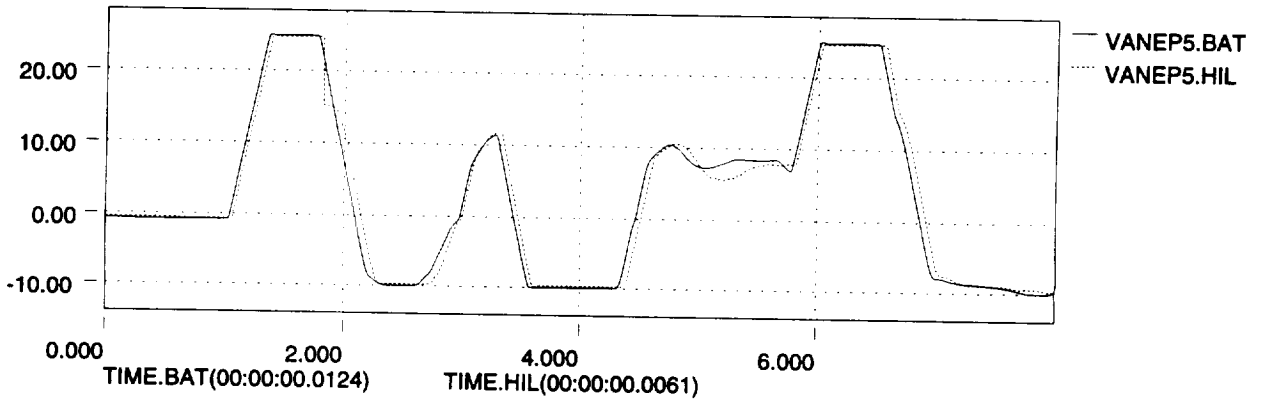

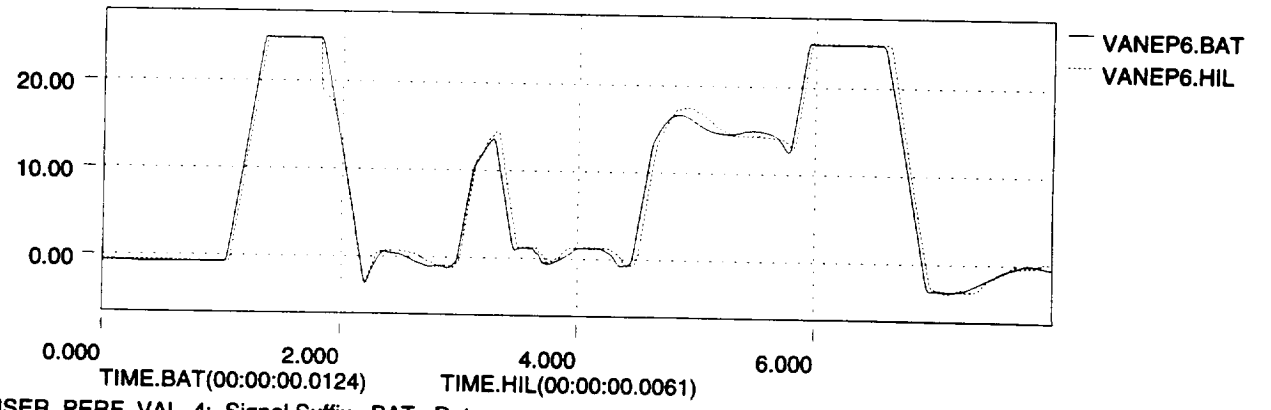

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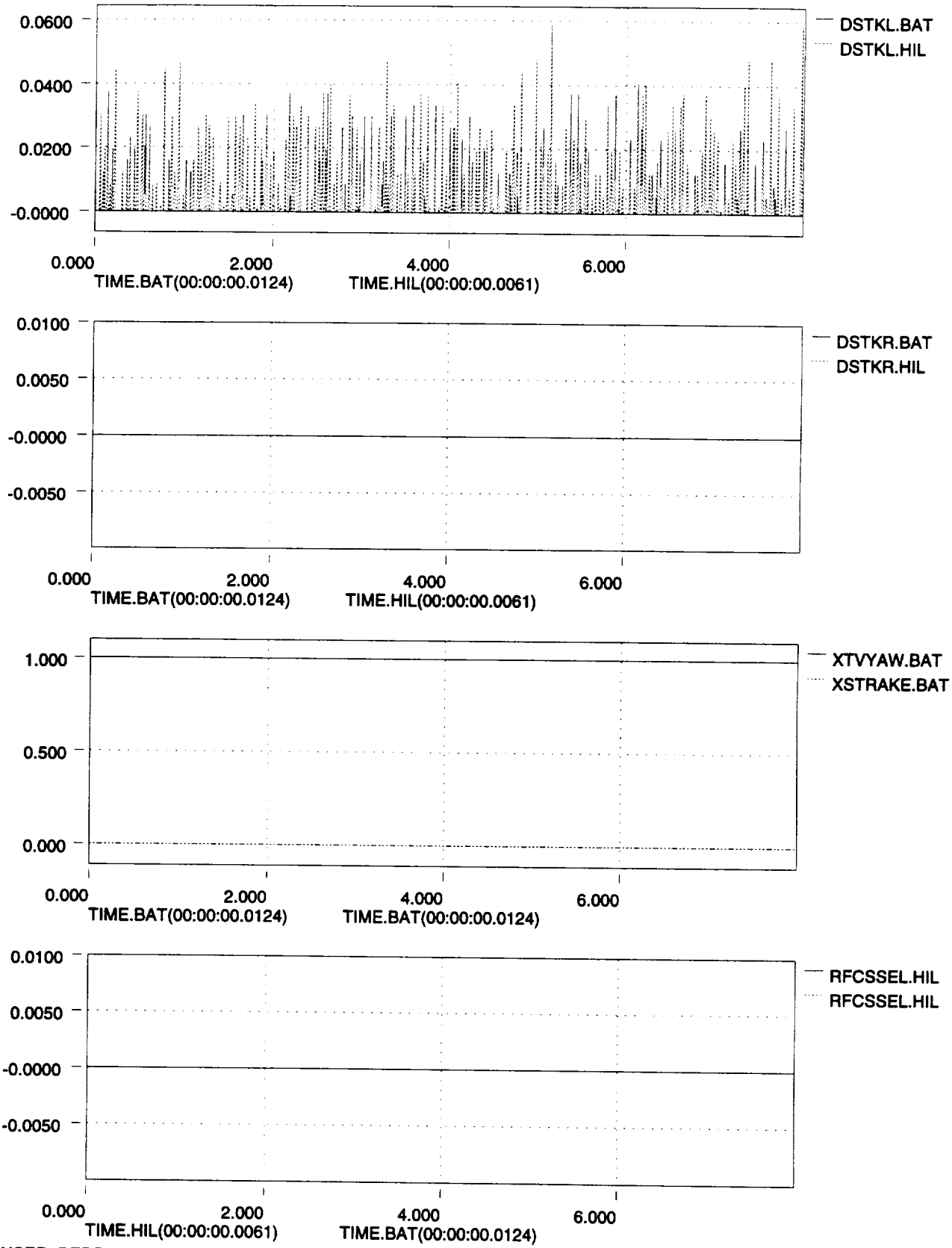

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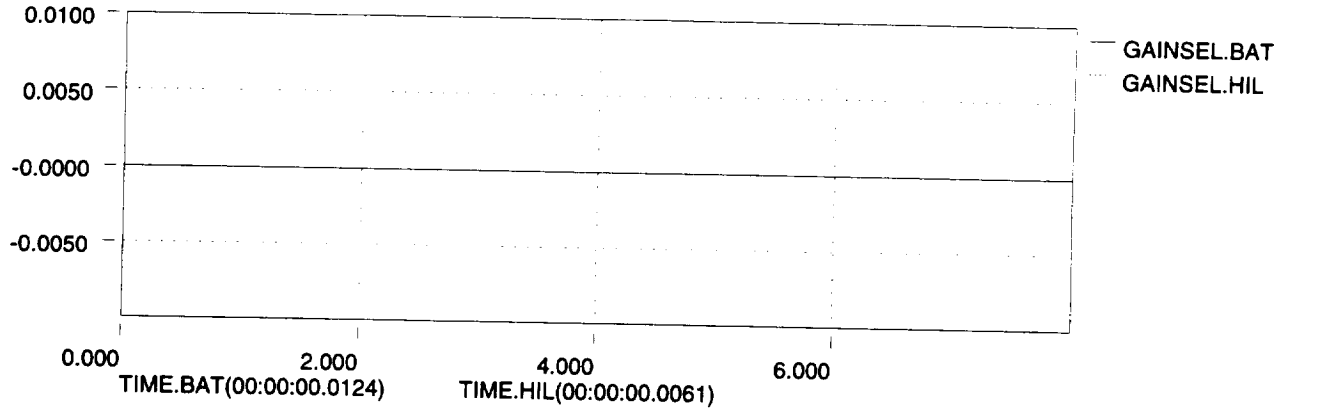

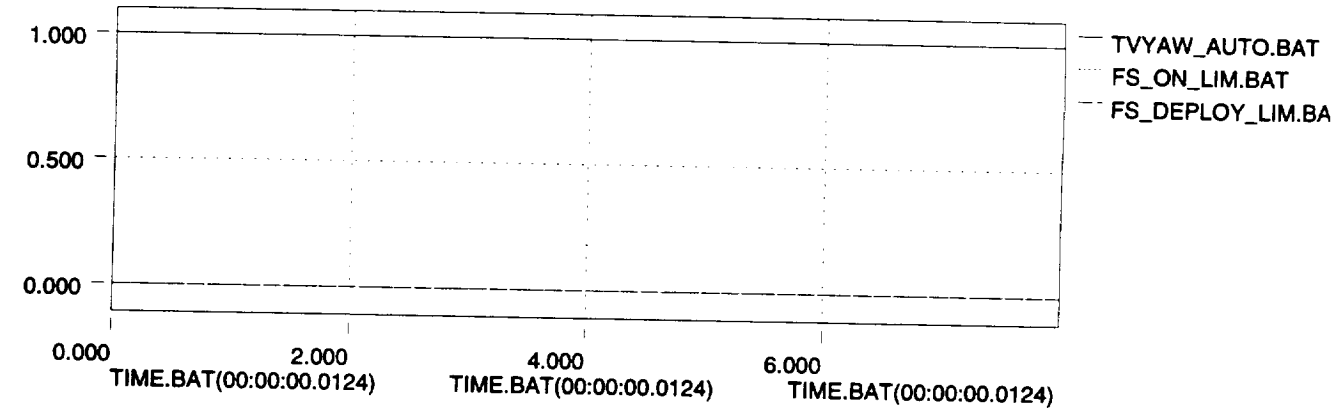

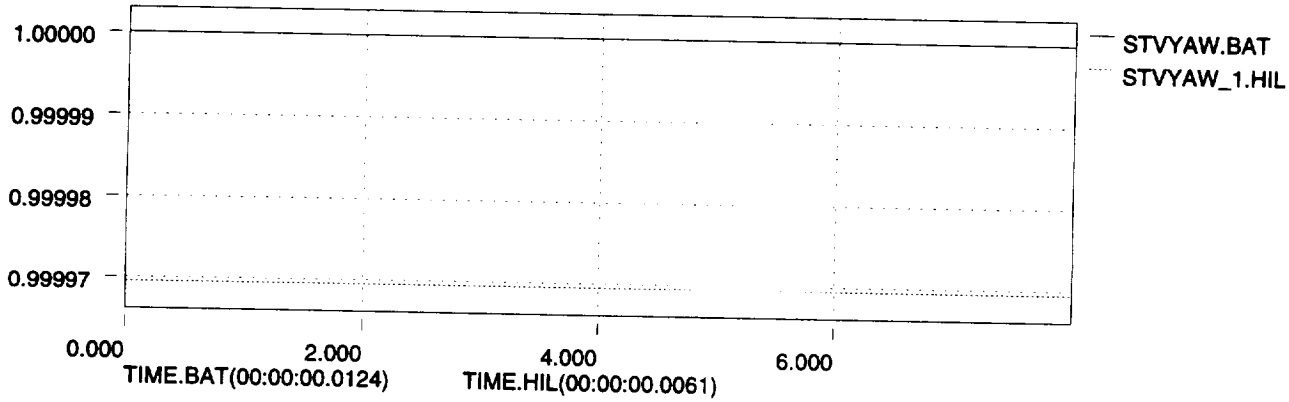

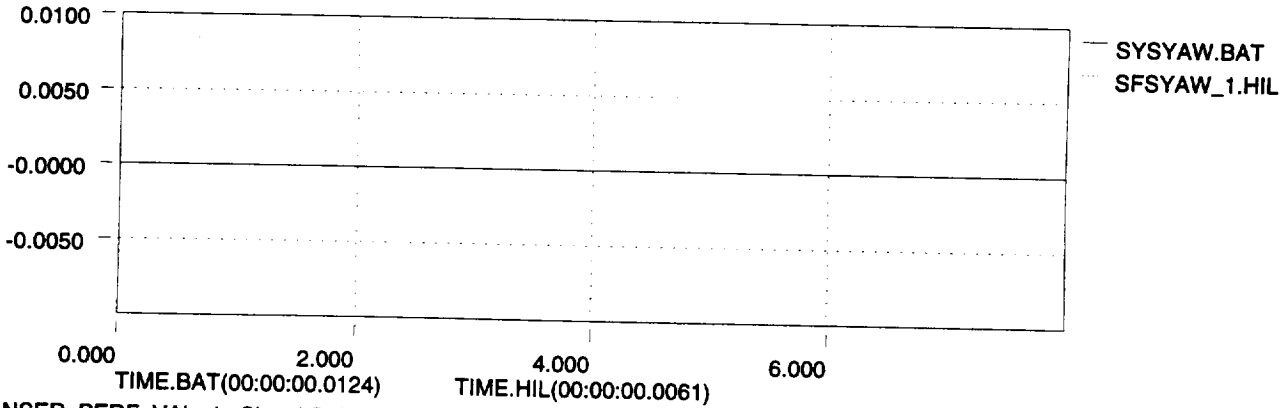

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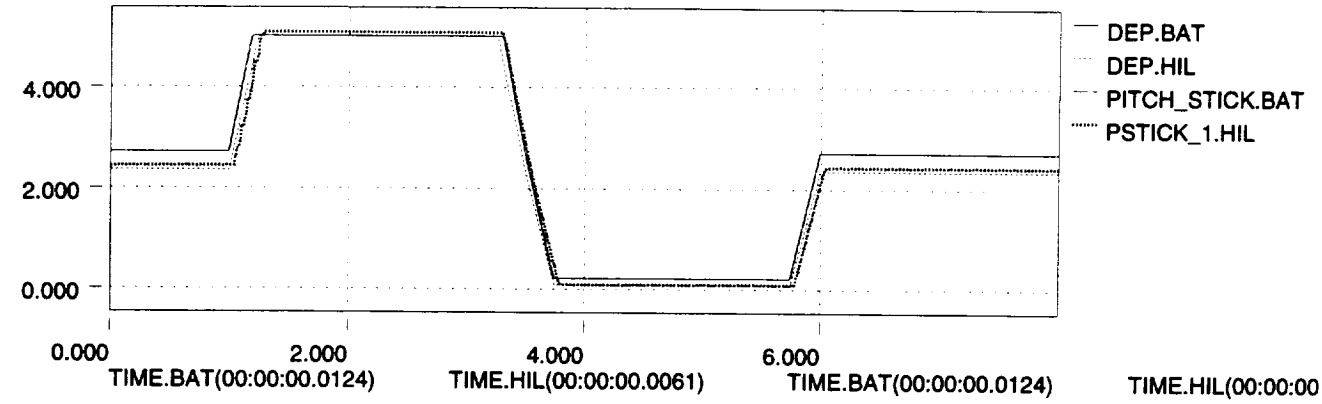

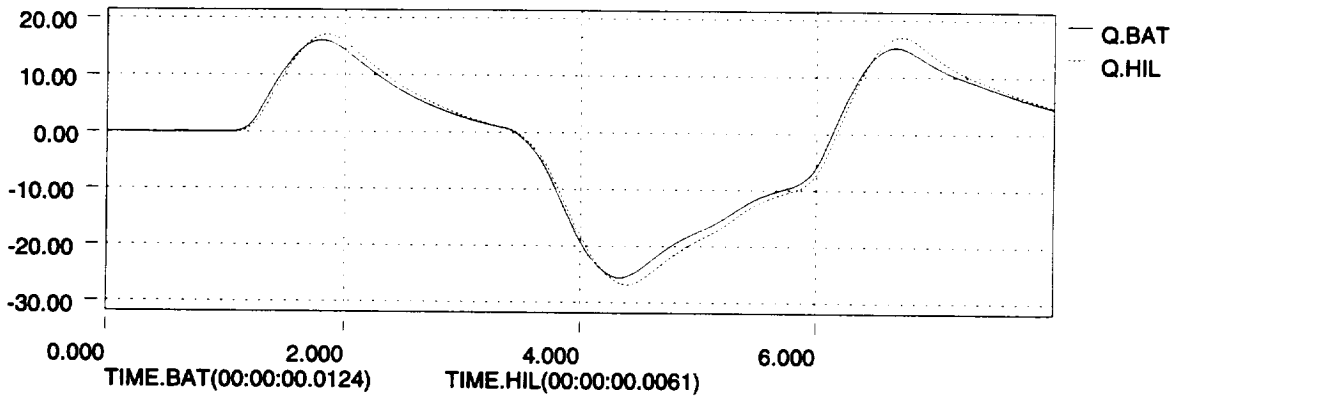

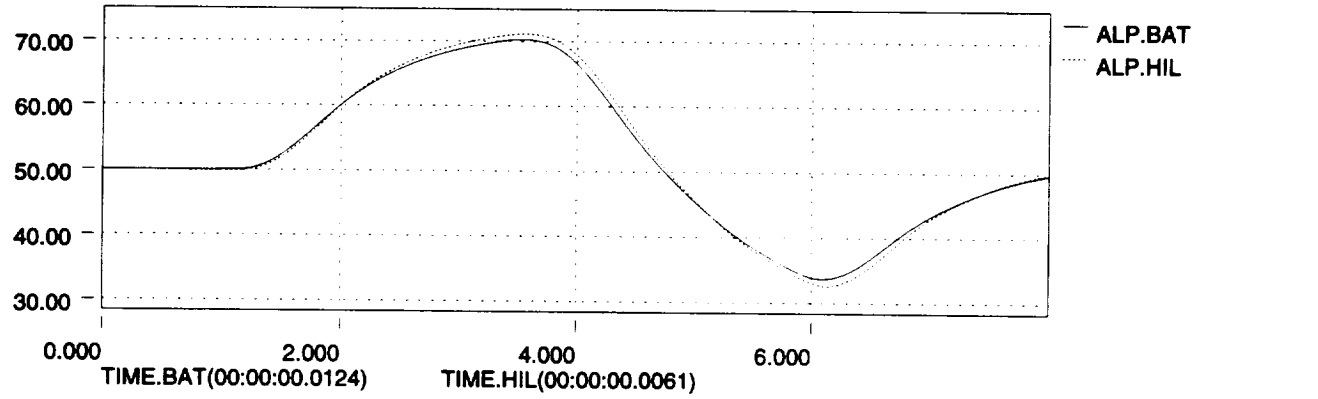

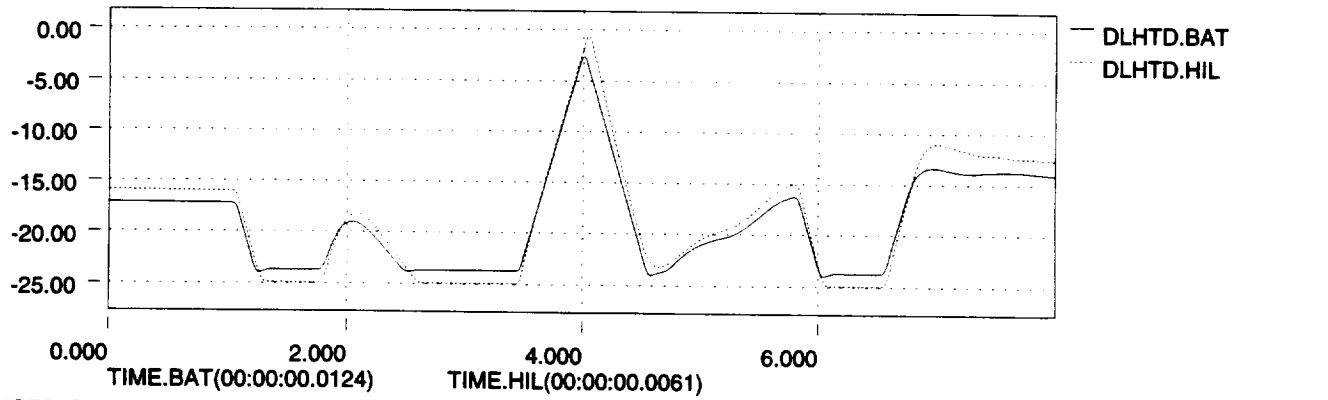

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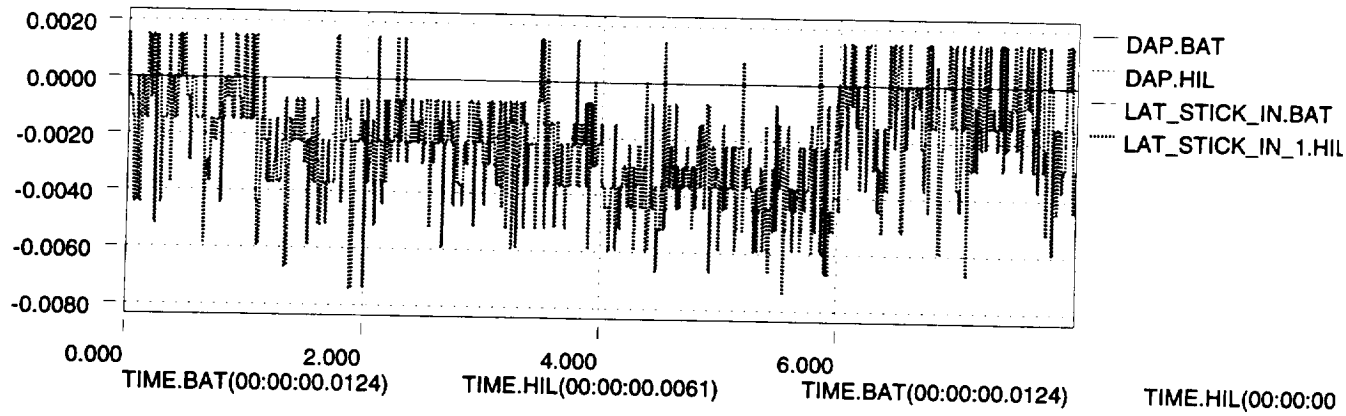

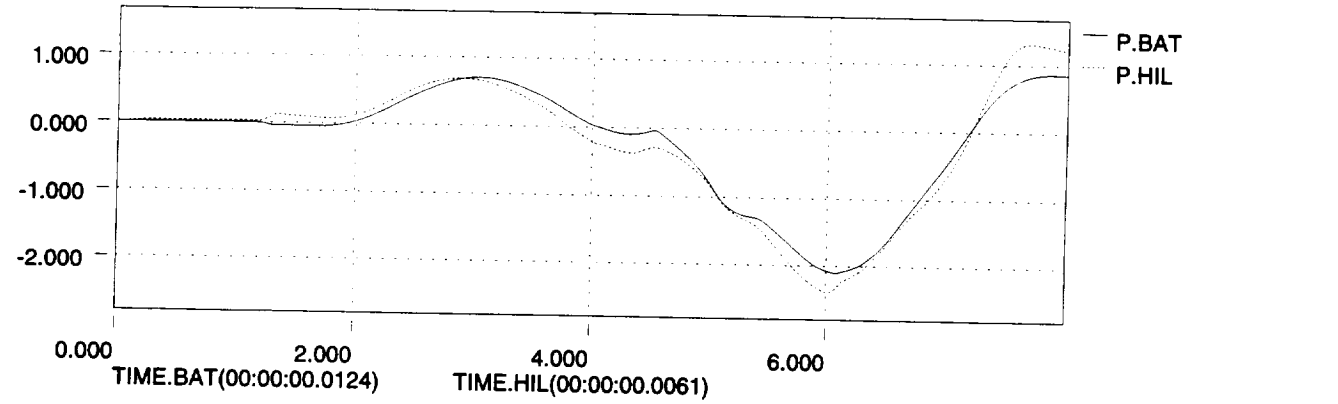

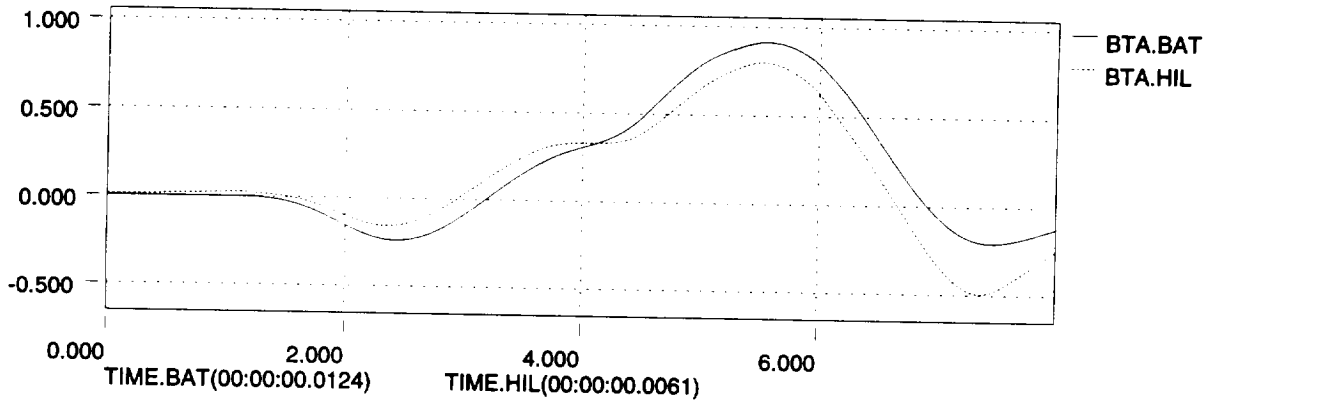

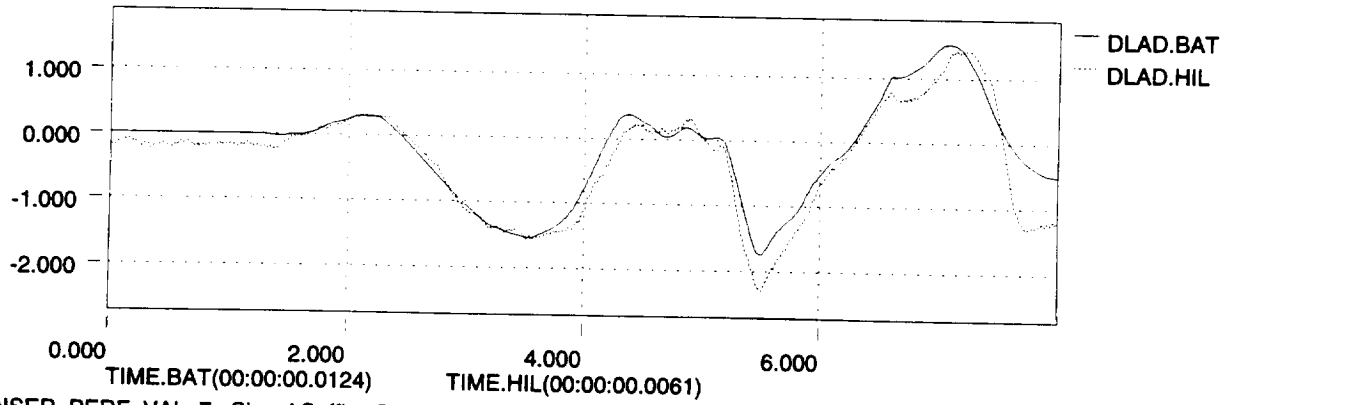

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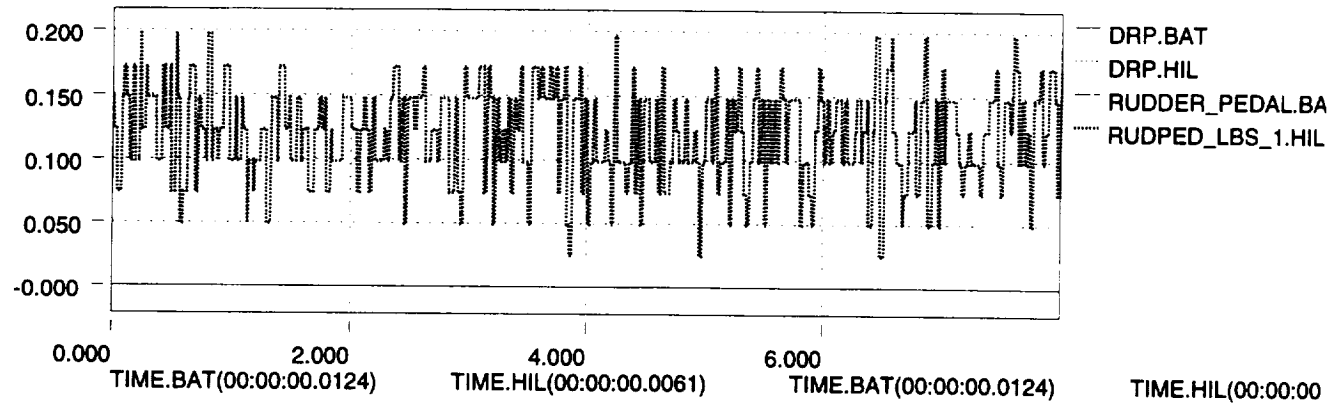

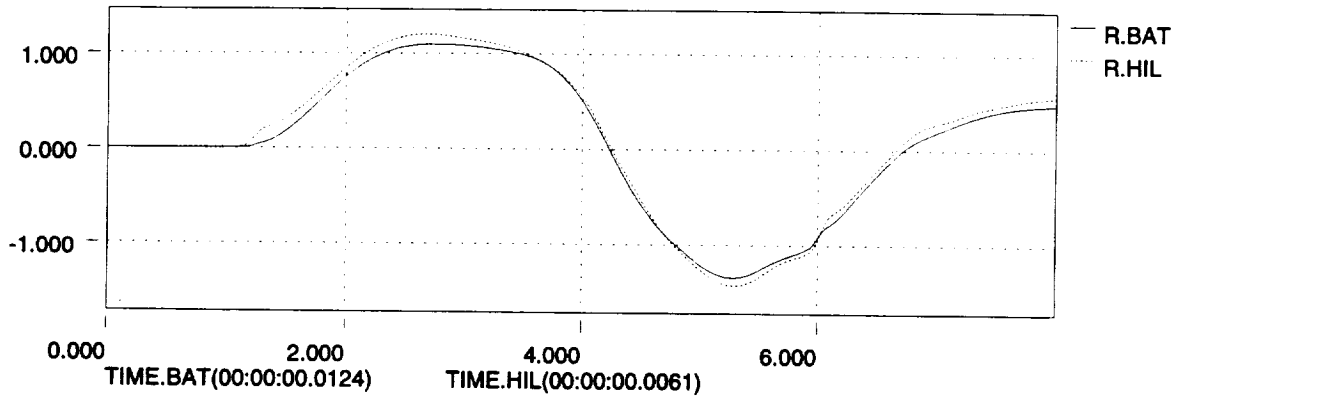

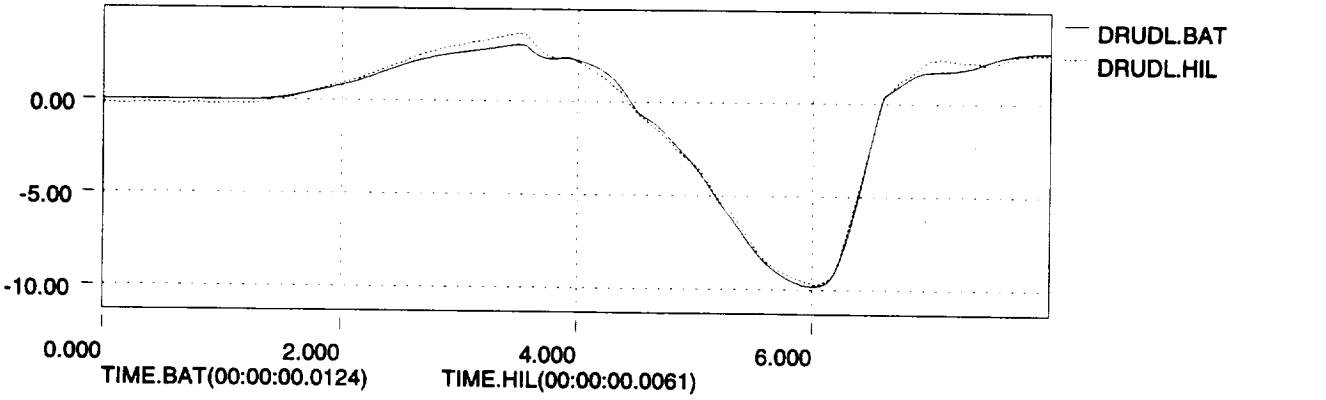

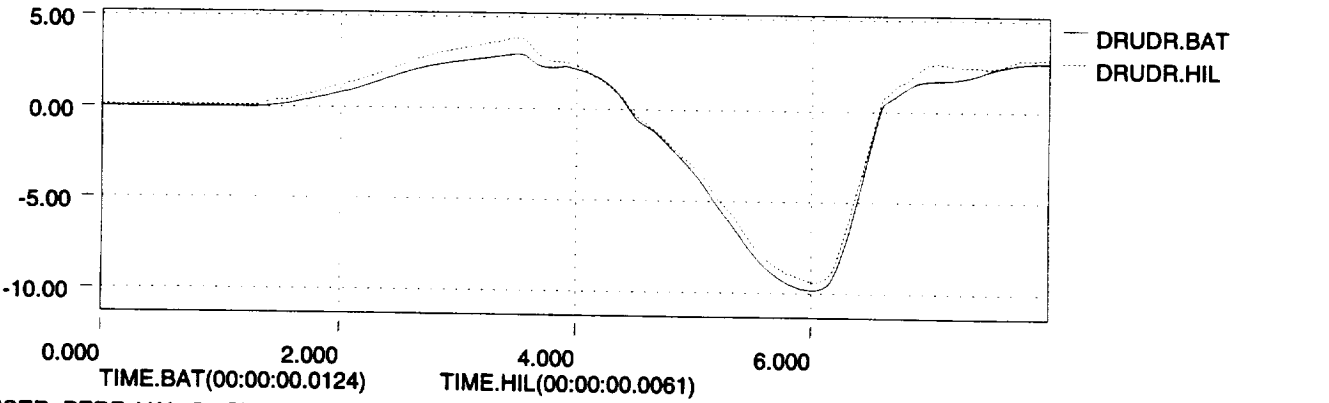

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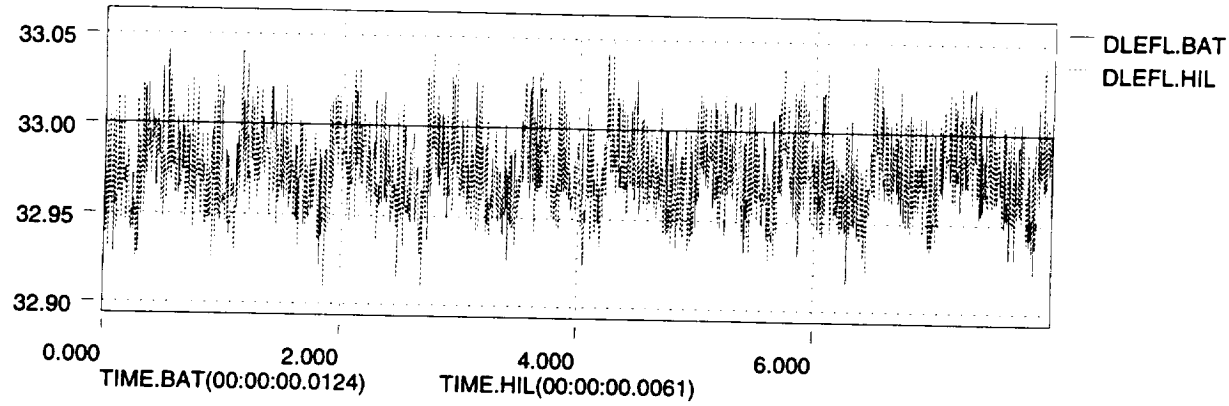

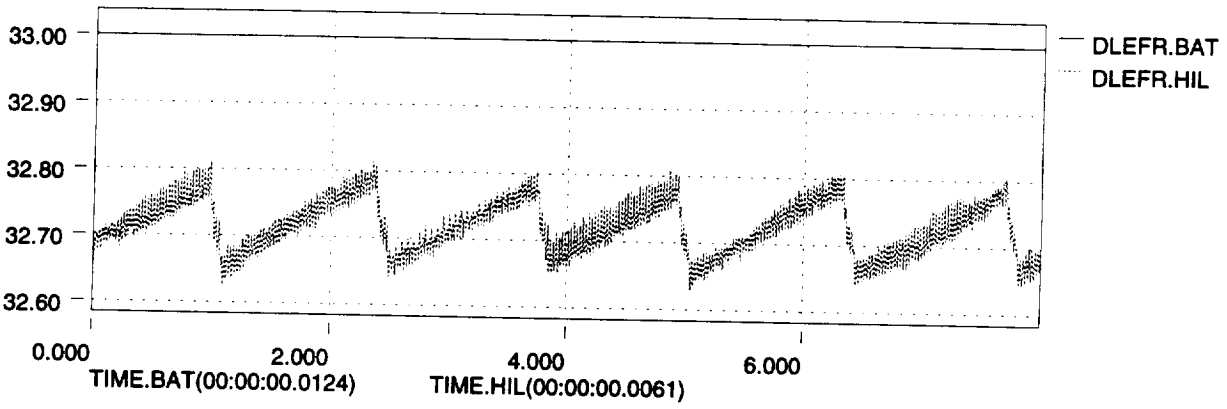

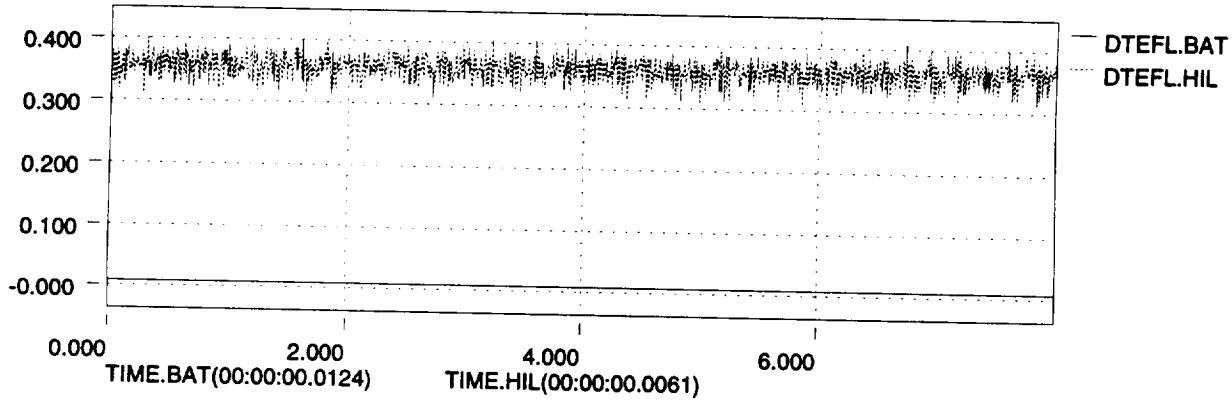

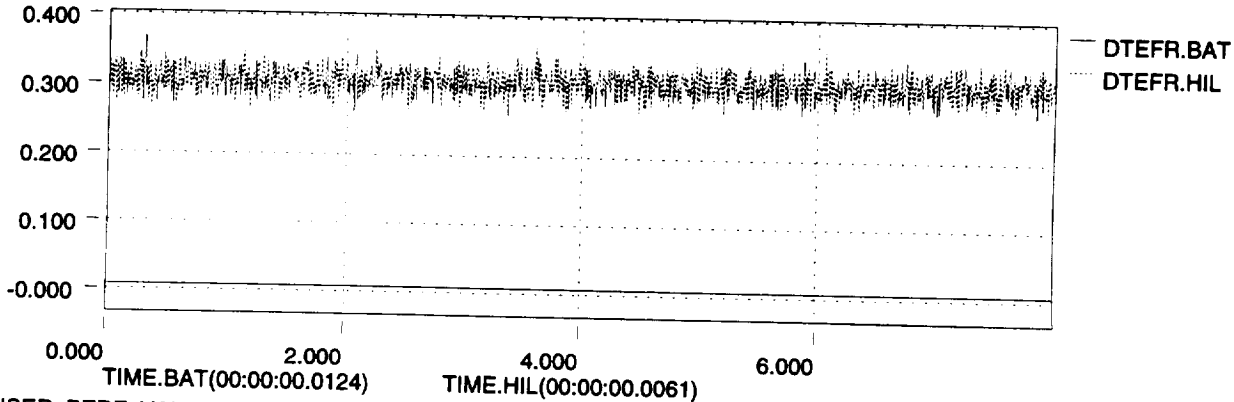

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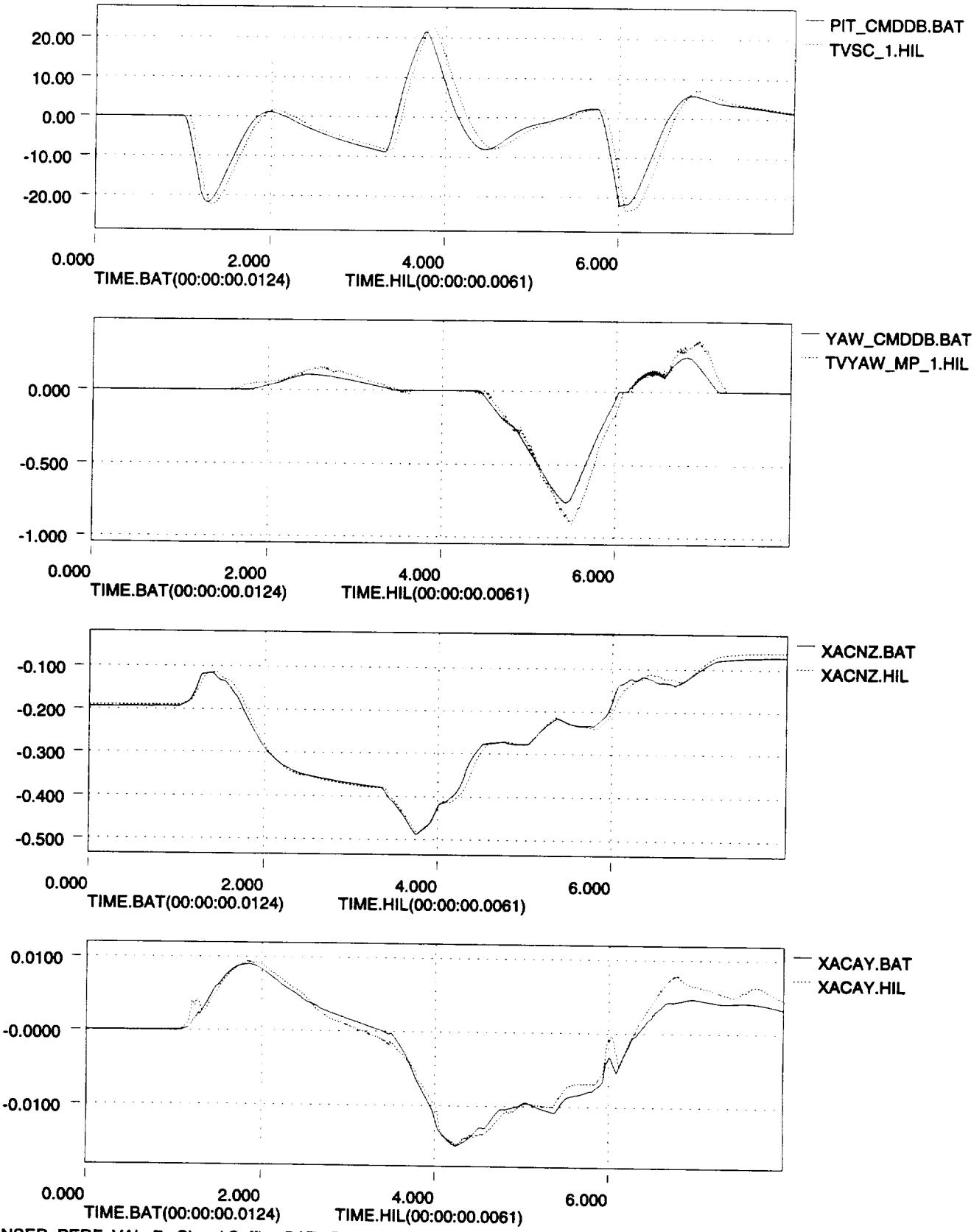

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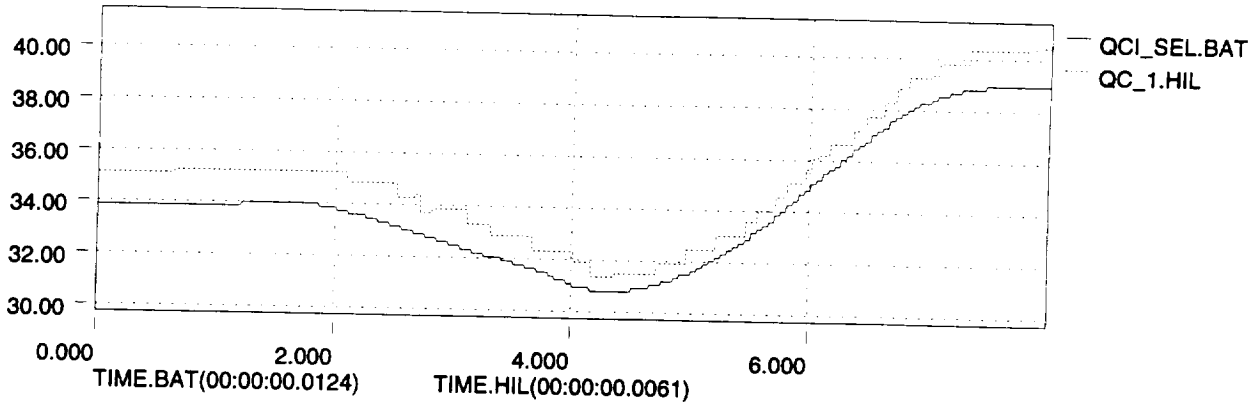

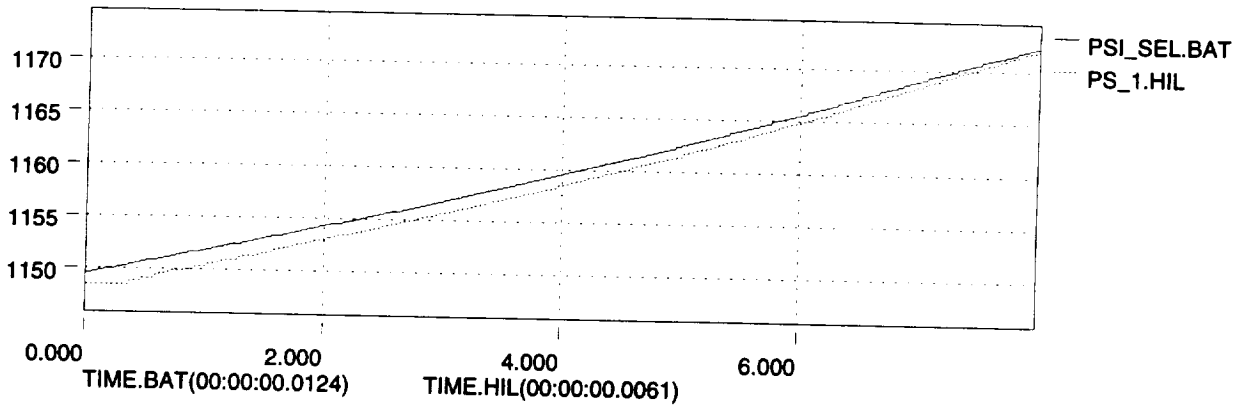

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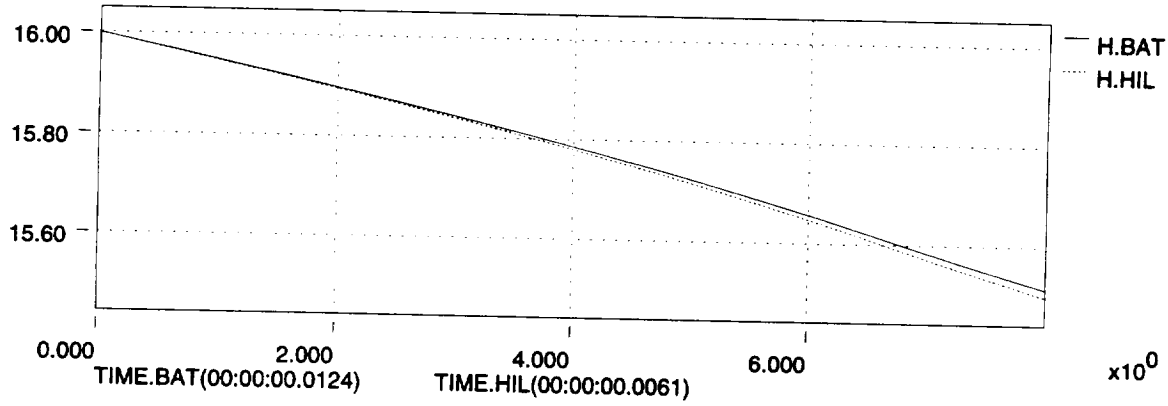

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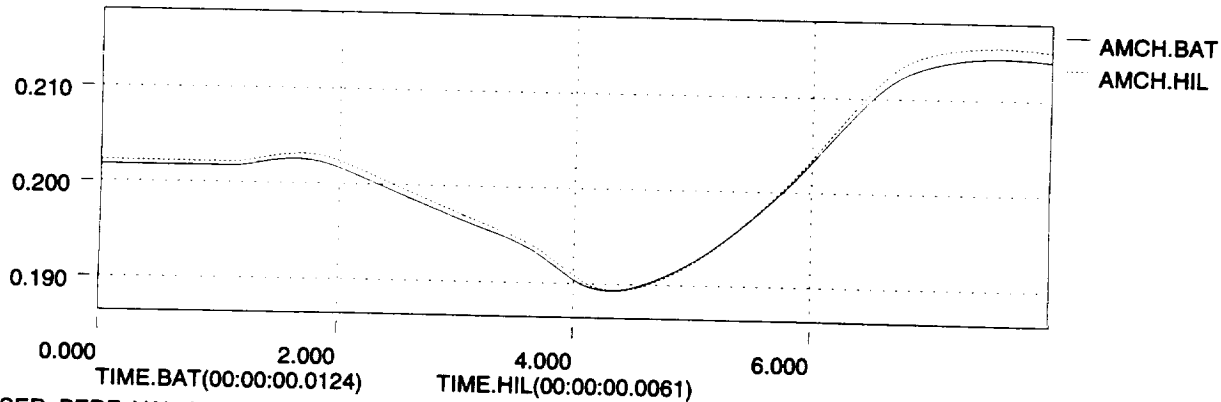

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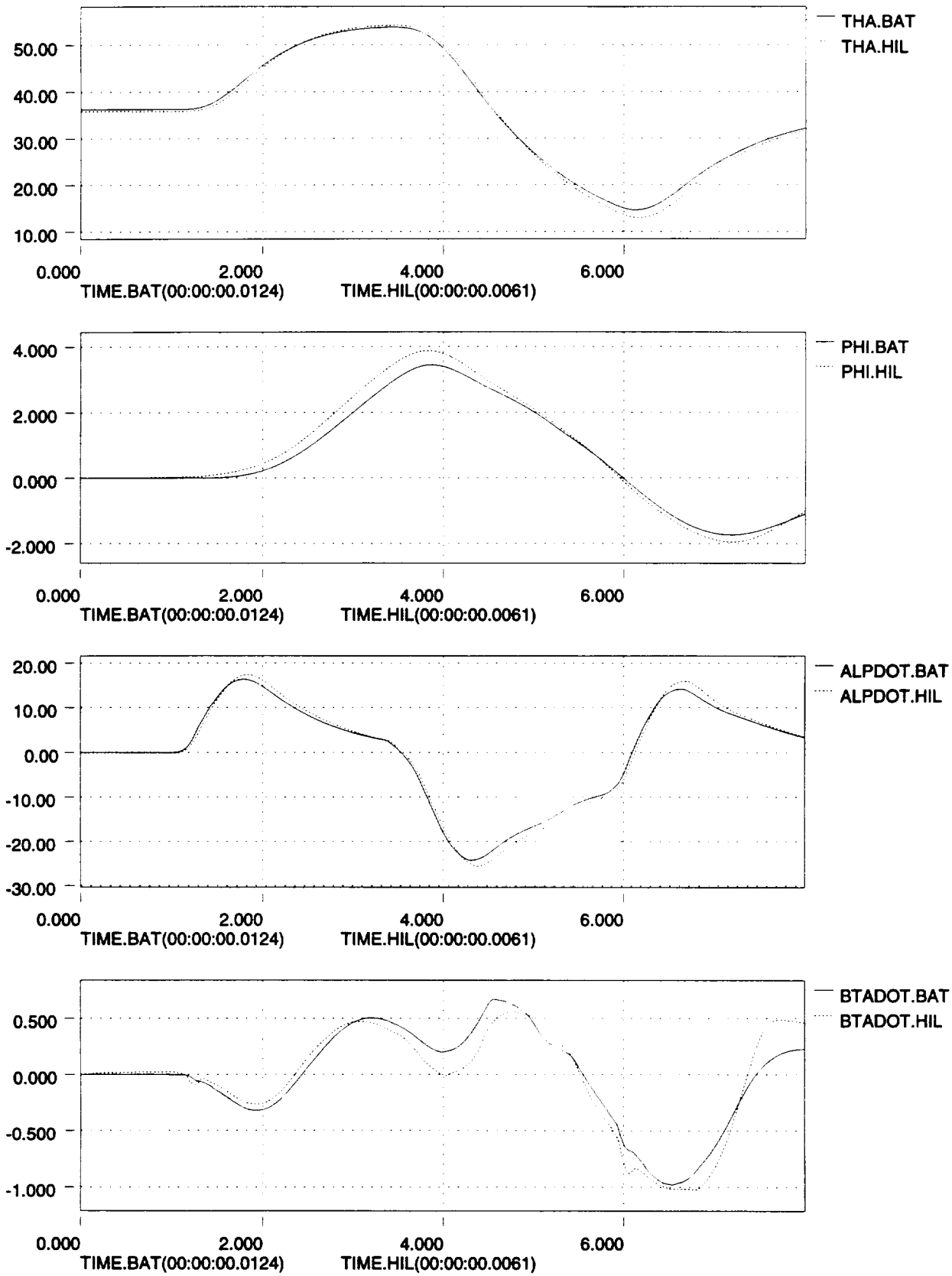

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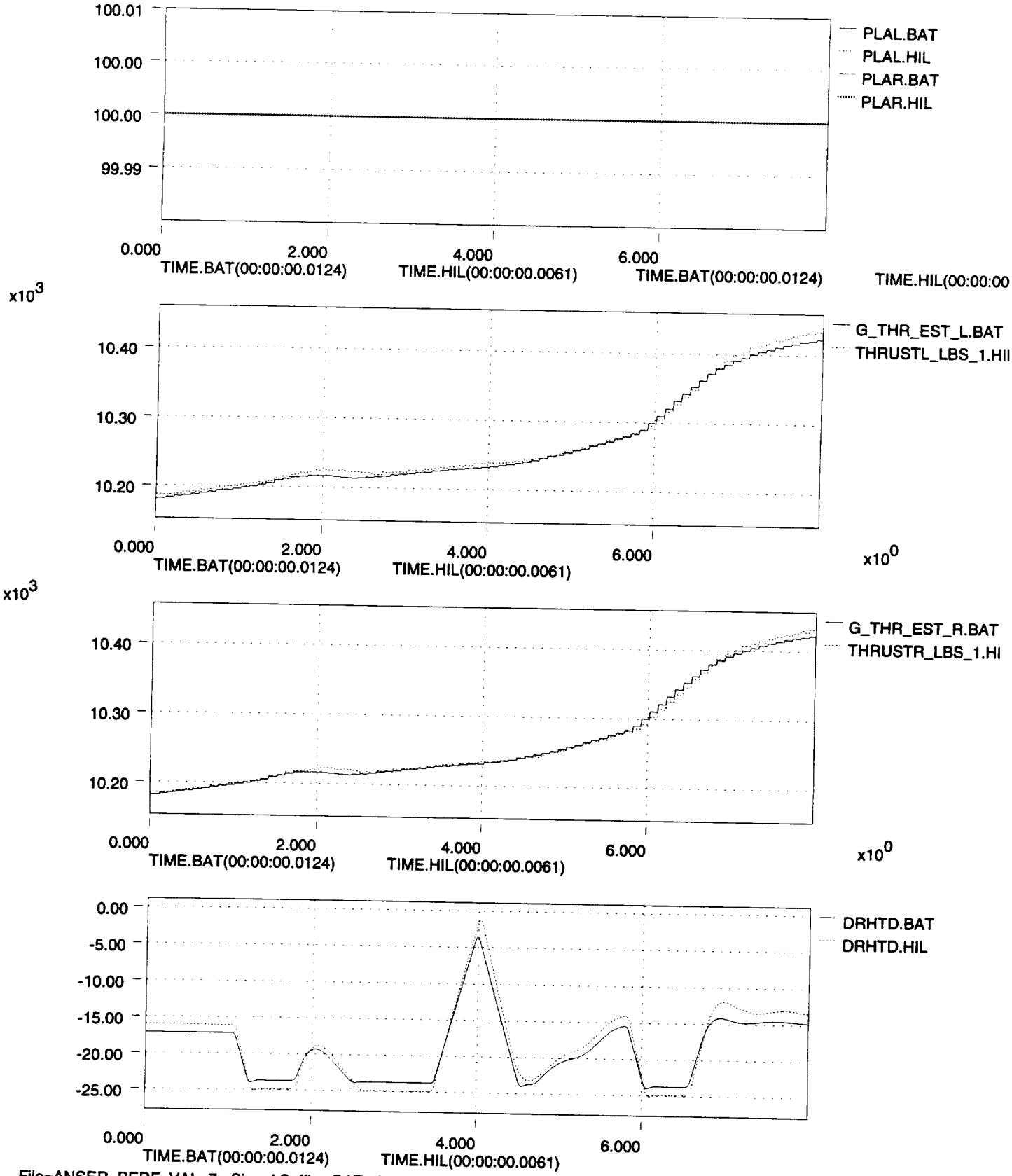

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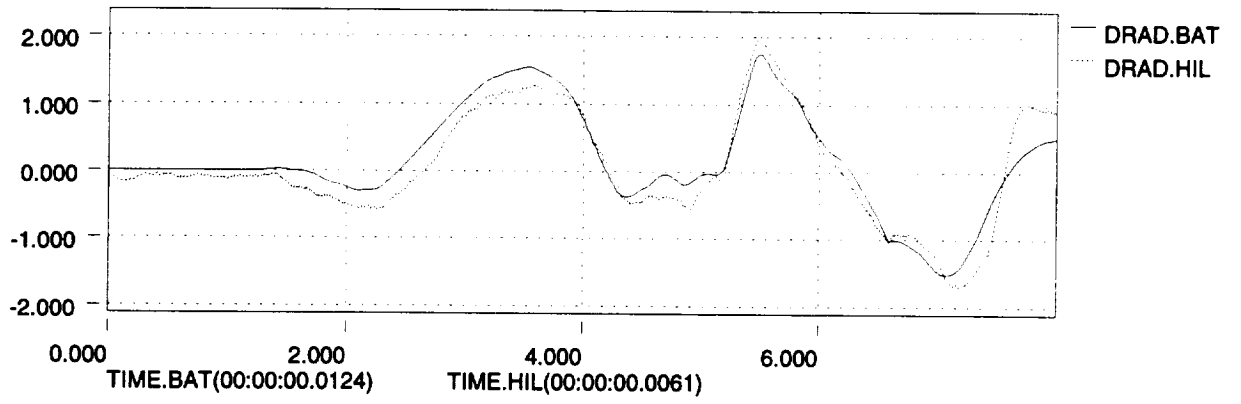

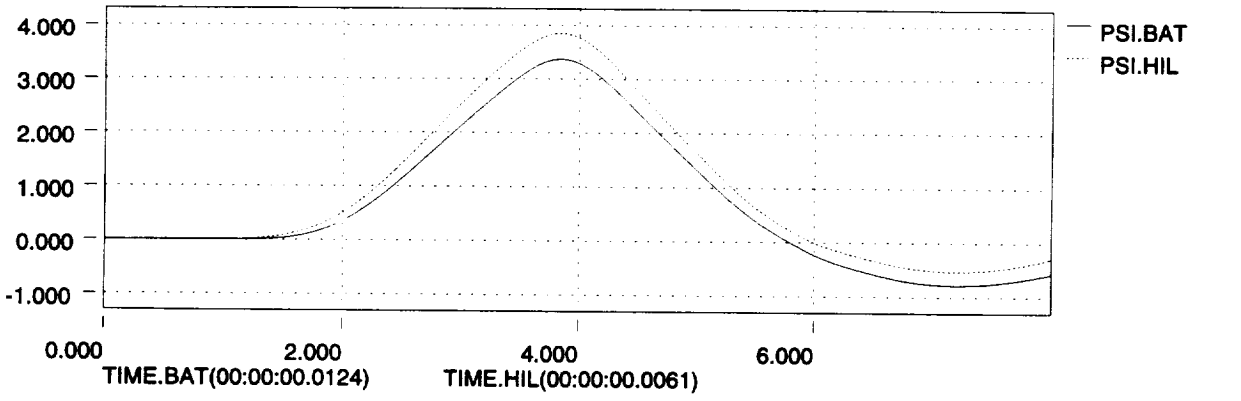

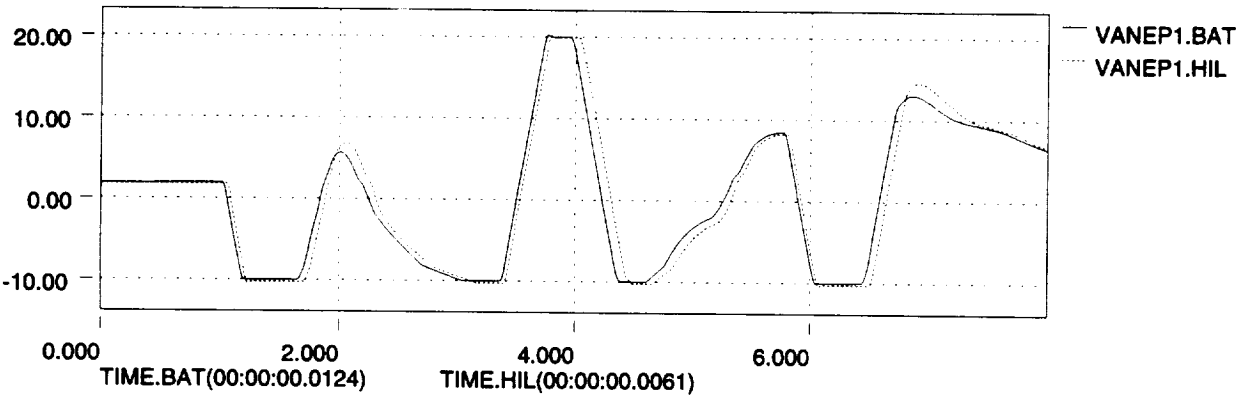

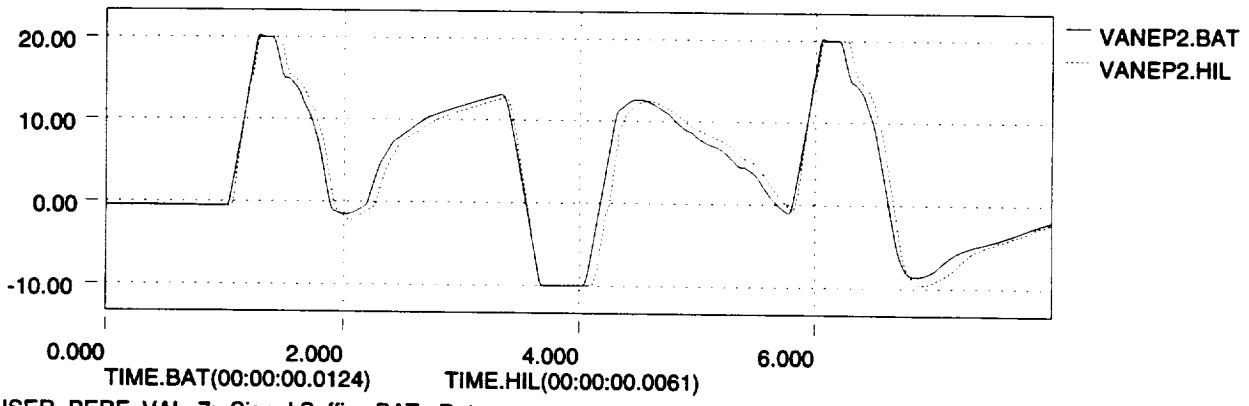

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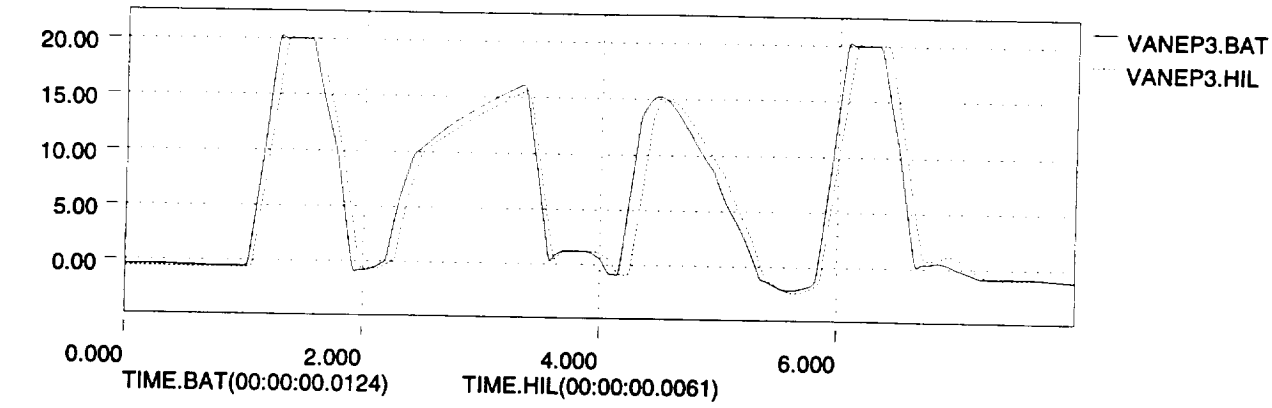

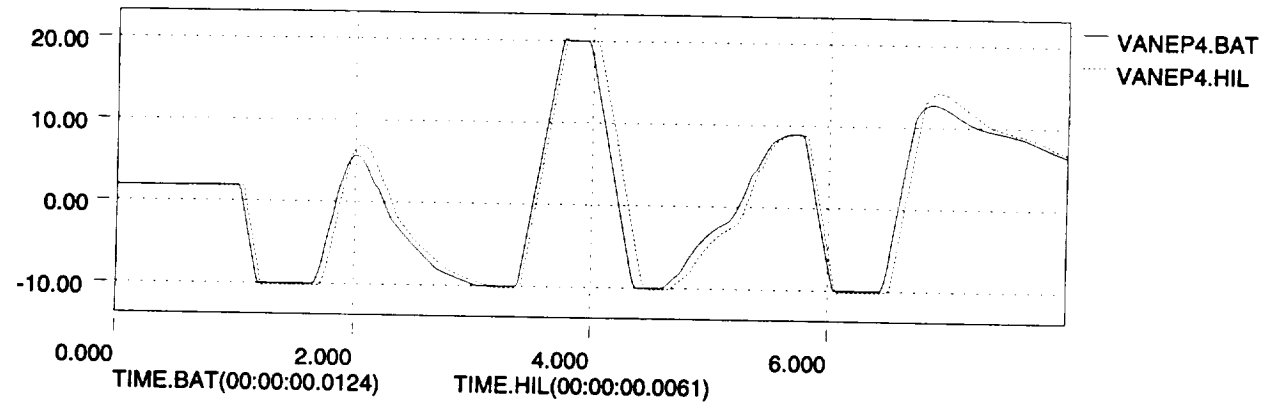

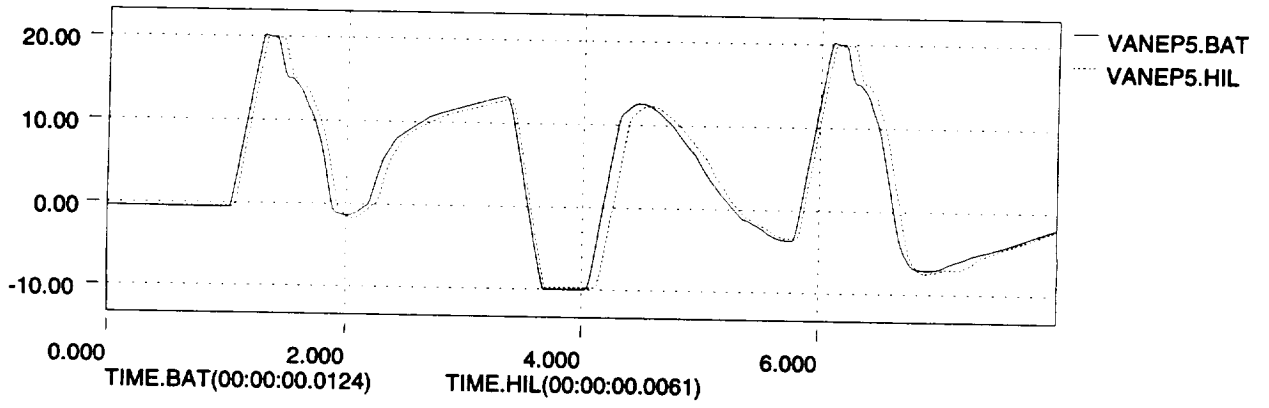

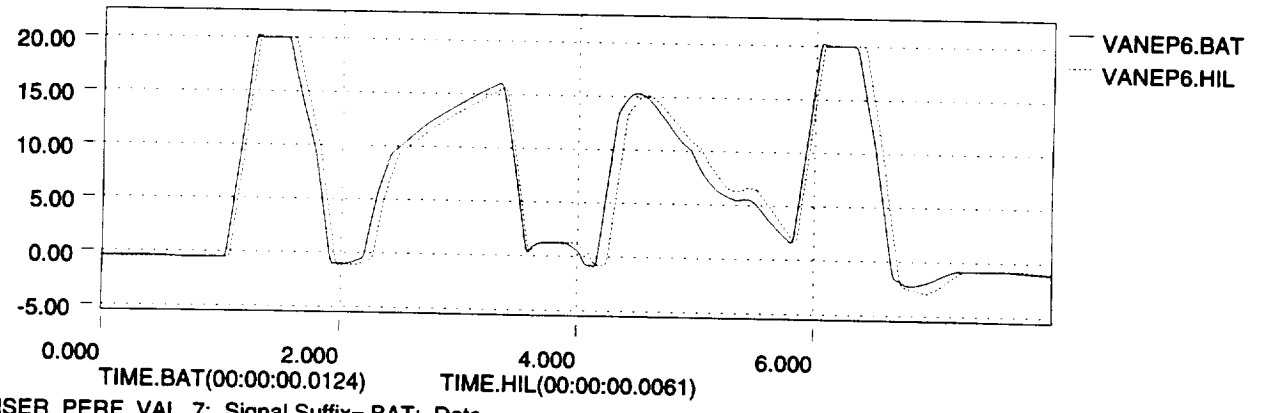

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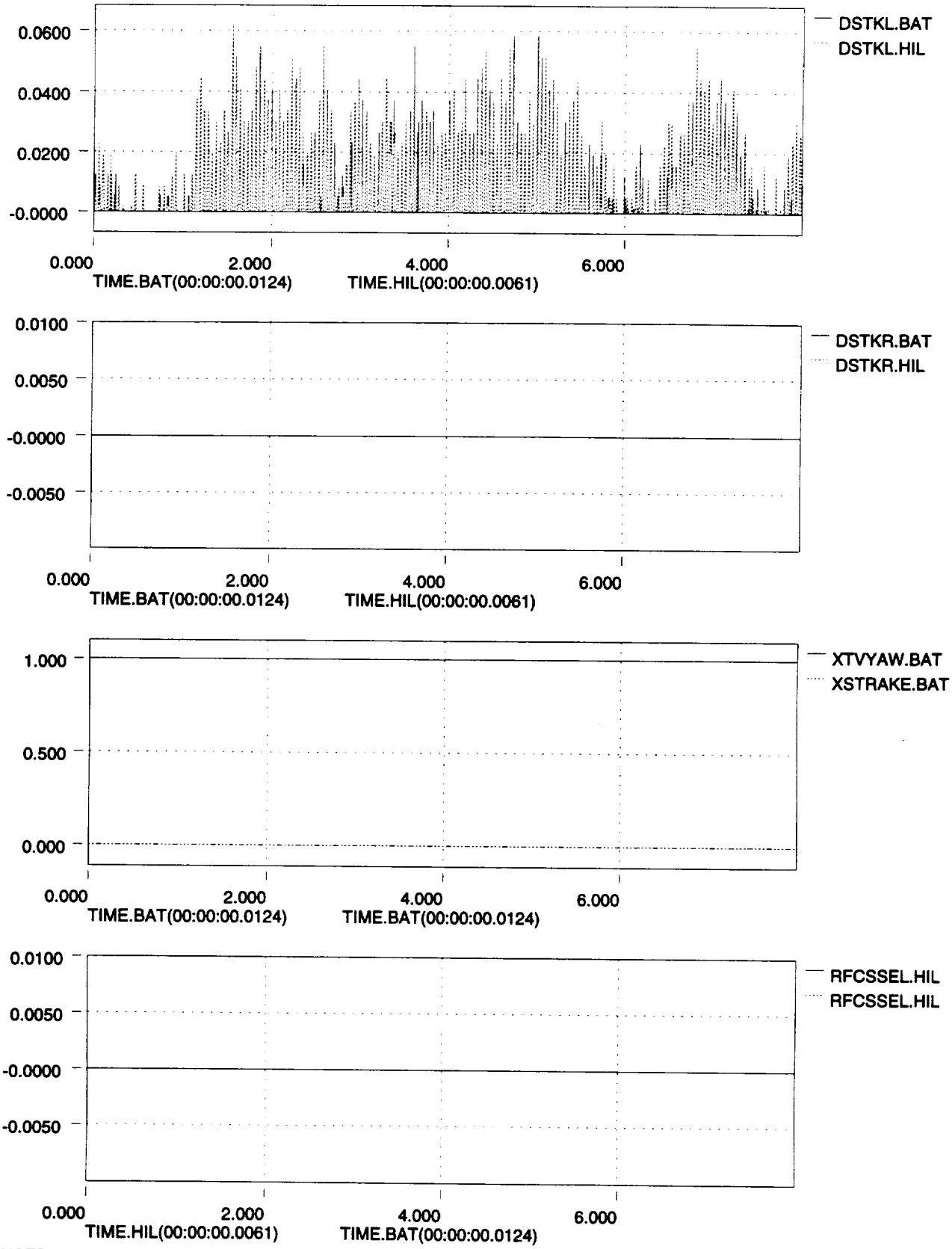

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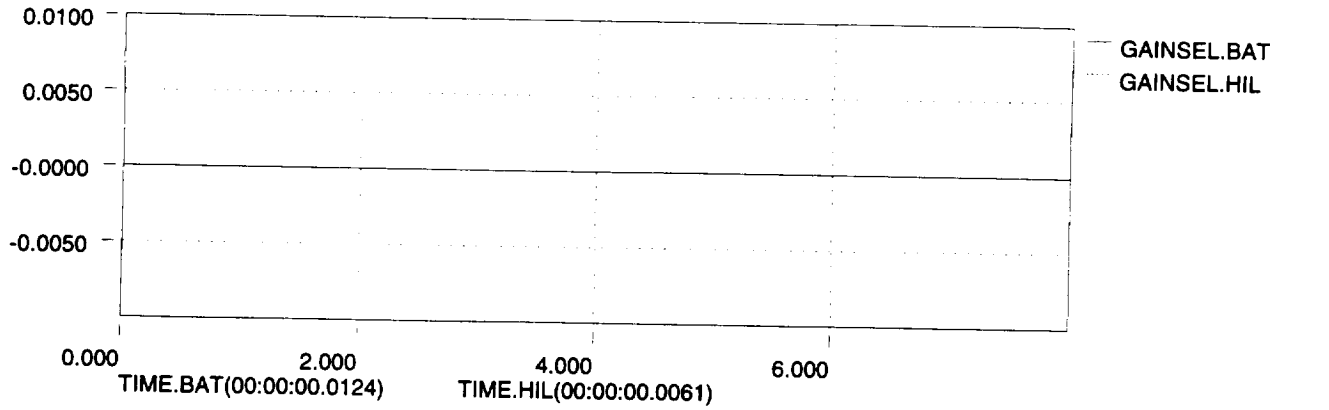

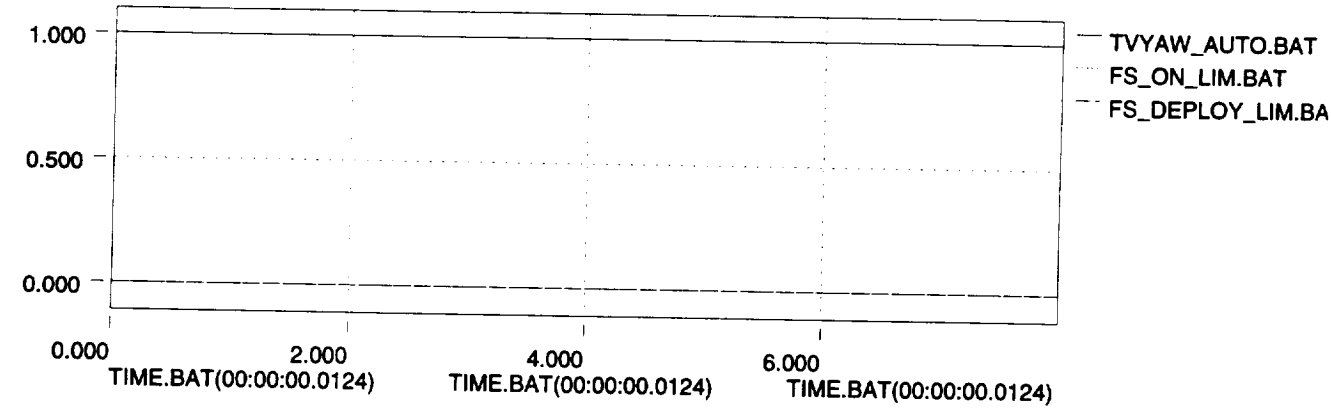

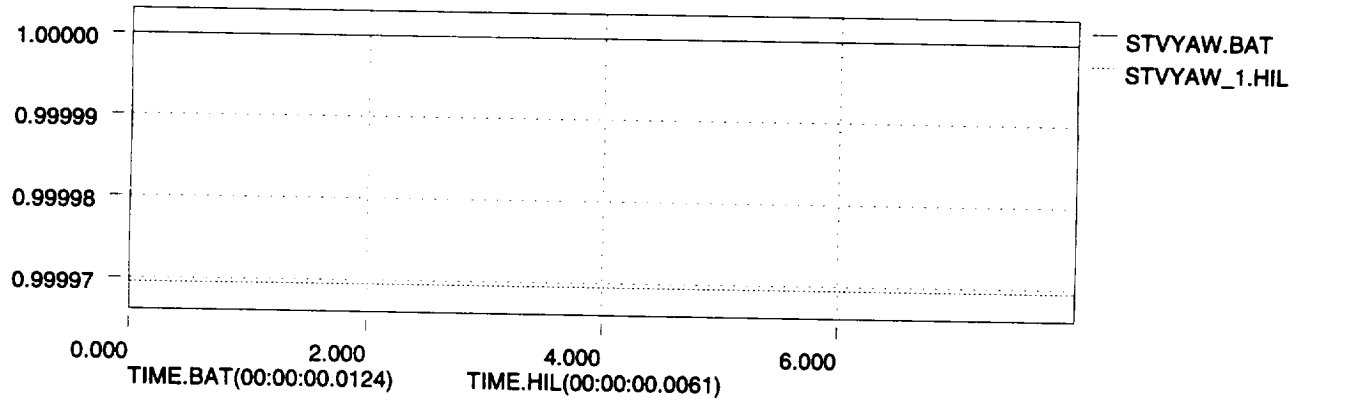

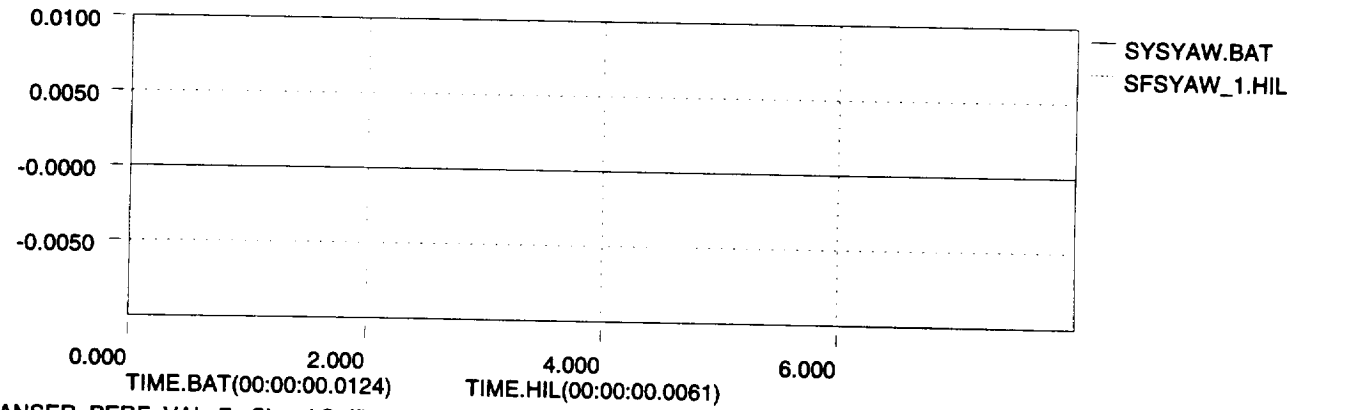

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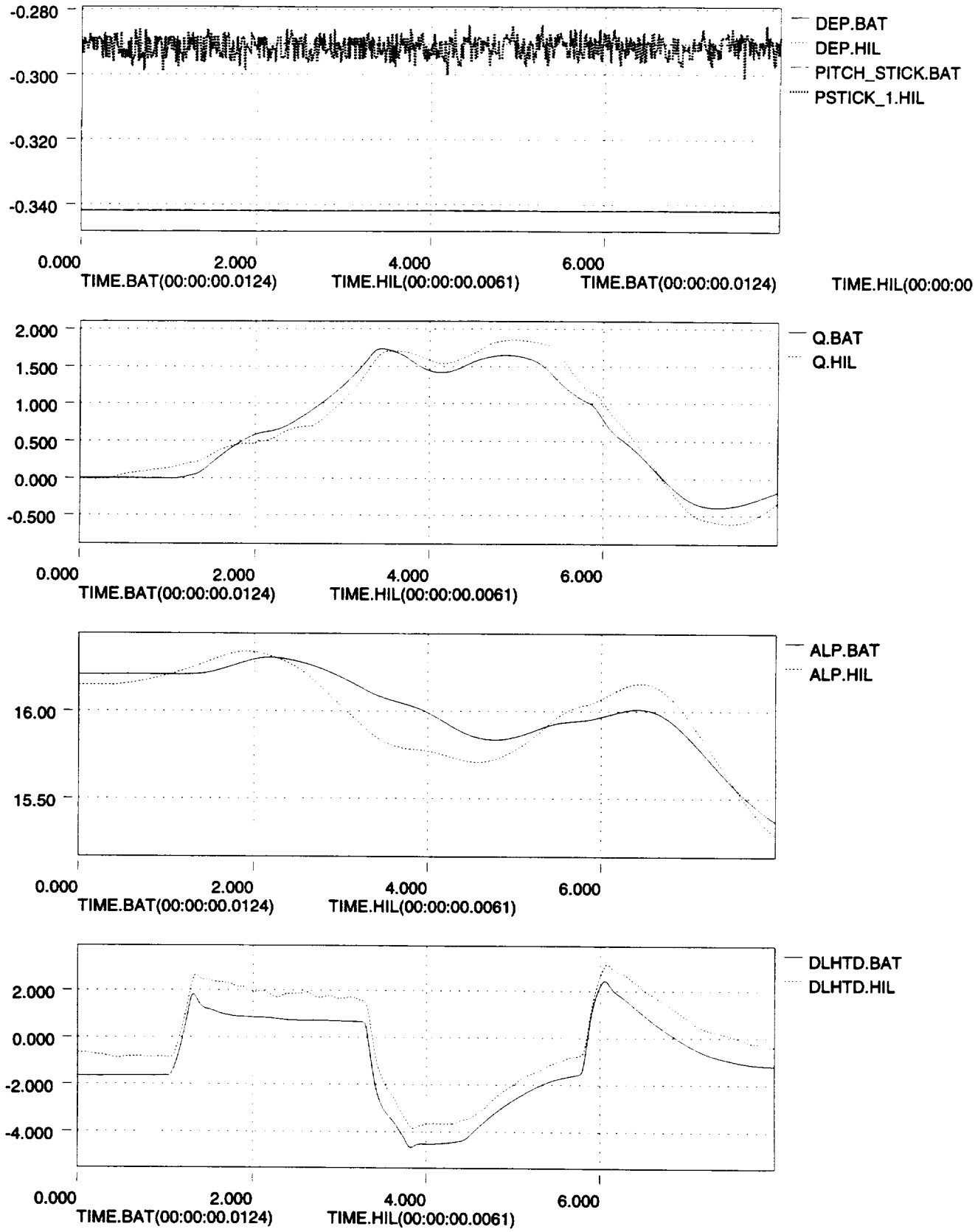

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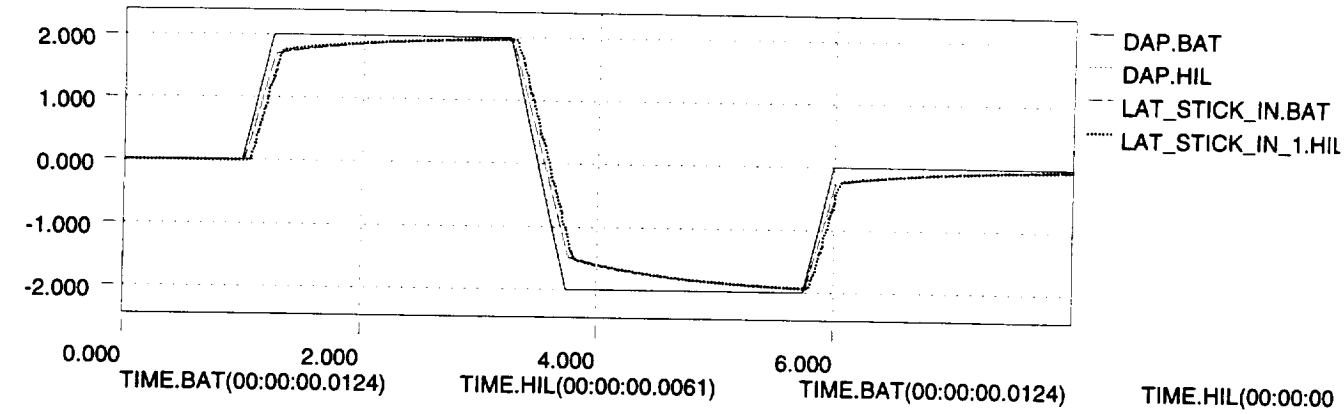

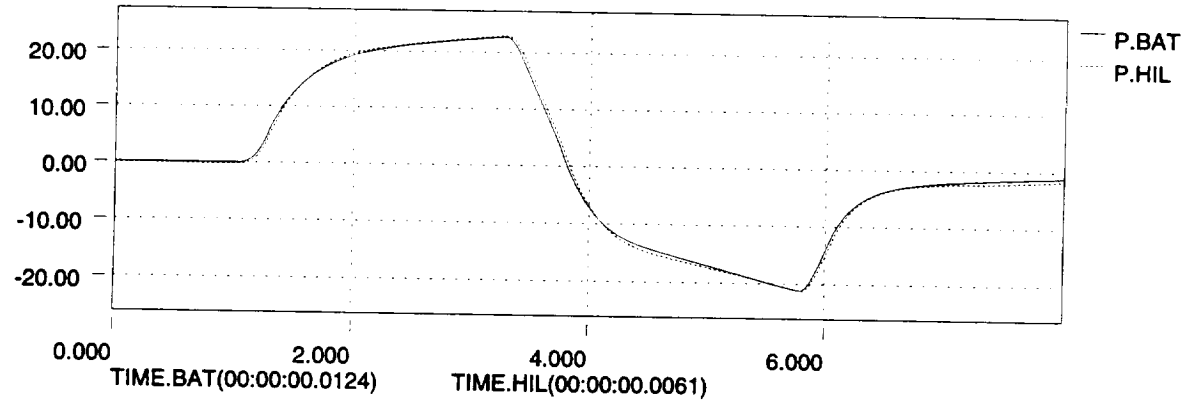

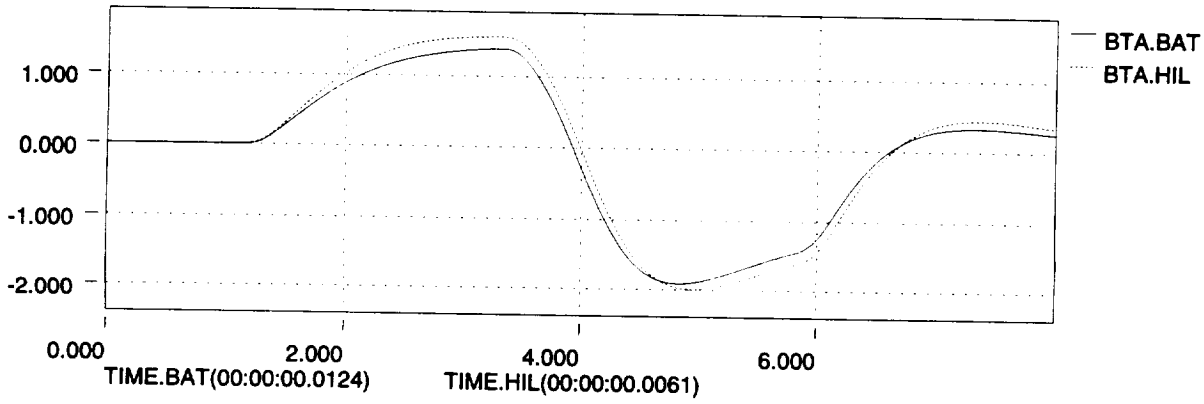

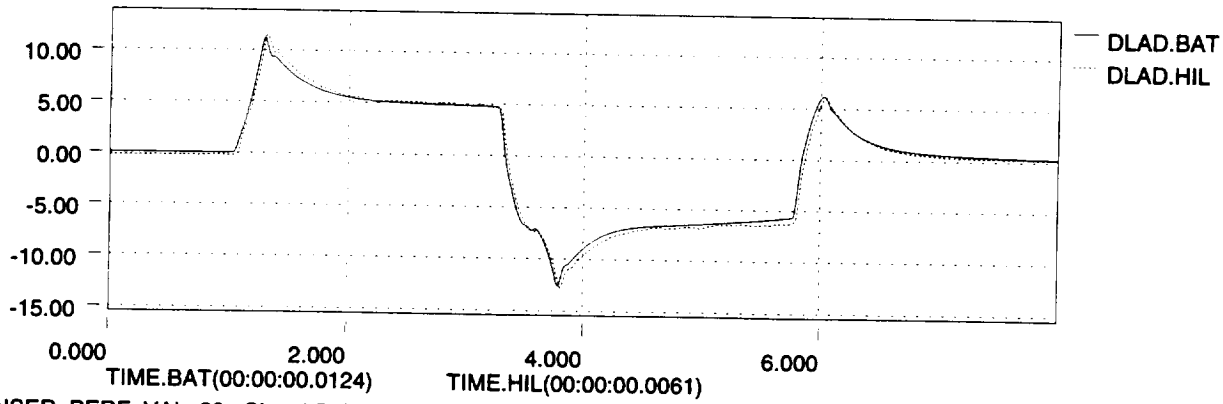

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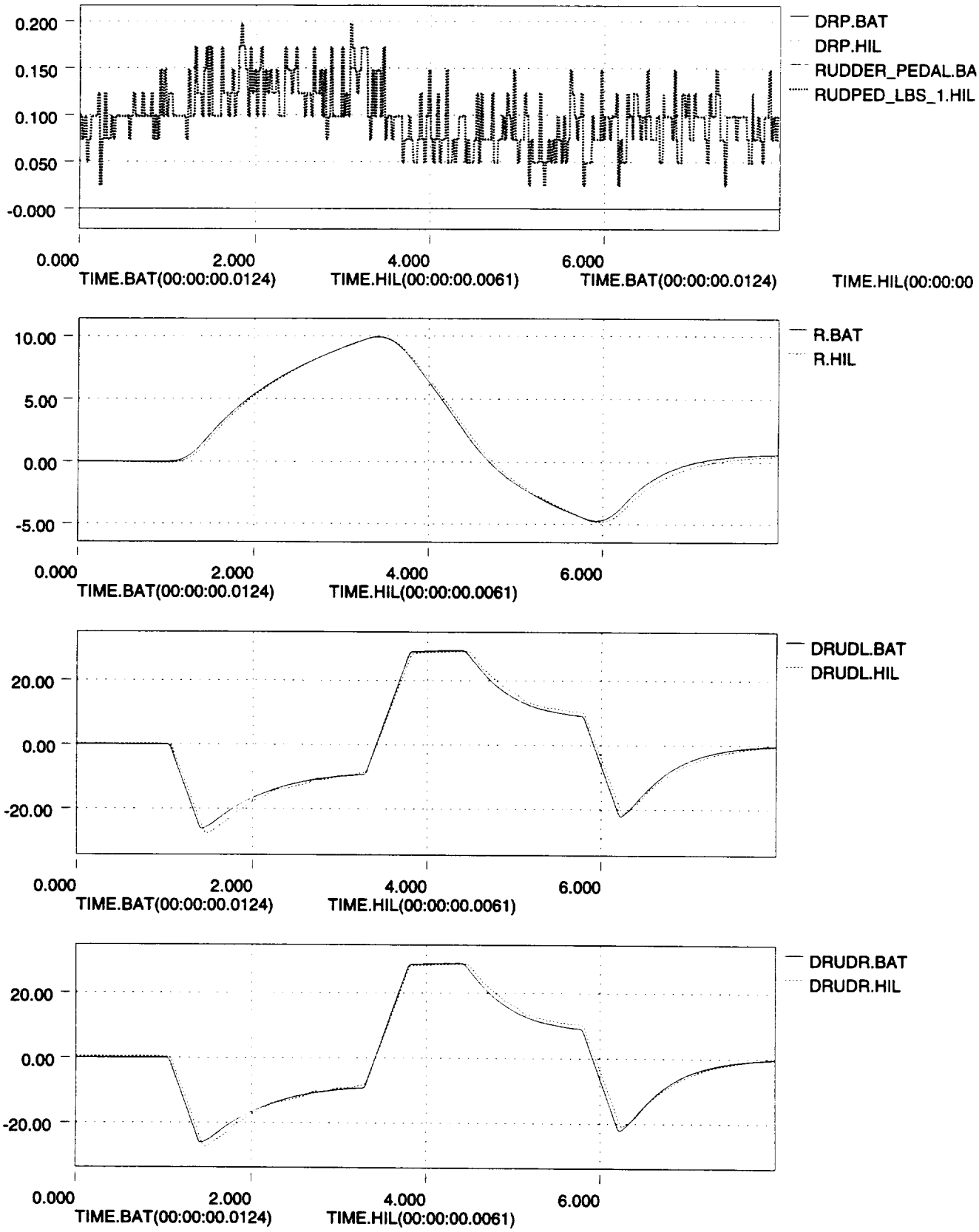

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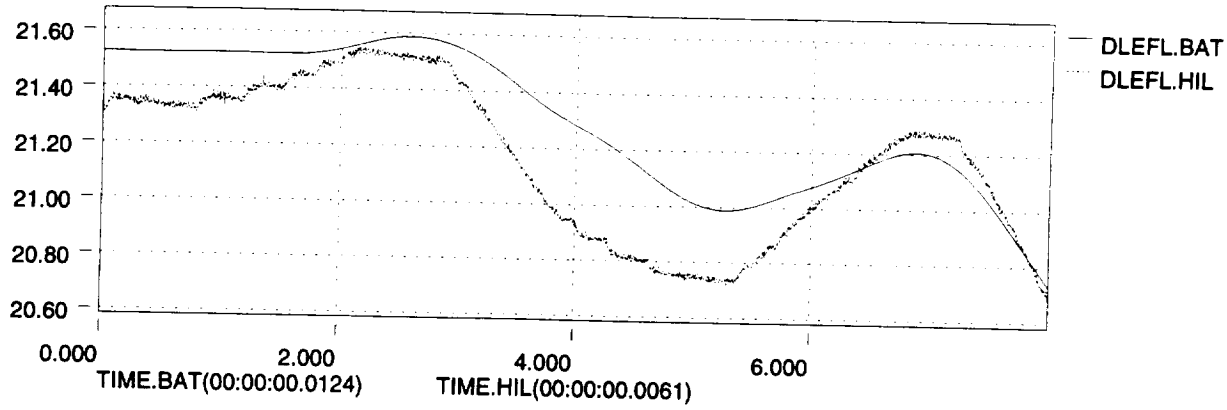

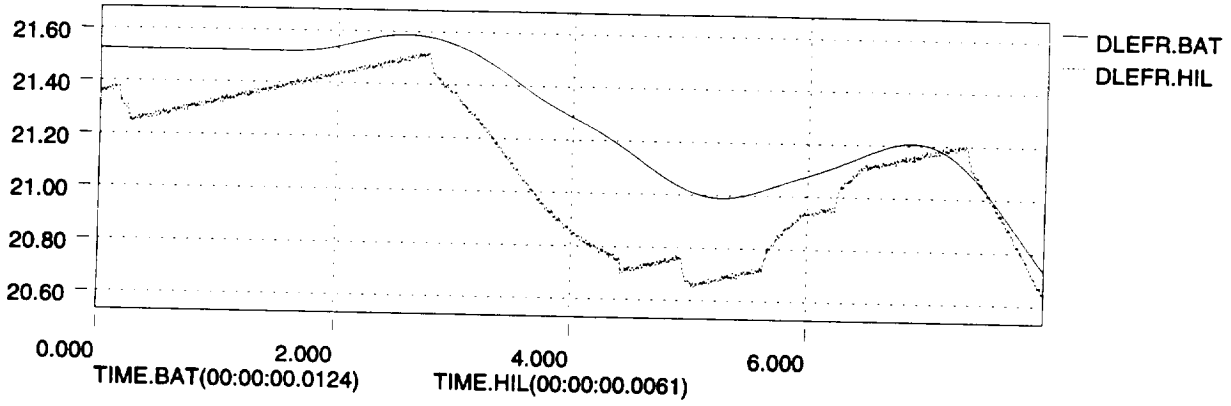

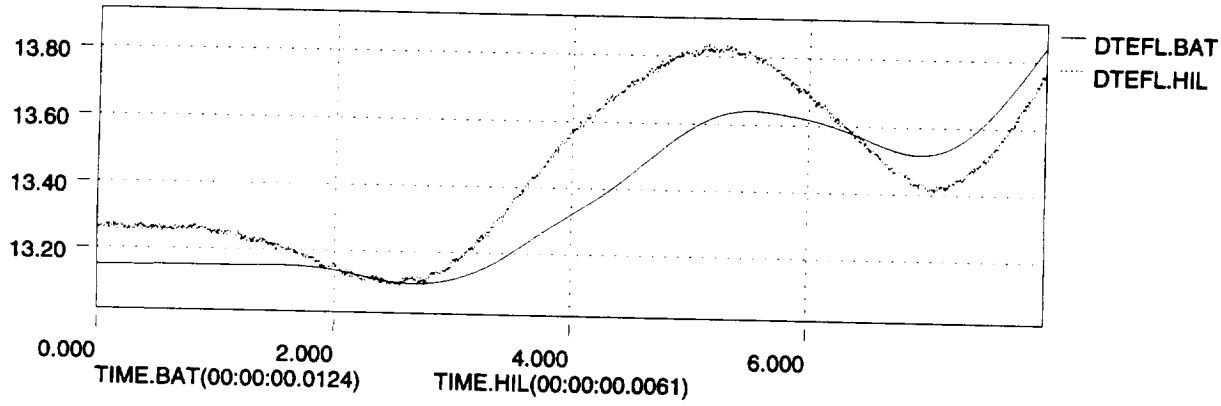

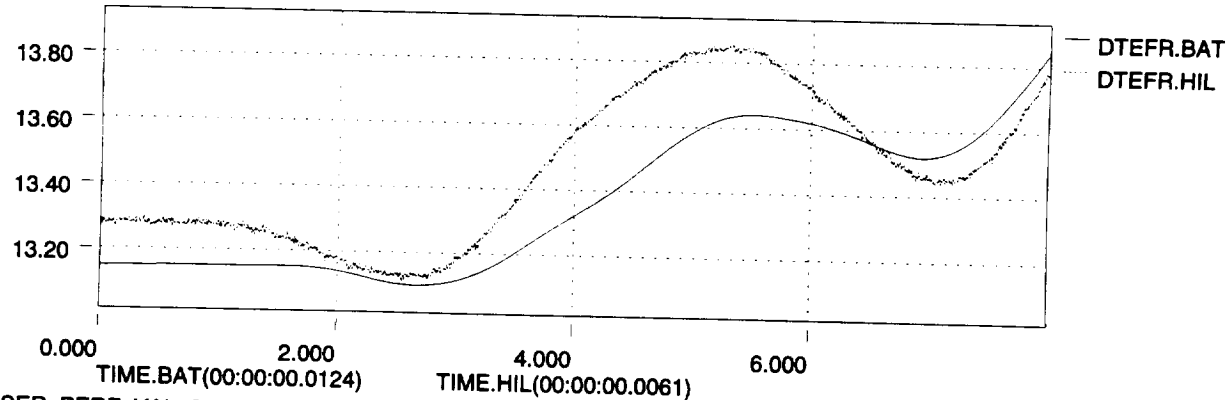

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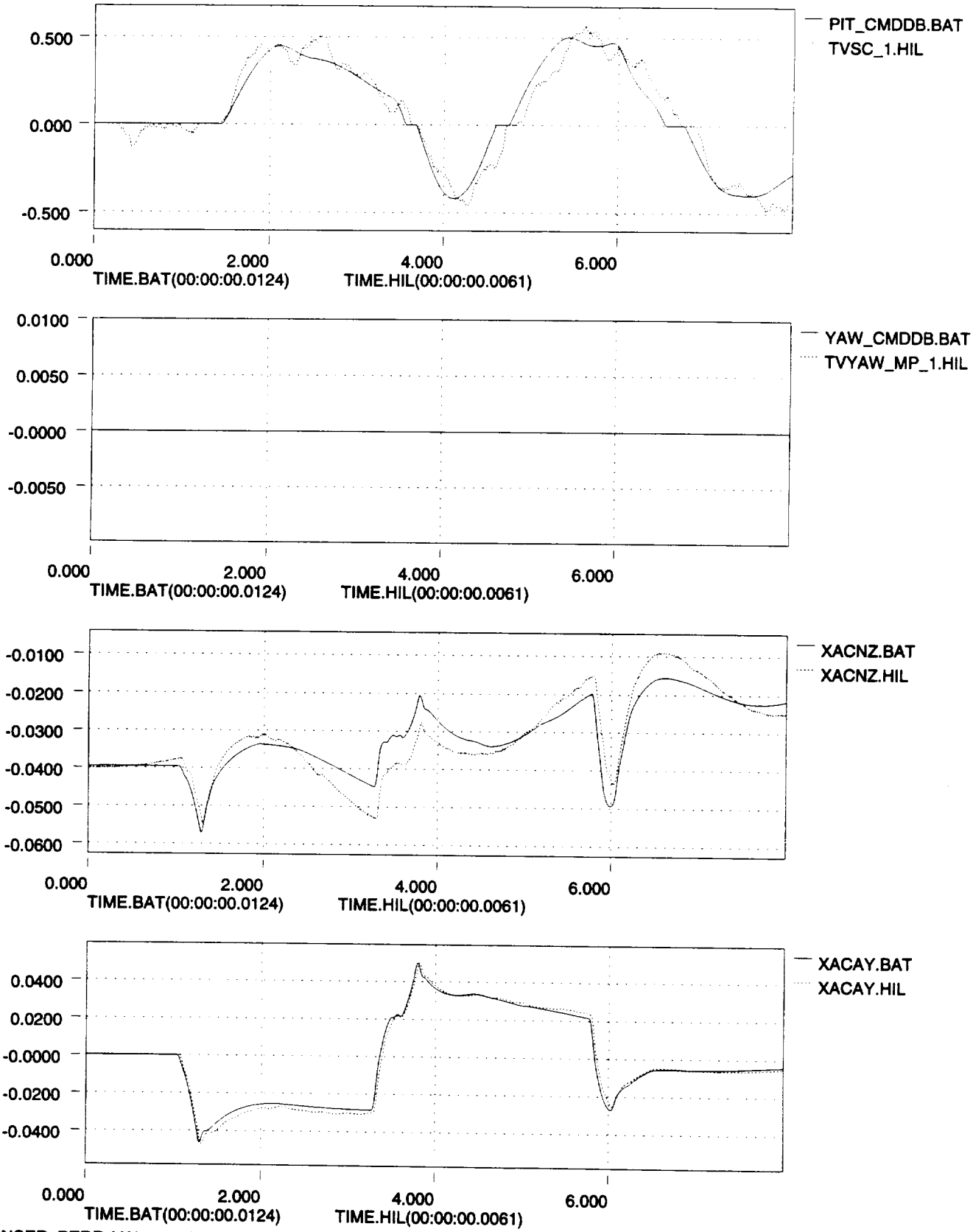

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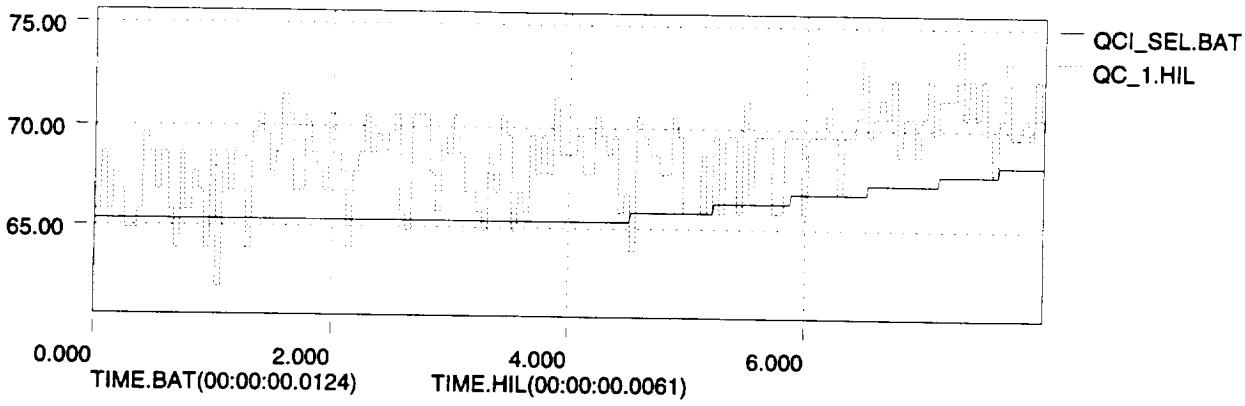

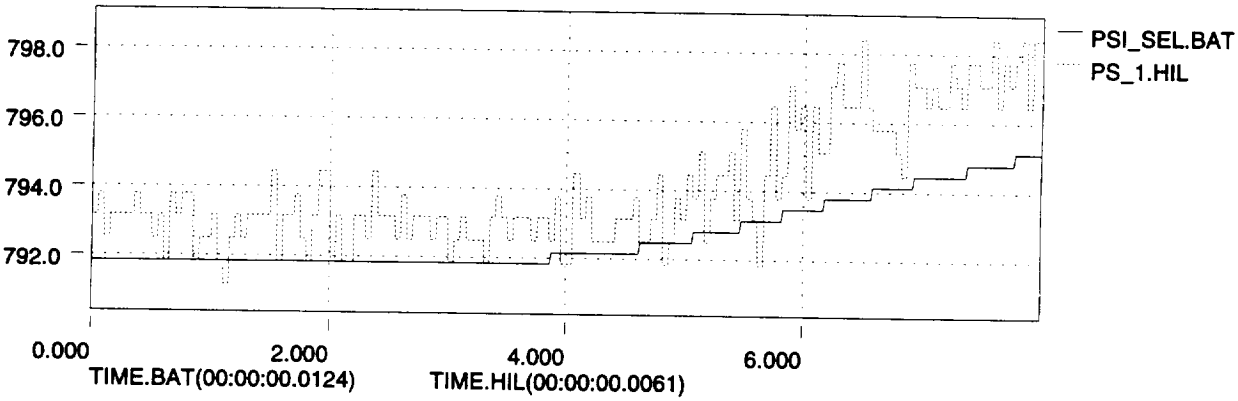

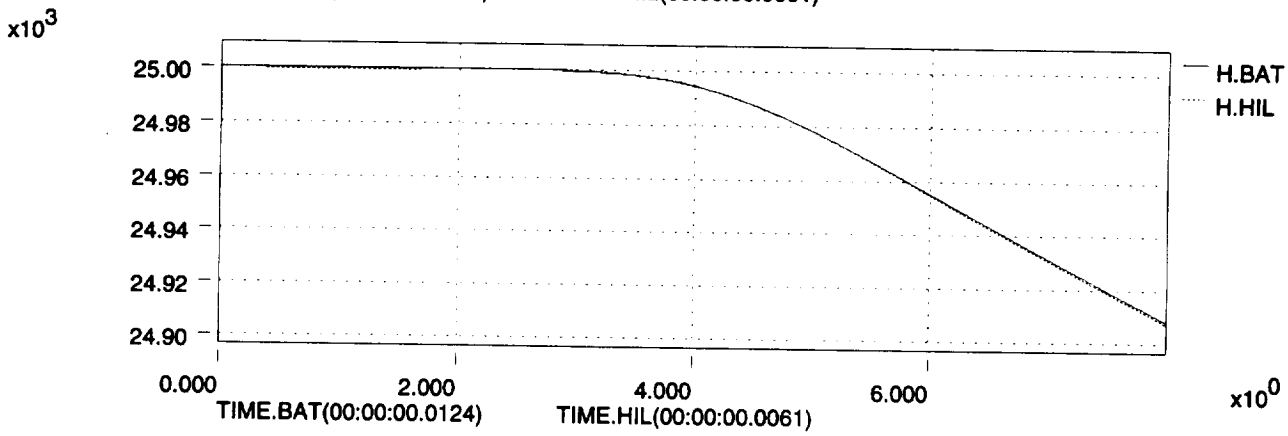

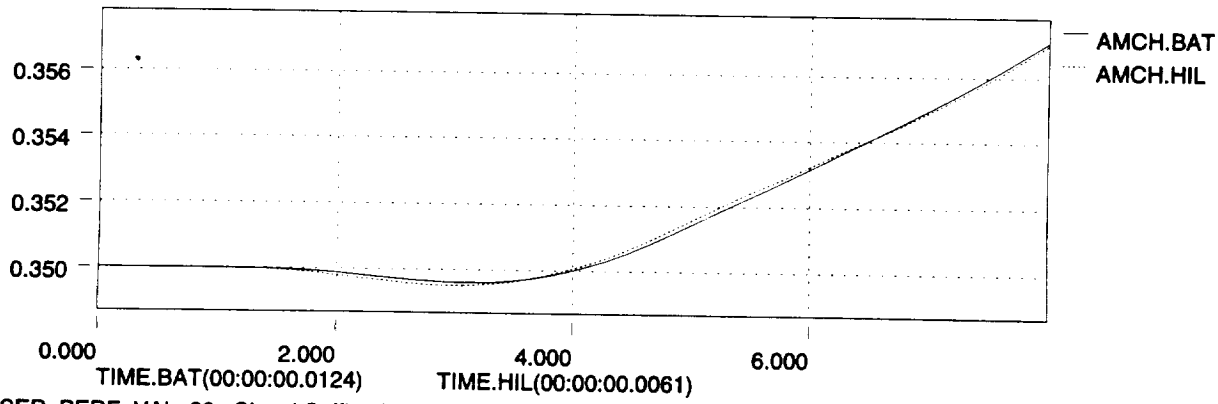

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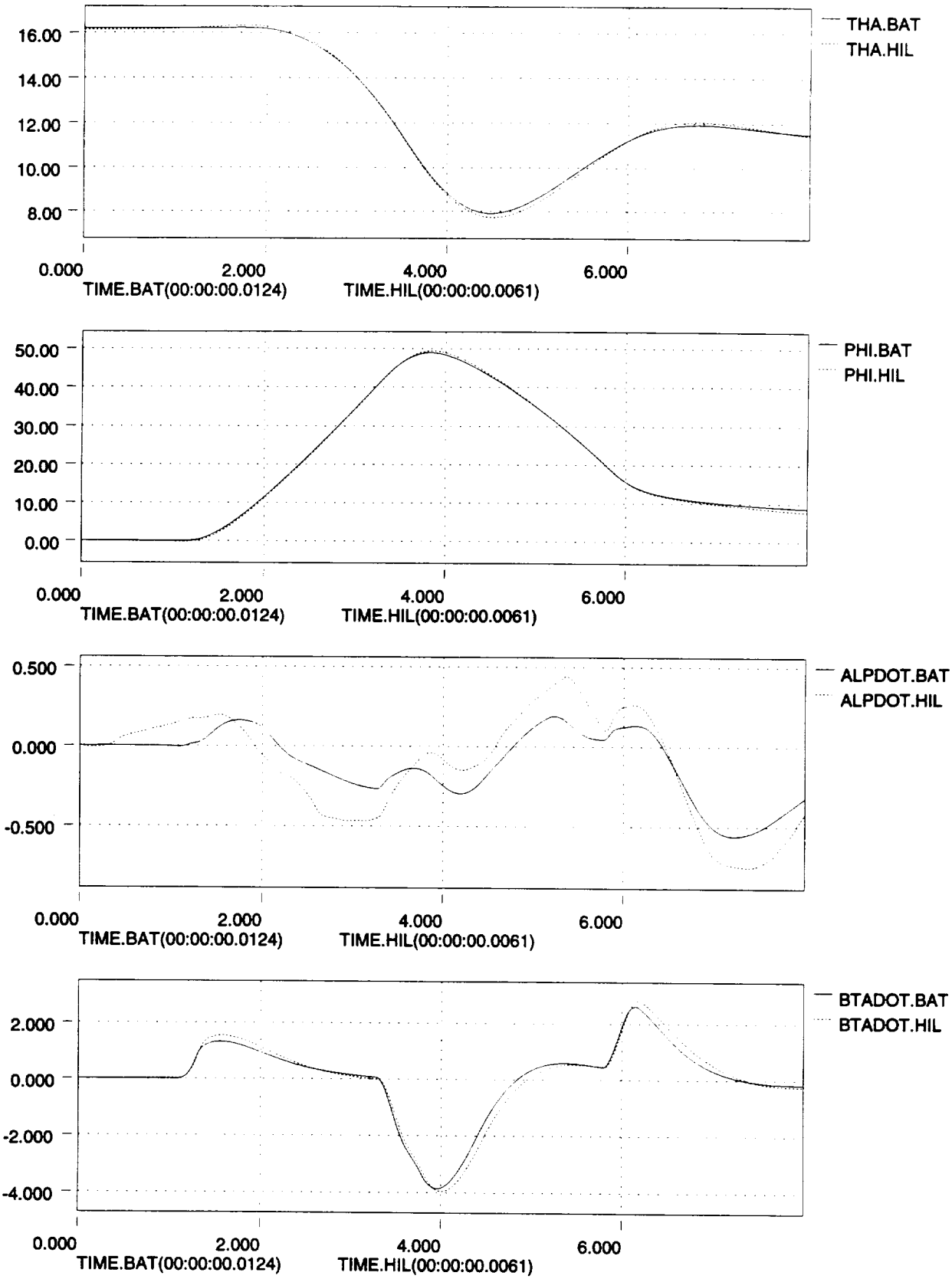

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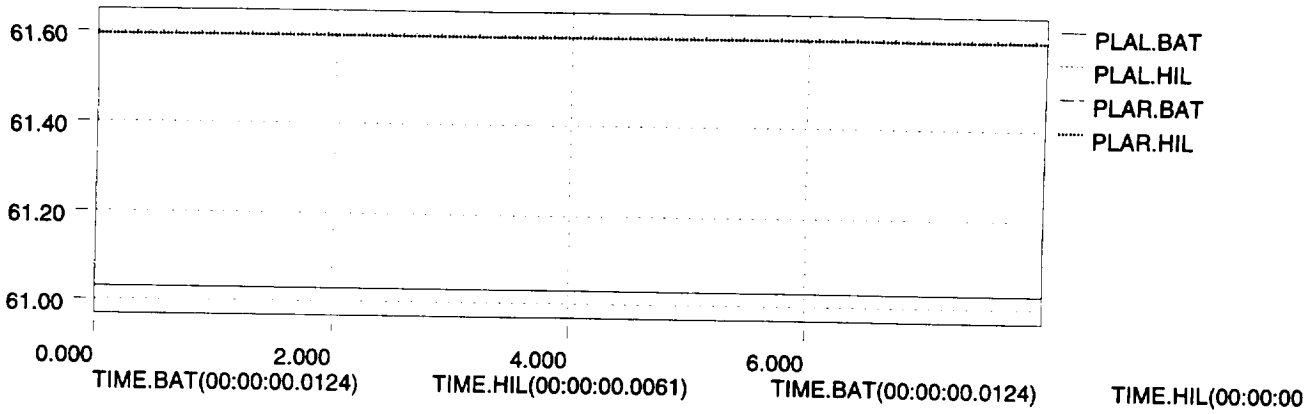

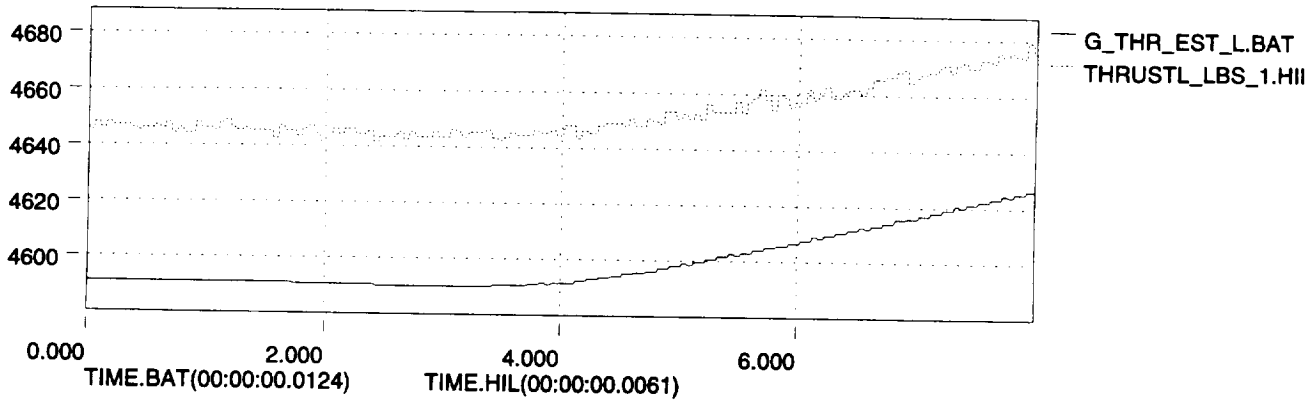

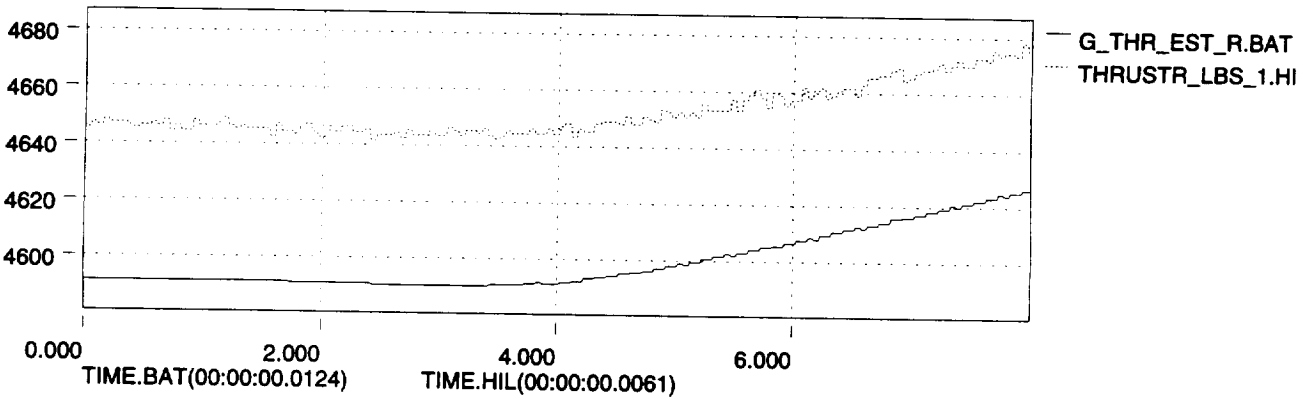

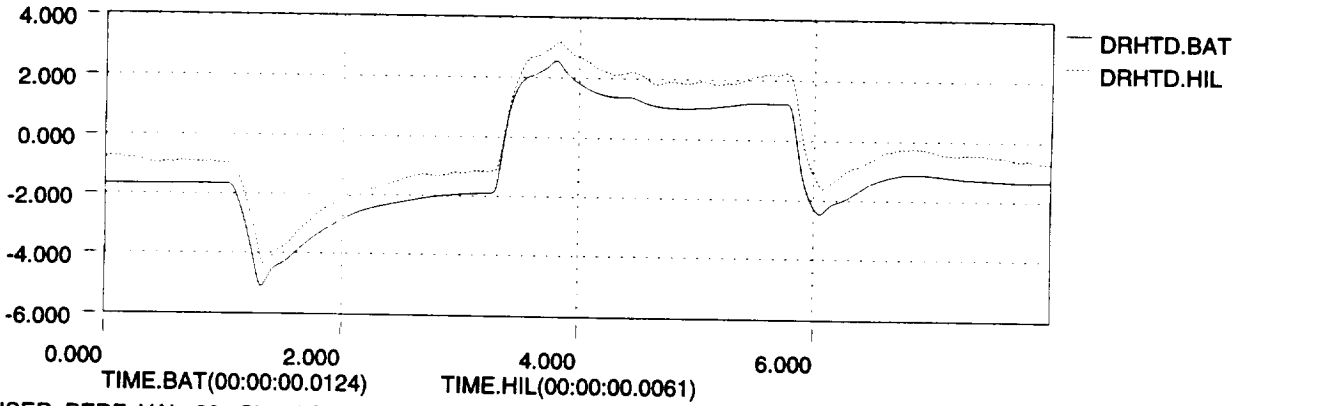

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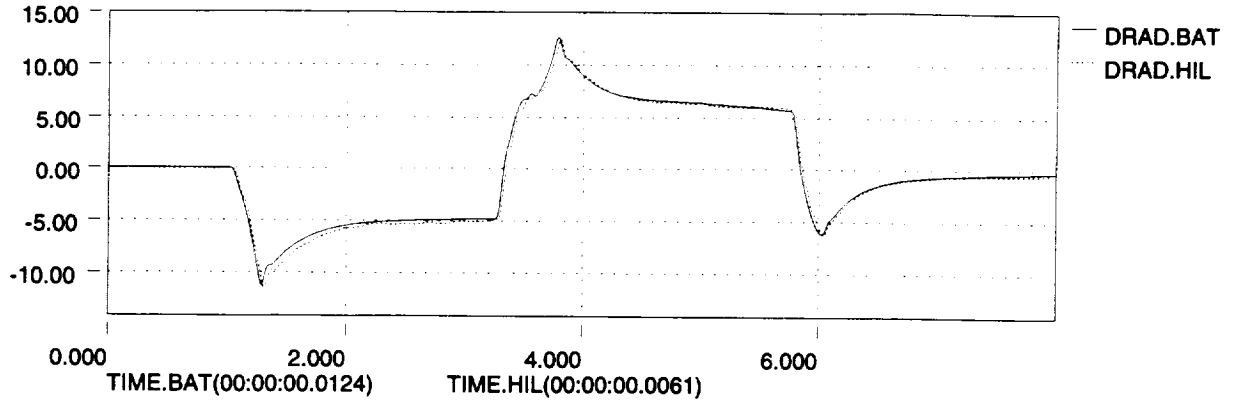

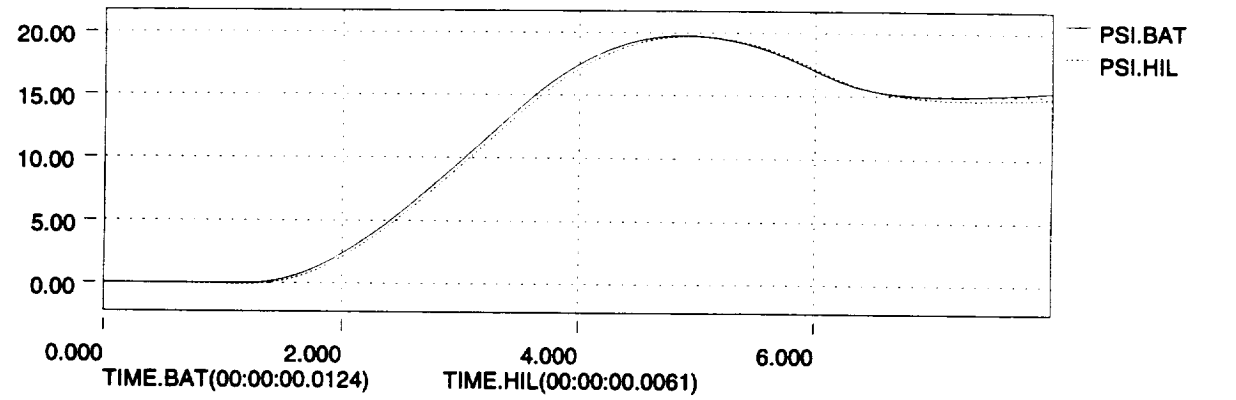

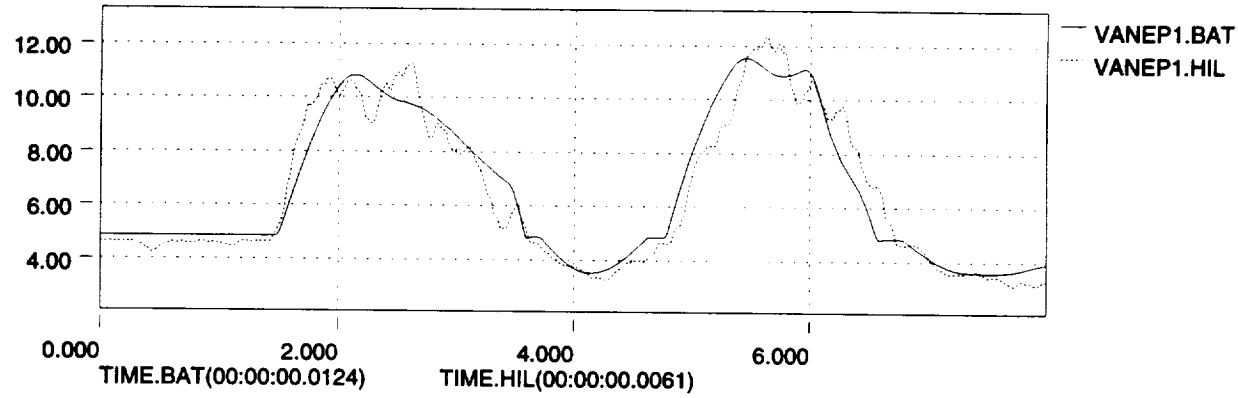

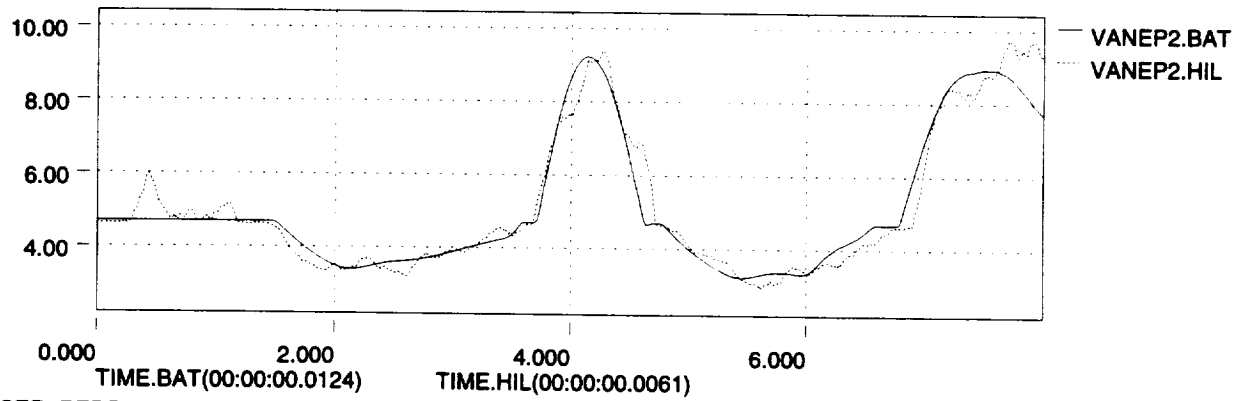

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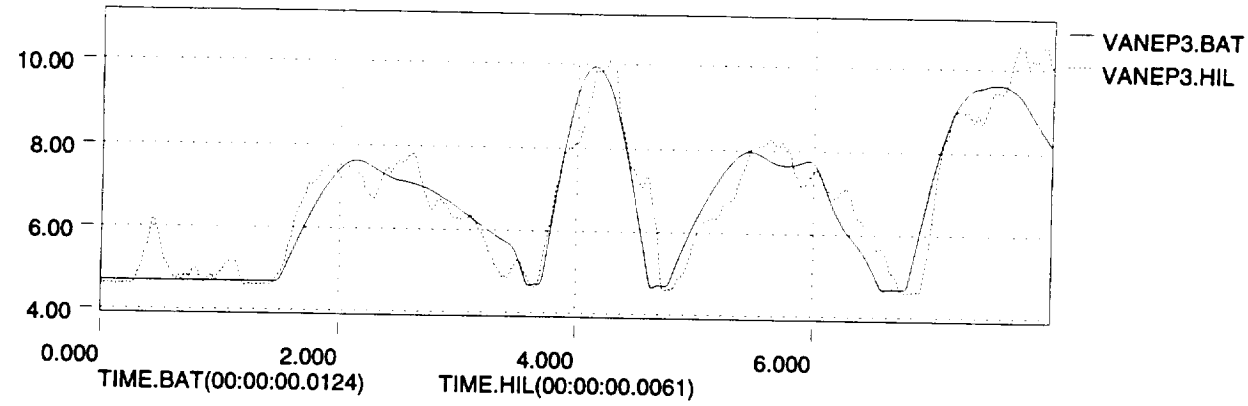

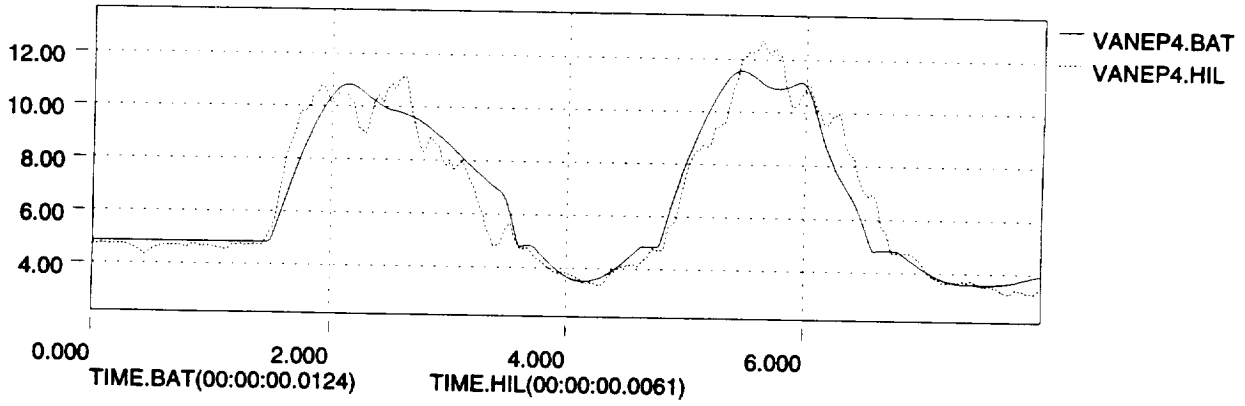

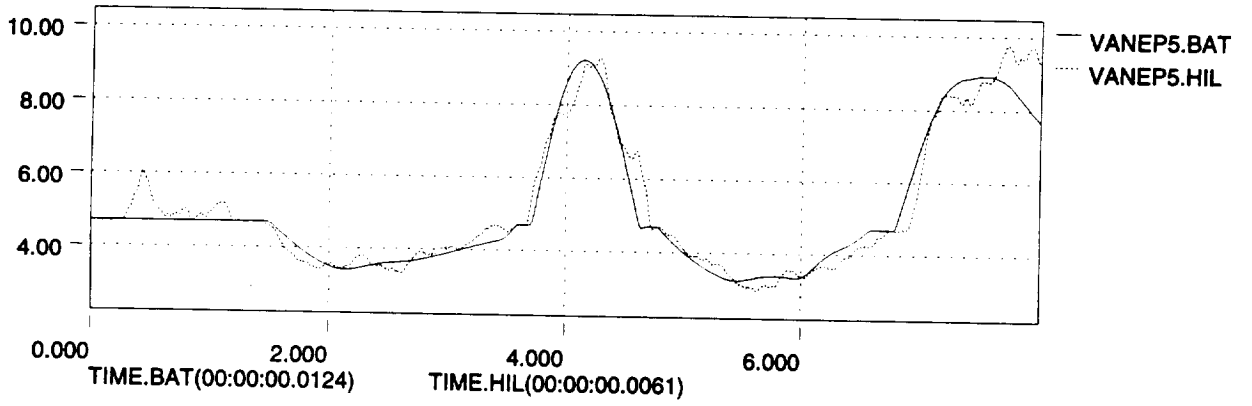

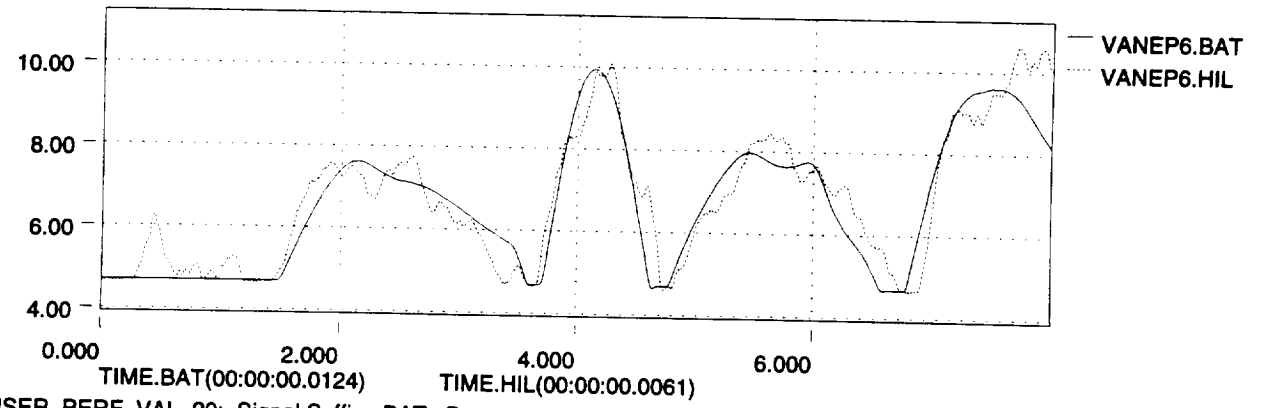

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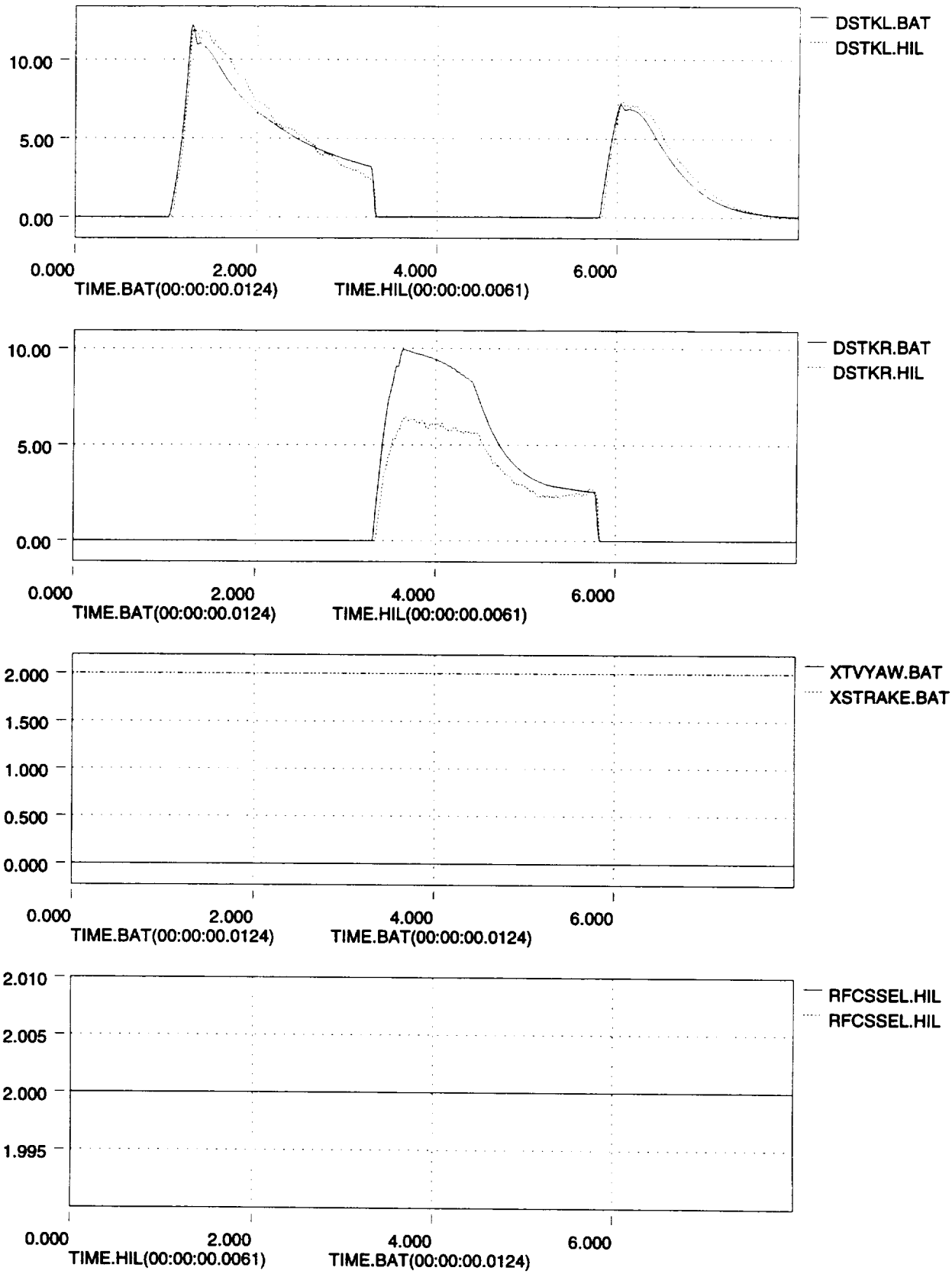

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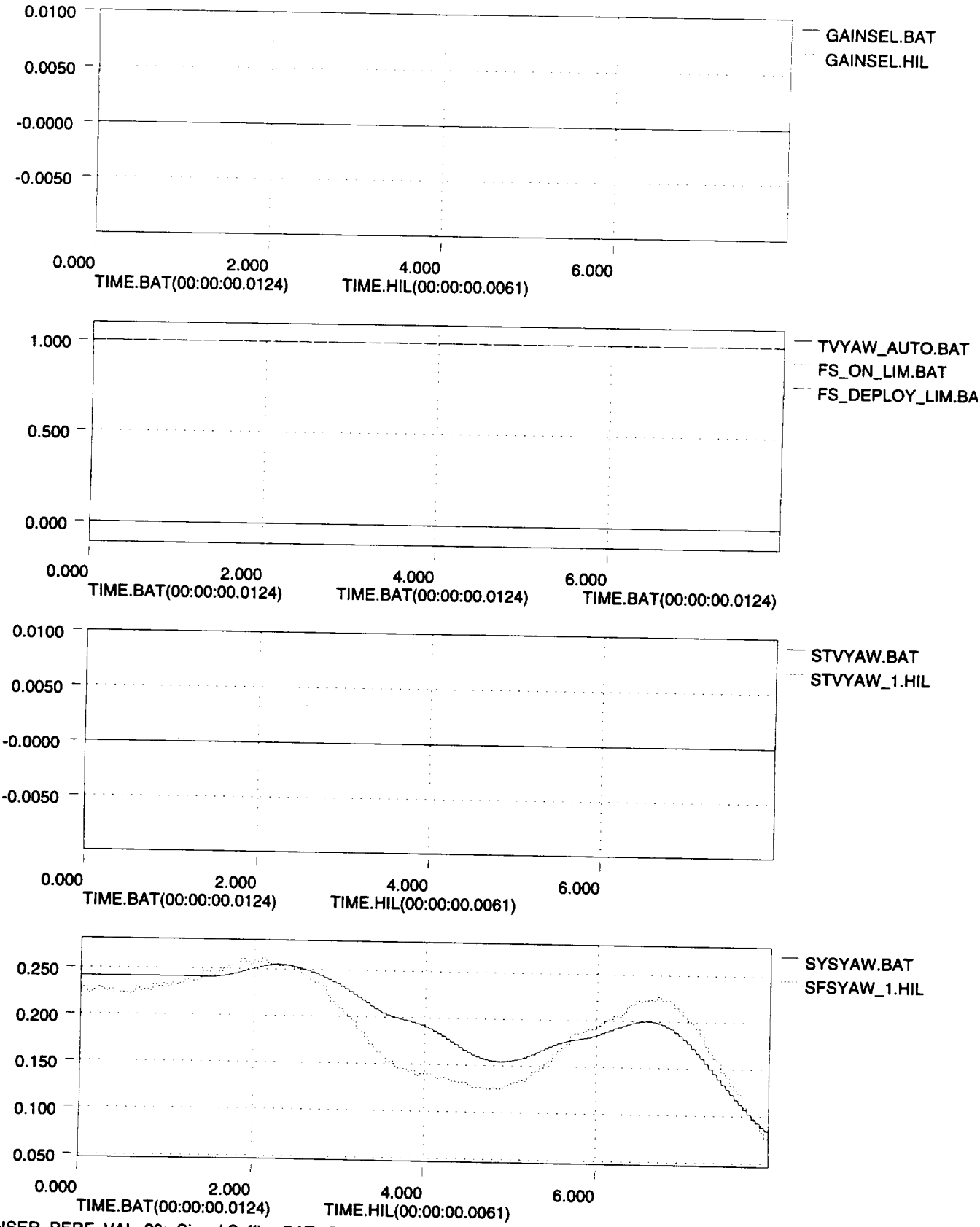

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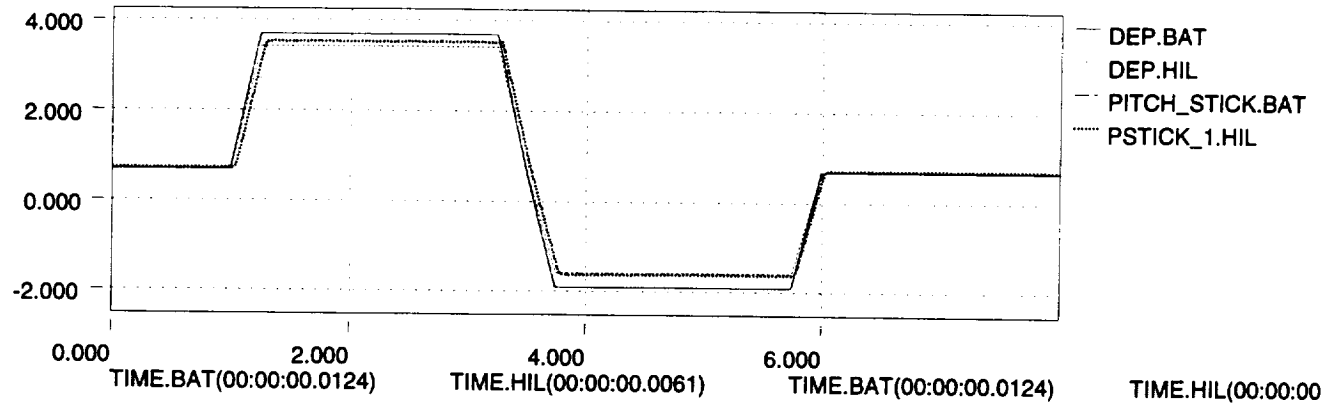

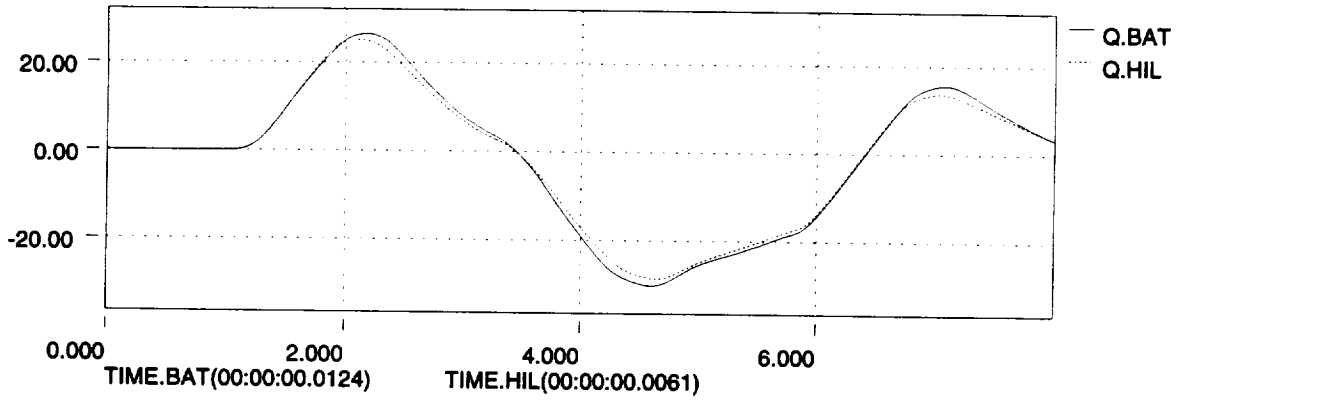

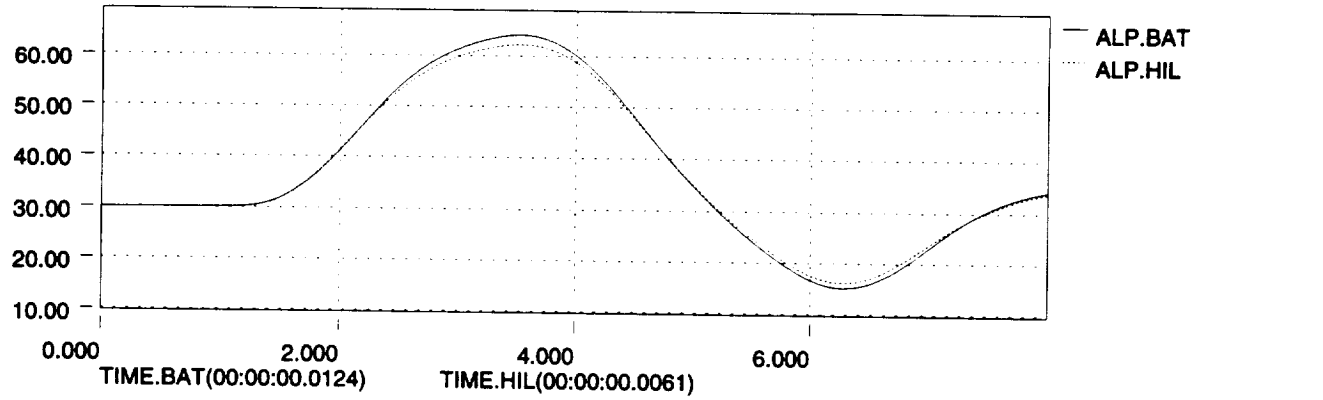

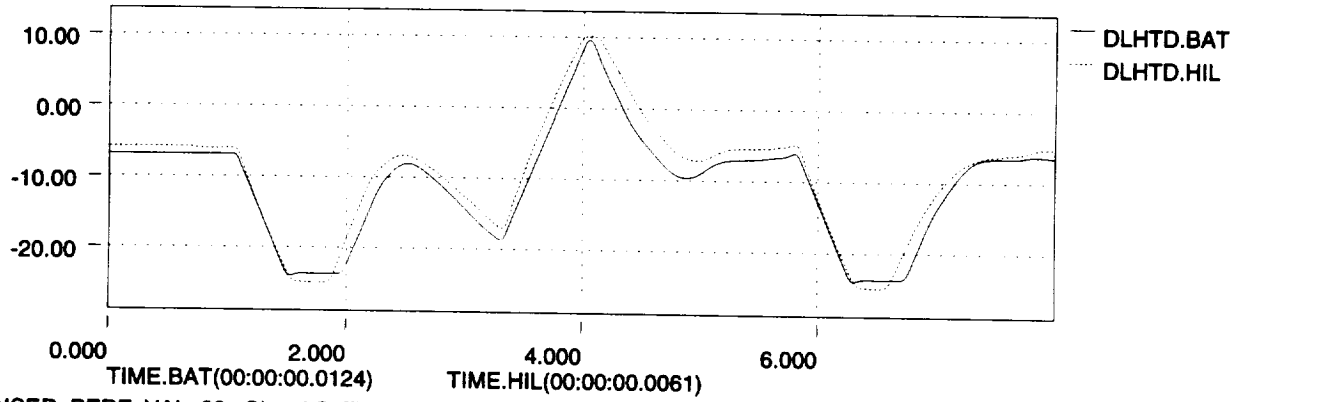

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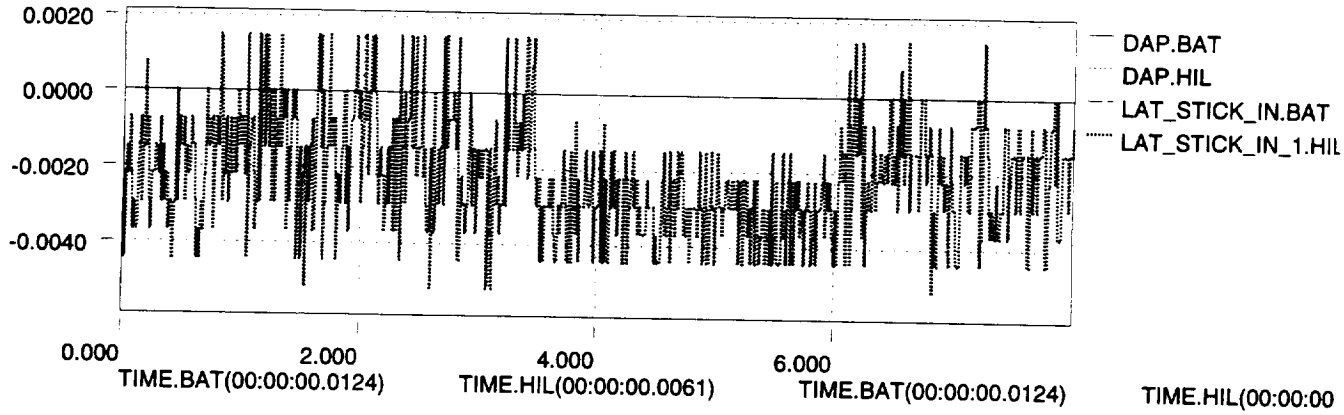

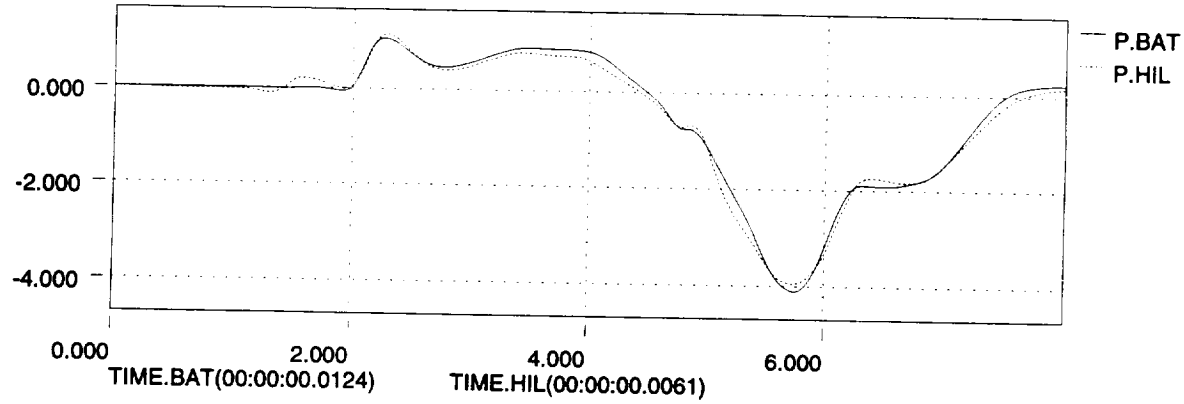

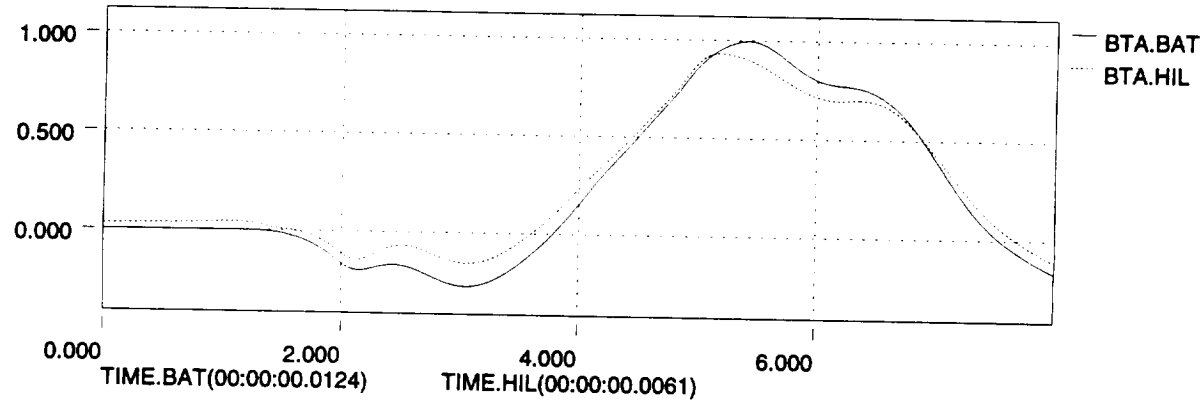

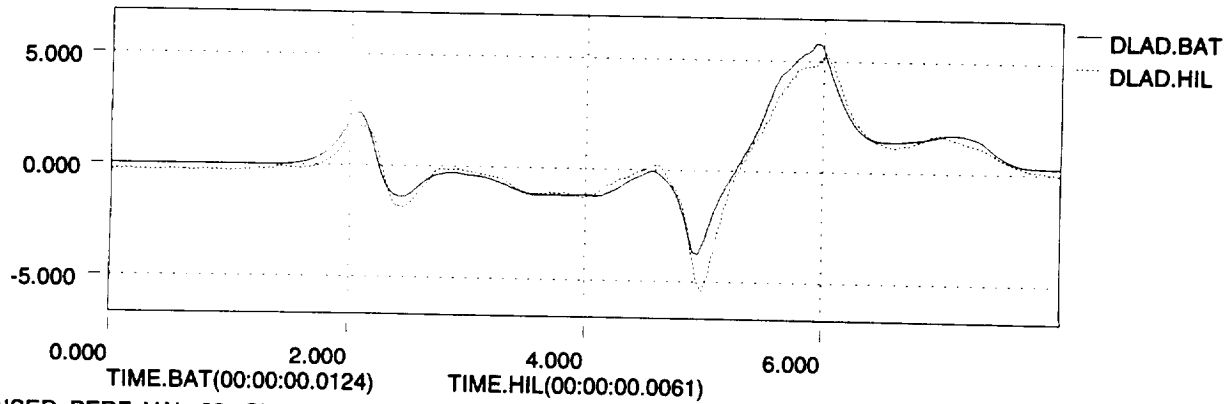

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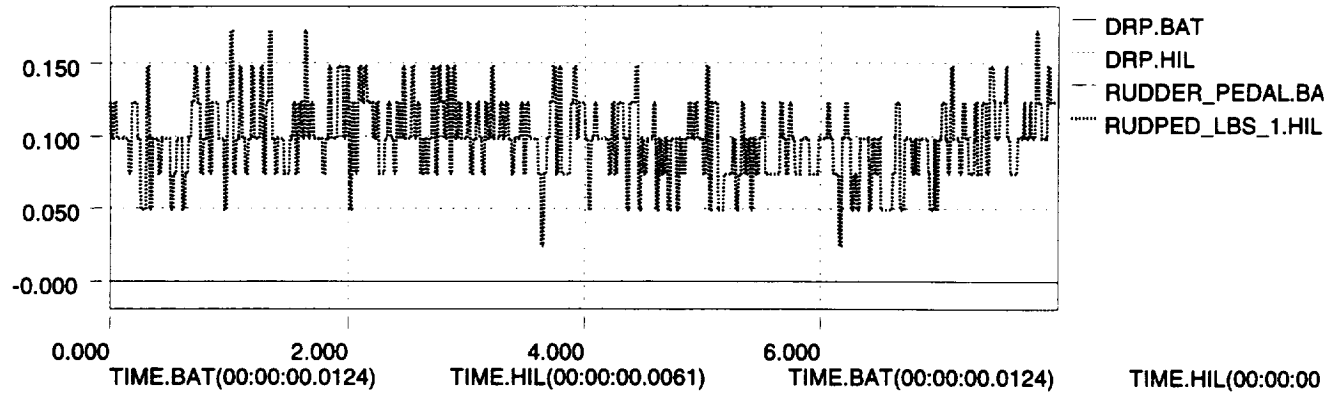

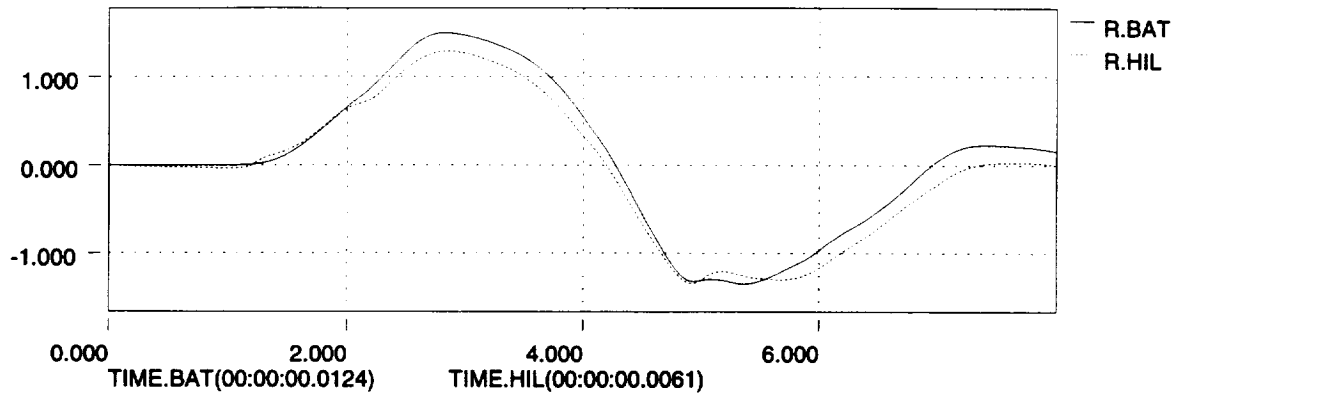

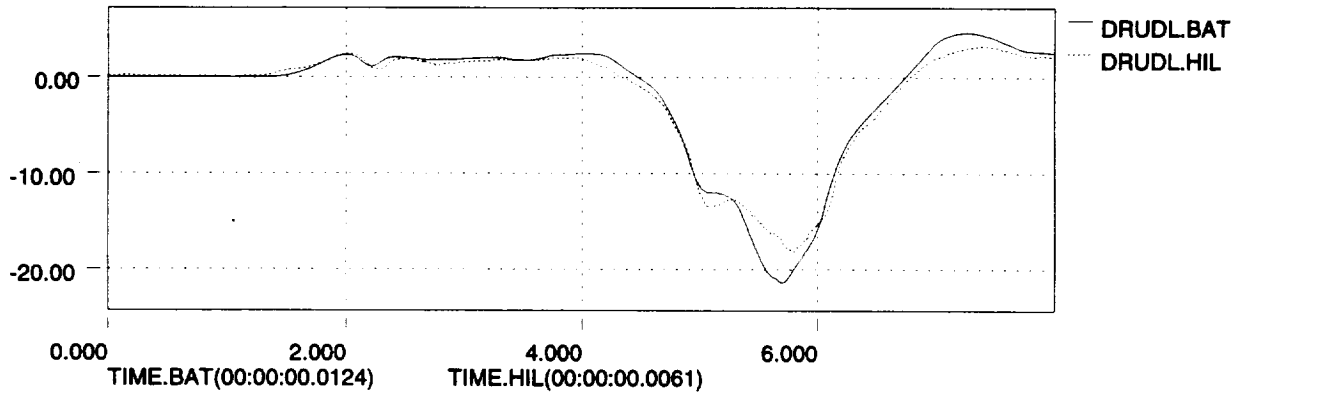

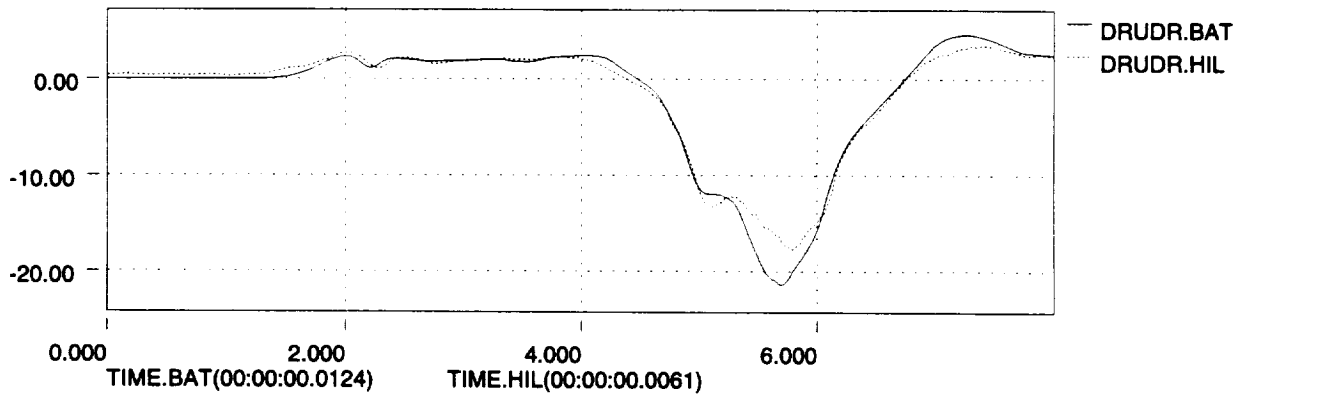

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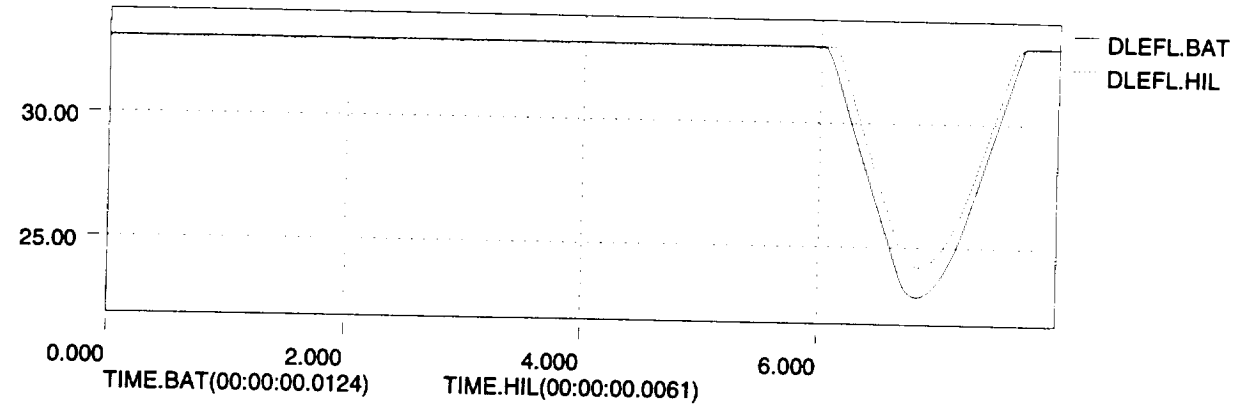

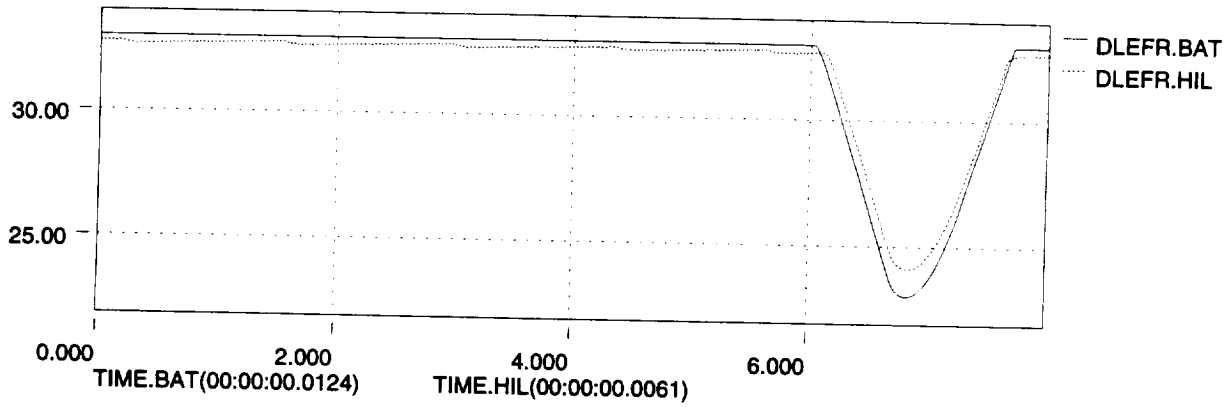

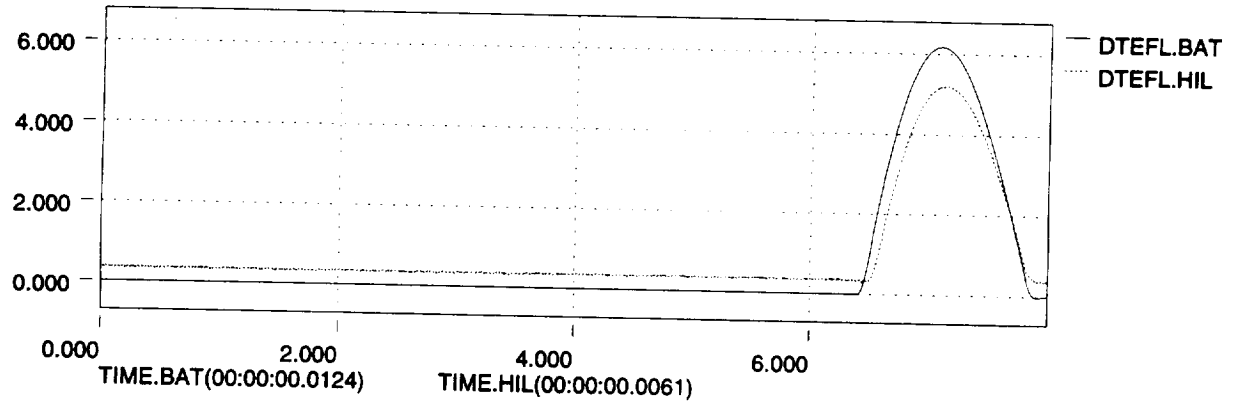

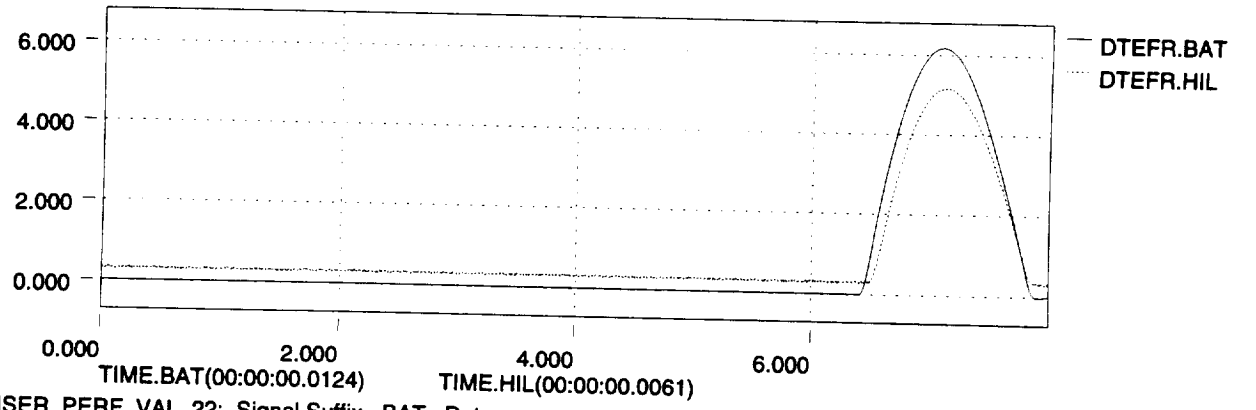

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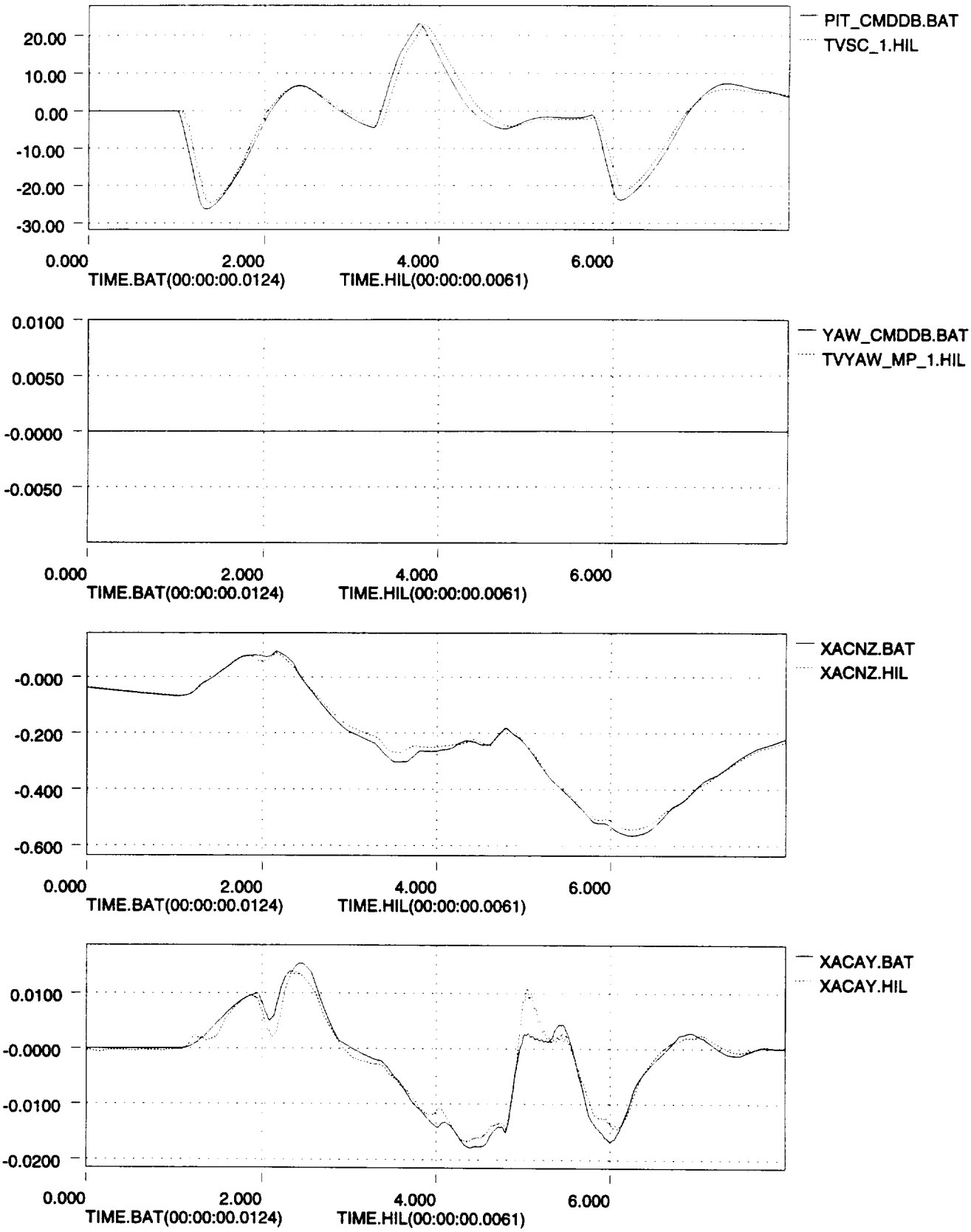

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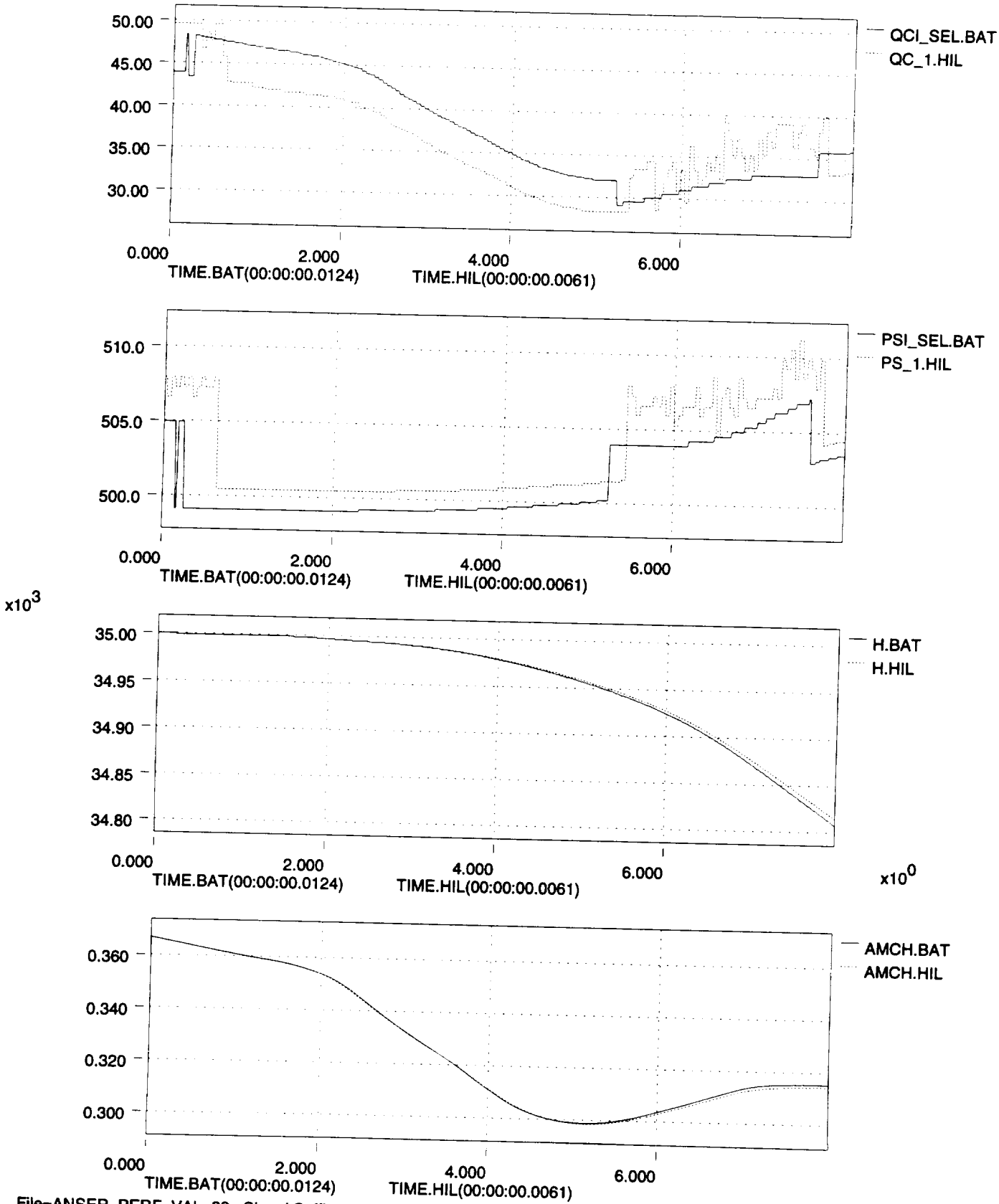

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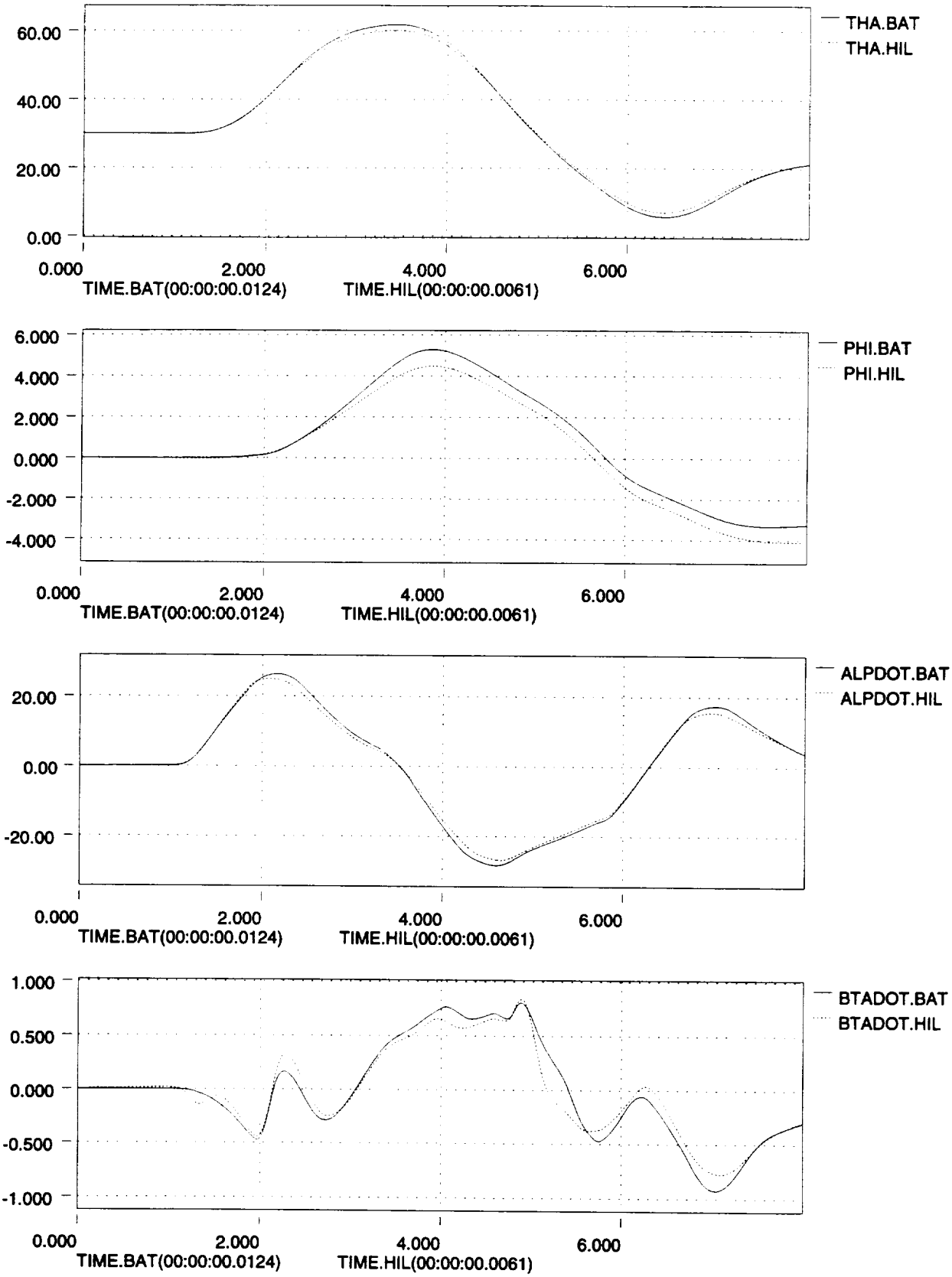

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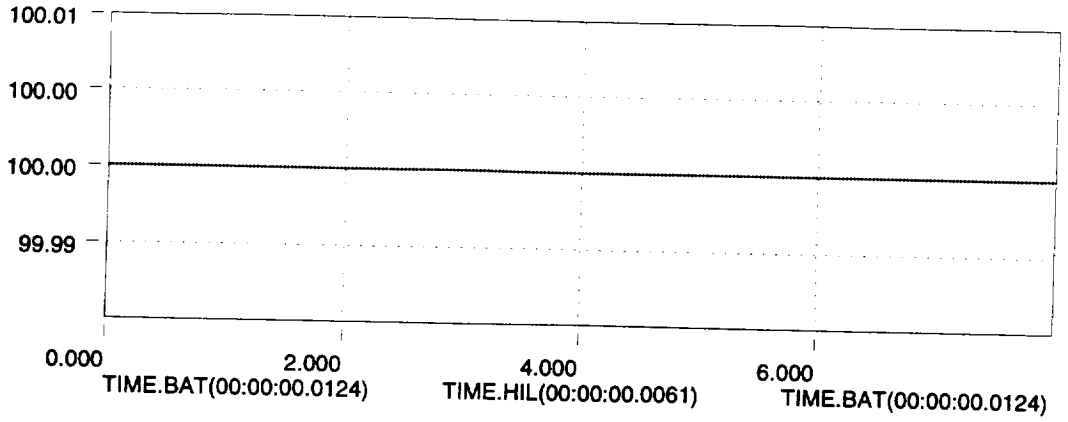

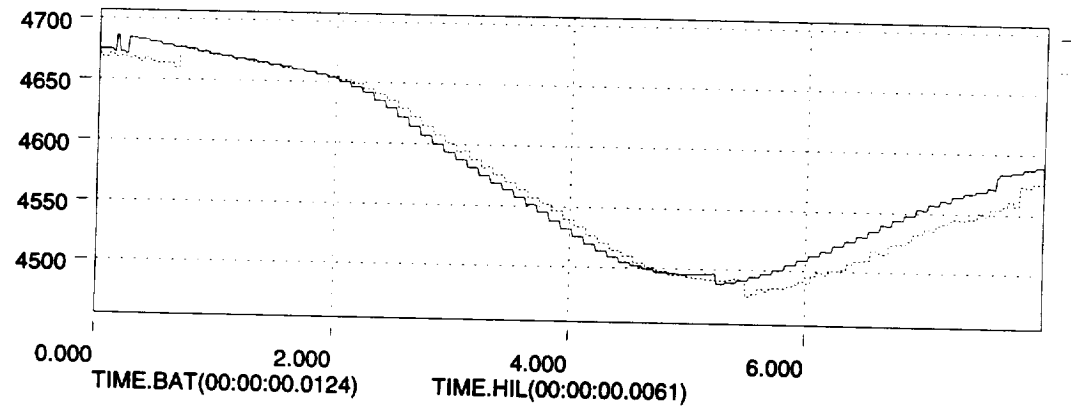

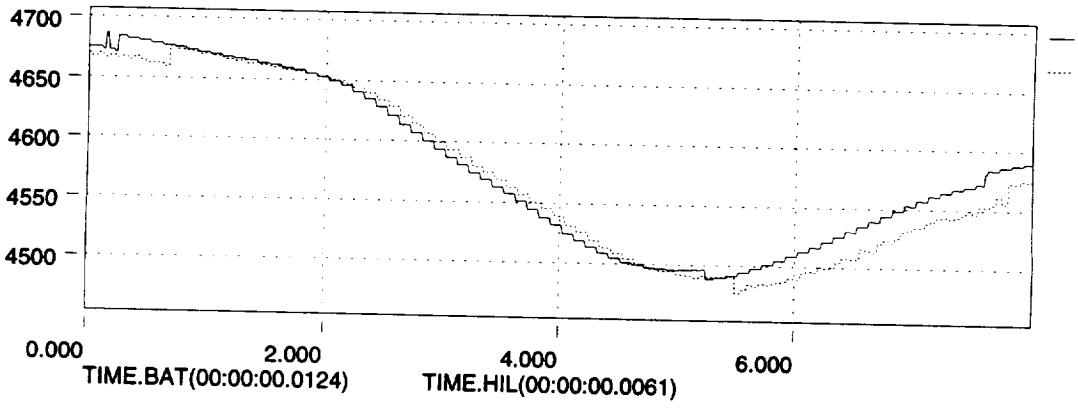

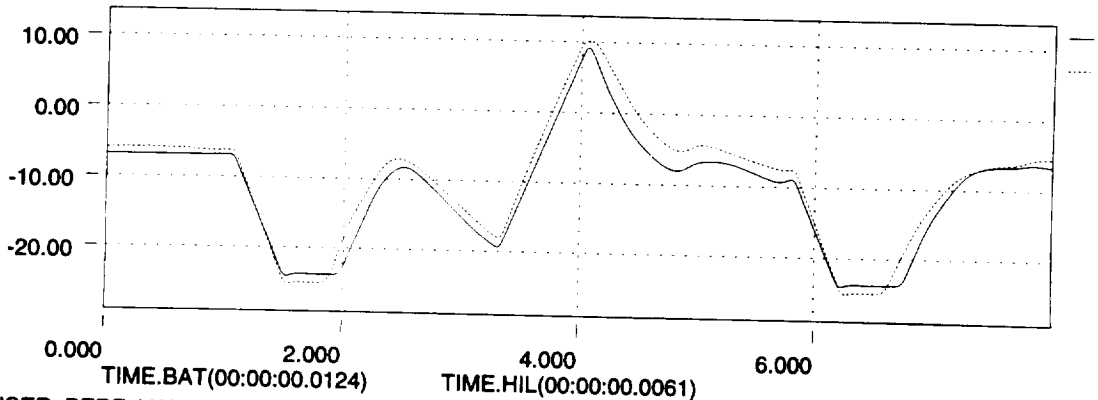

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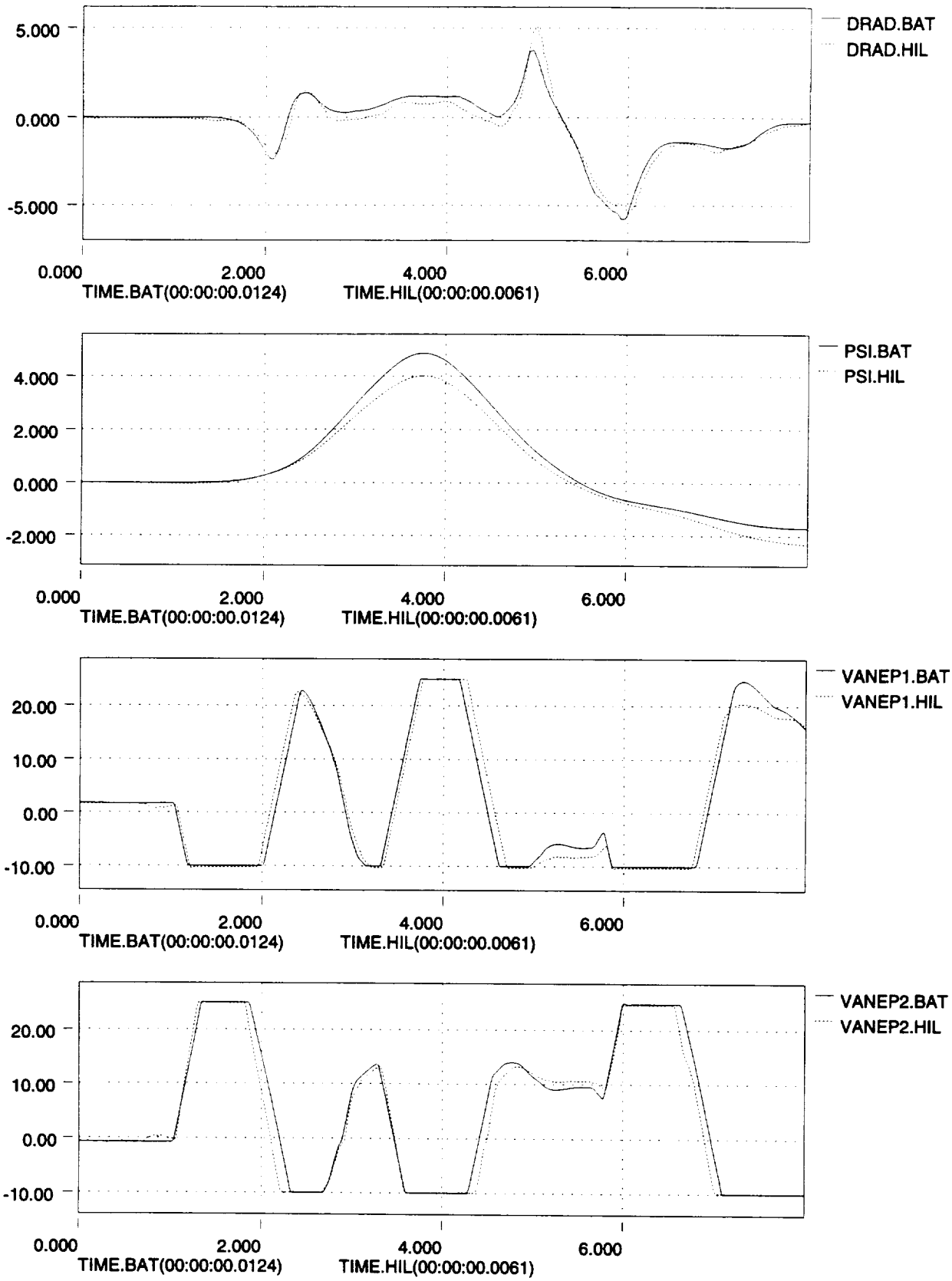

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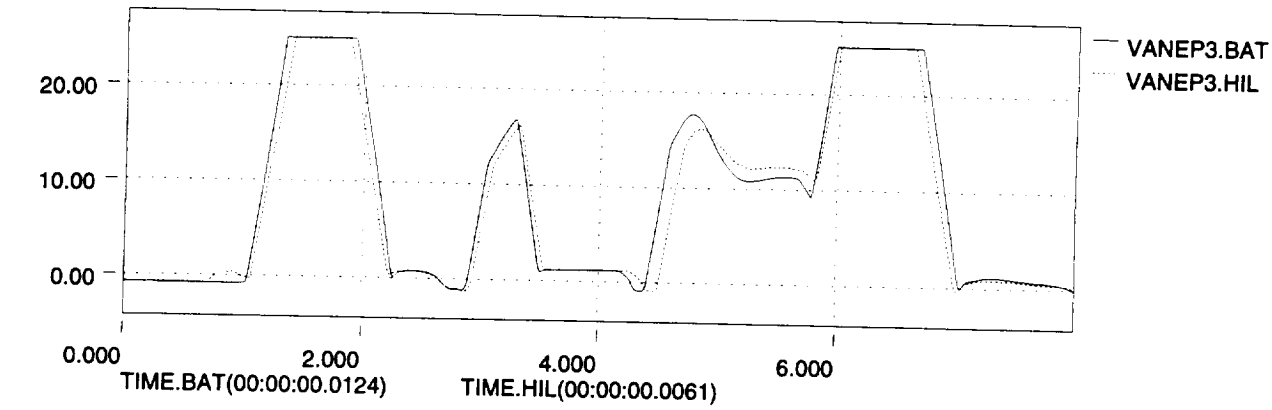

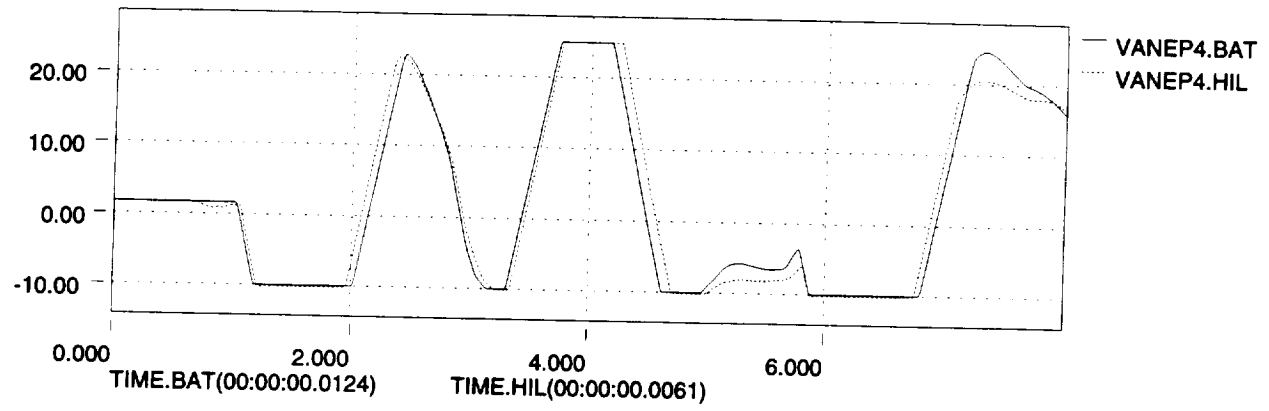

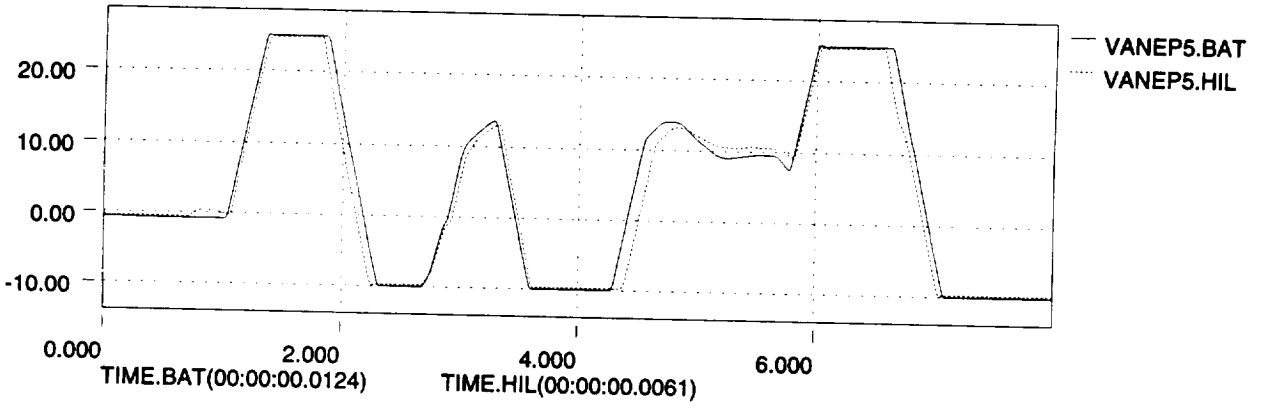

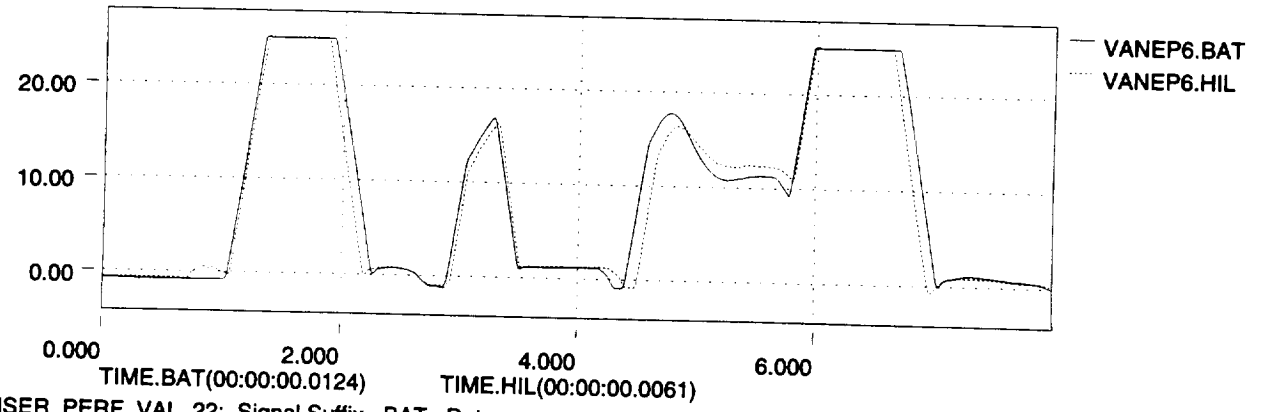

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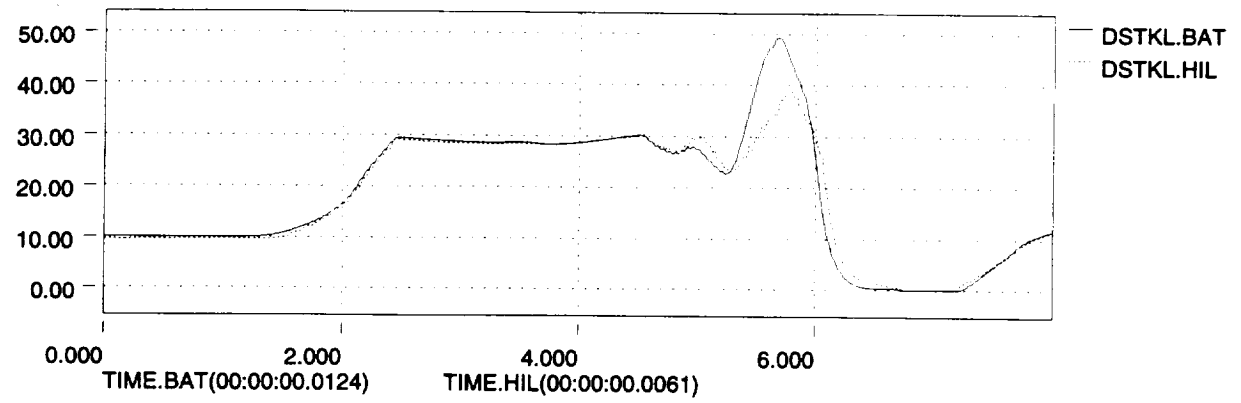

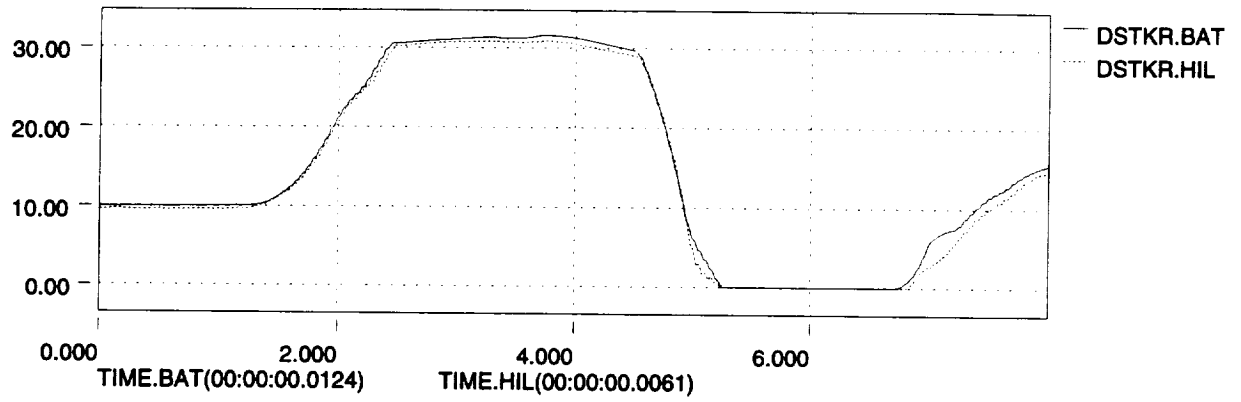

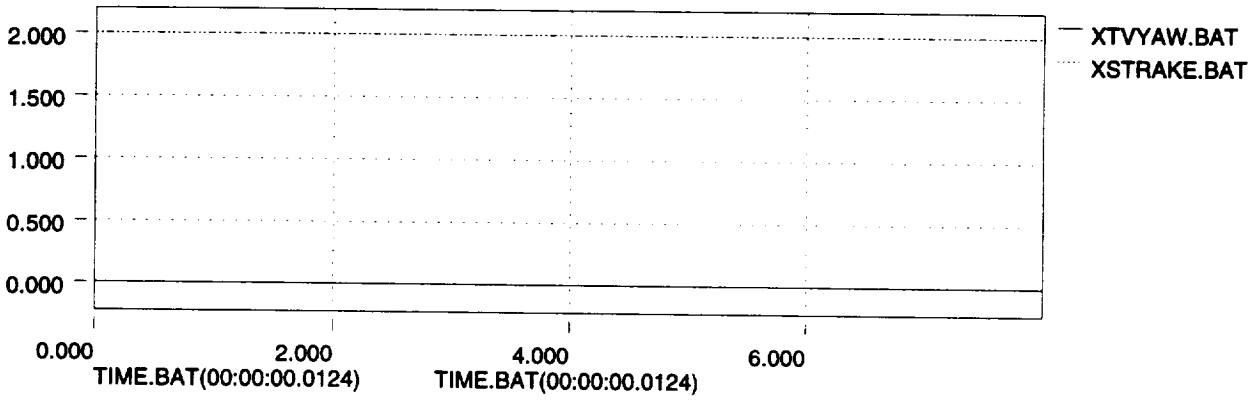

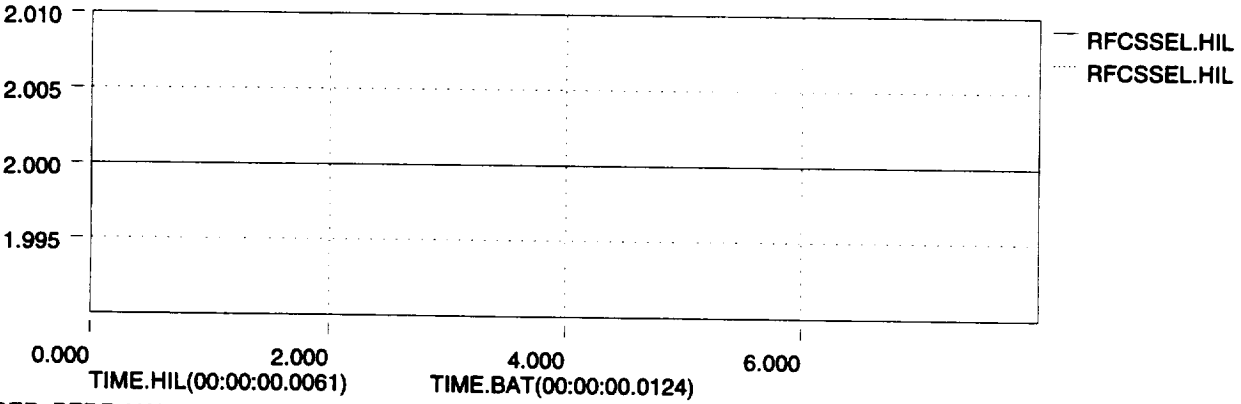

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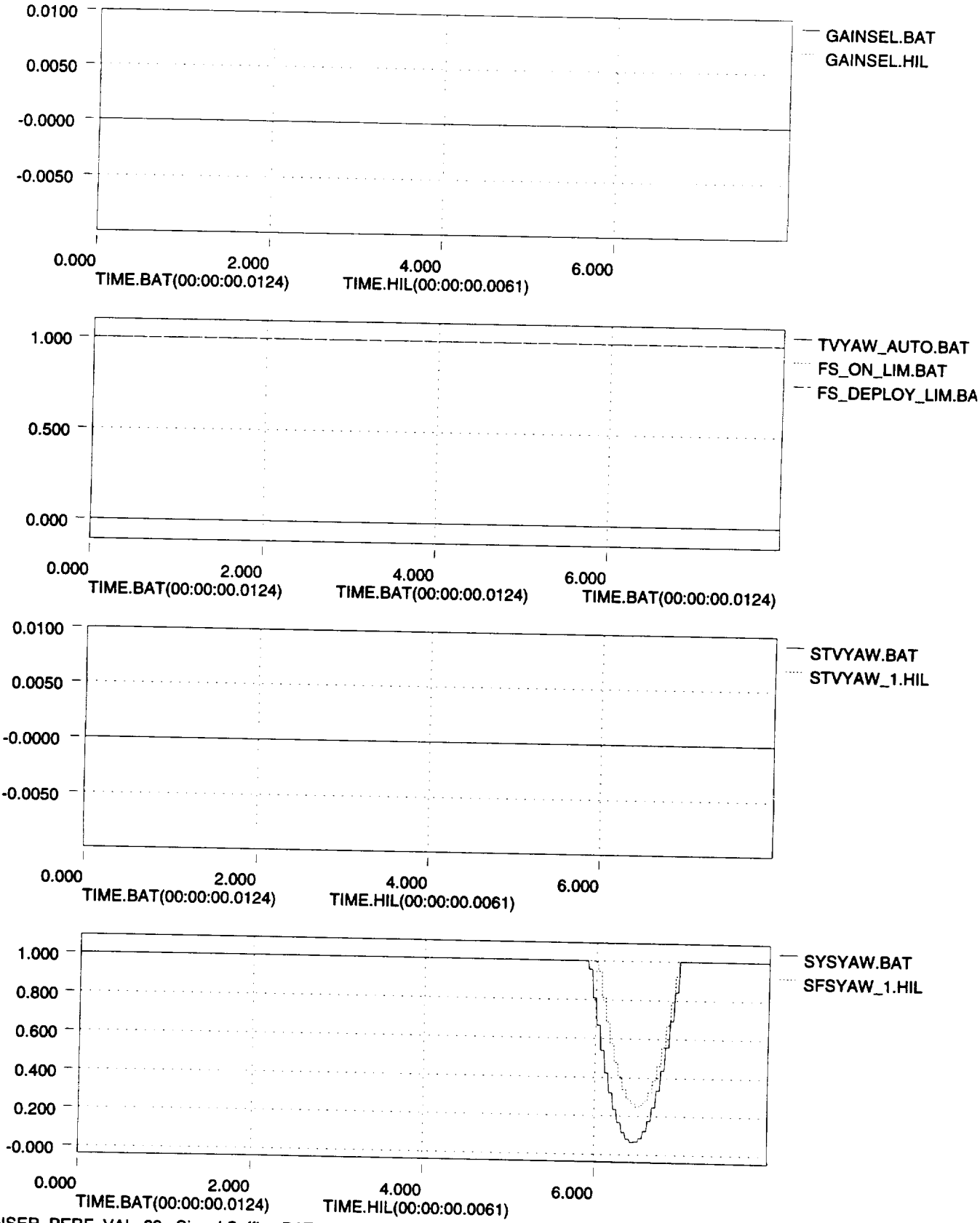

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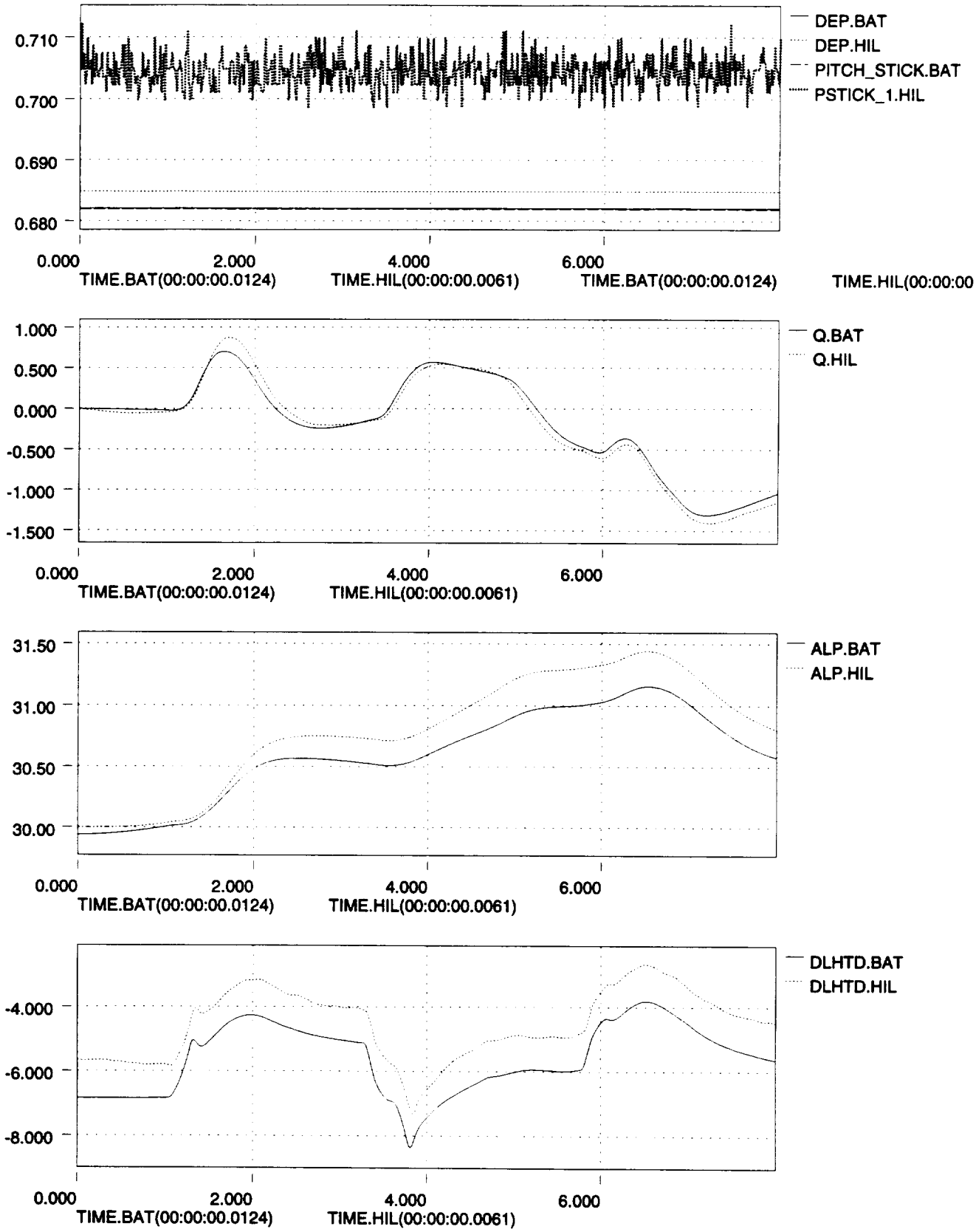

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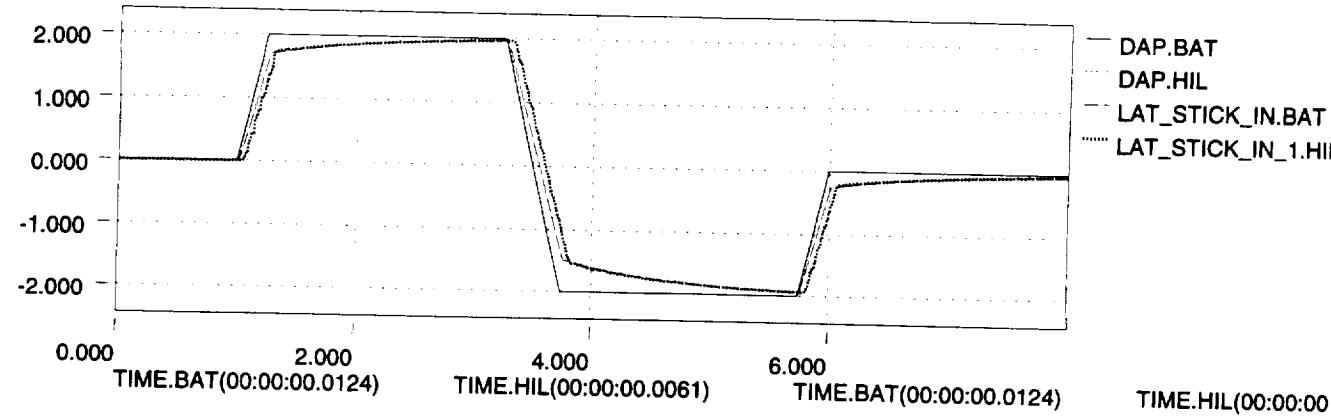

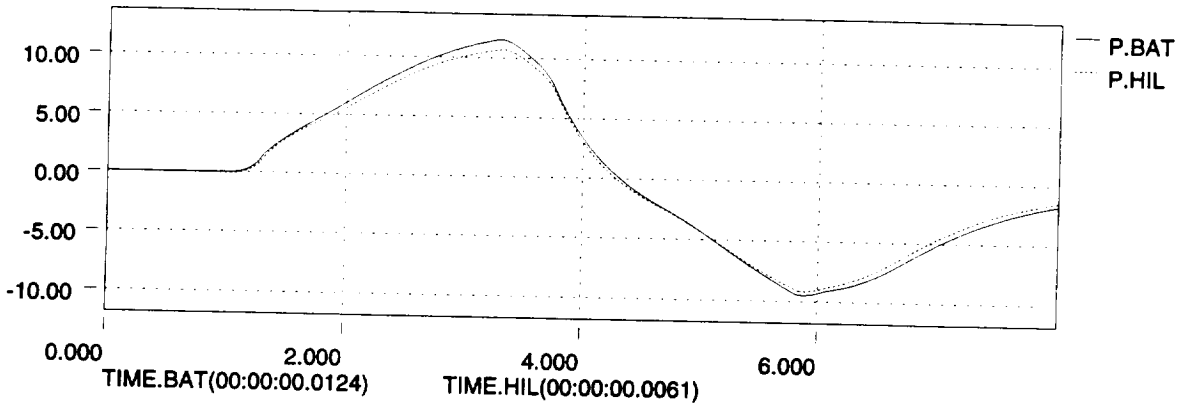

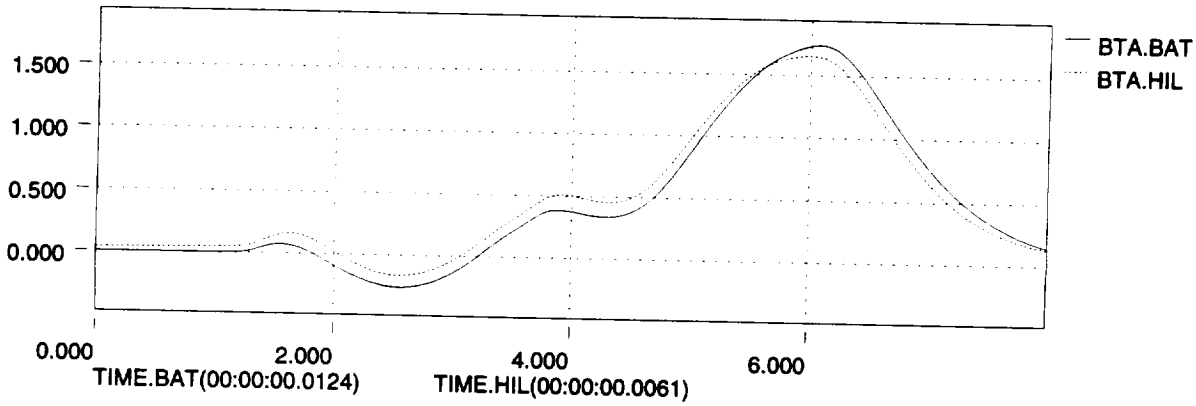

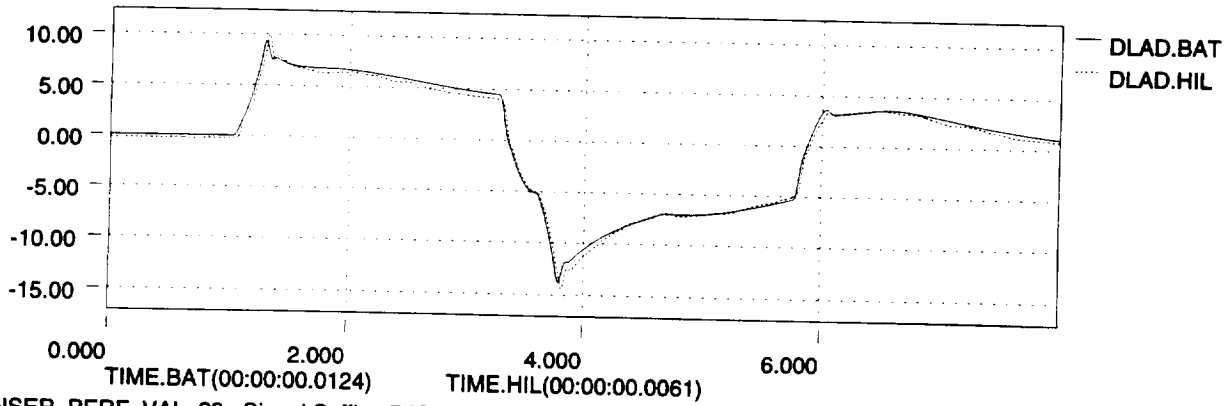

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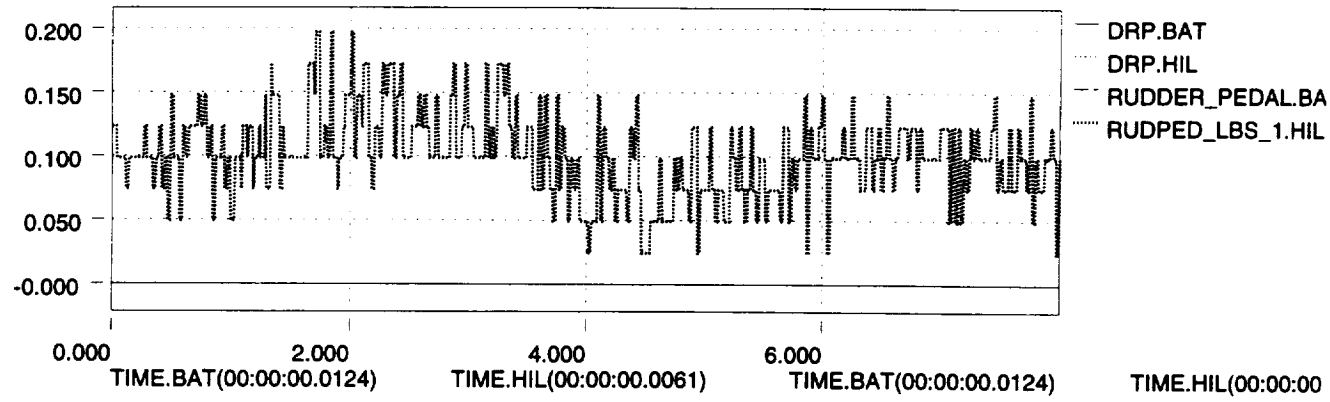

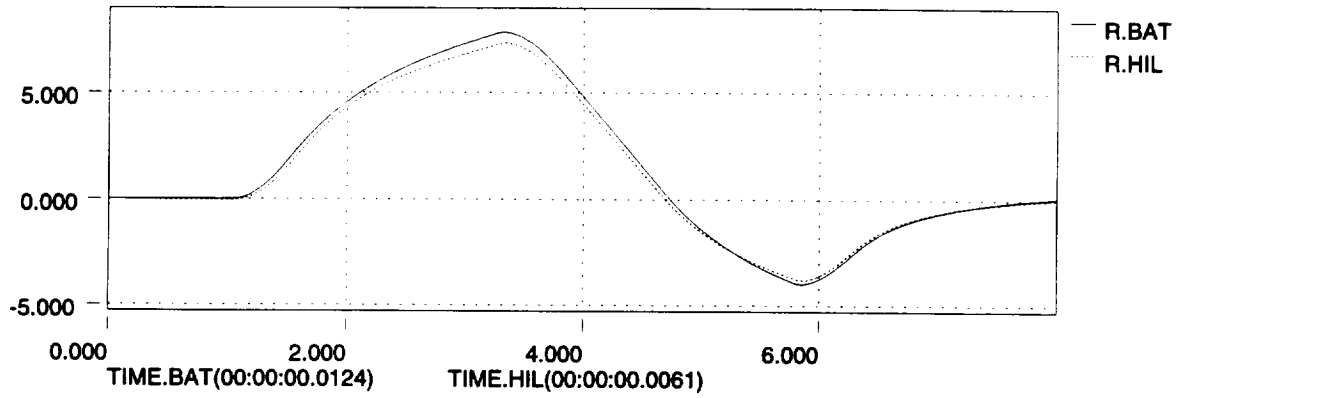

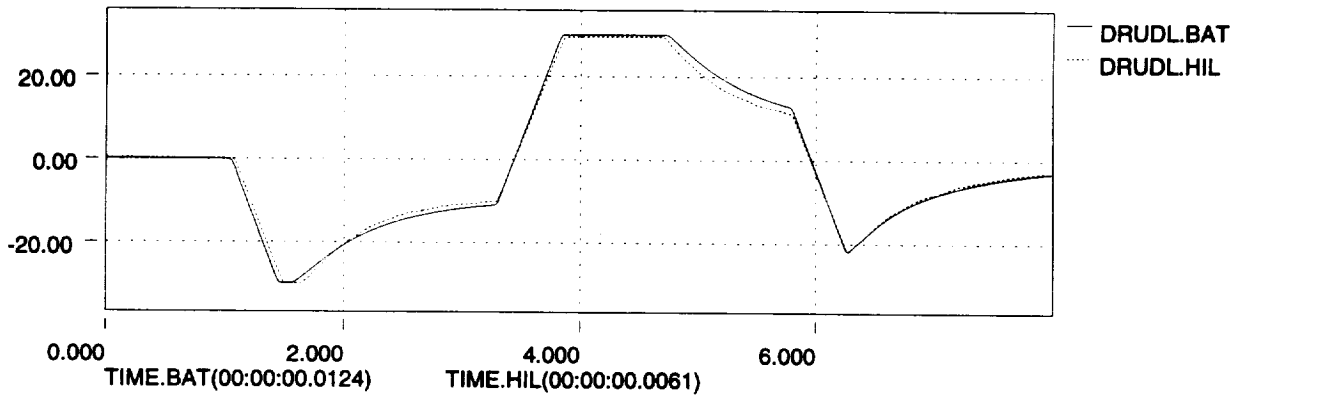

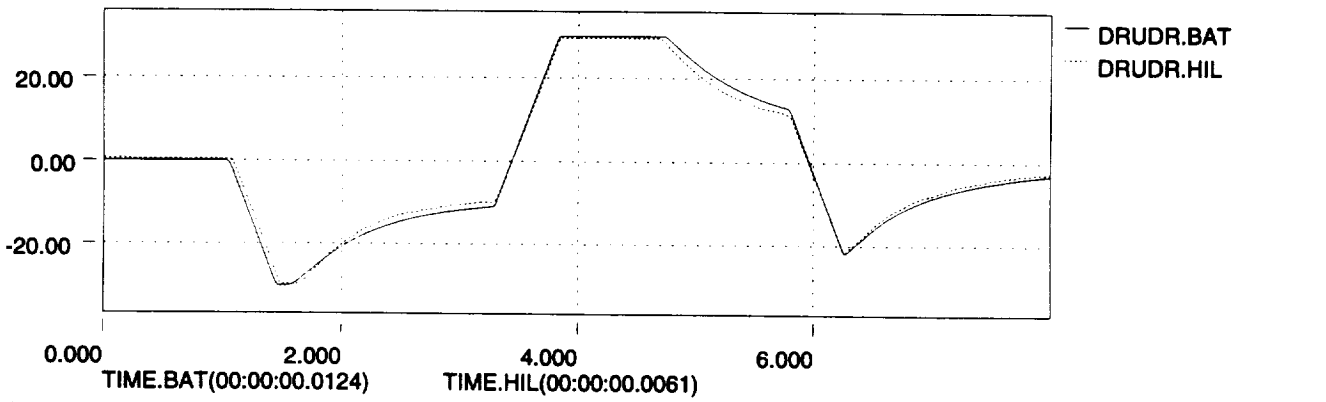

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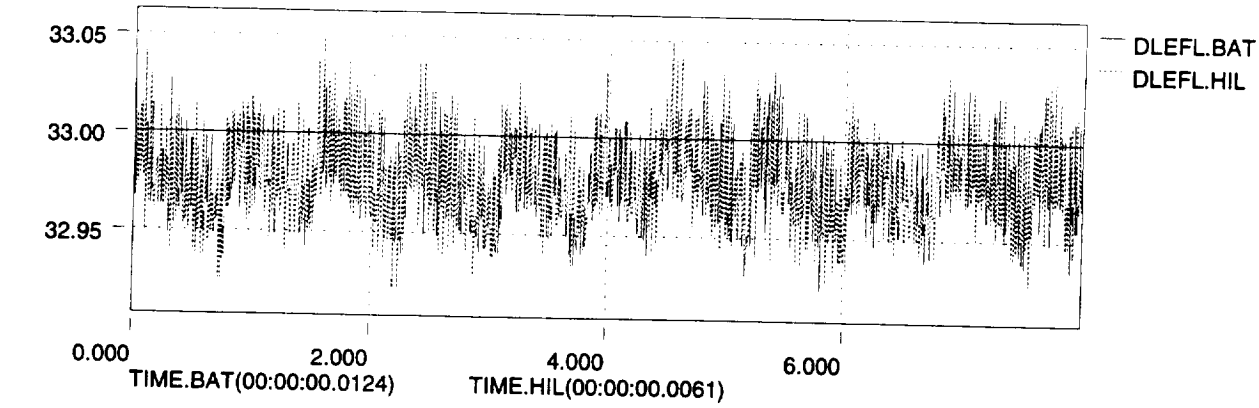

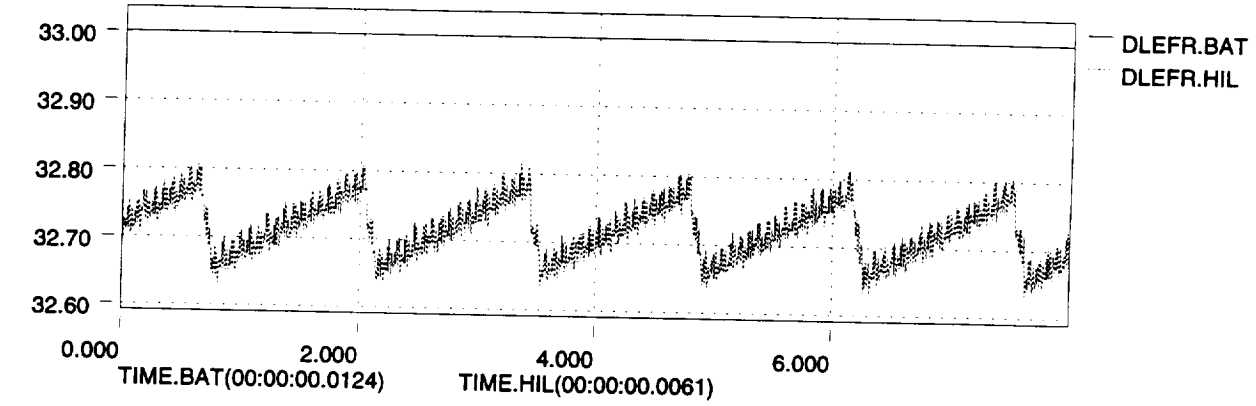

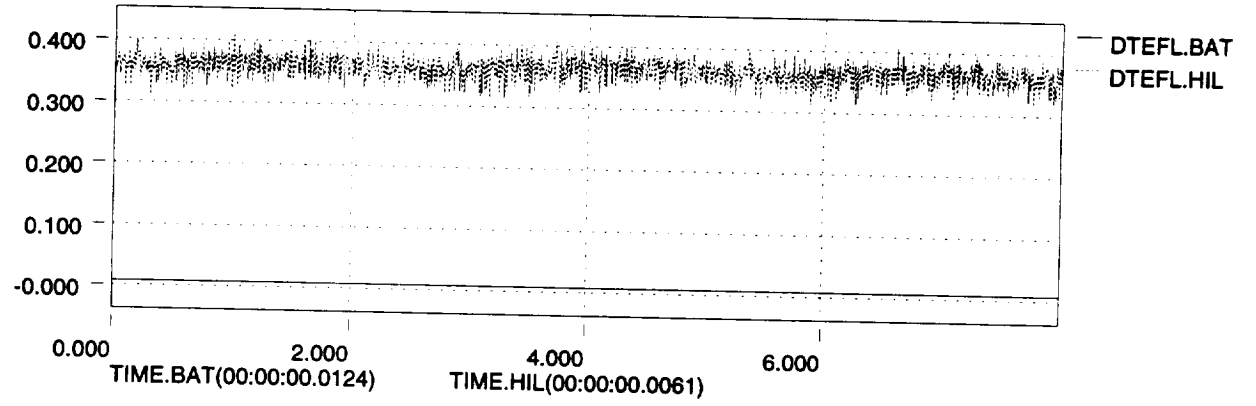

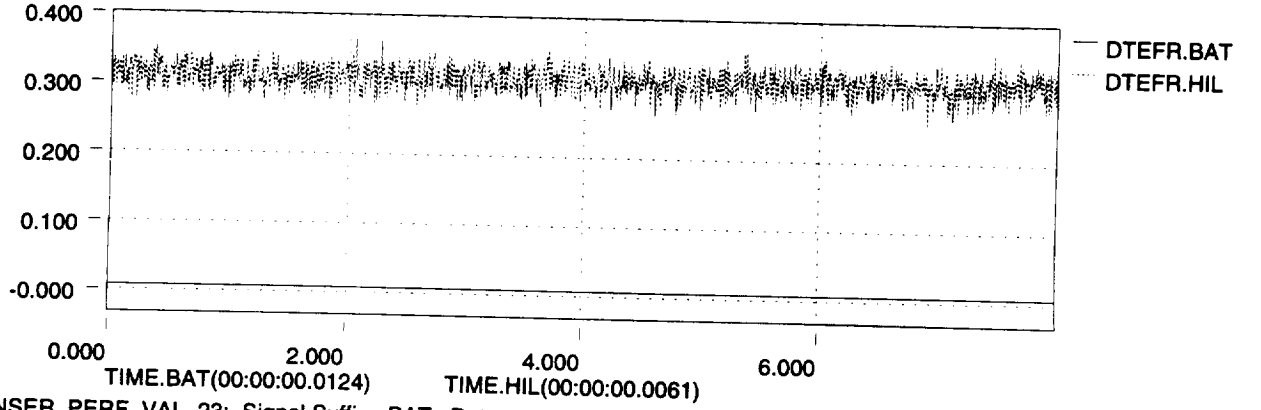

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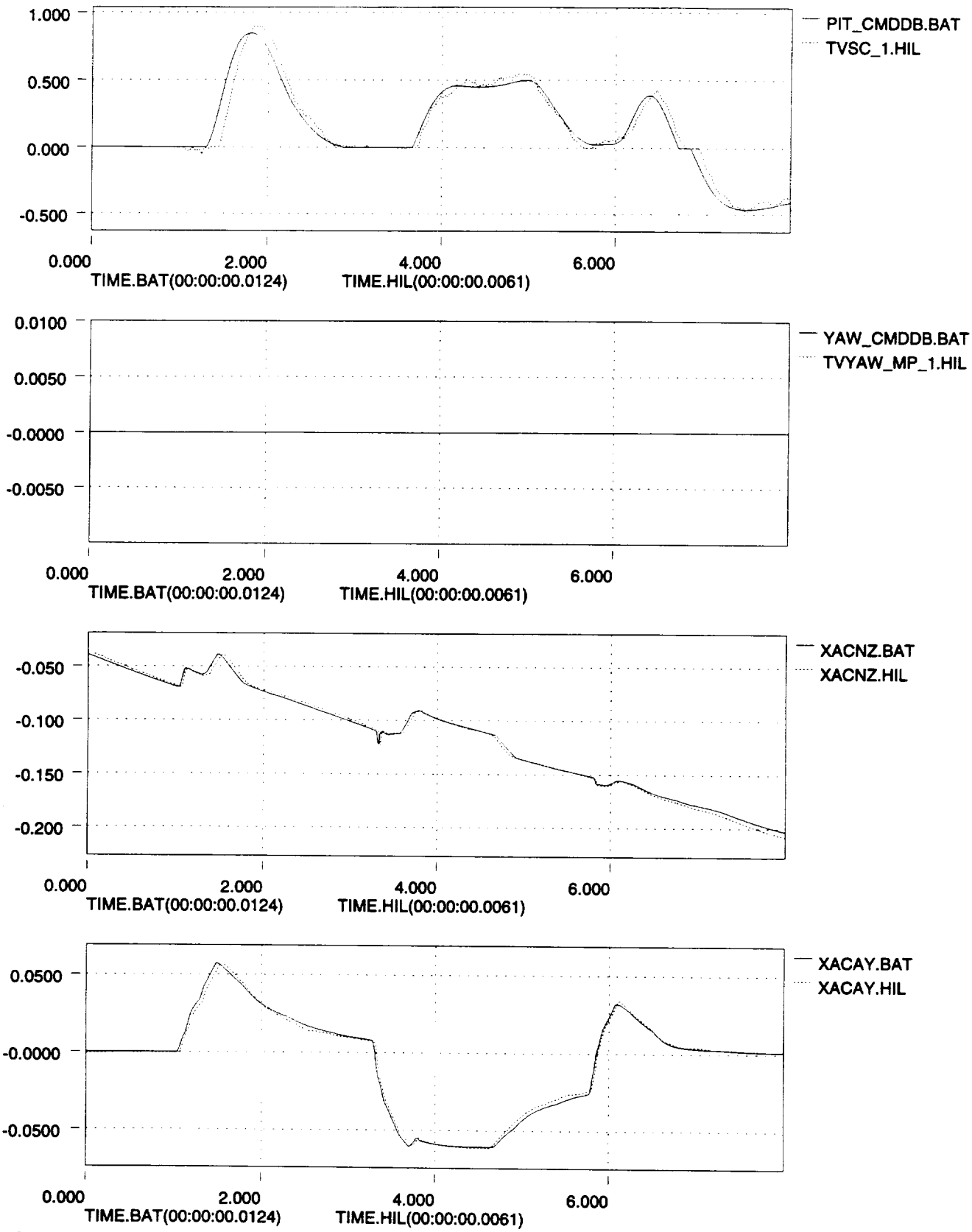

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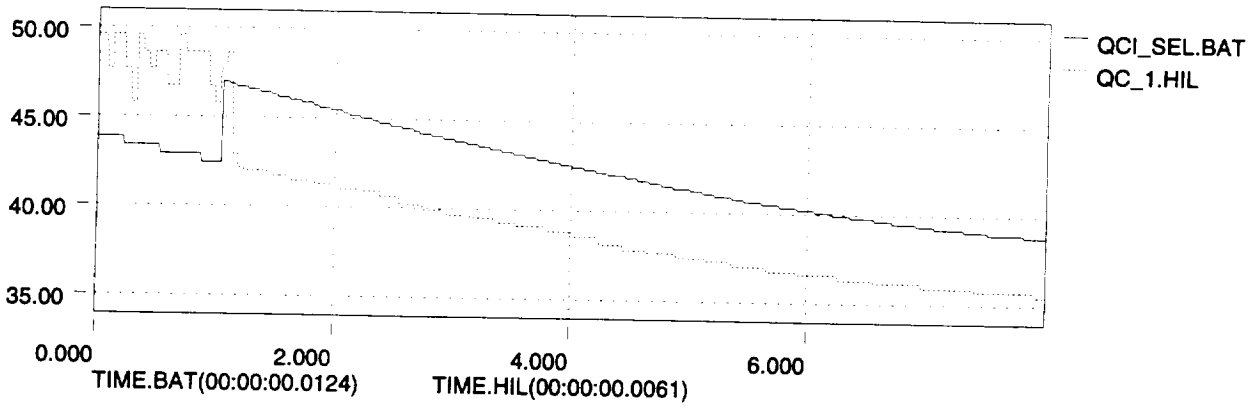

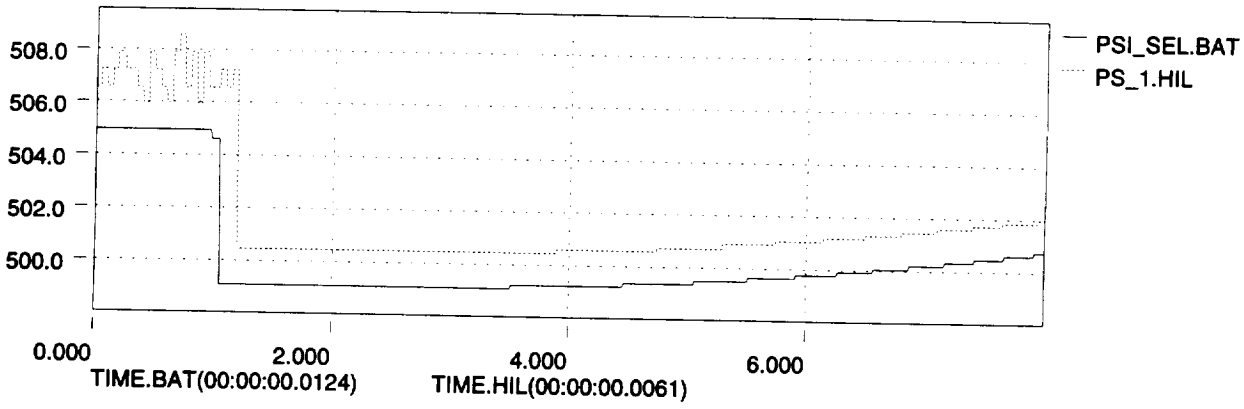

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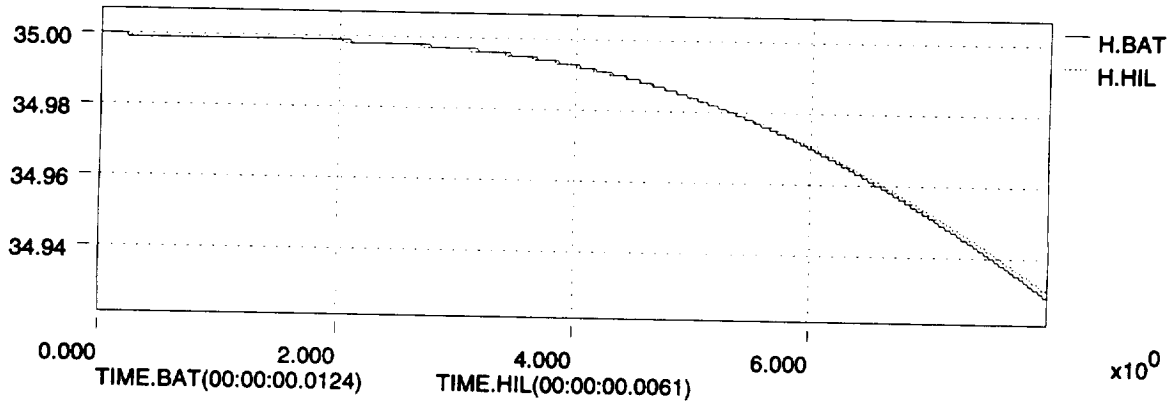

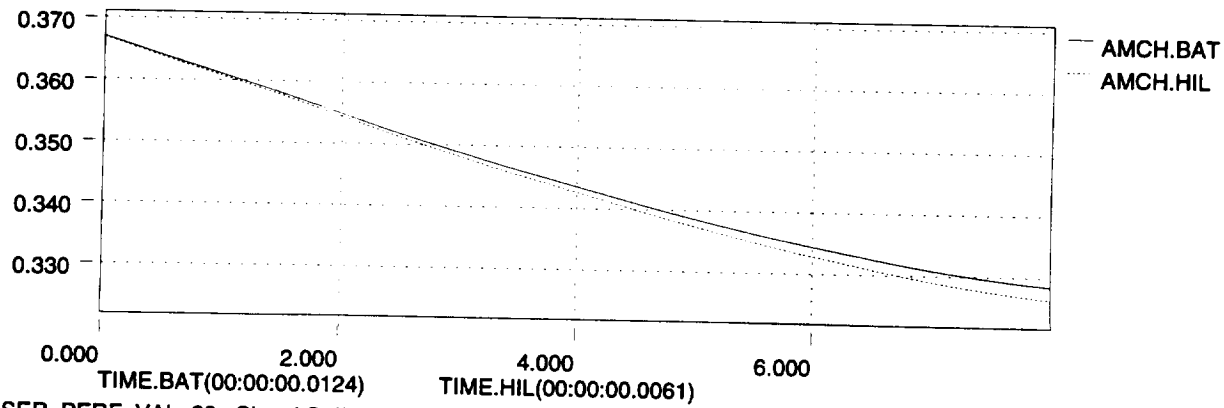

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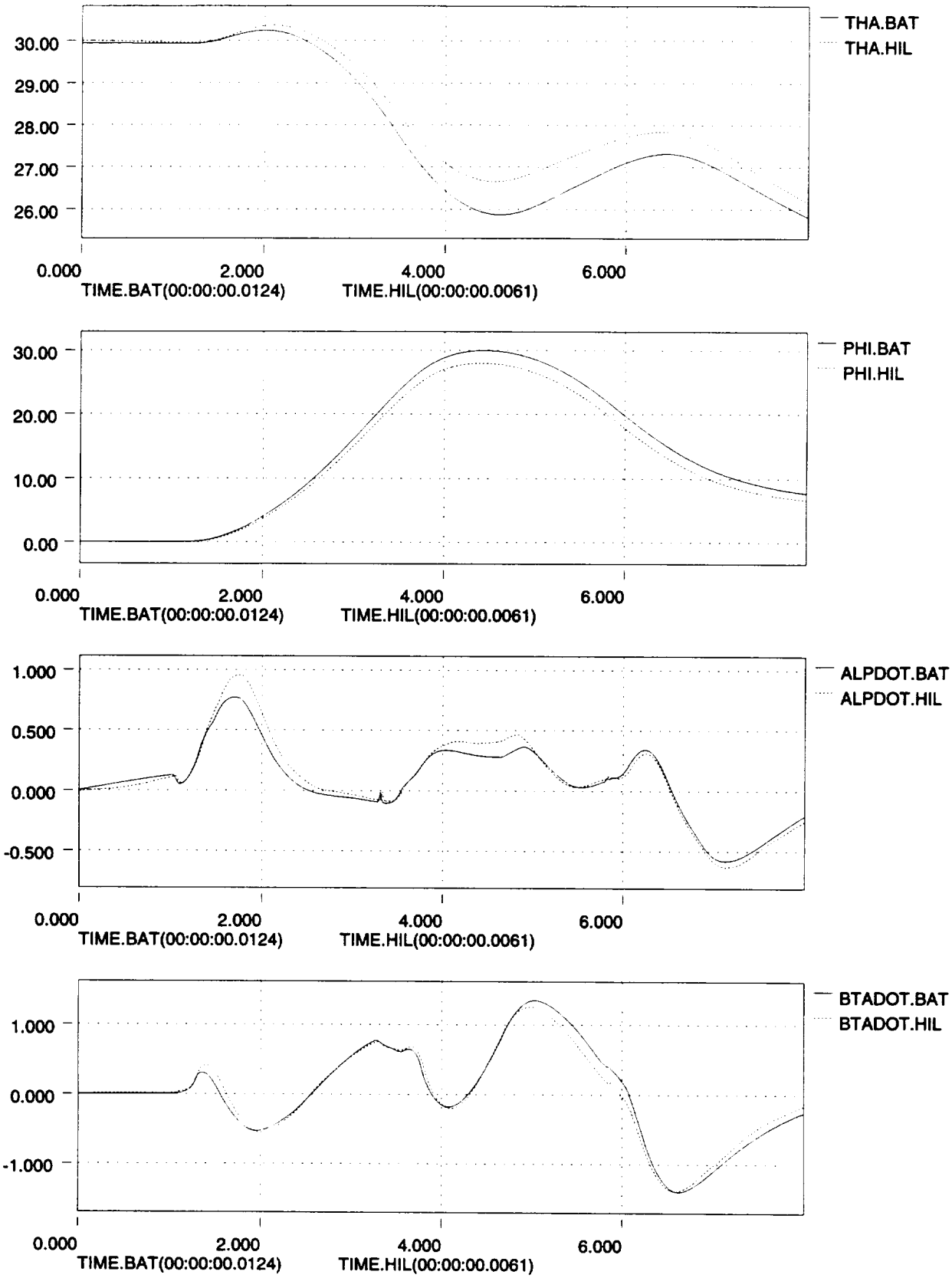

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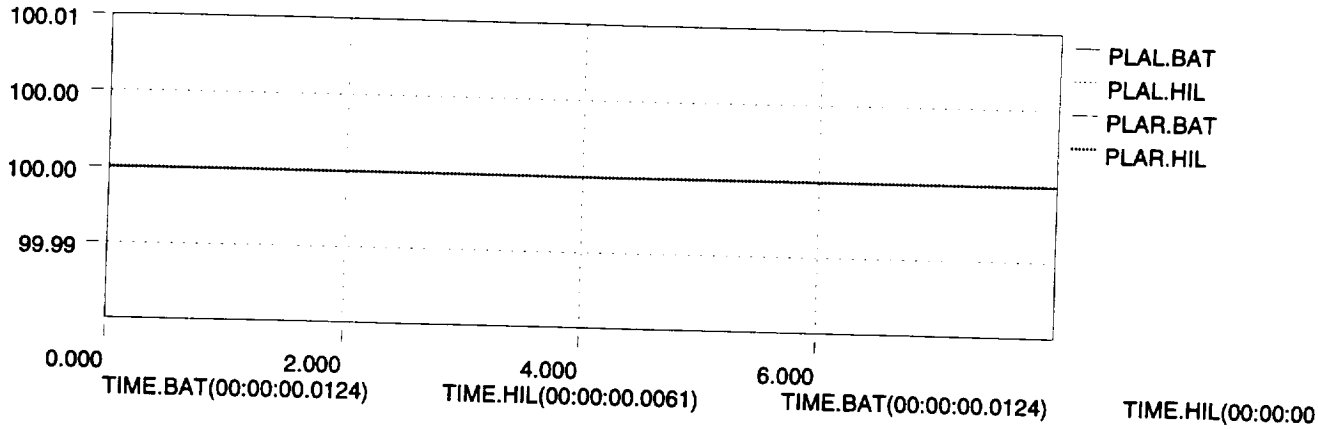

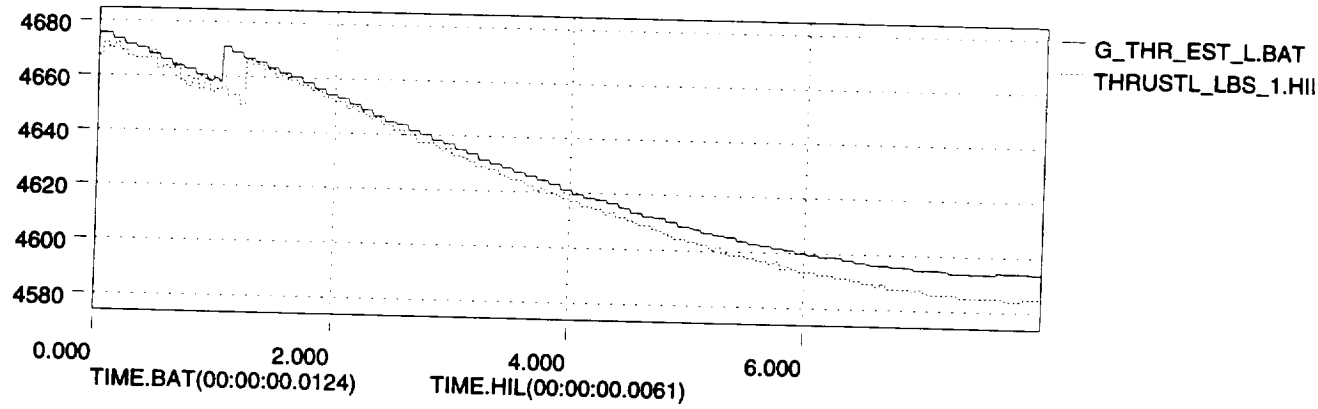

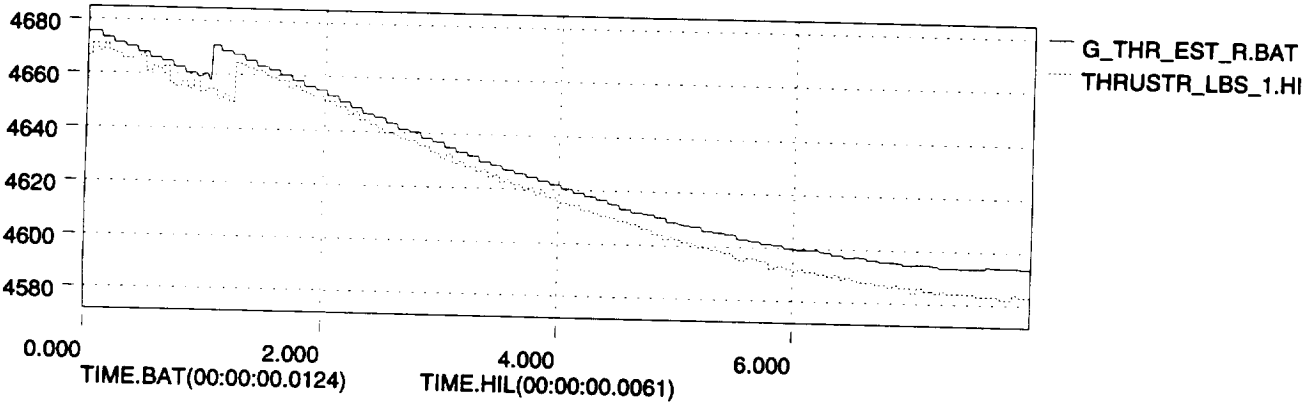

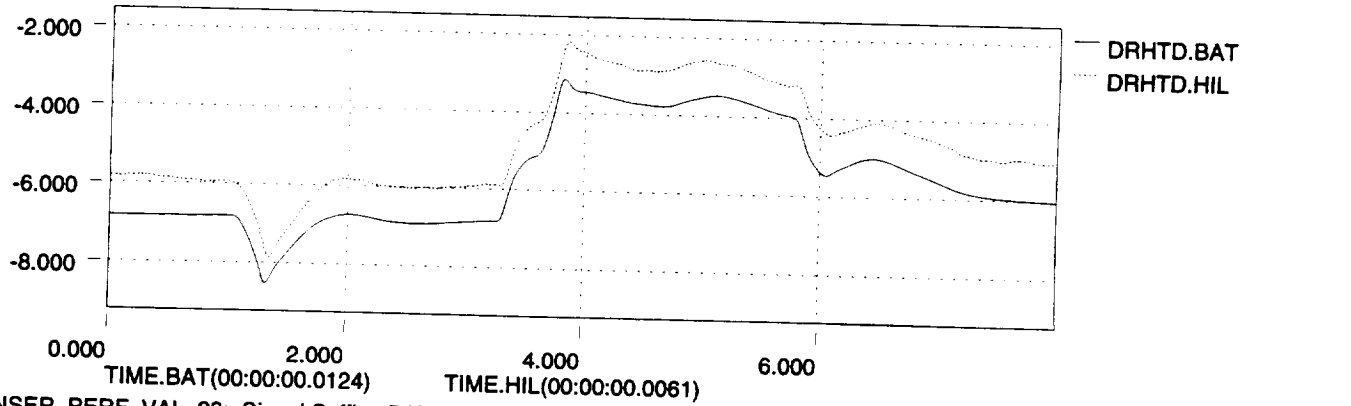

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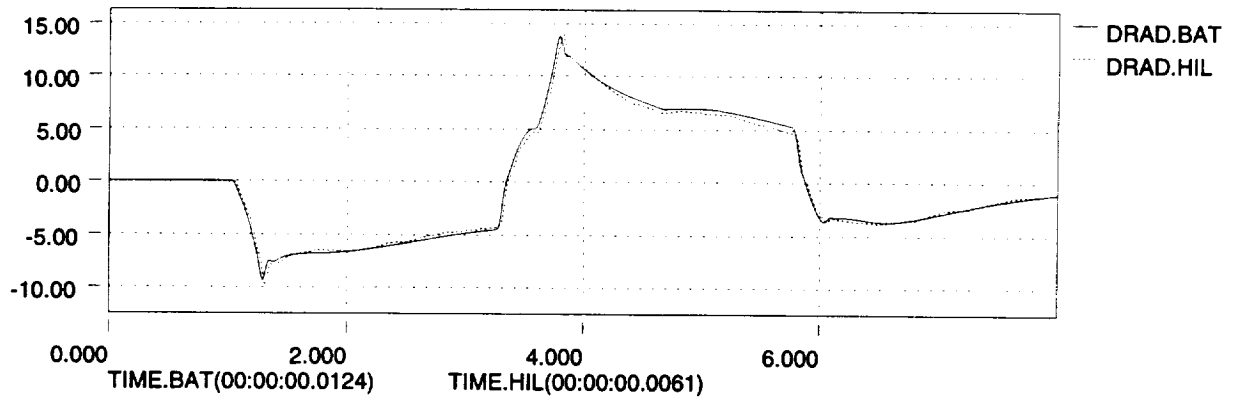

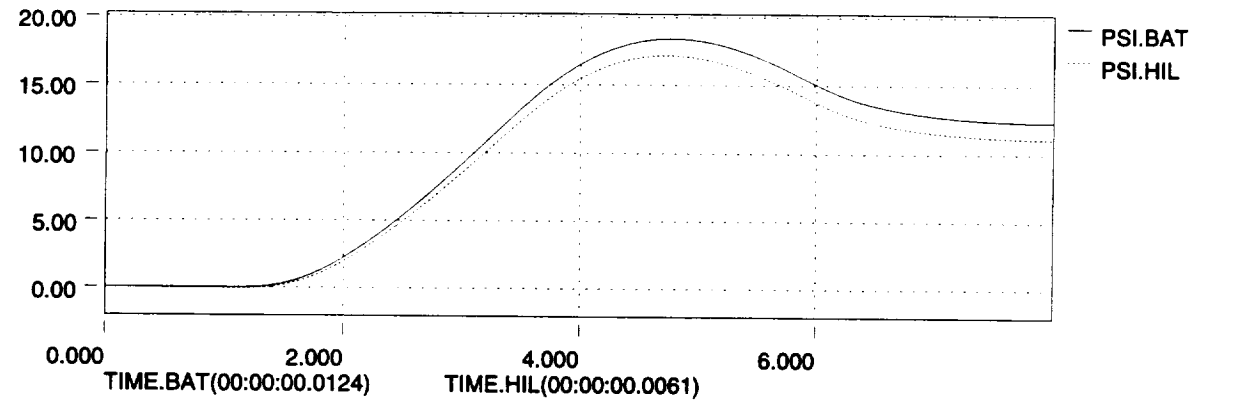

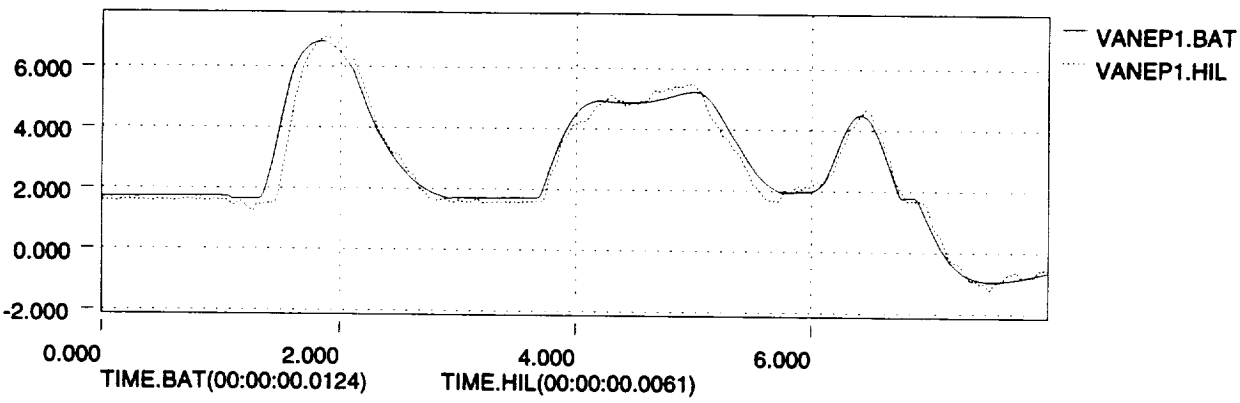

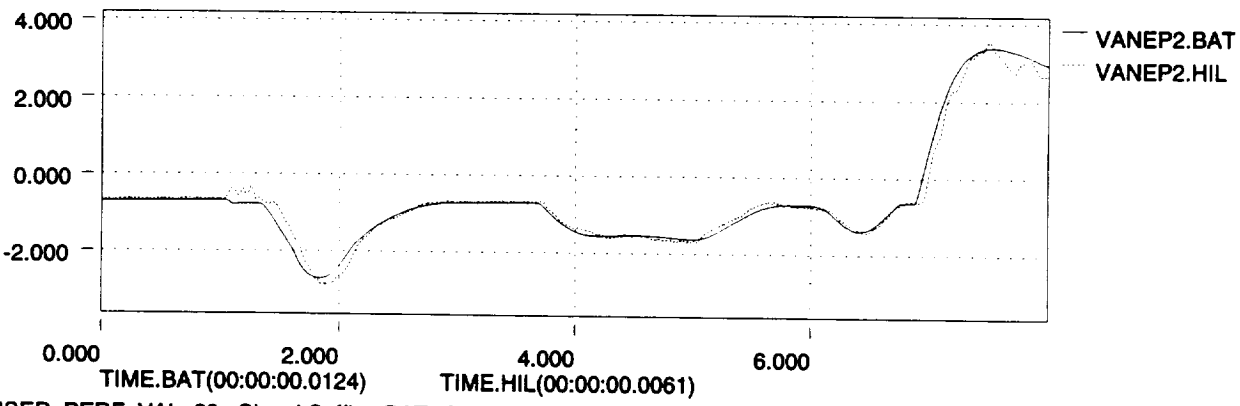

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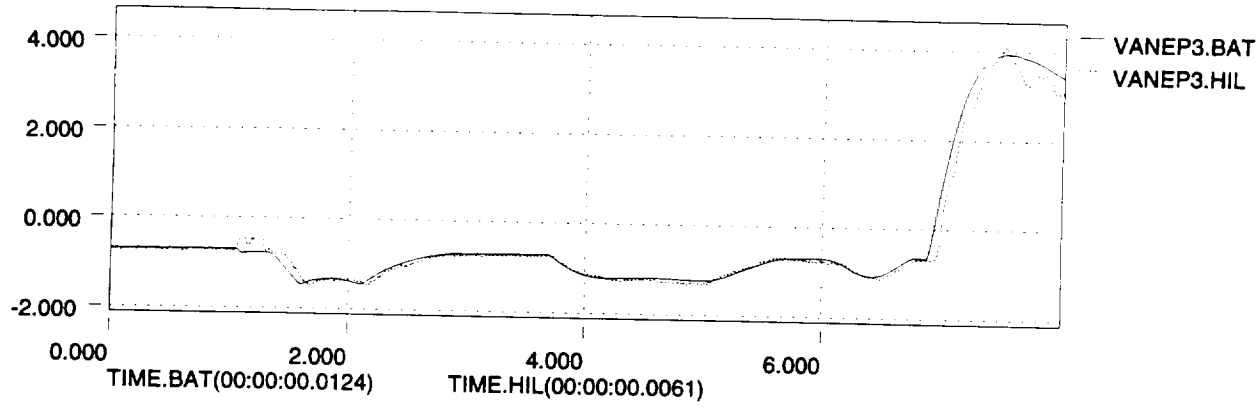

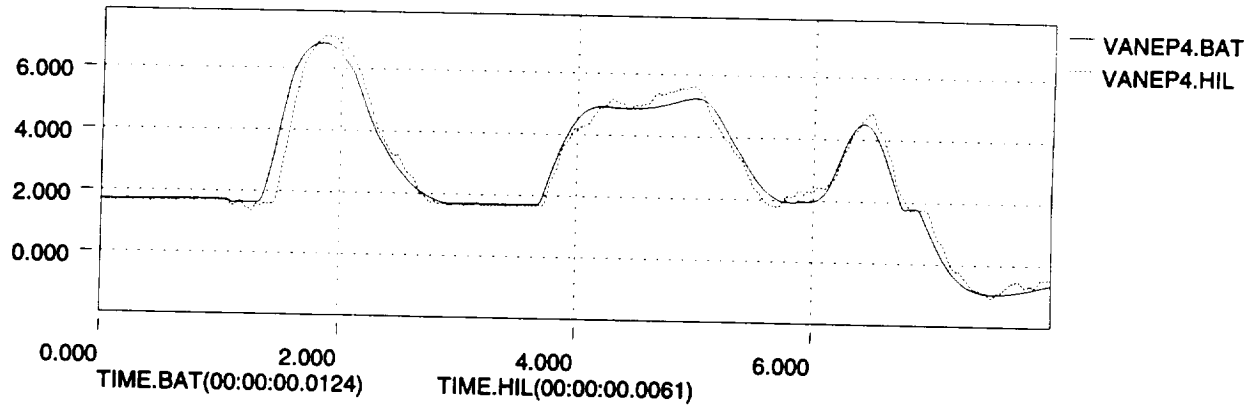

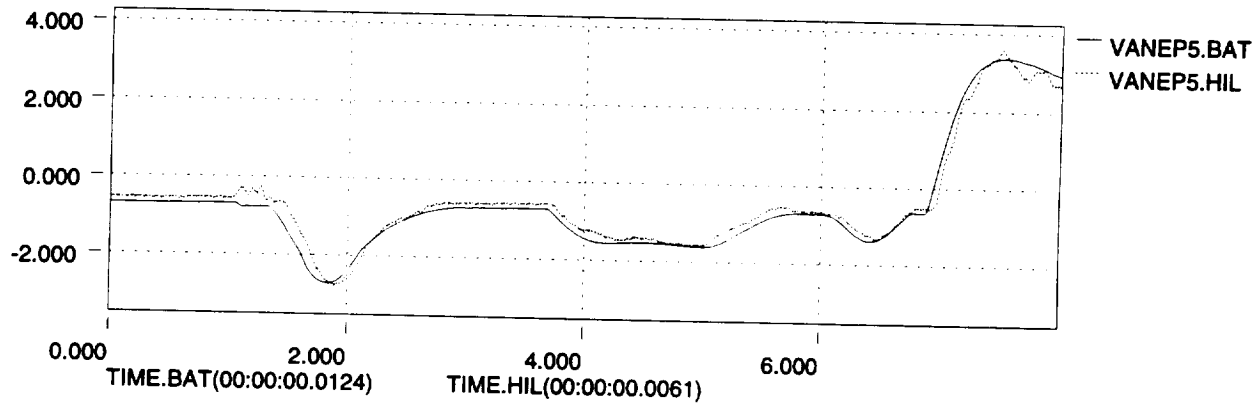

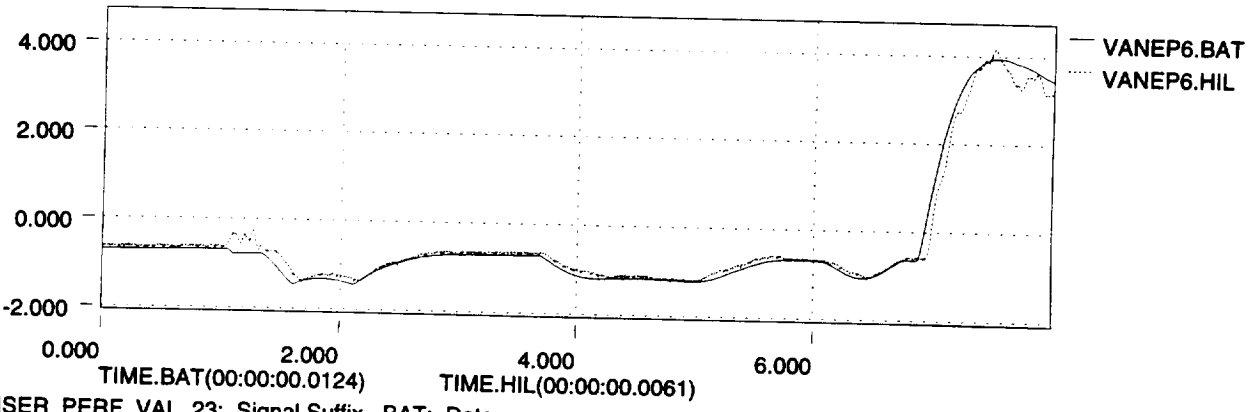

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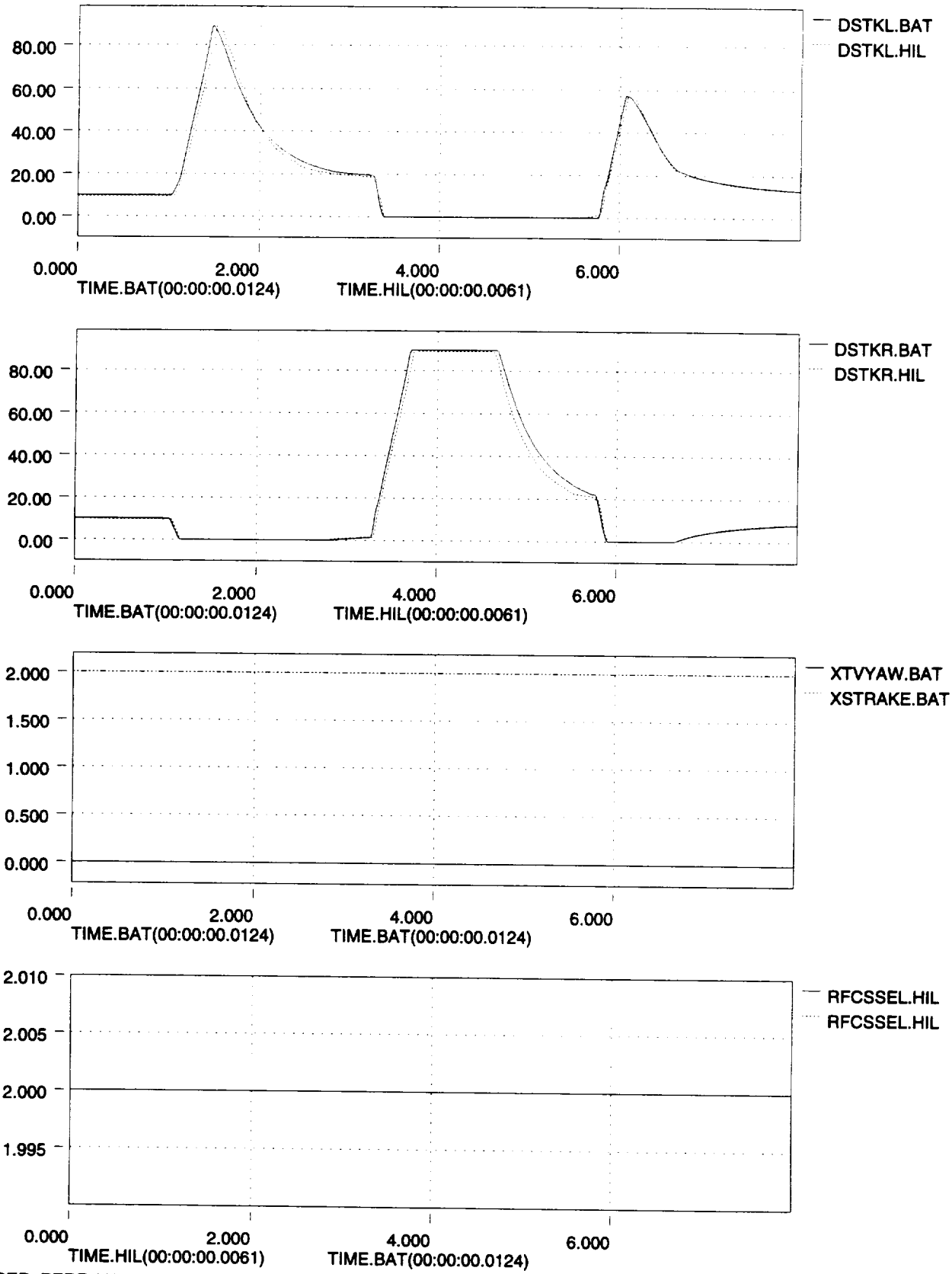

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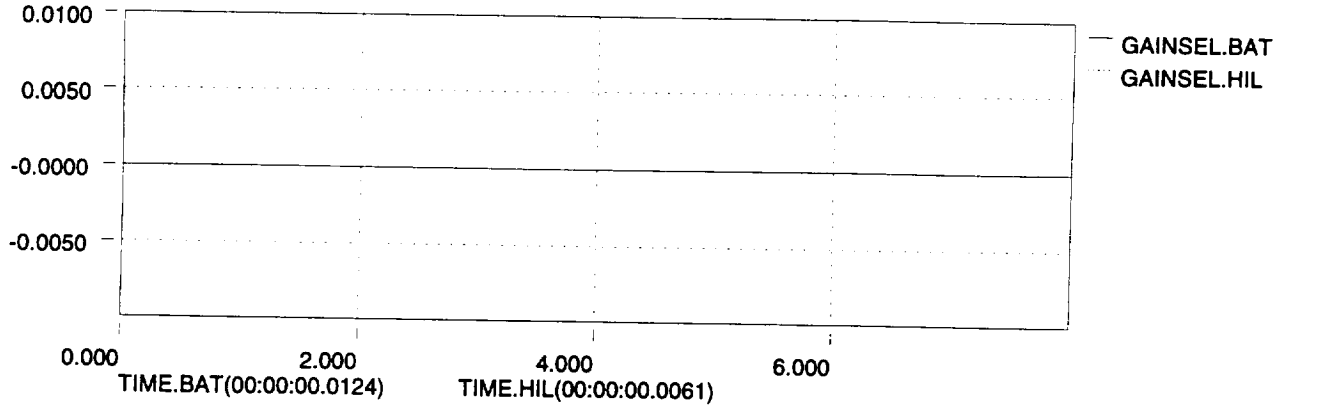

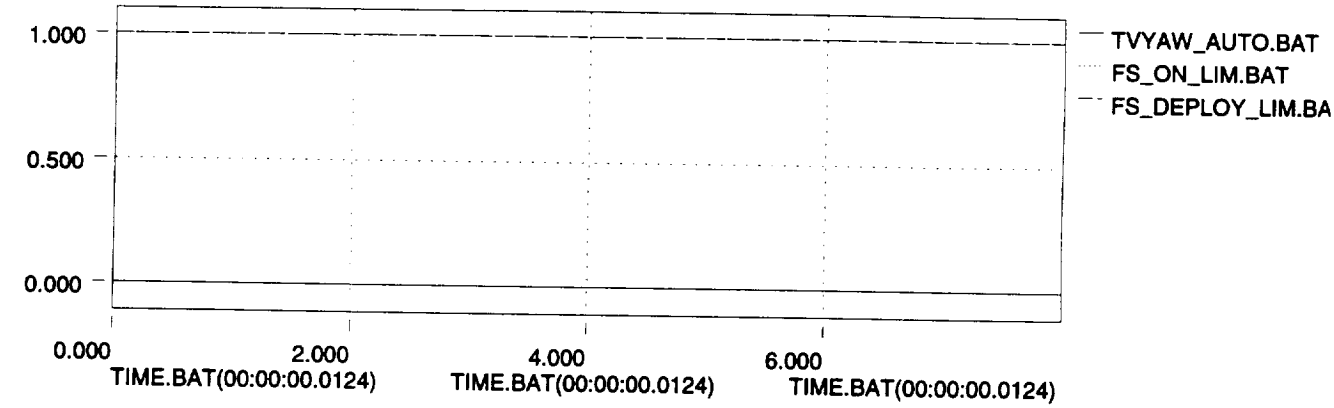

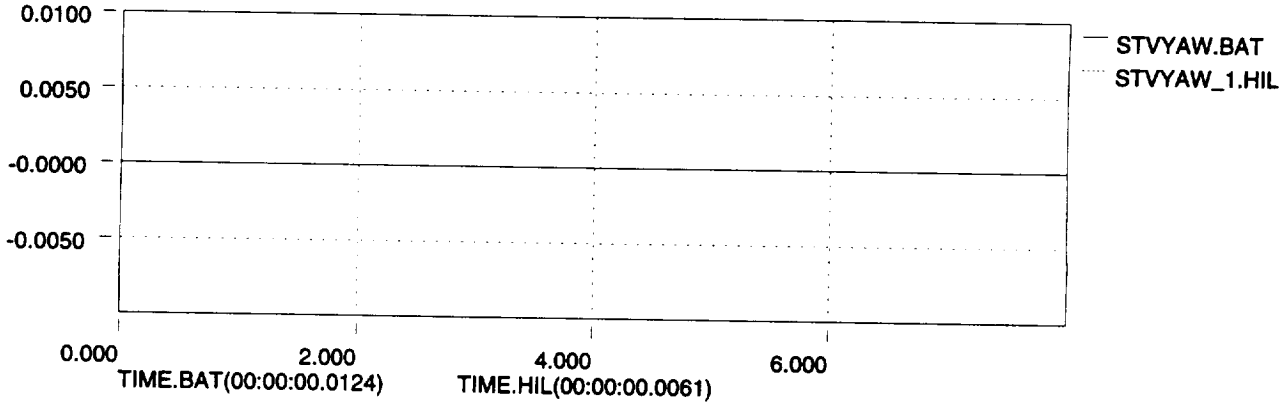

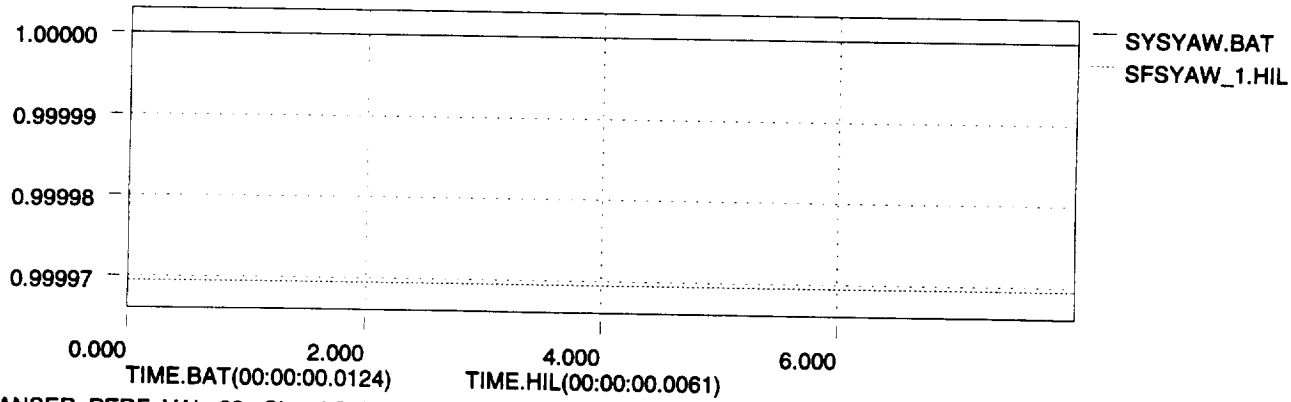

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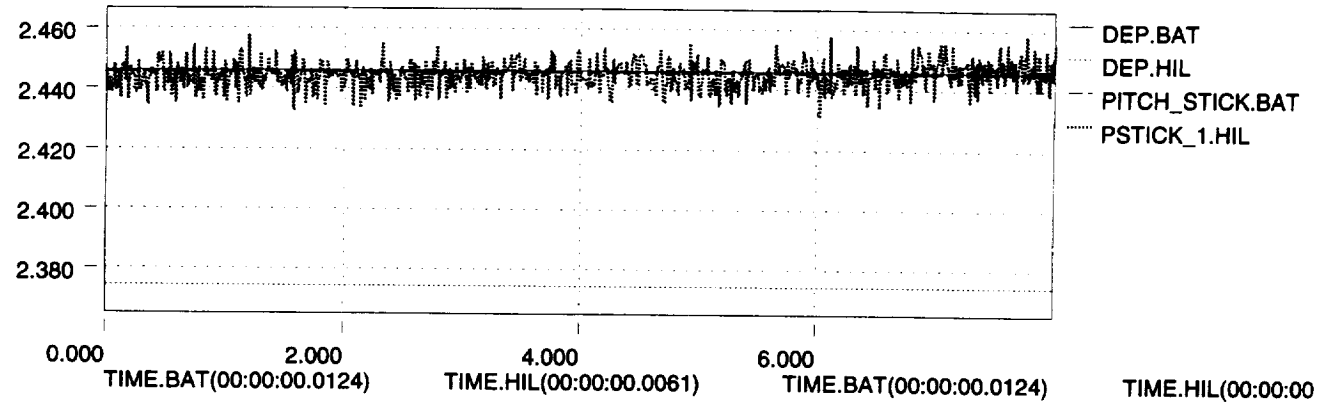

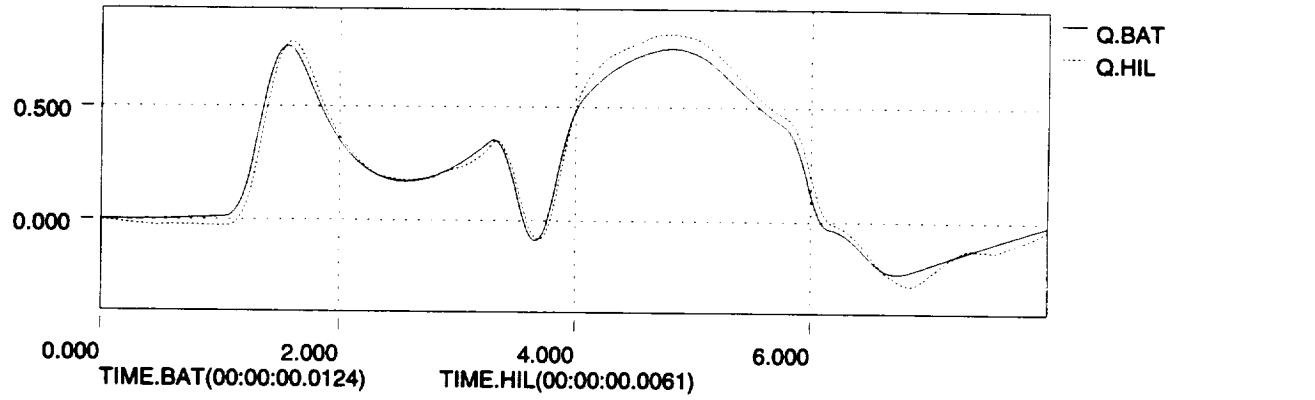

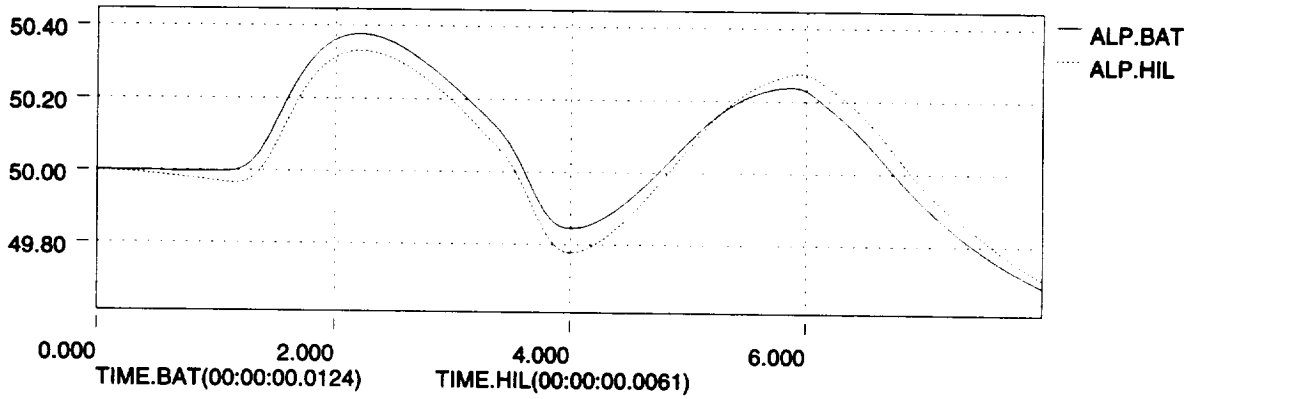

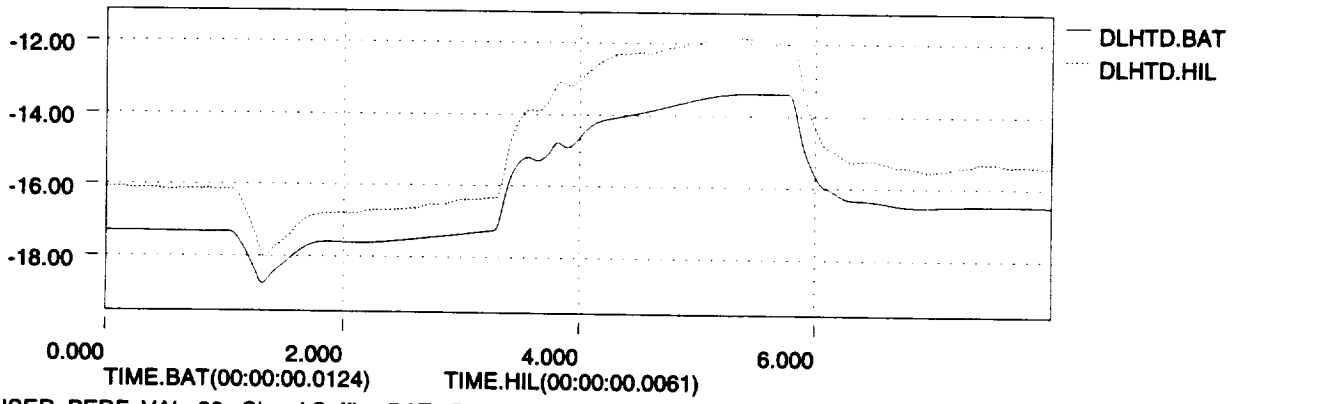

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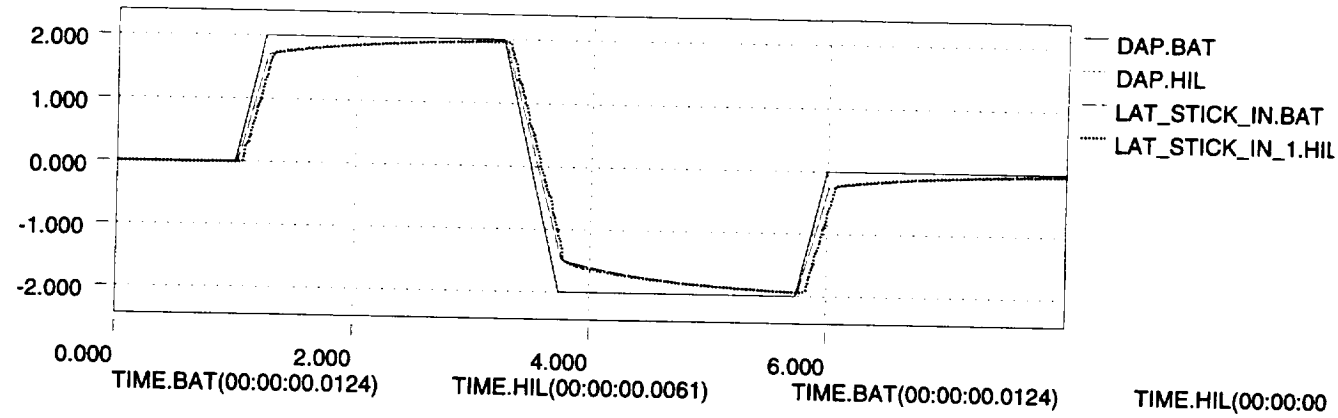

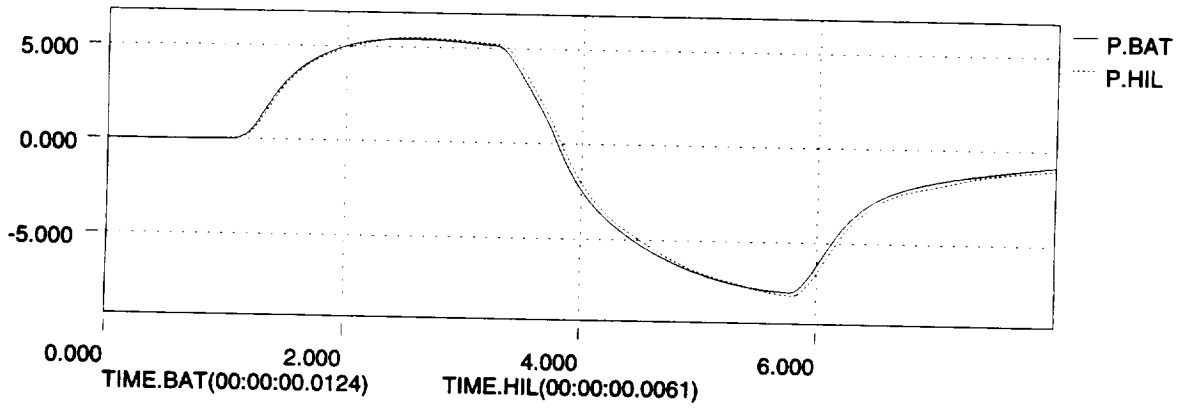

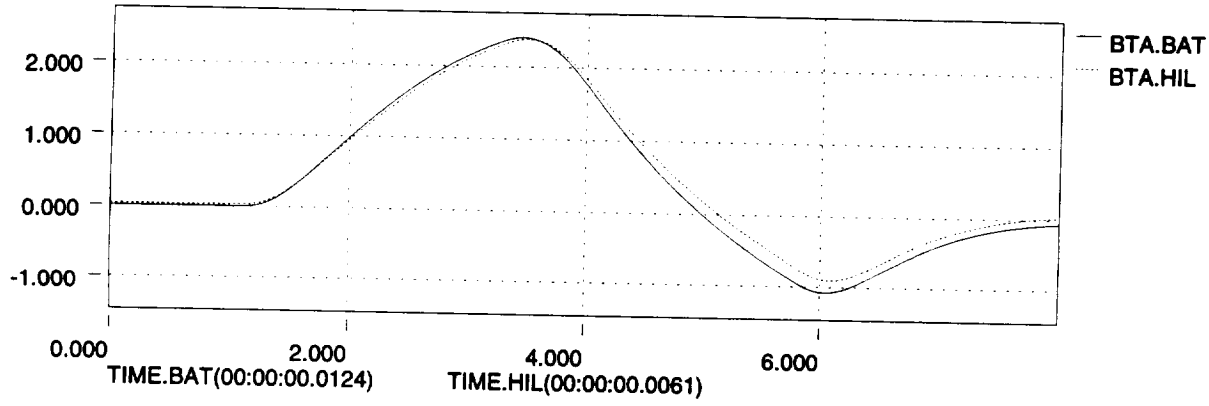

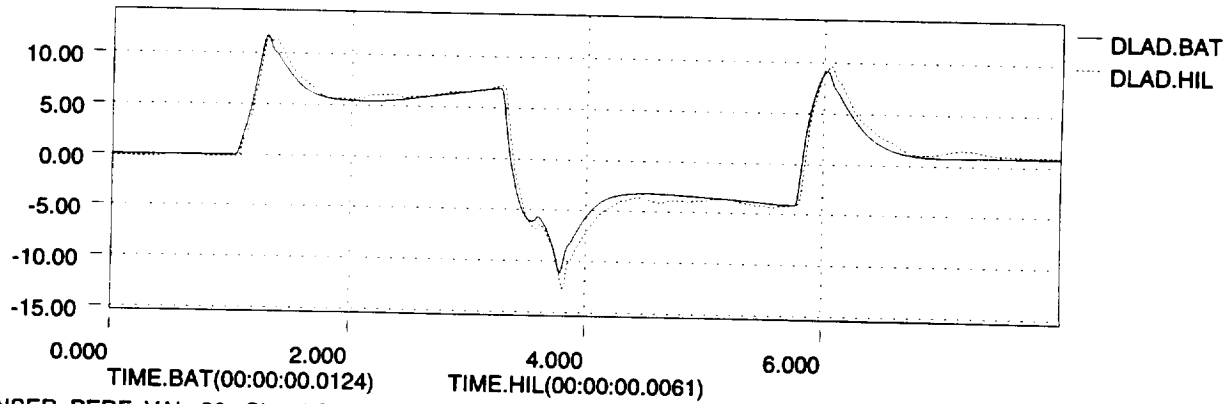

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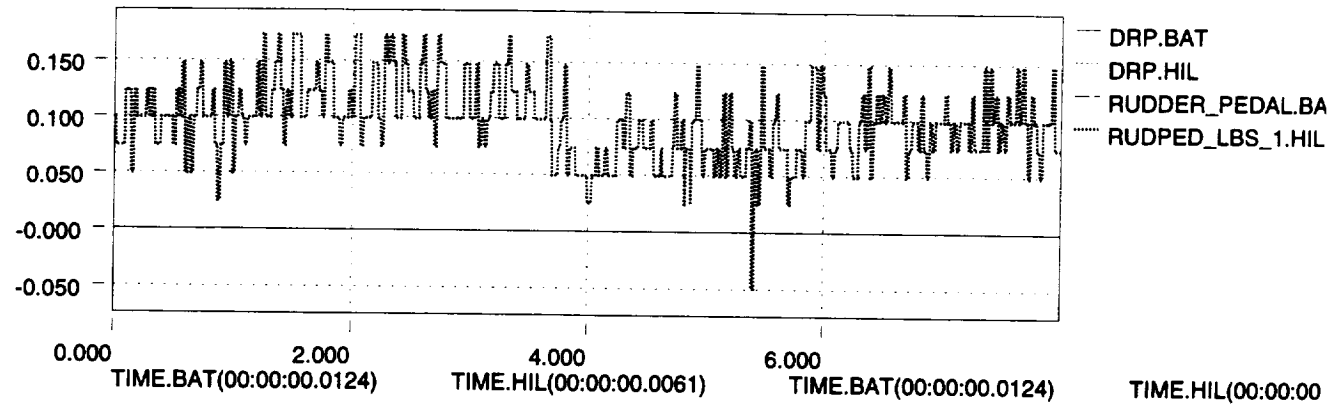

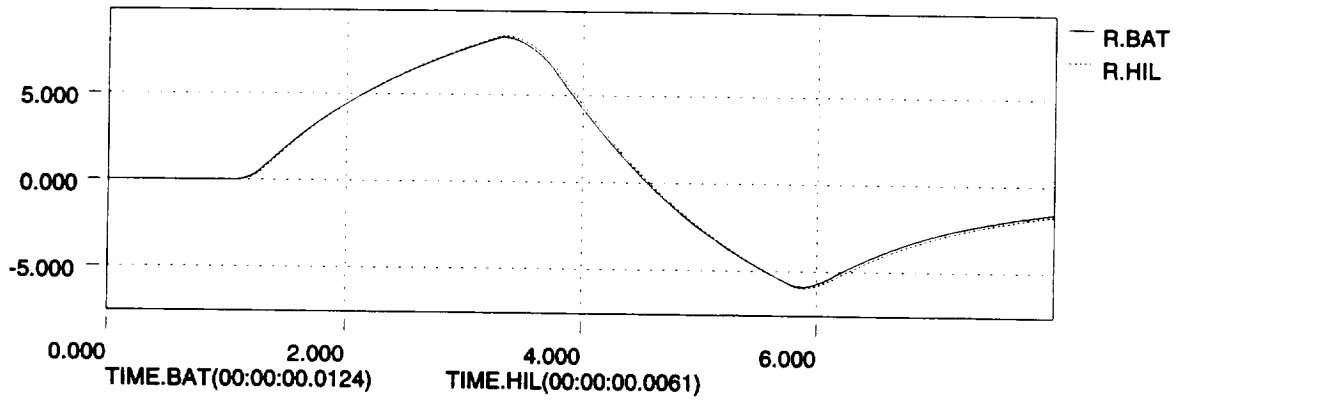

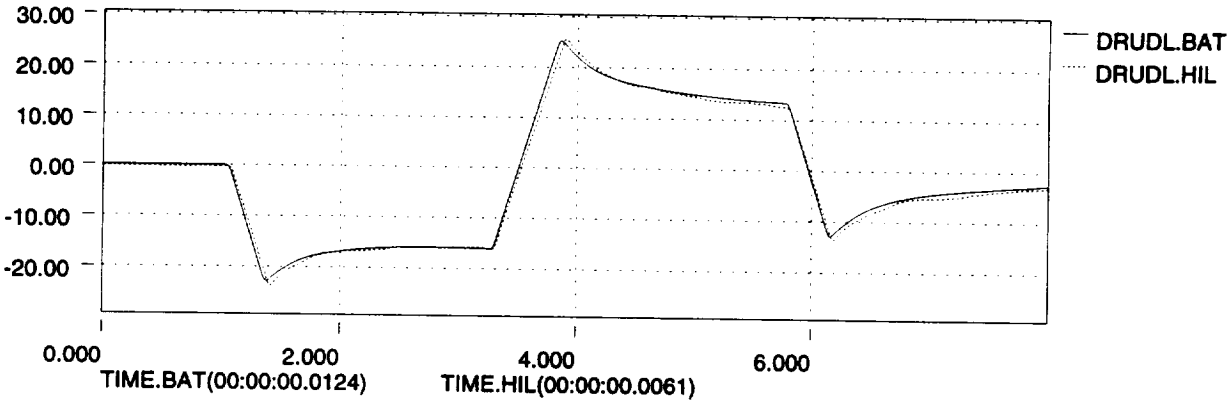

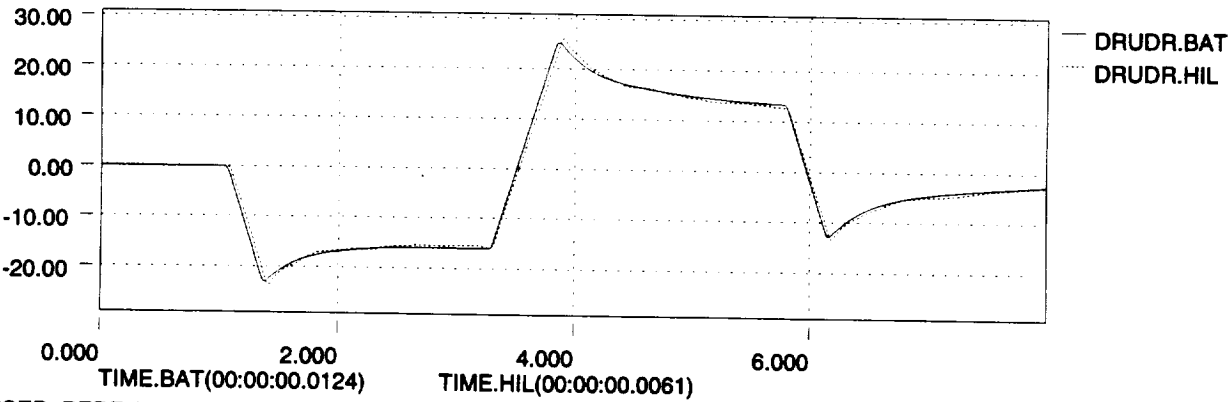

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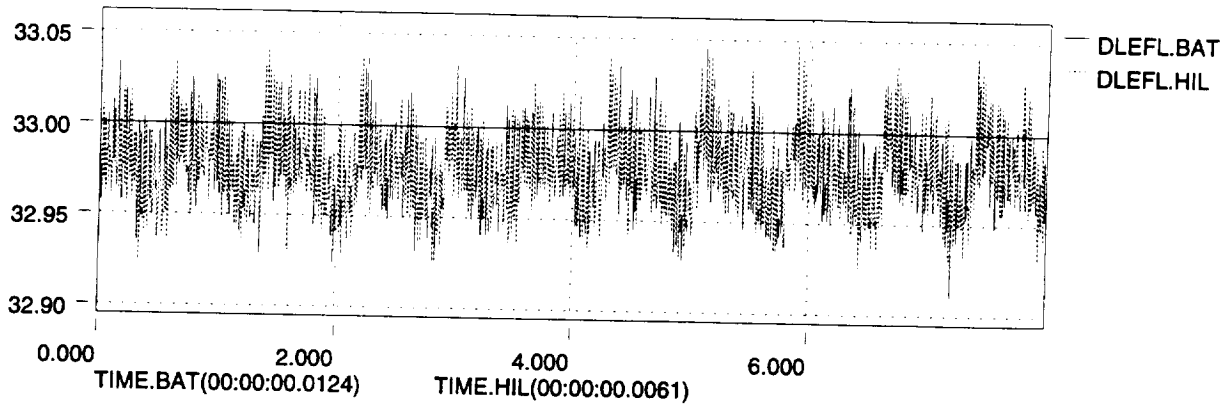

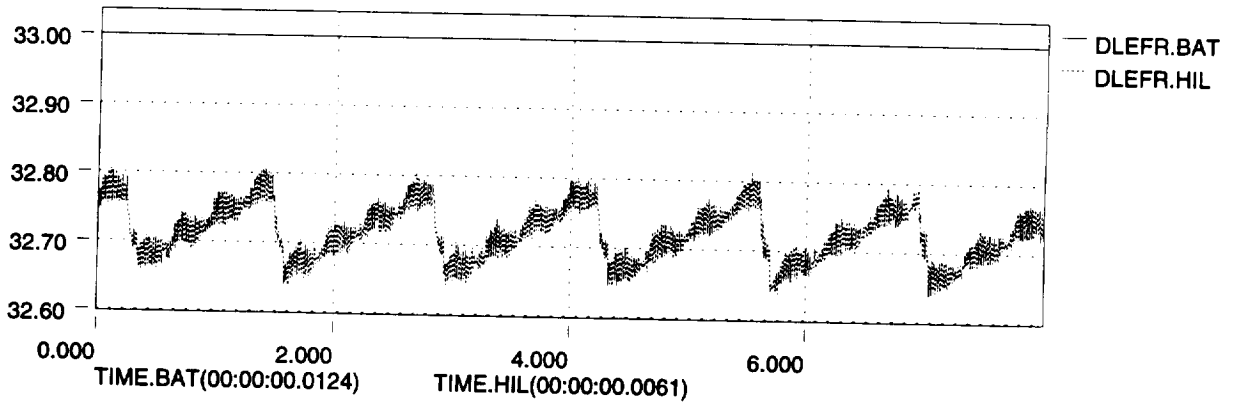

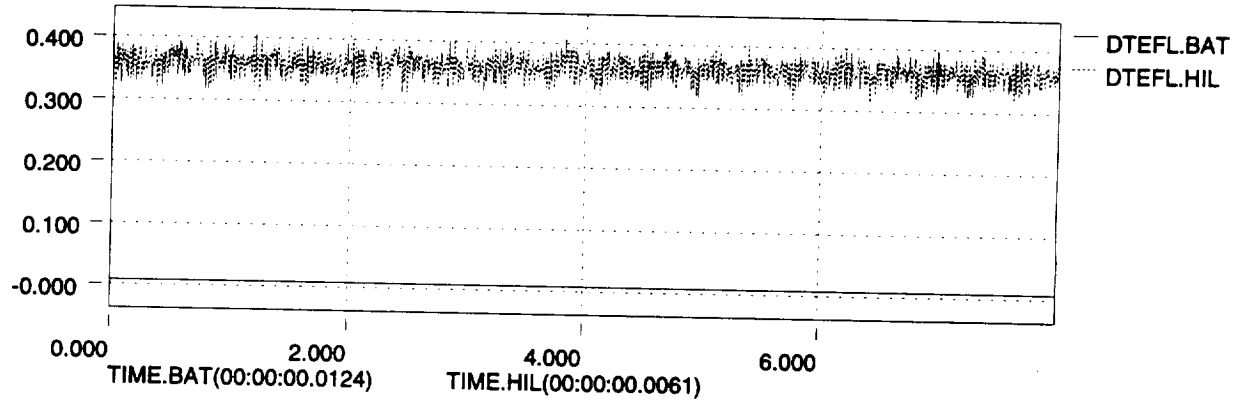

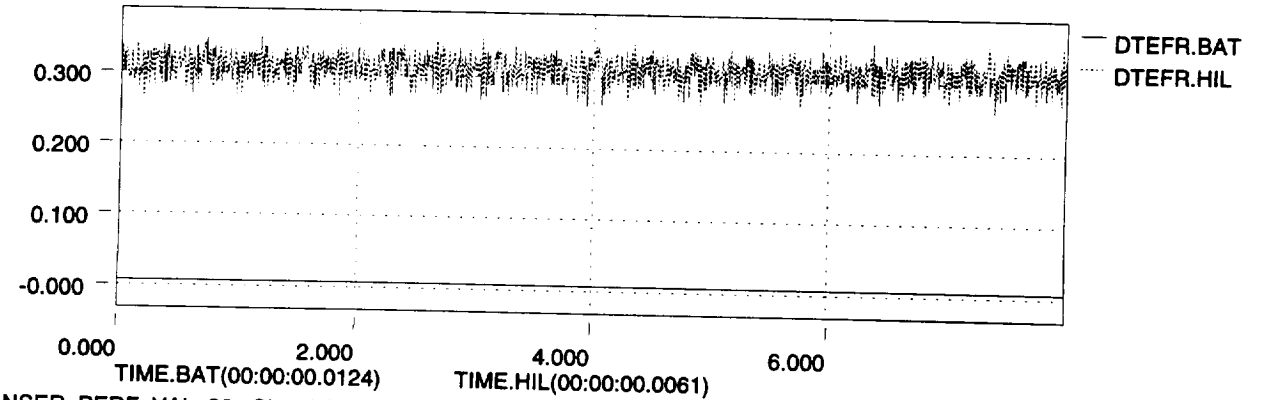

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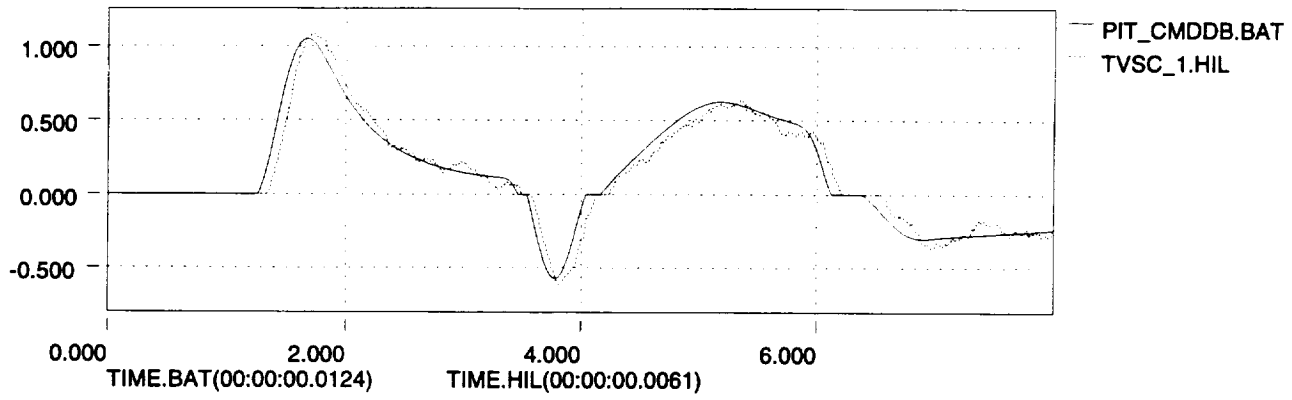

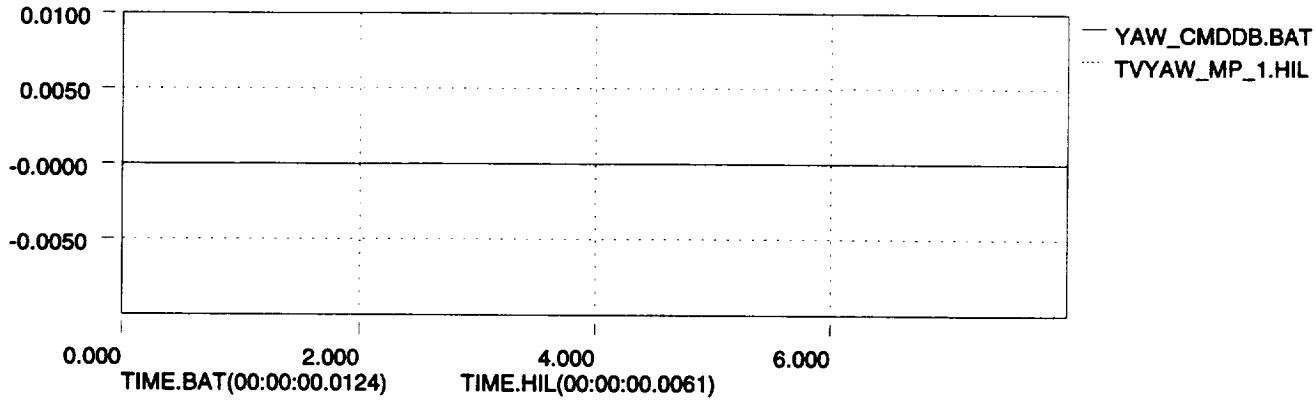

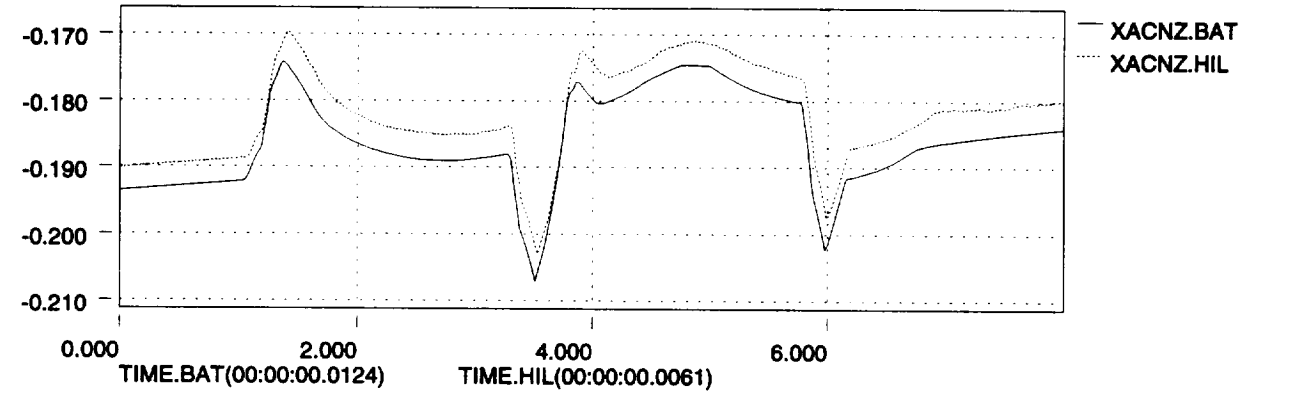

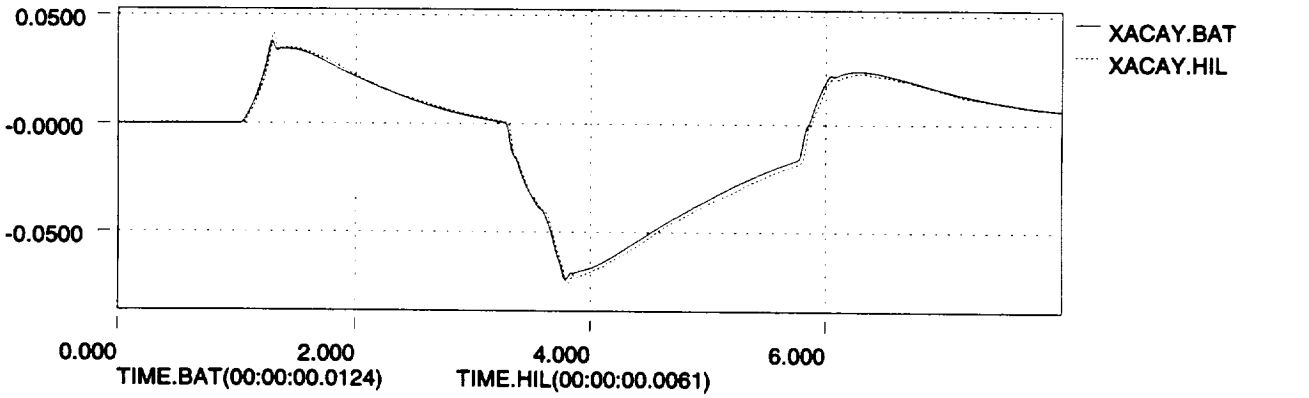

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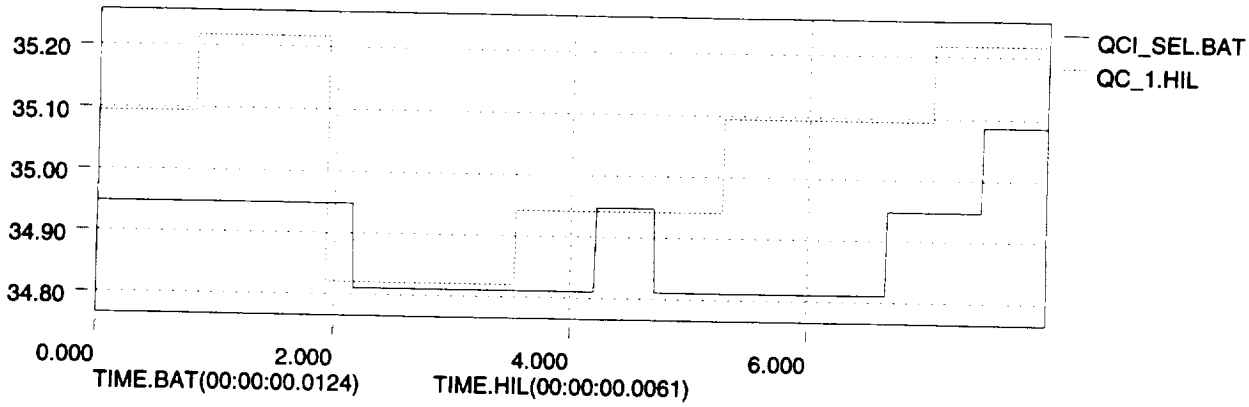

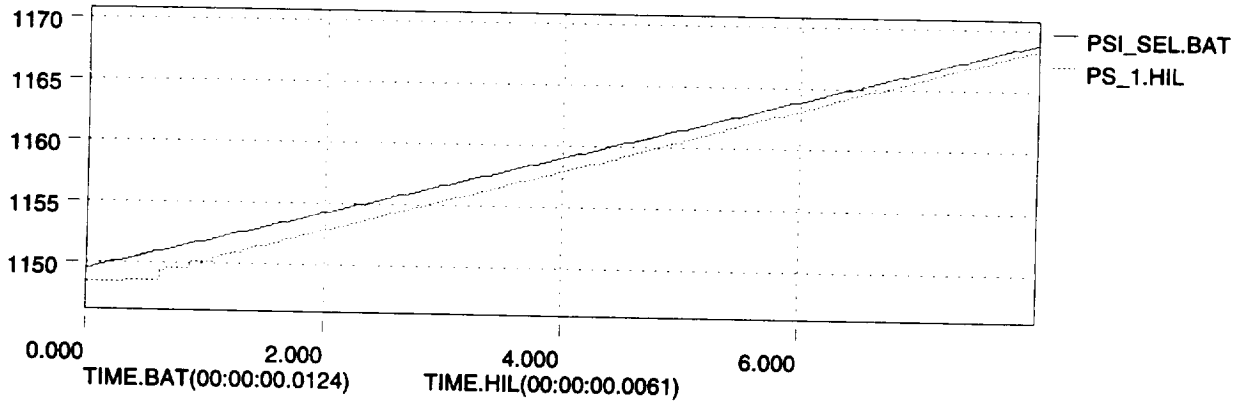

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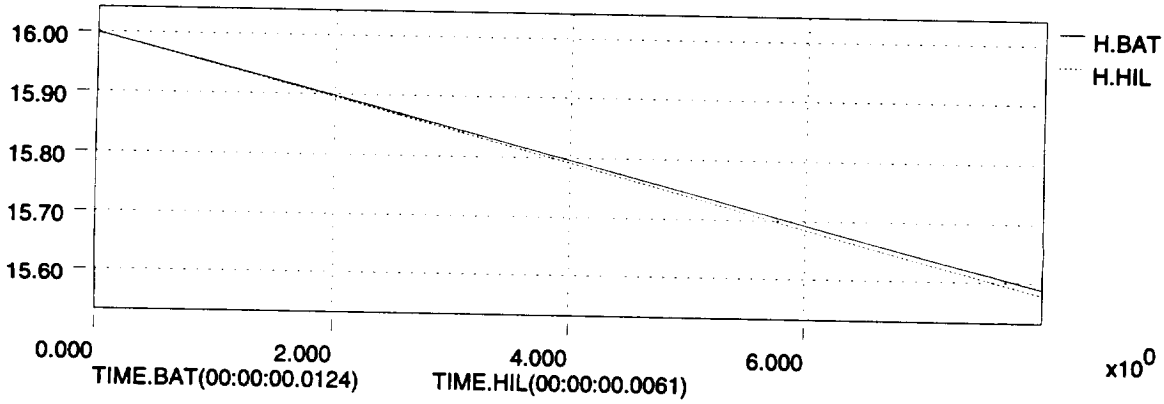

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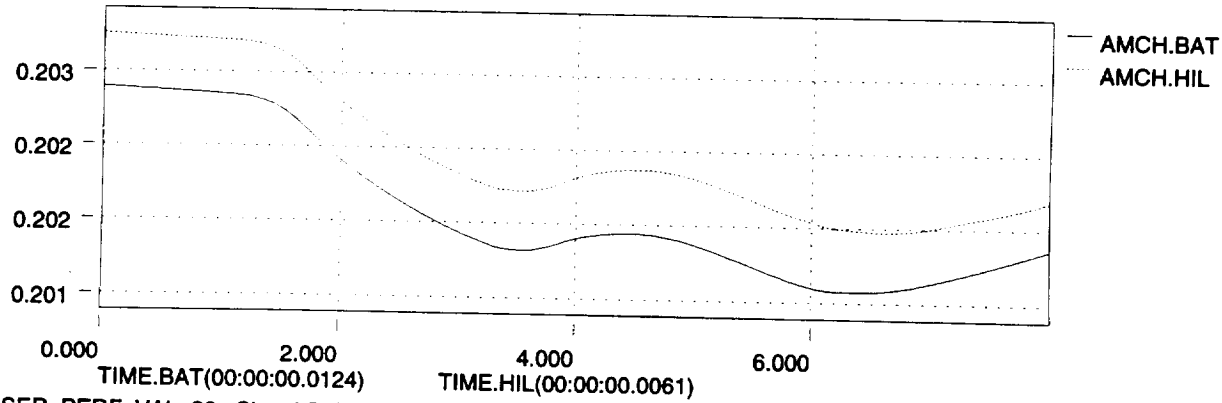

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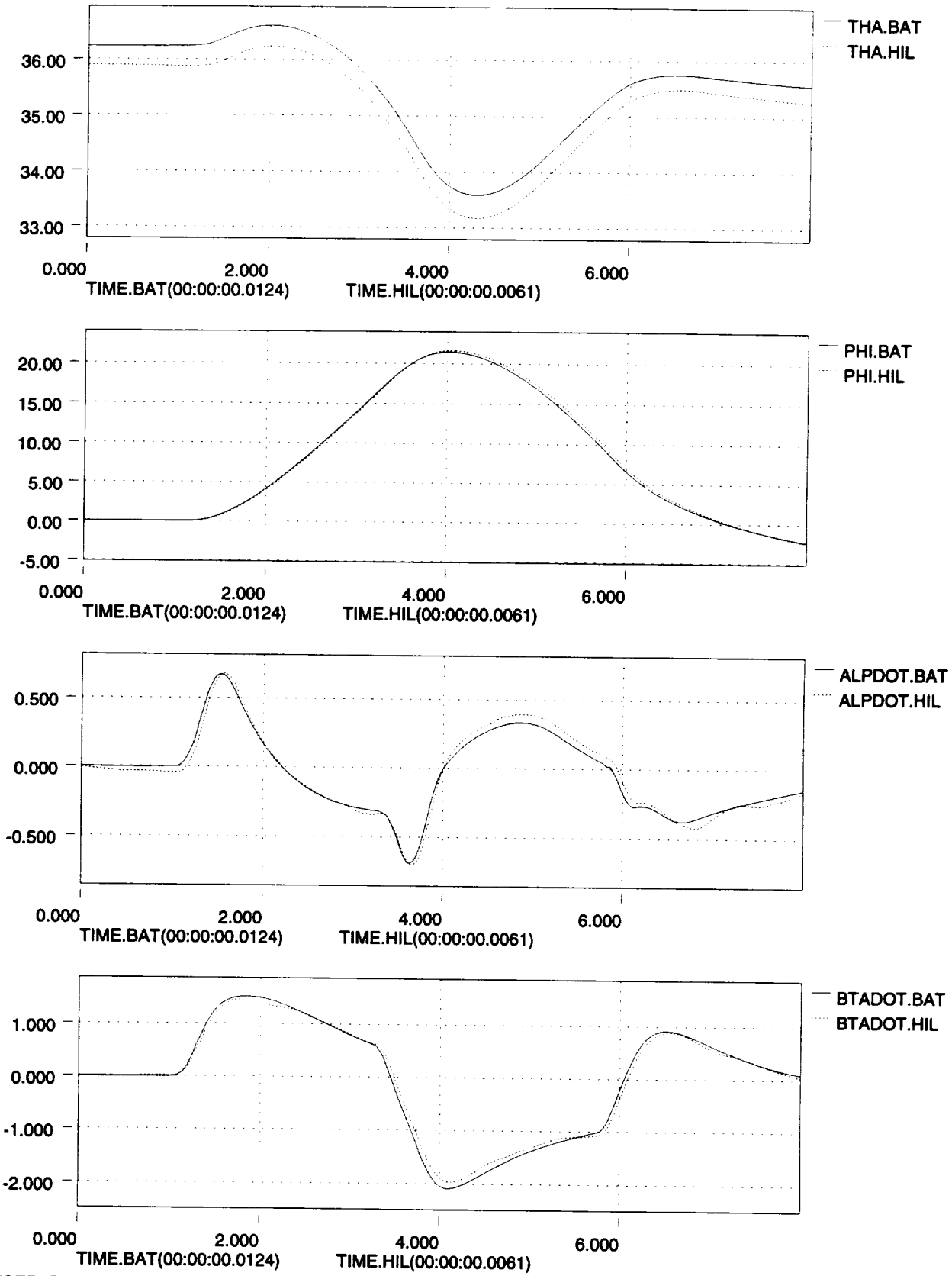

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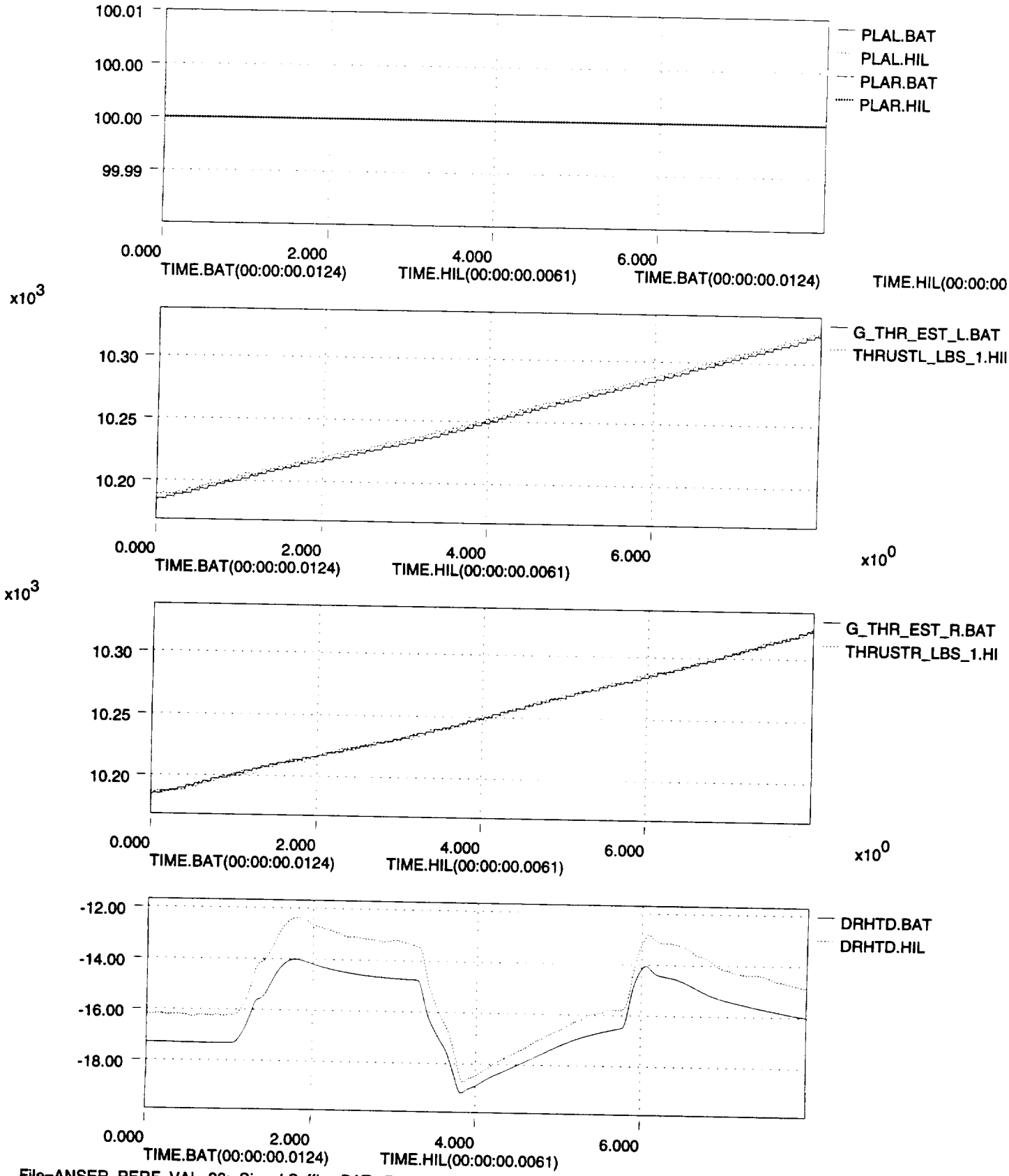

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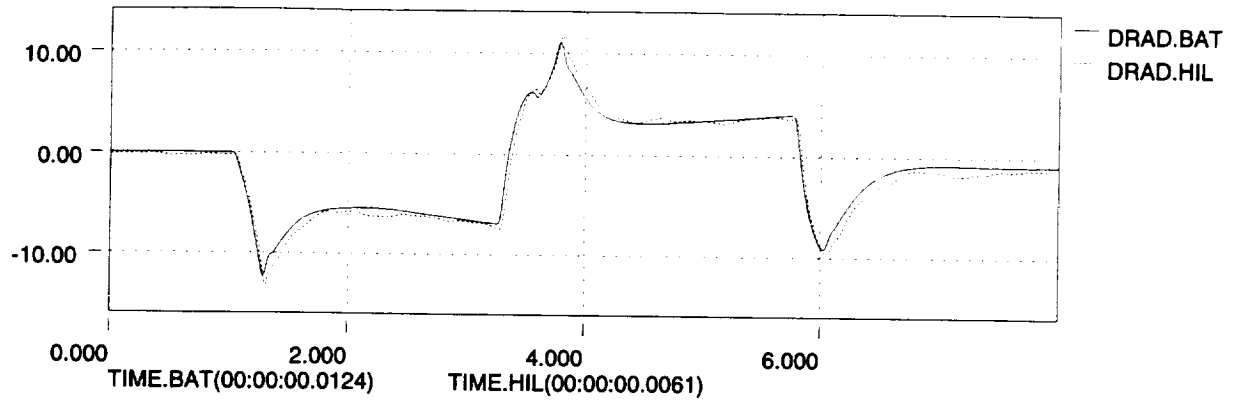

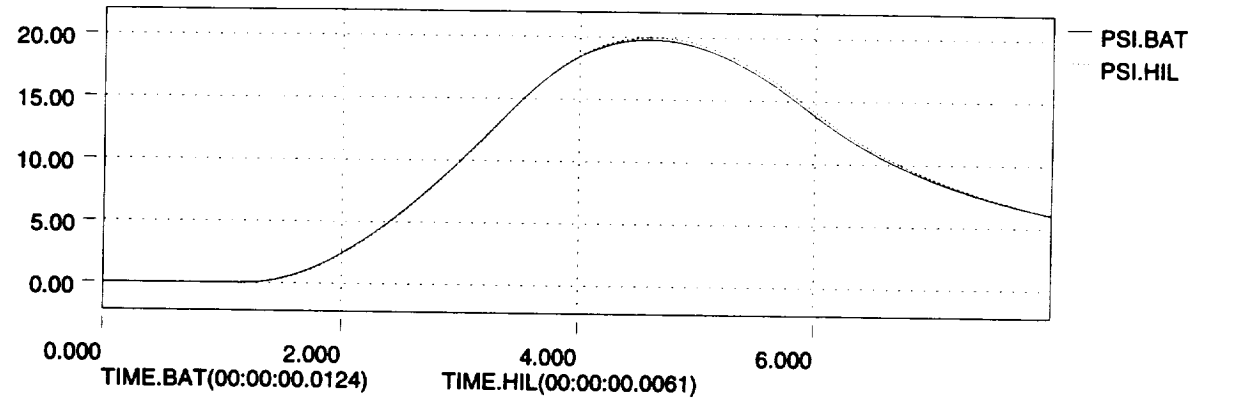

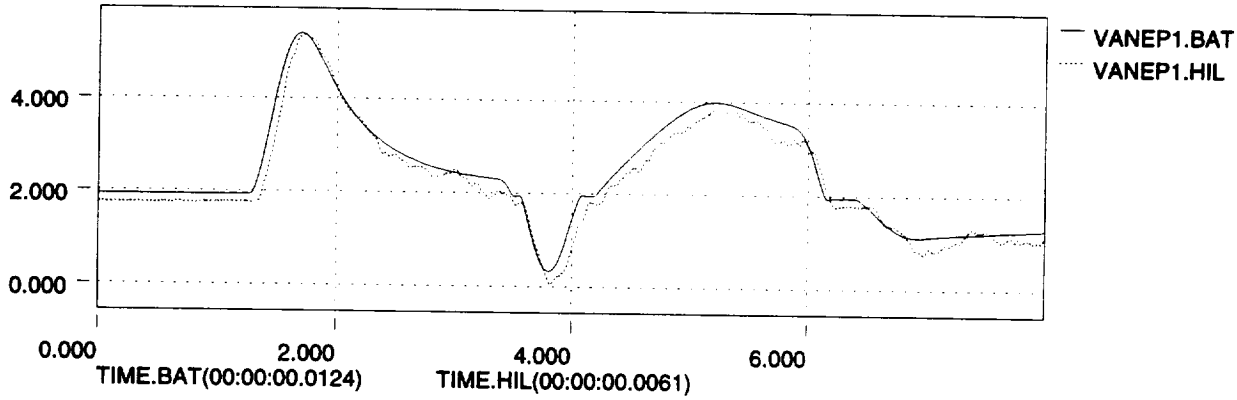

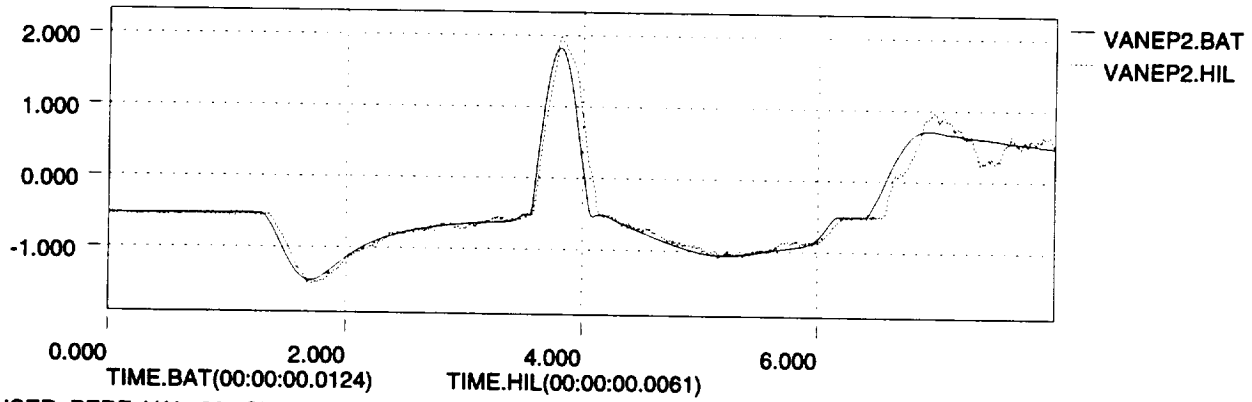

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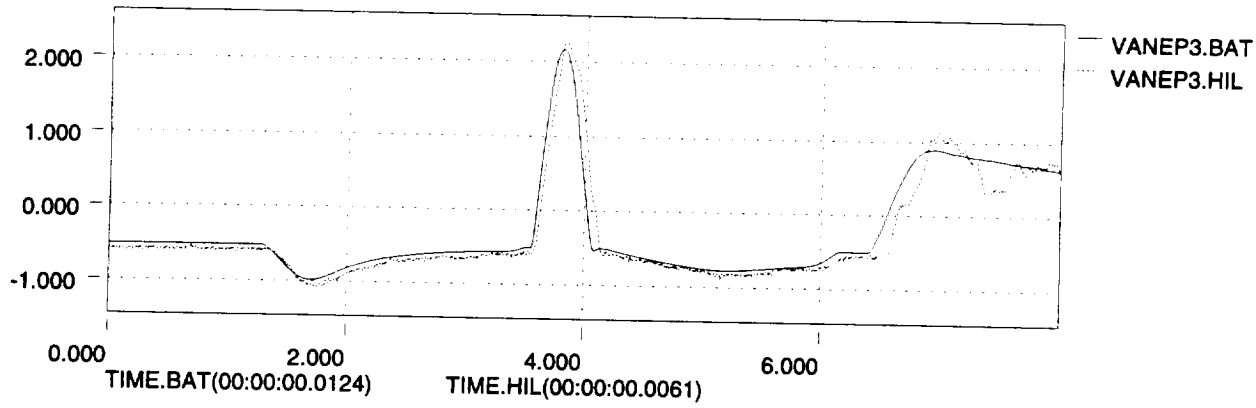

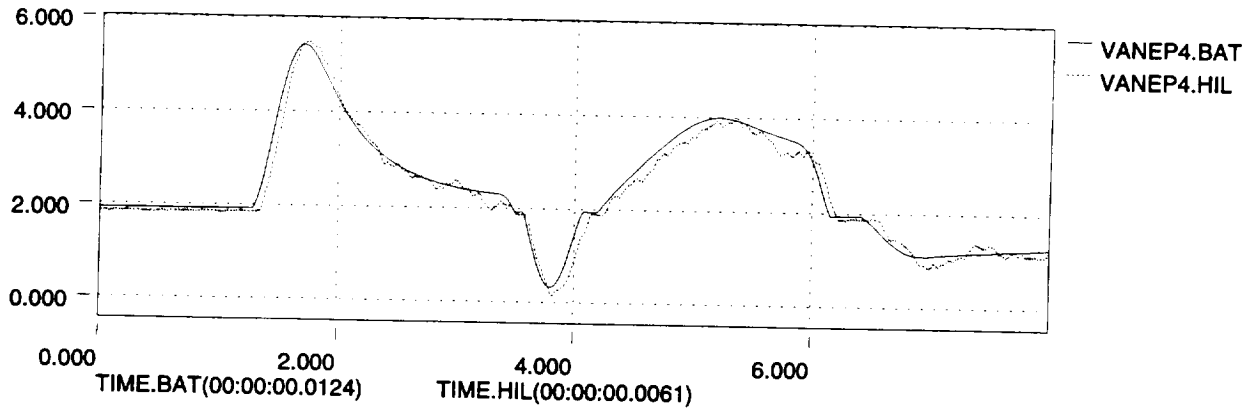

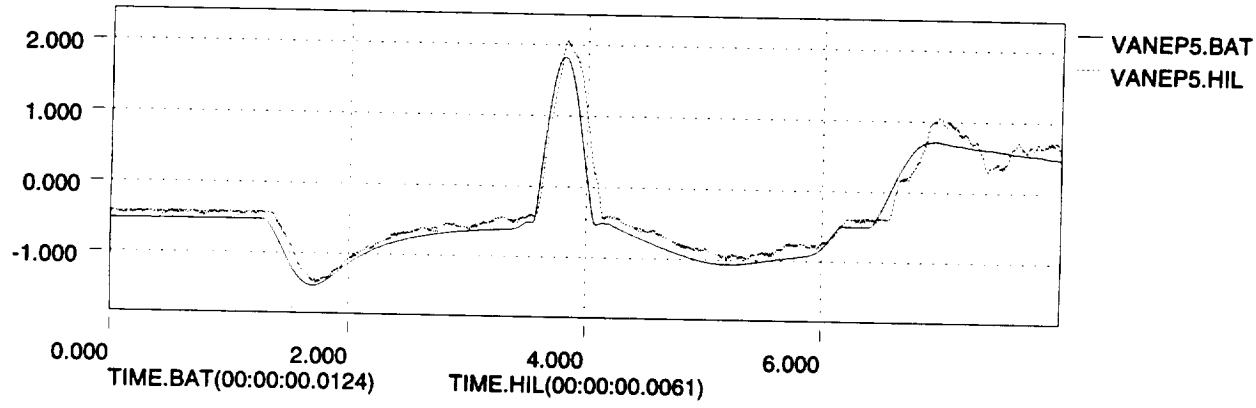

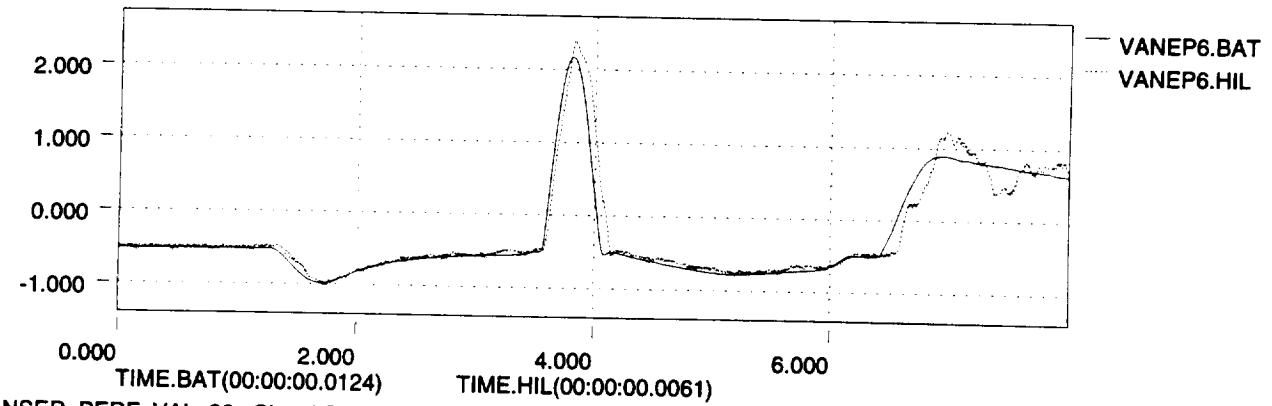

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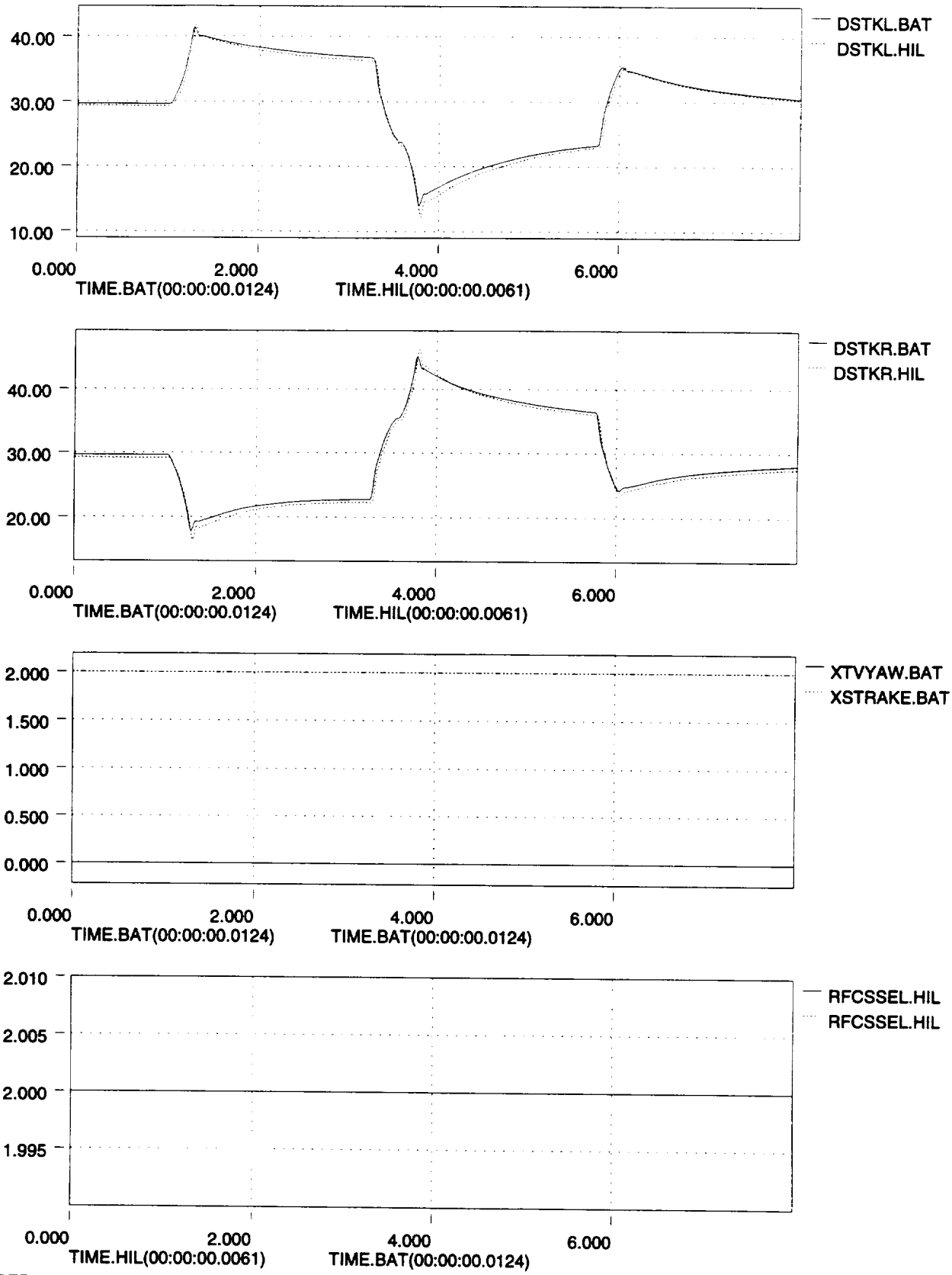

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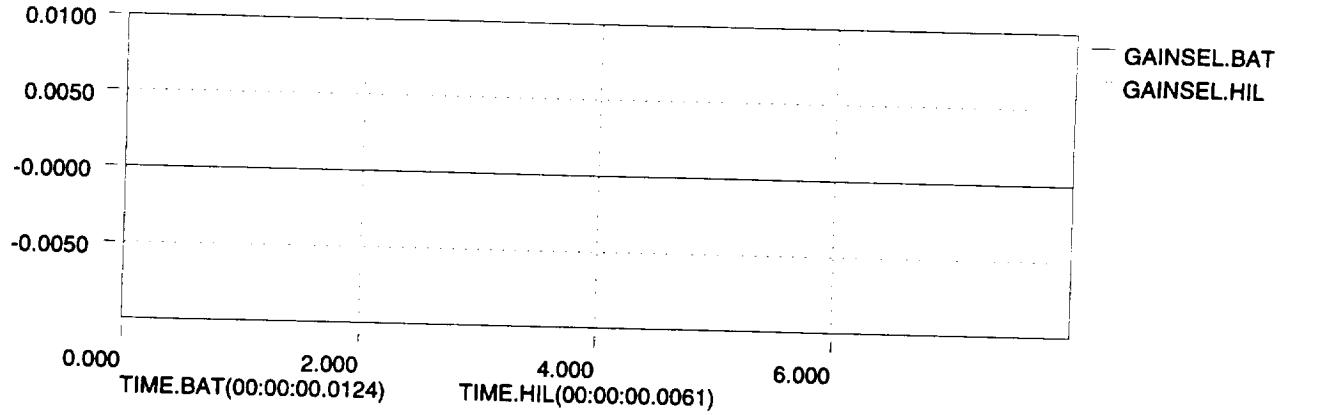

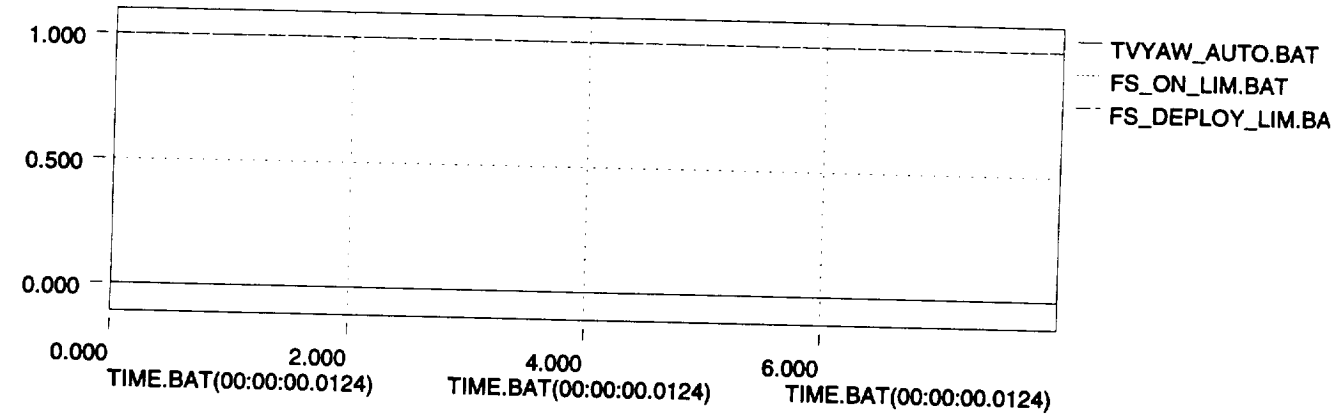

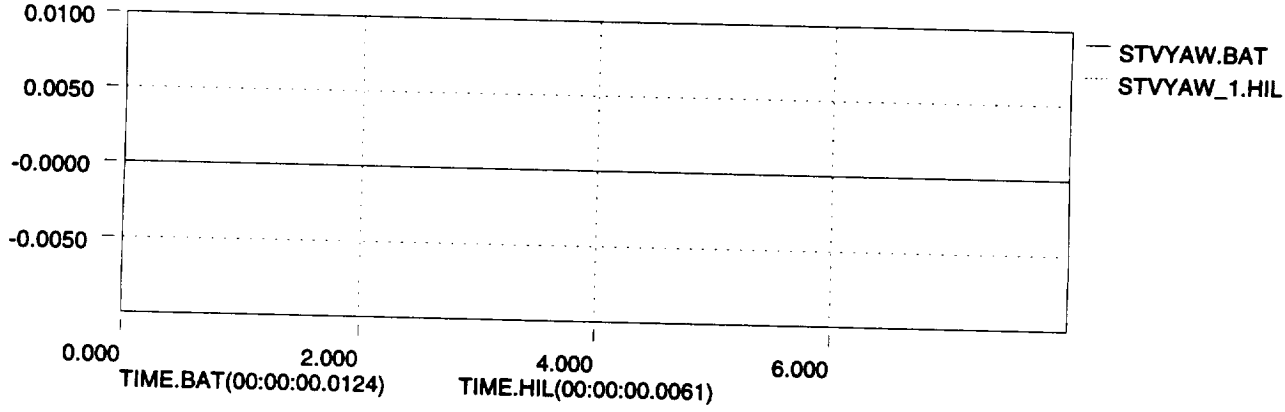

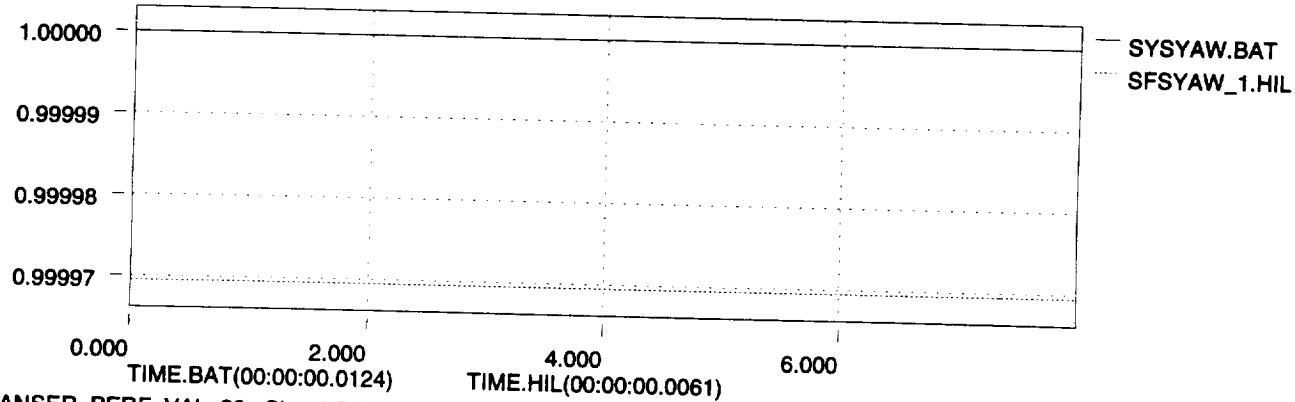

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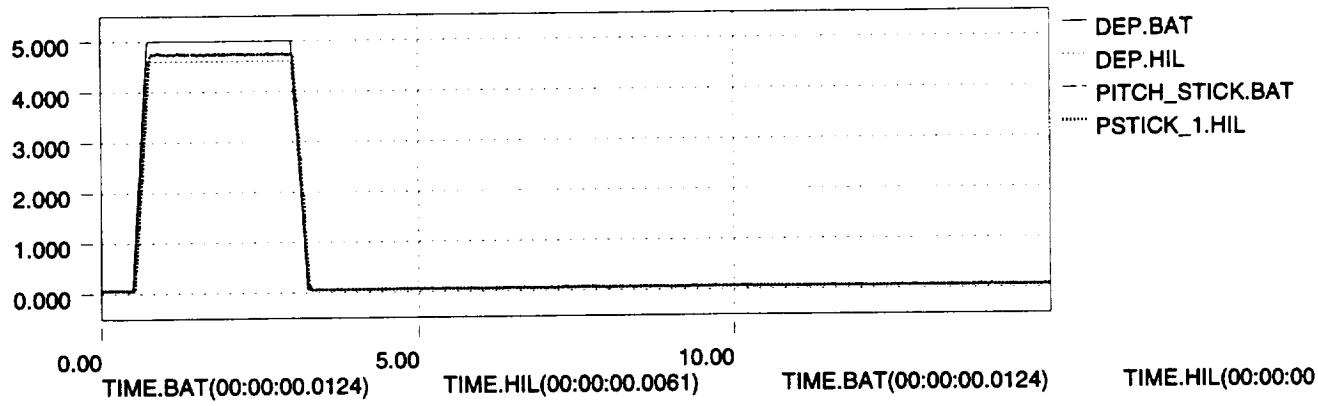
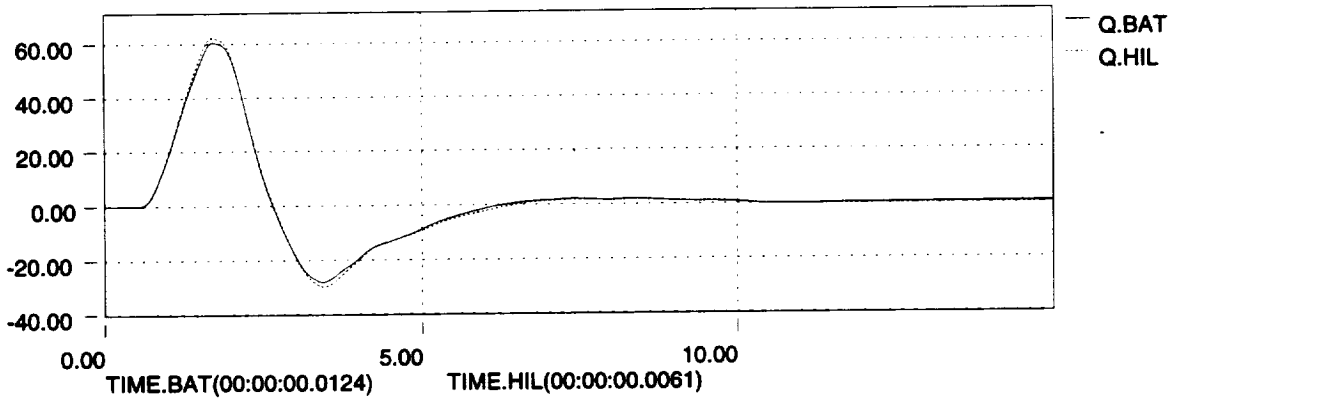
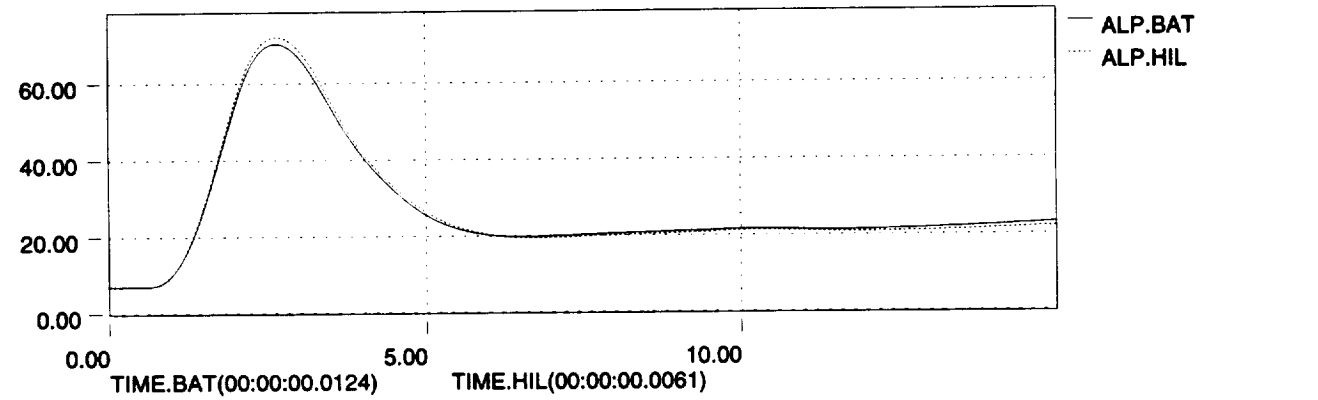
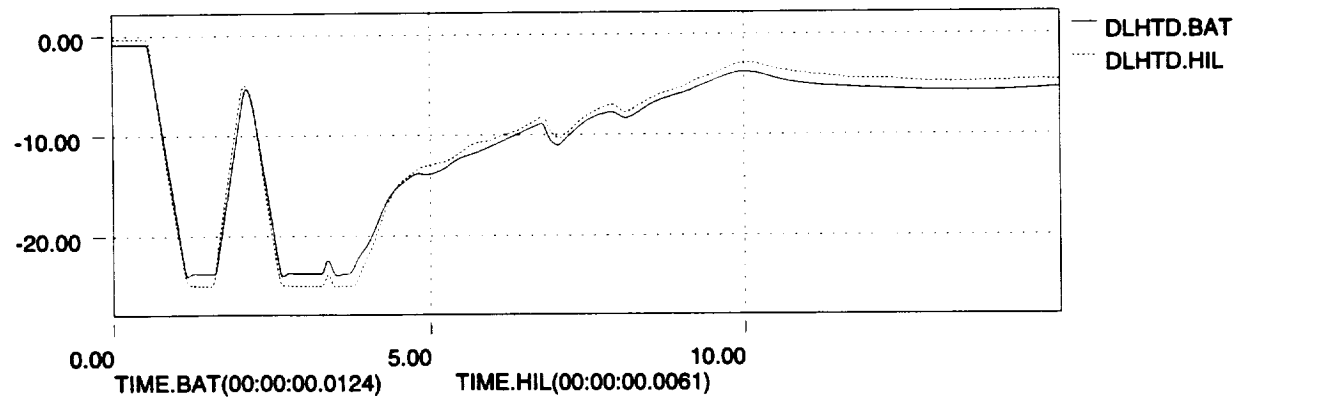
Performance Validation Checkcases Batch versus HIL Version 152
CASE_30__S_Mode__.68-40k_trim--3_axis_input page 1/12









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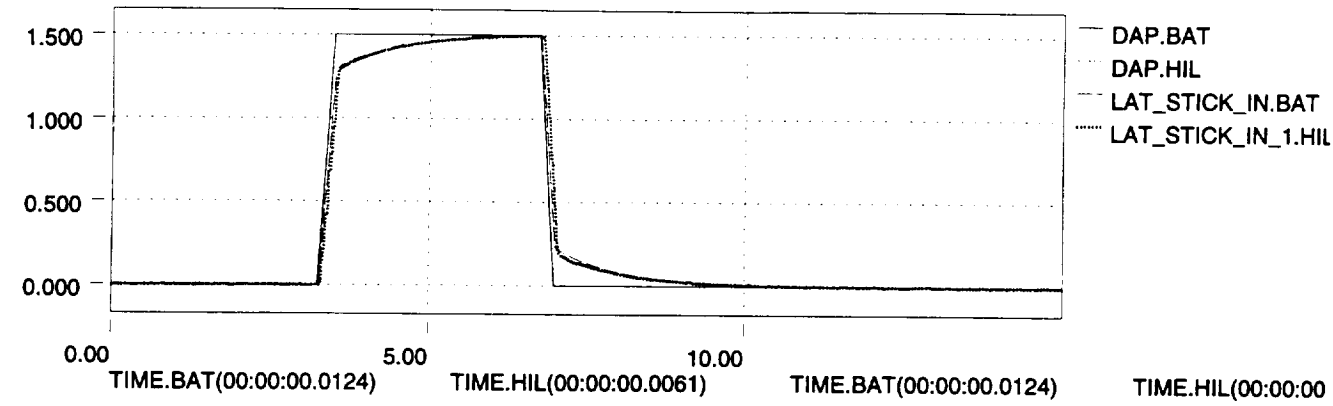

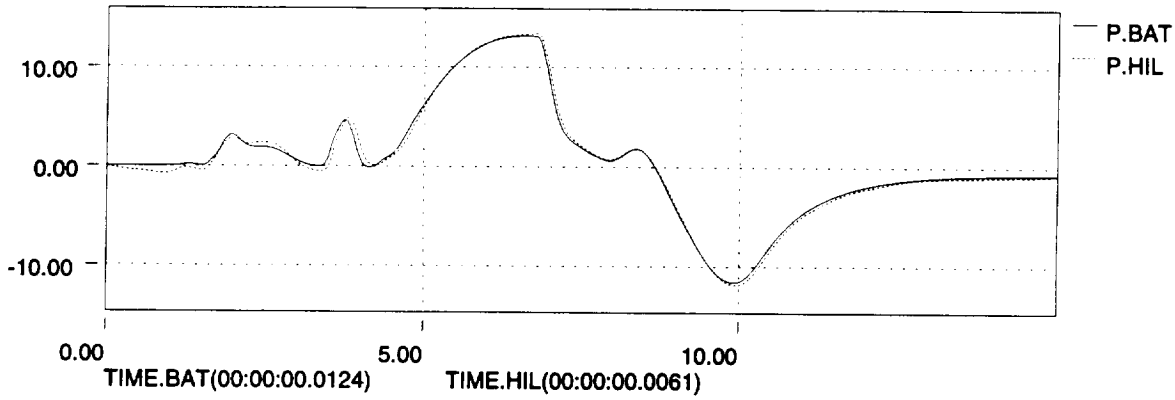

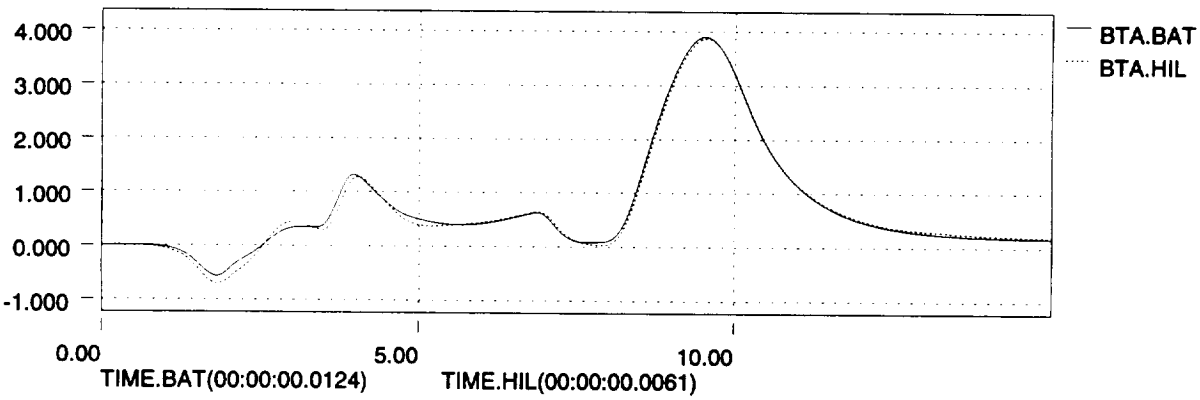

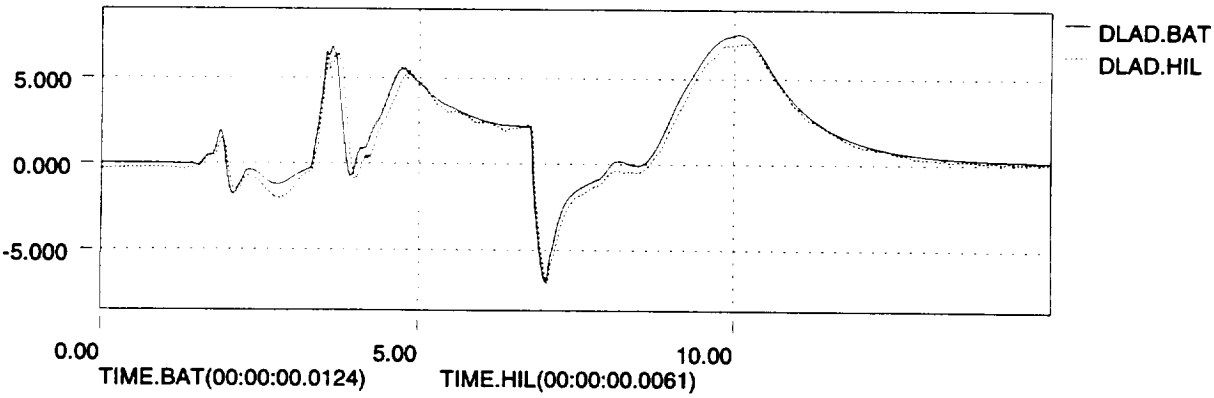

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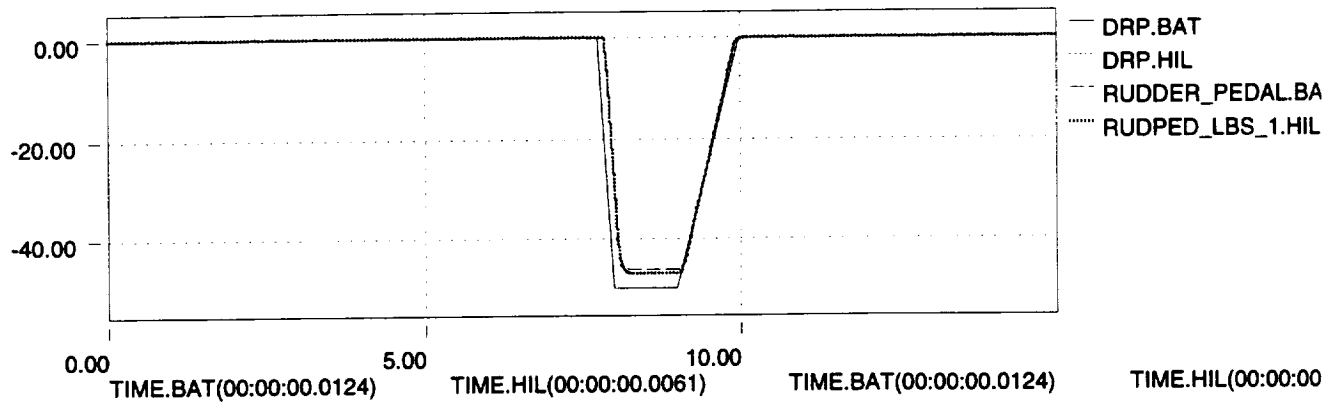

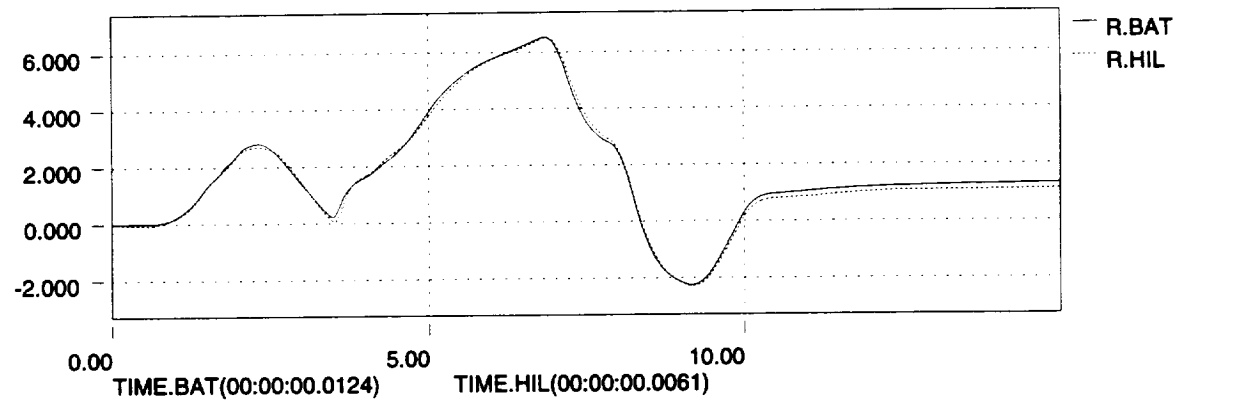

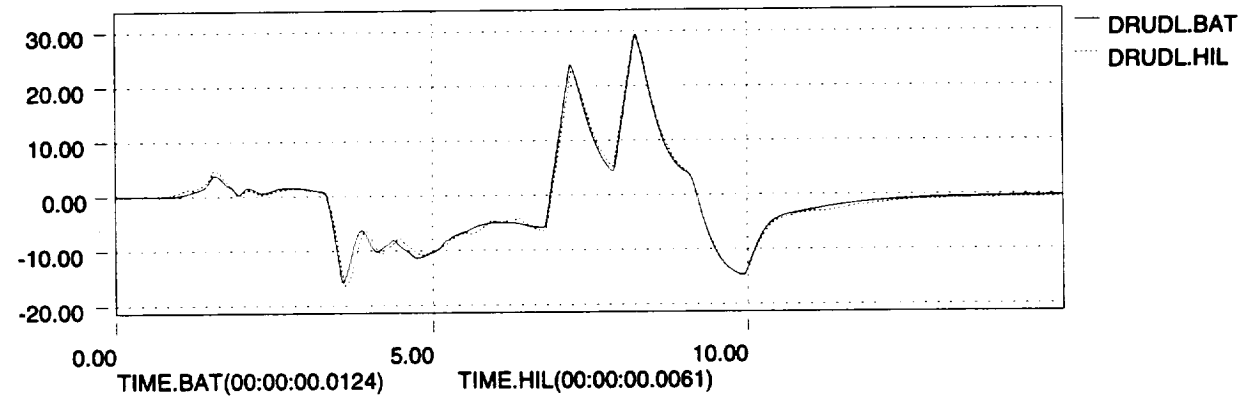

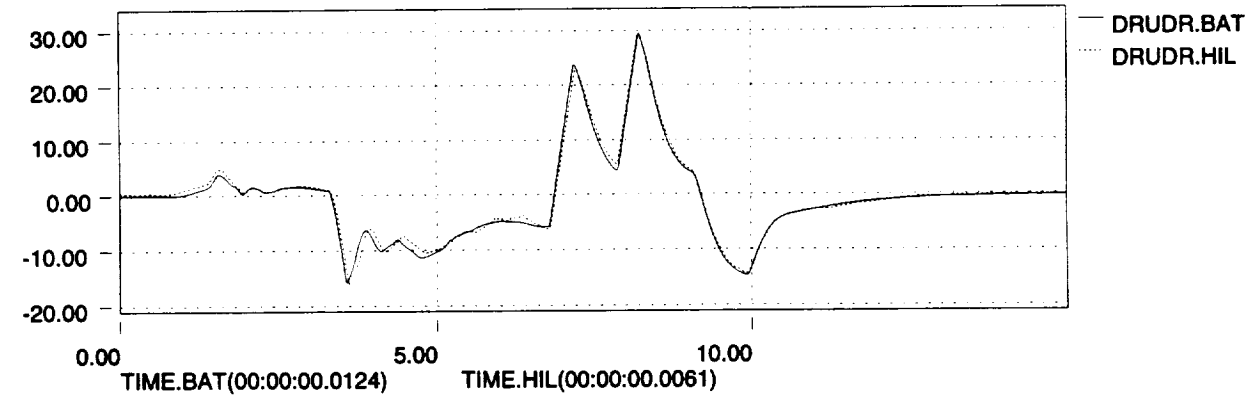

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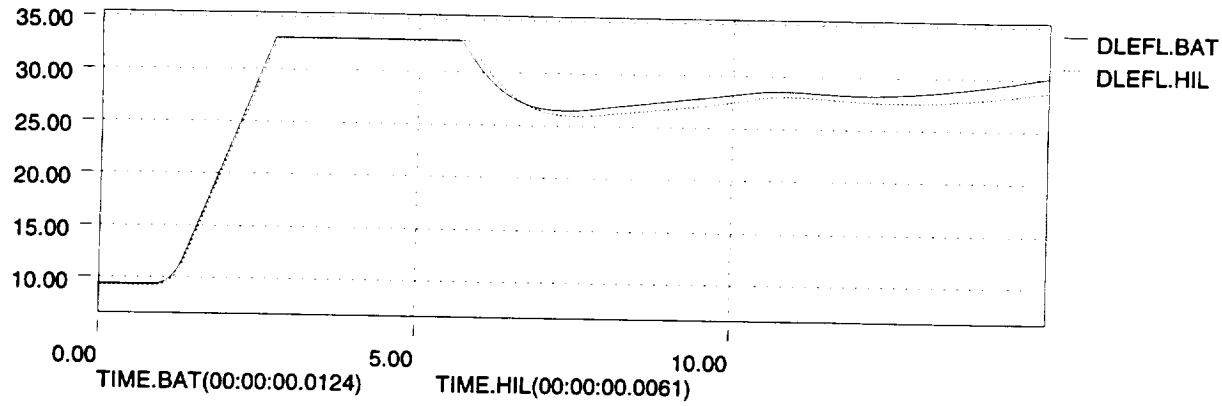

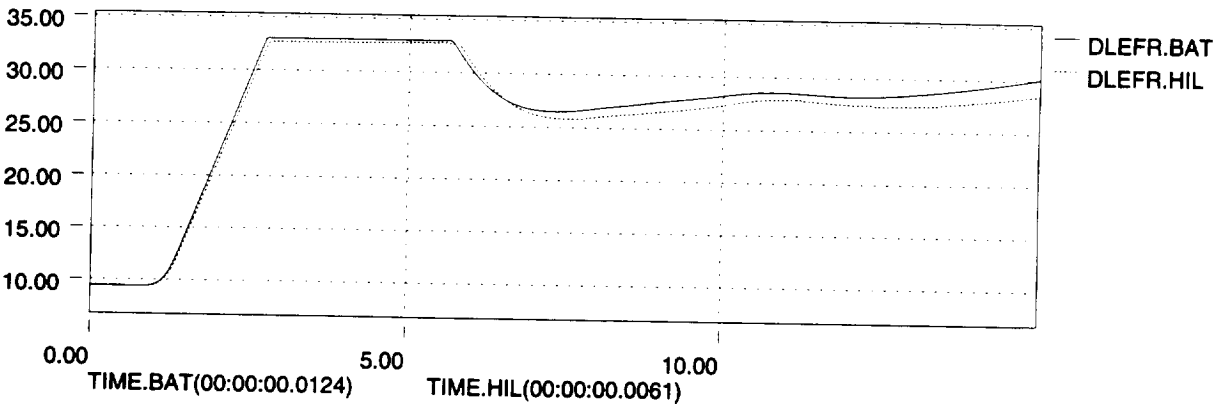

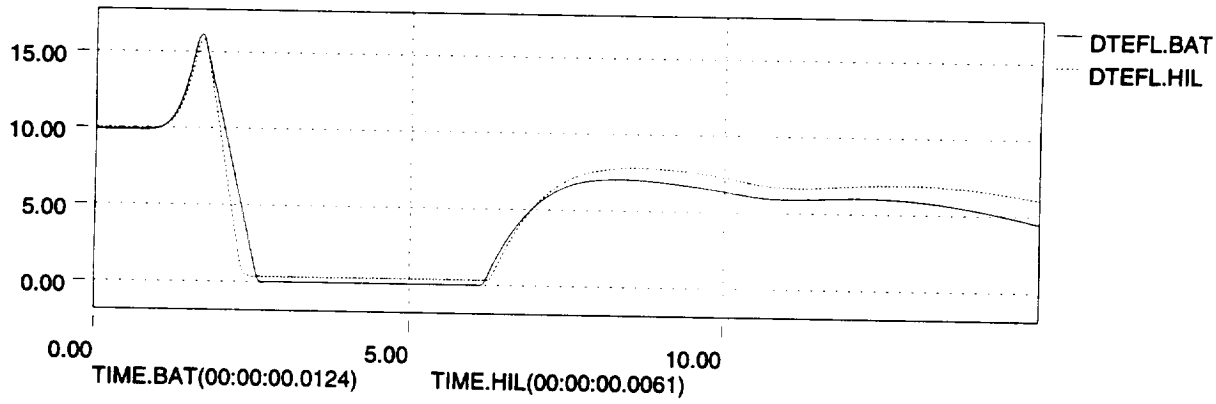

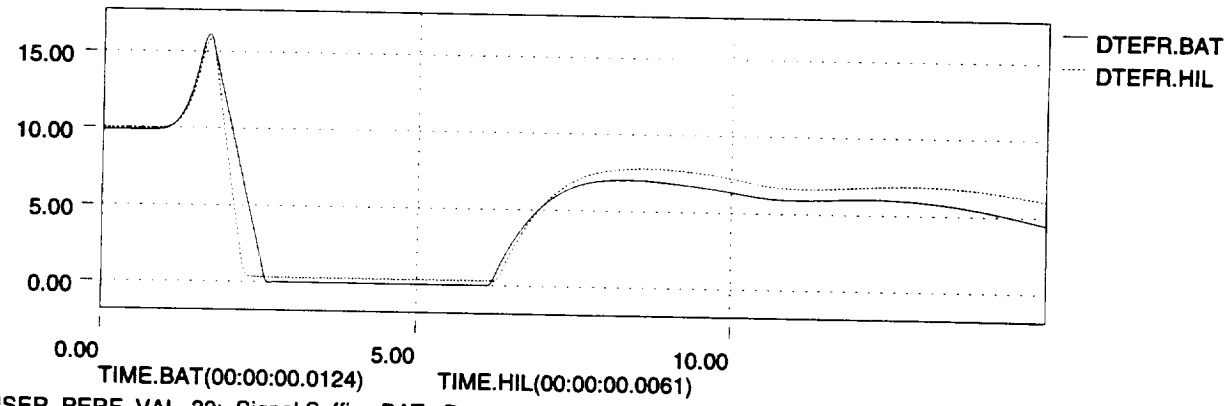

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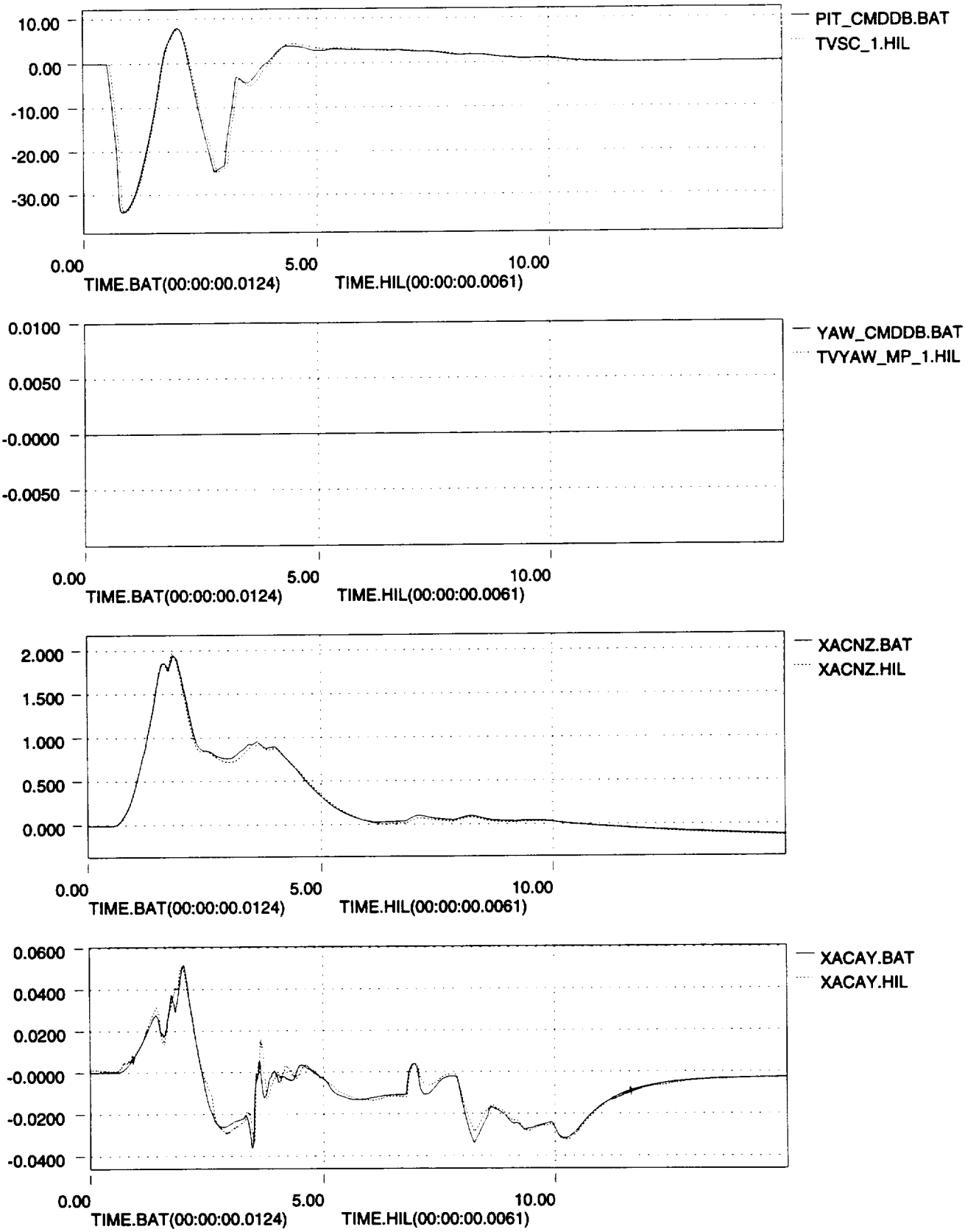

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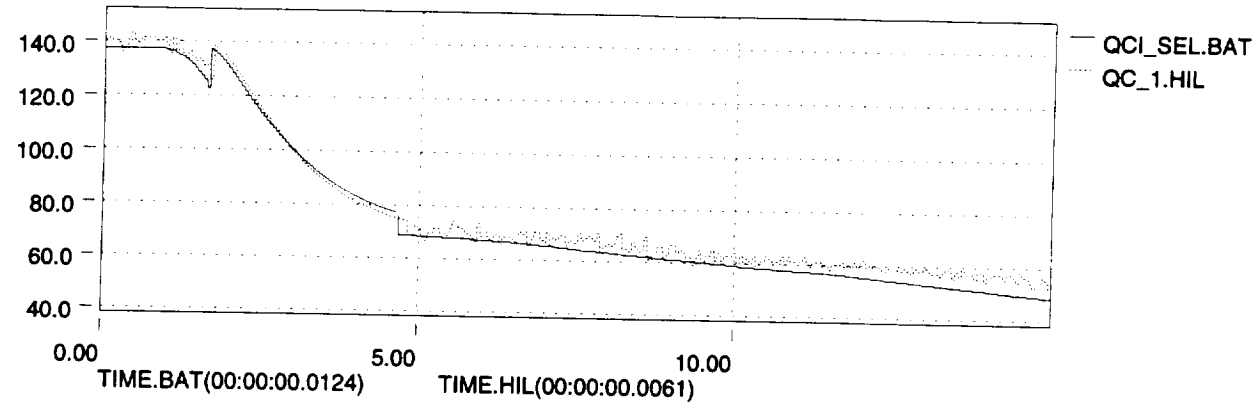

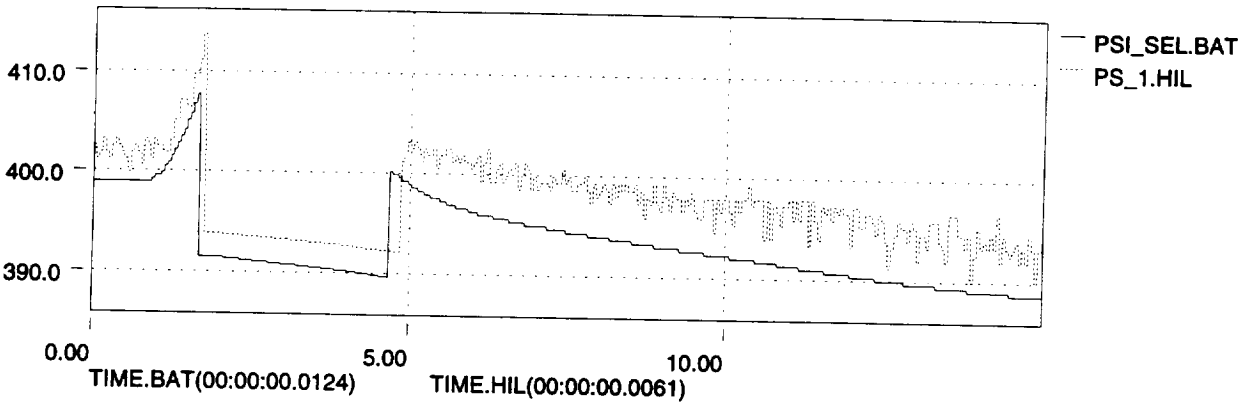

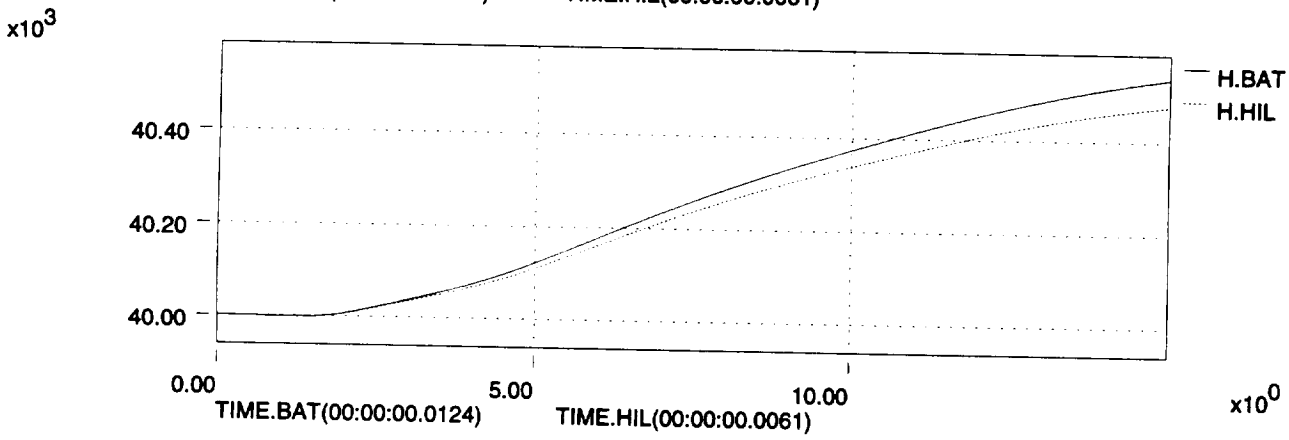

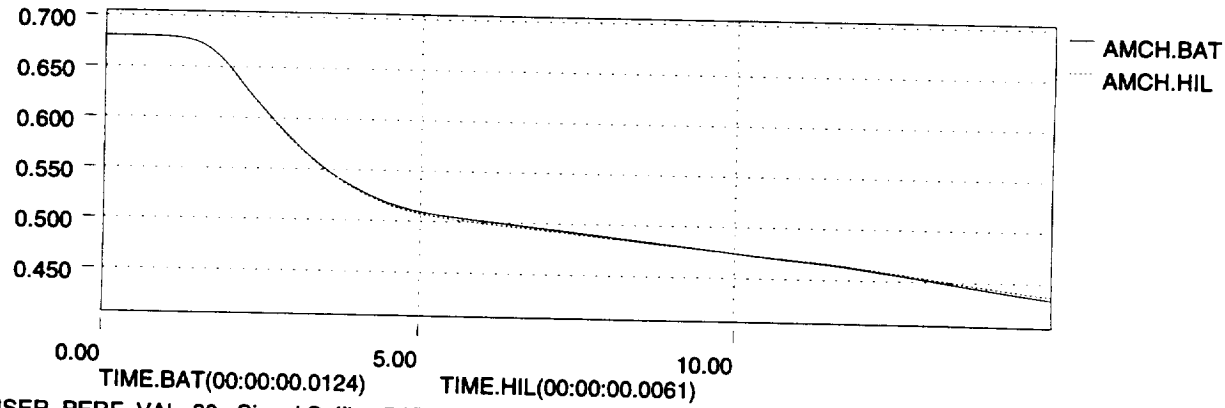

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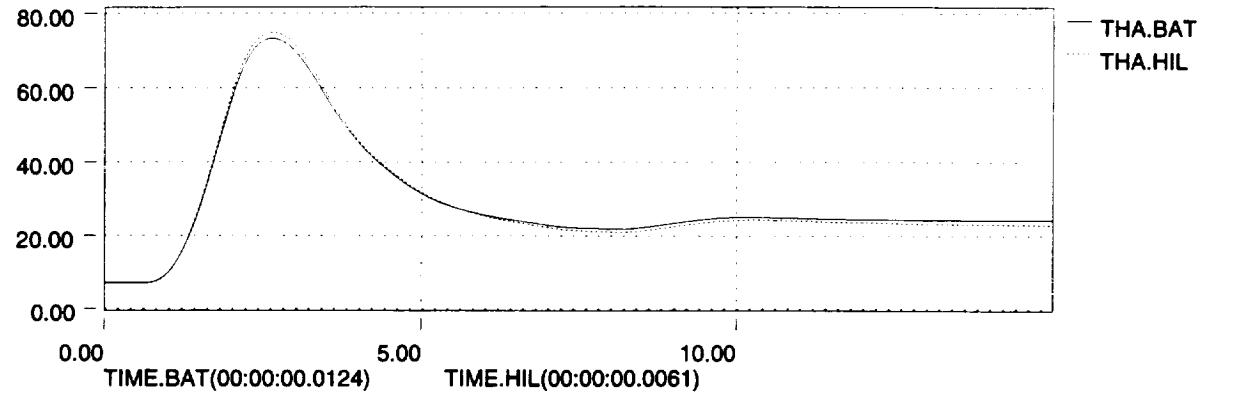

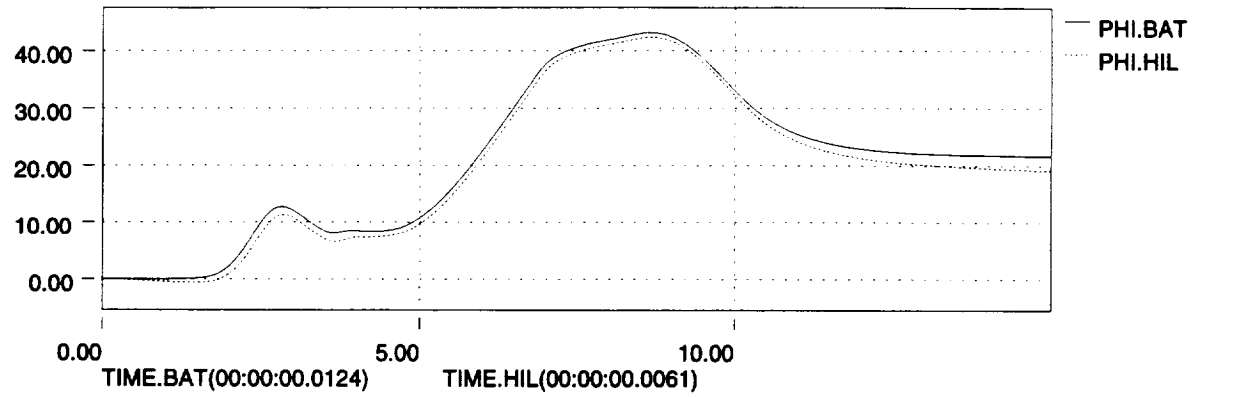

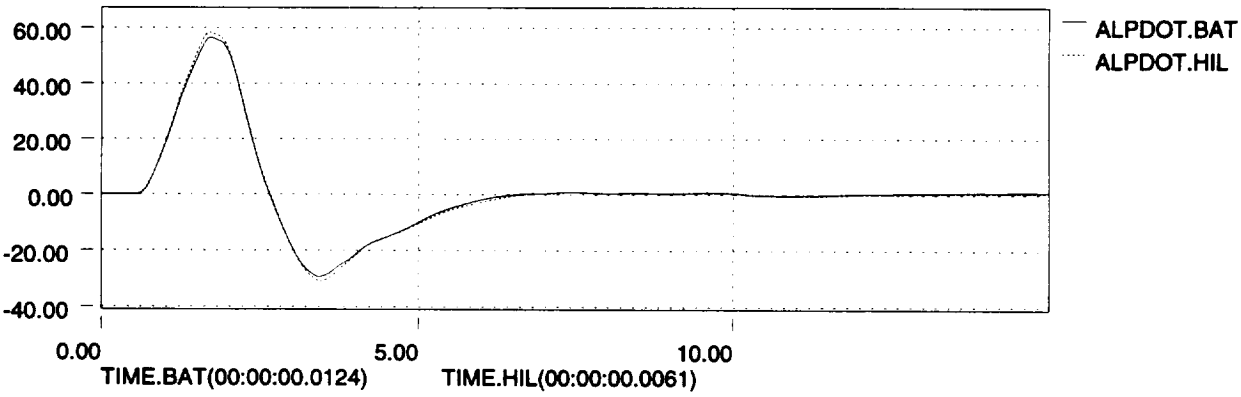

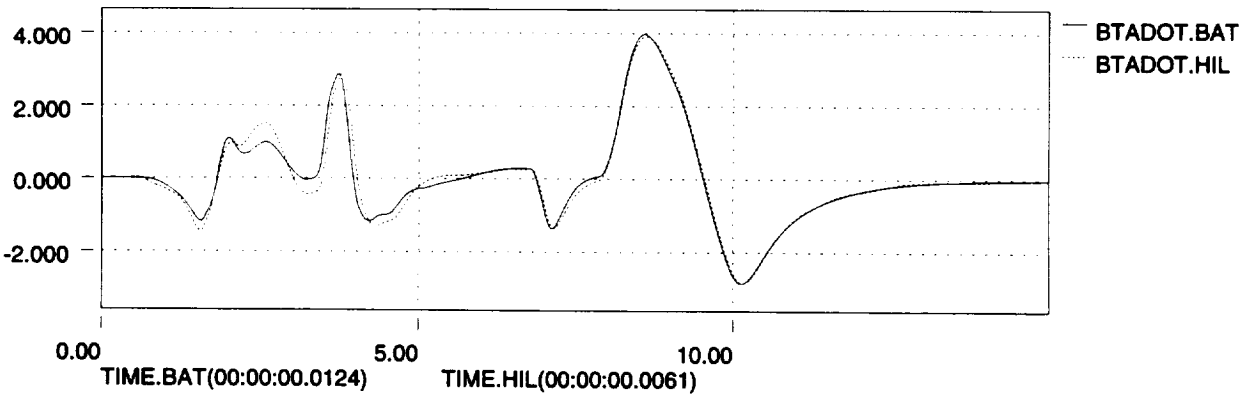

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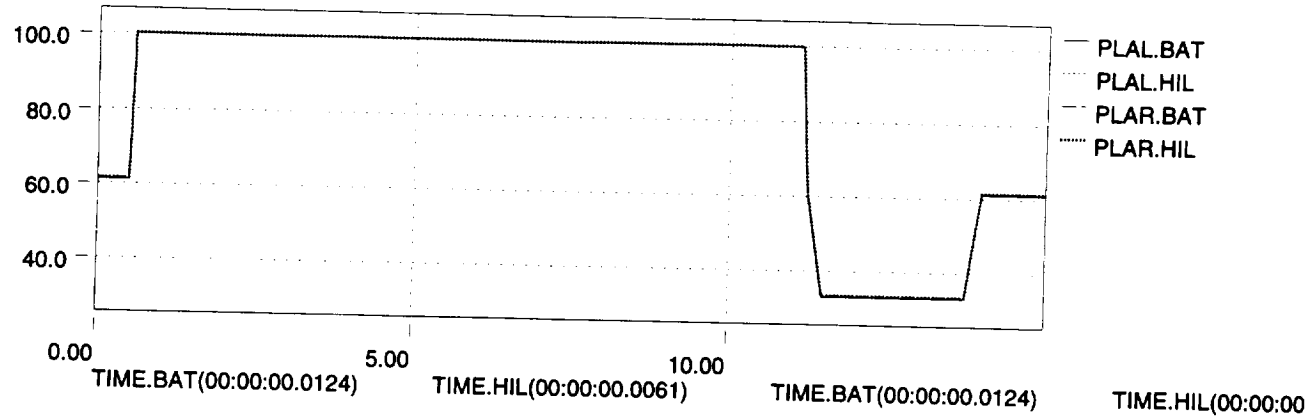

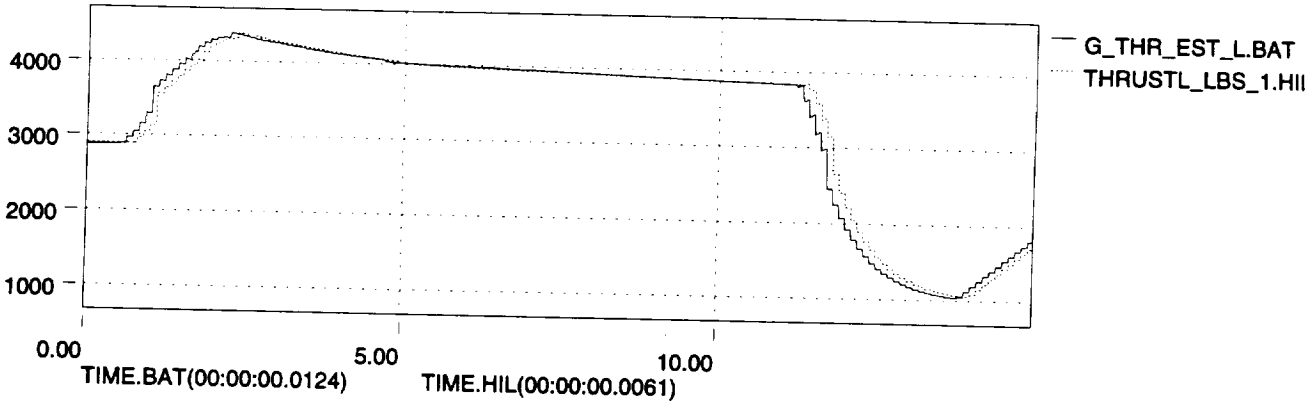

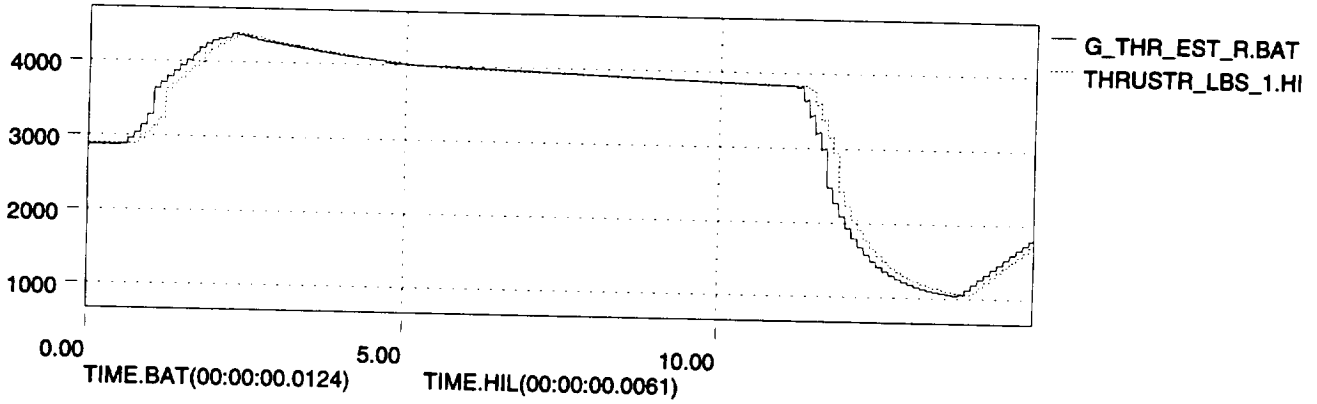

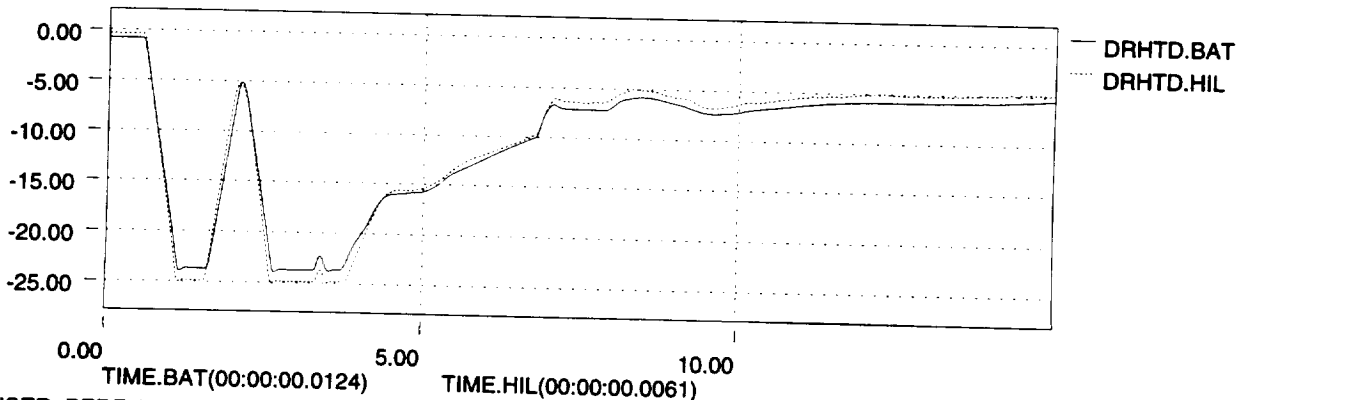

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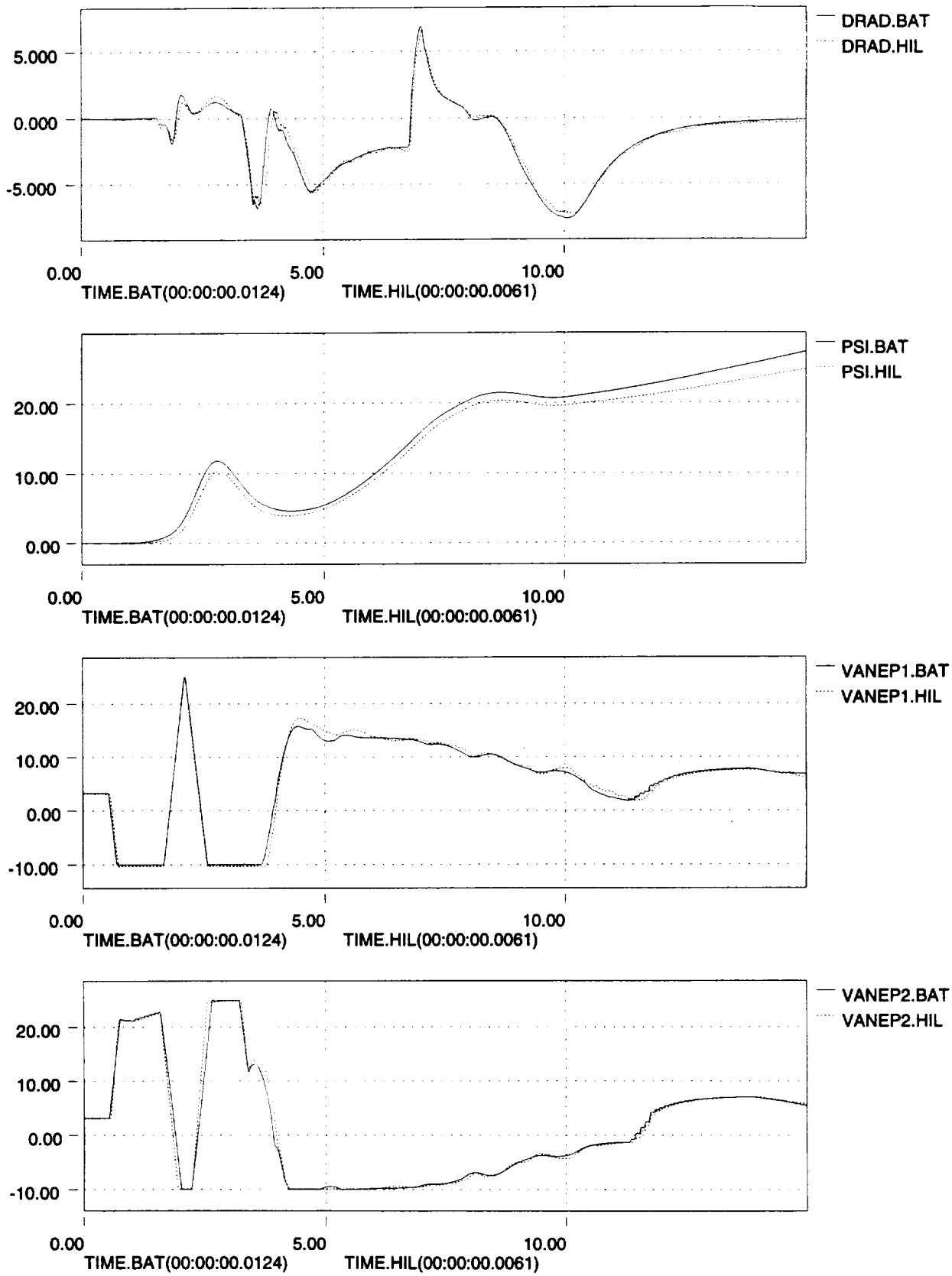

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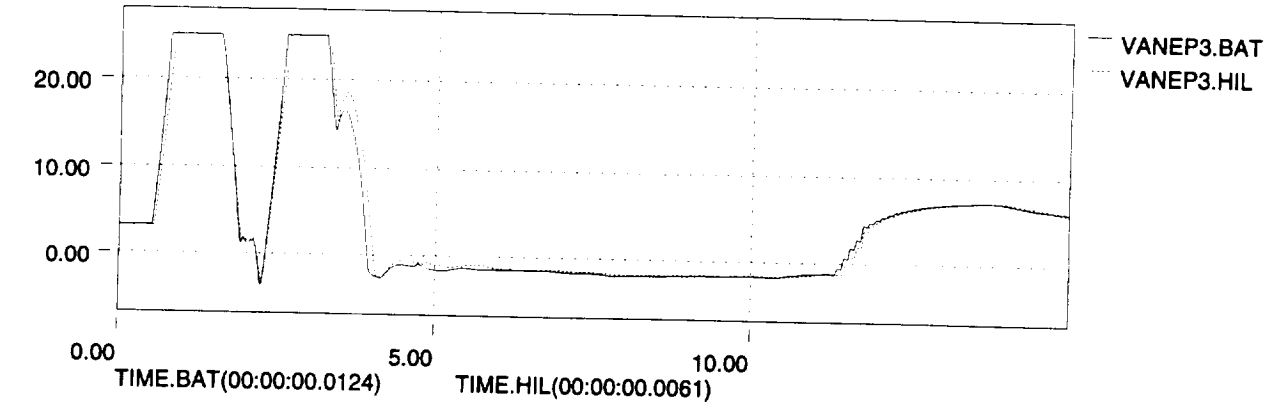

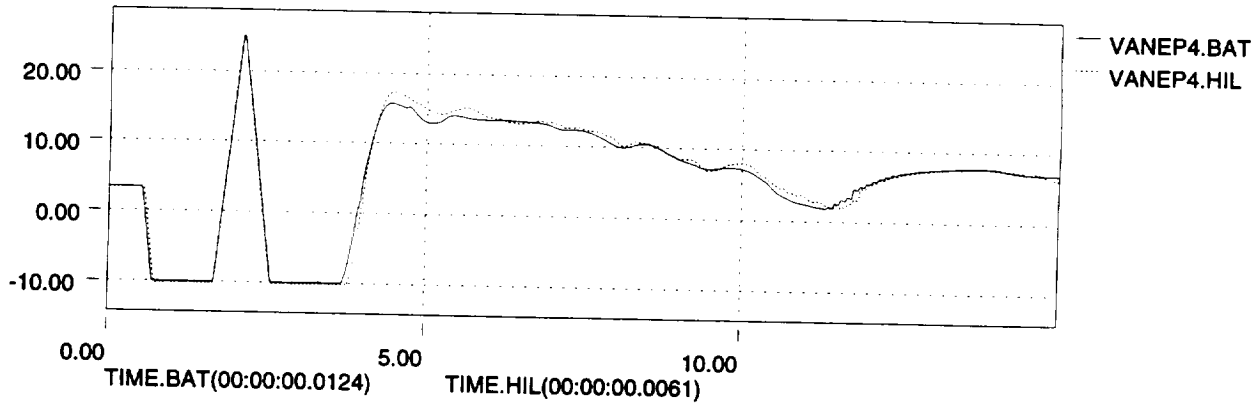

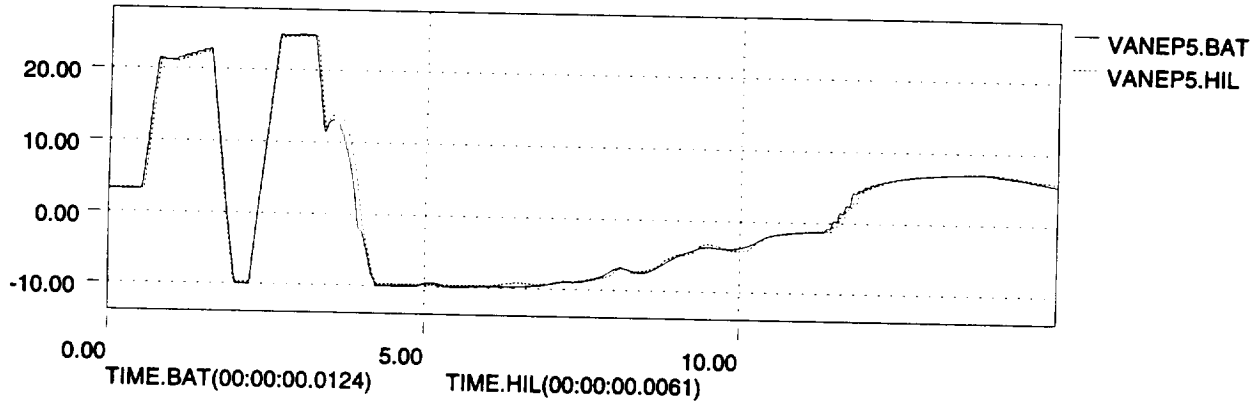

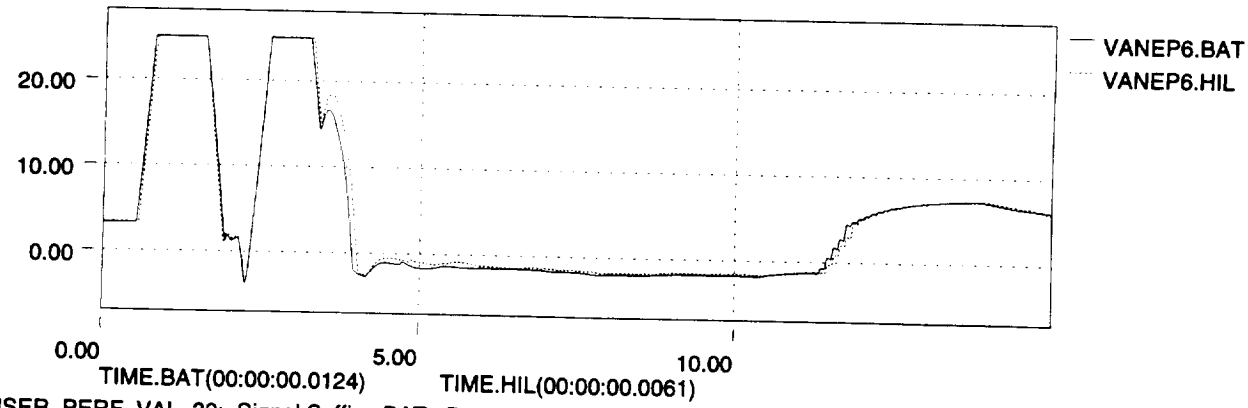

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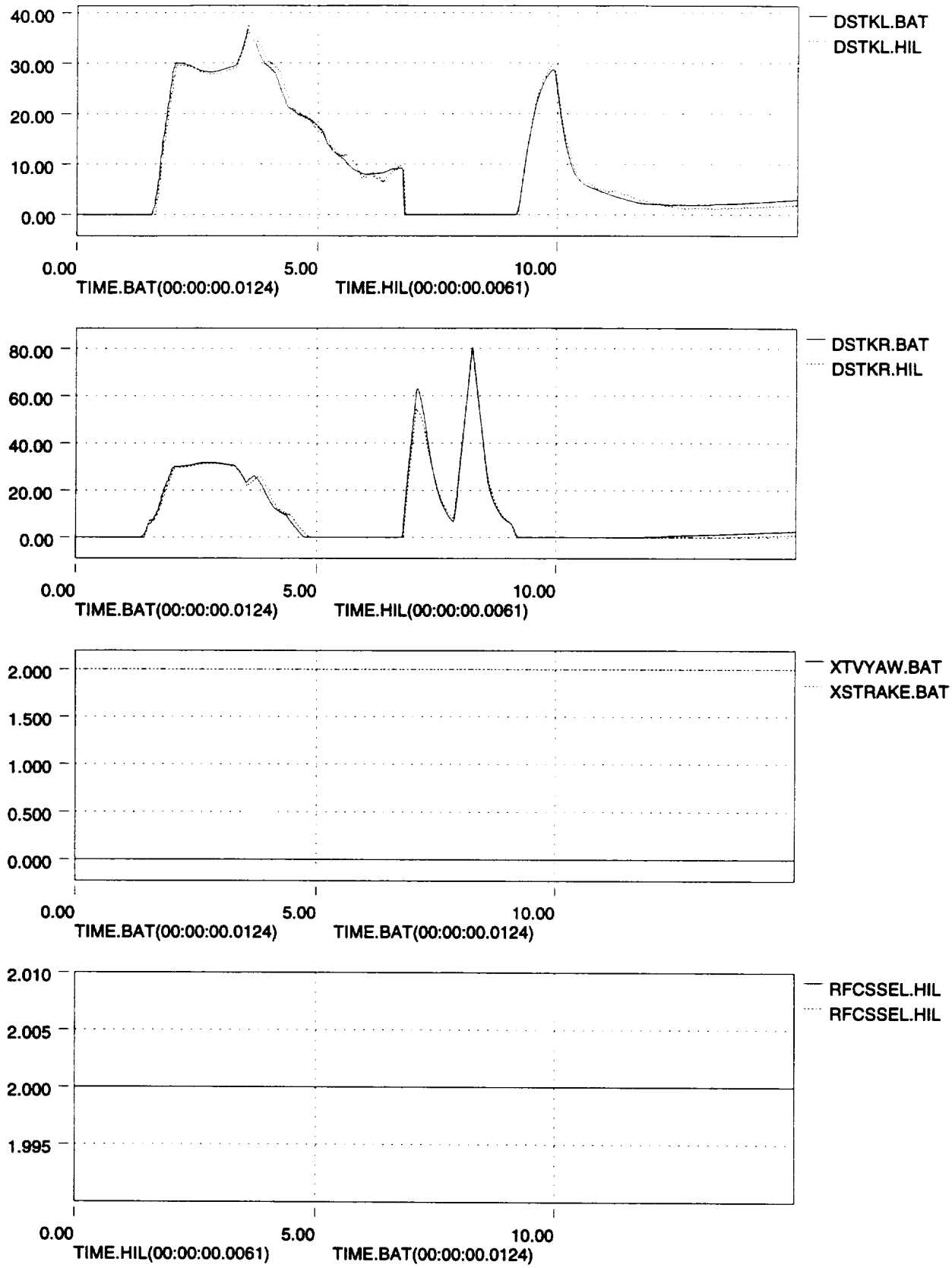

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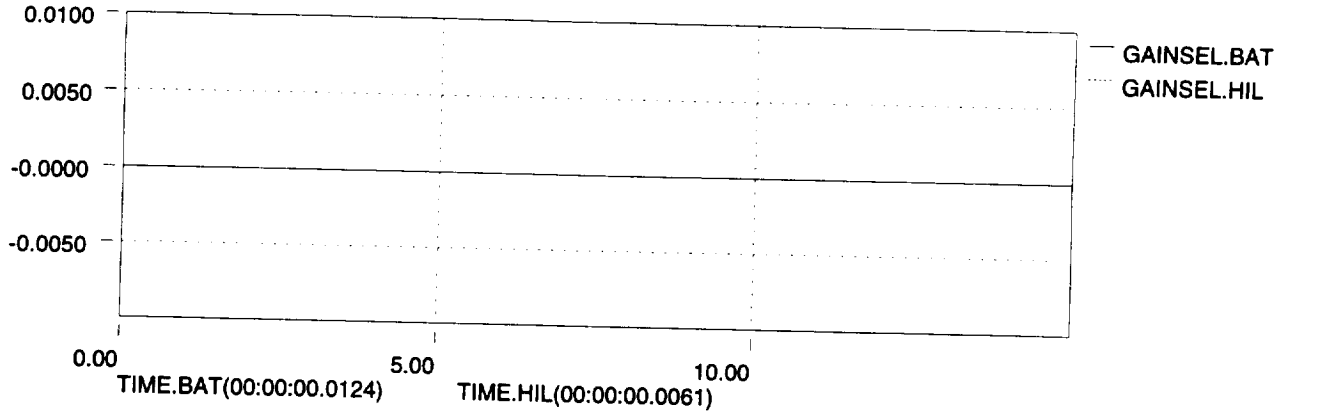

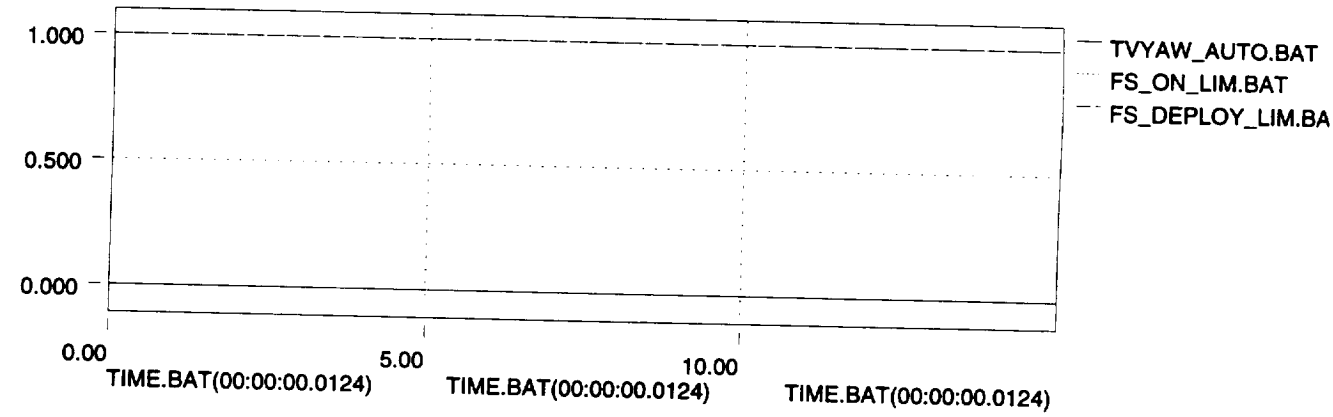

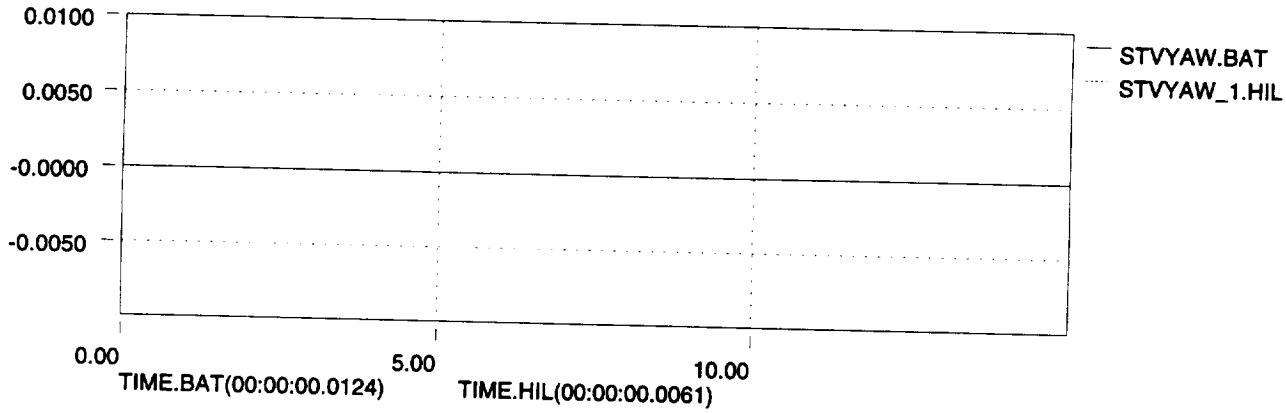

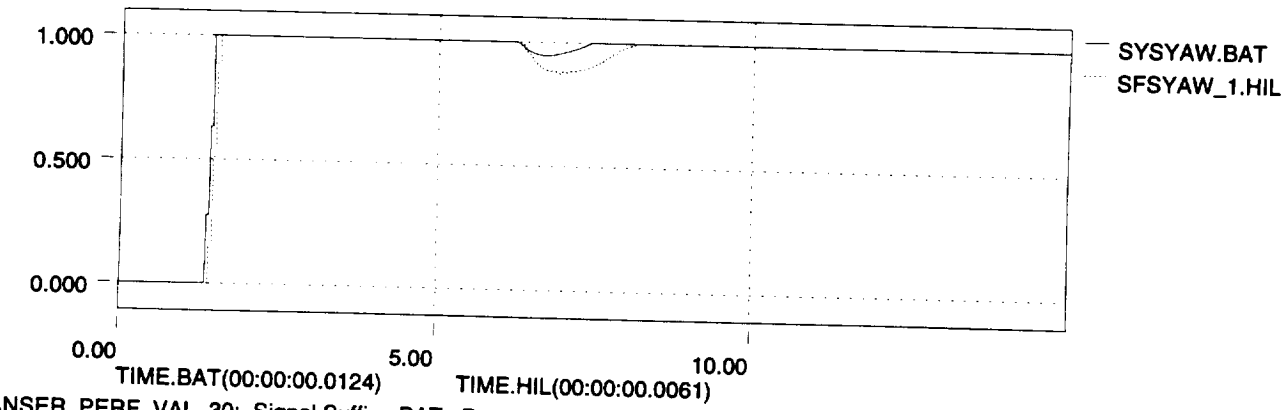

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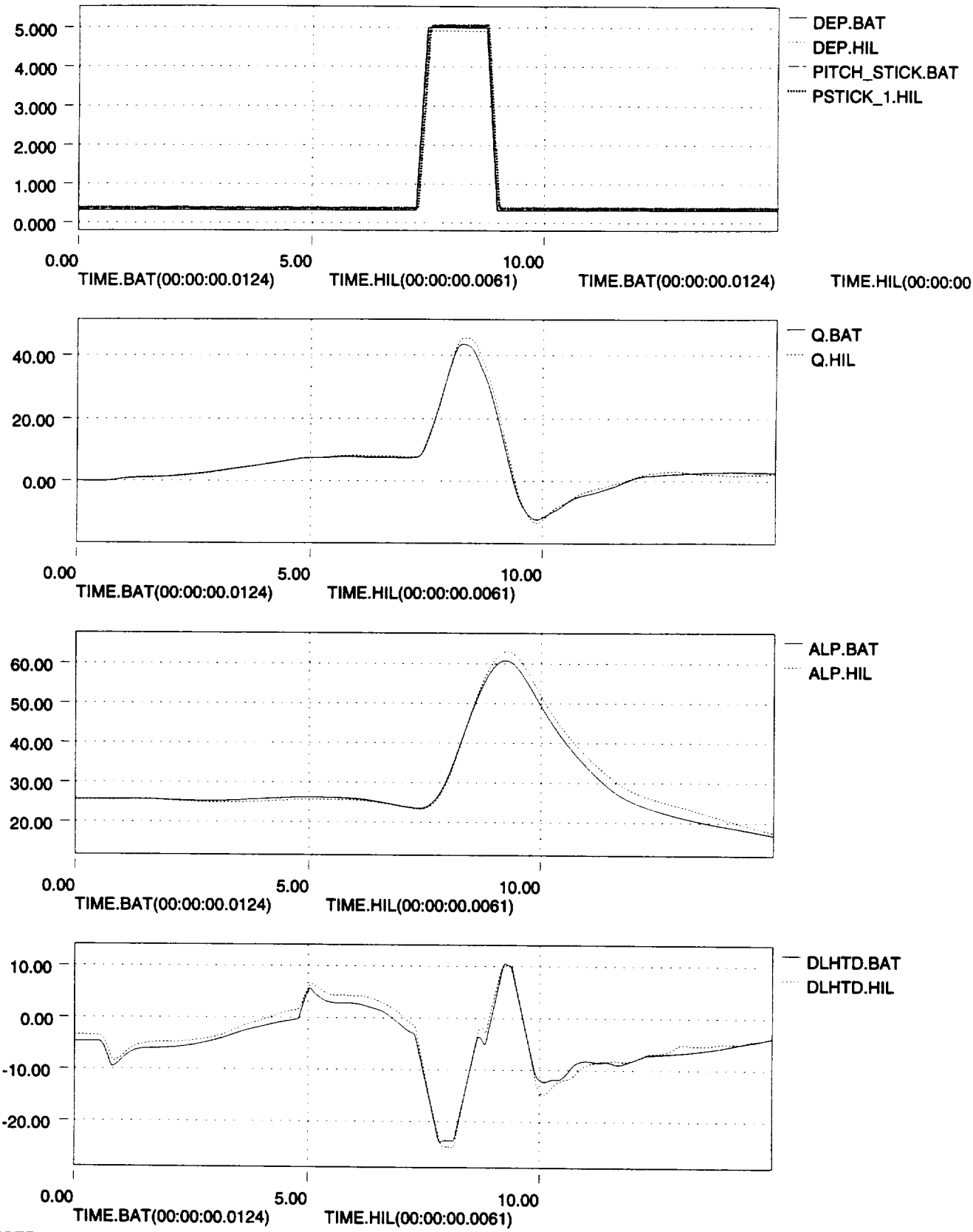

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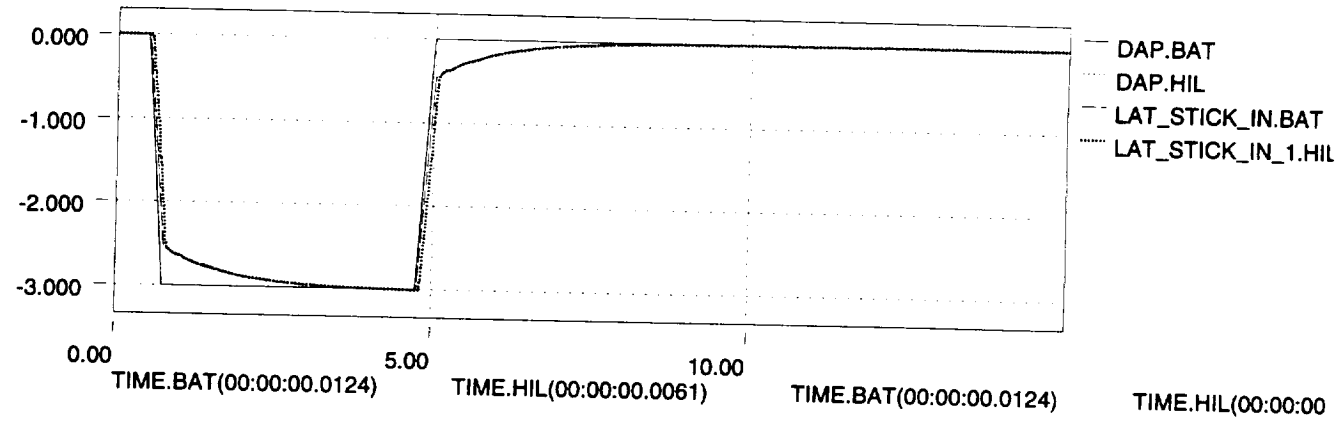

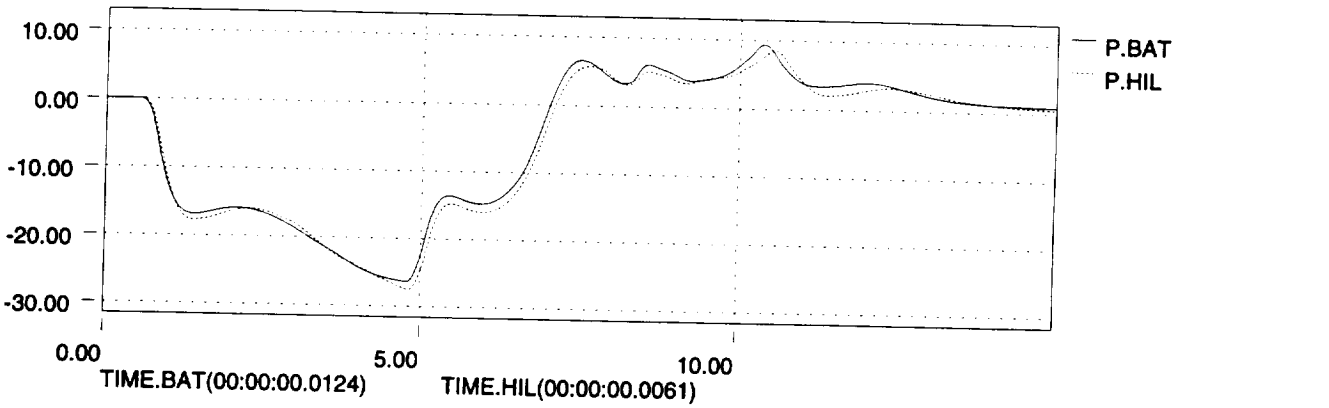

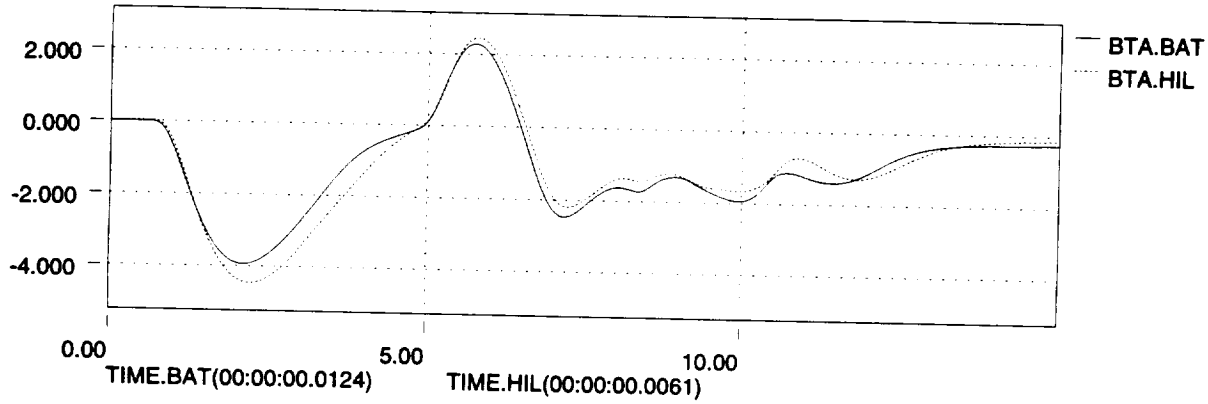

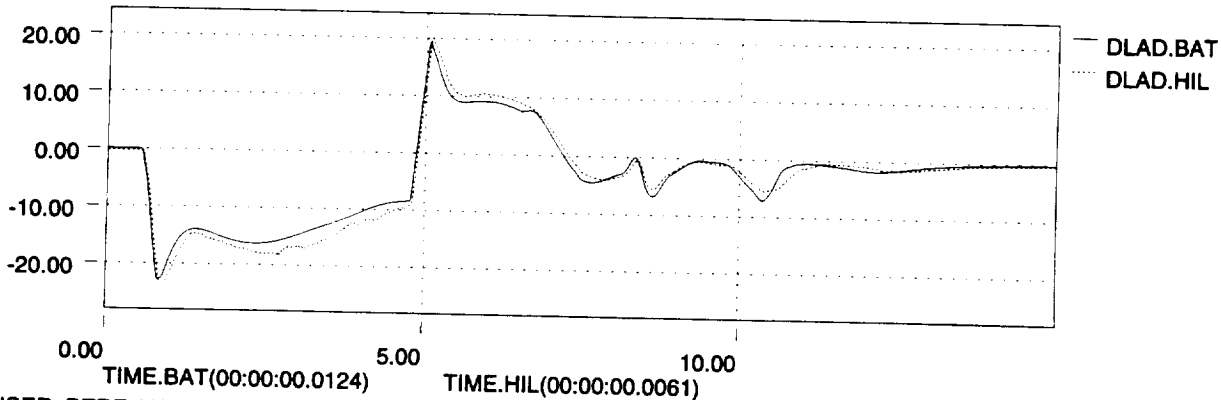

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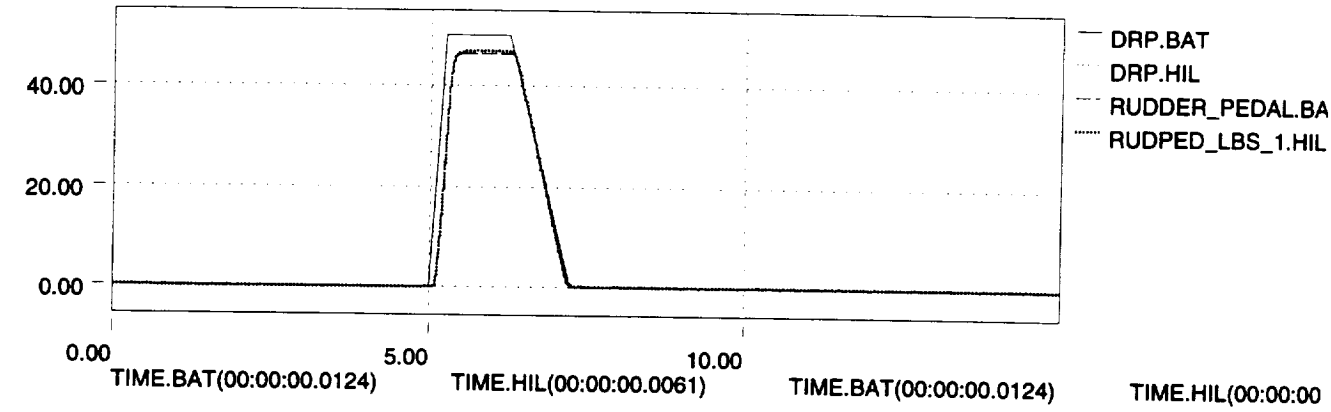

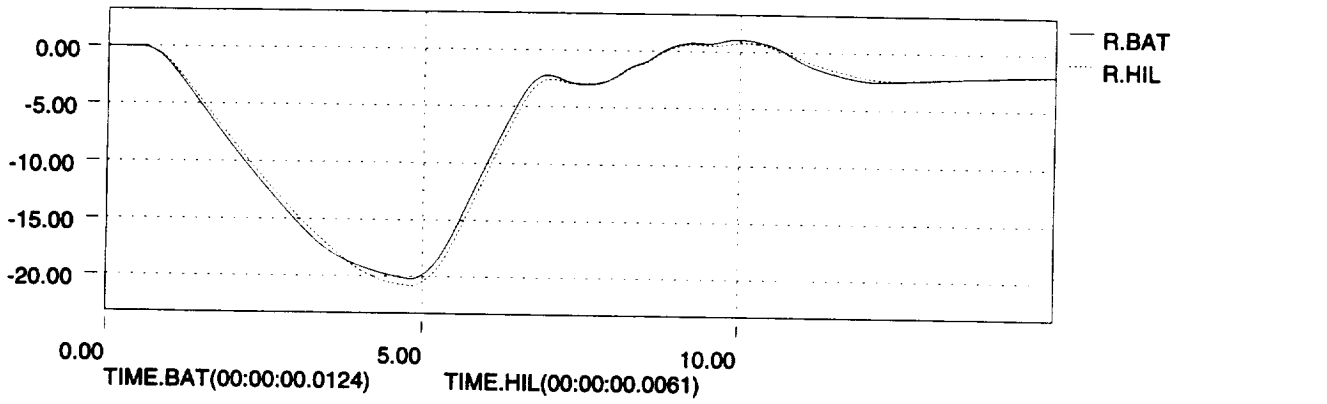

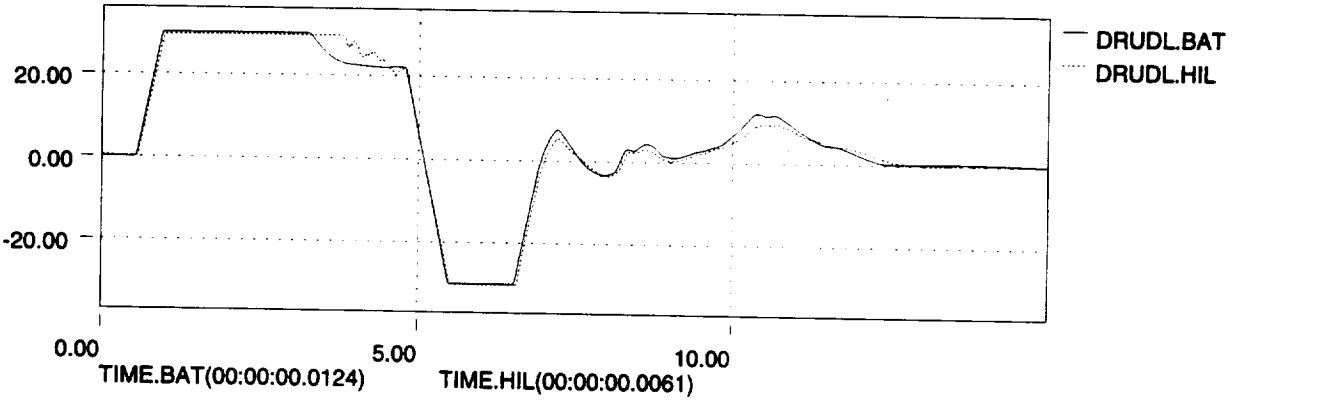

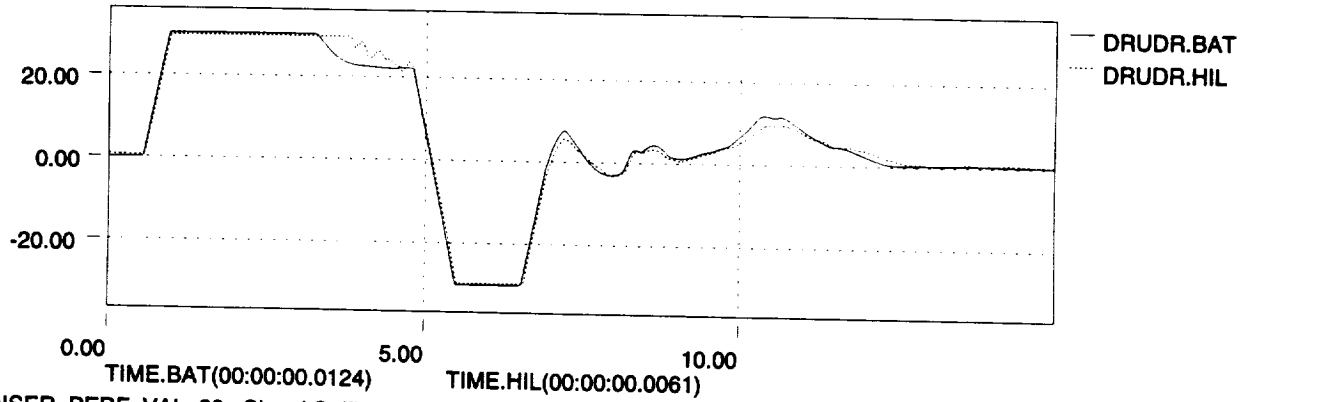

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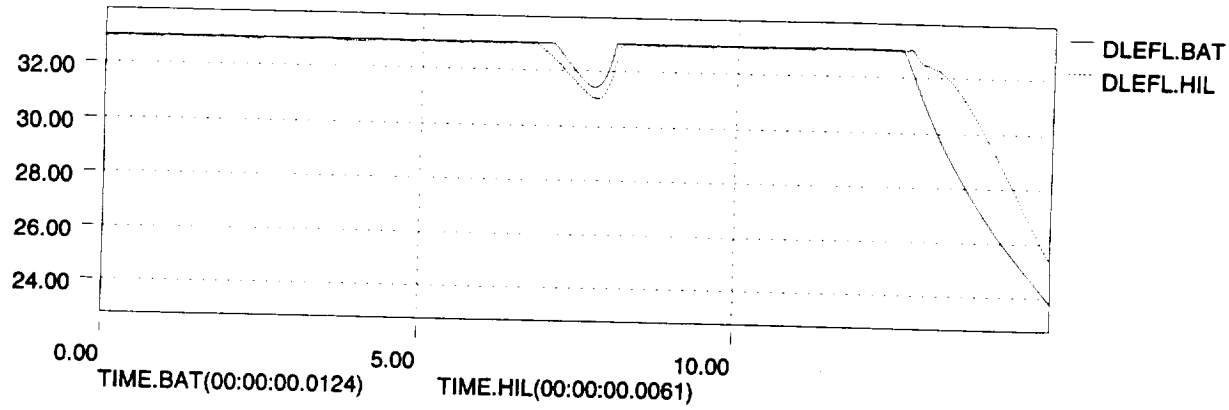

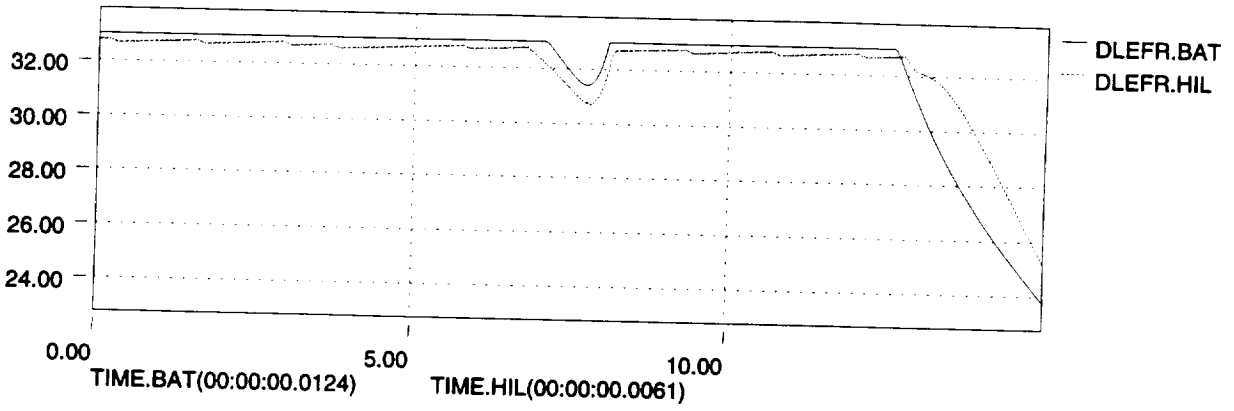

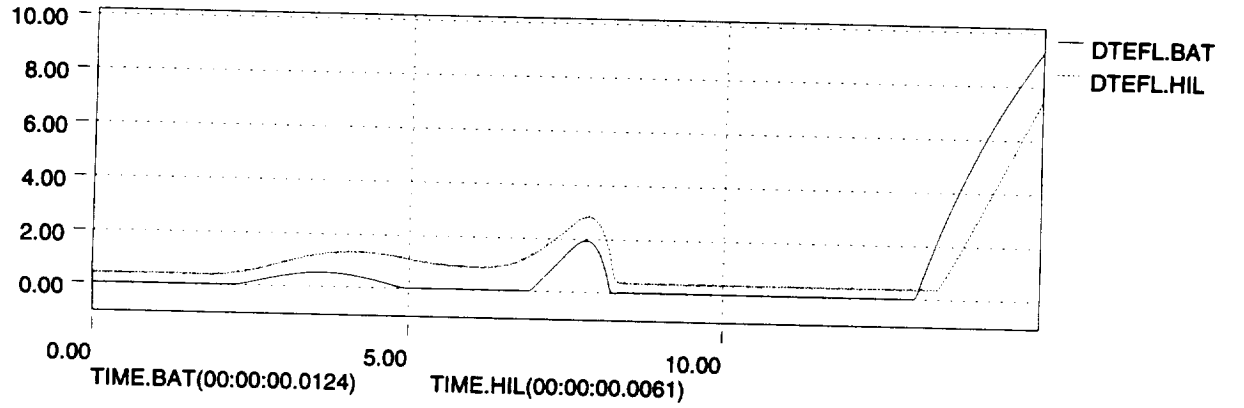

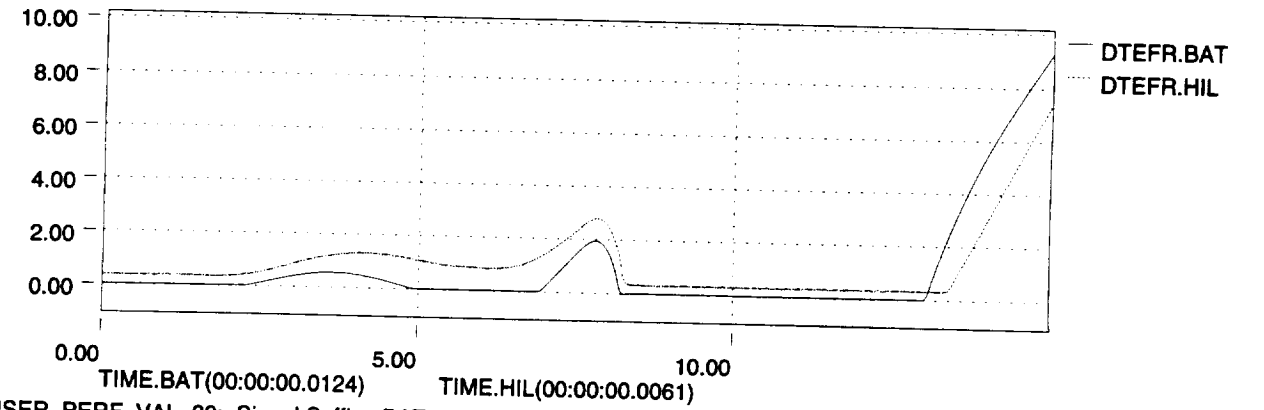

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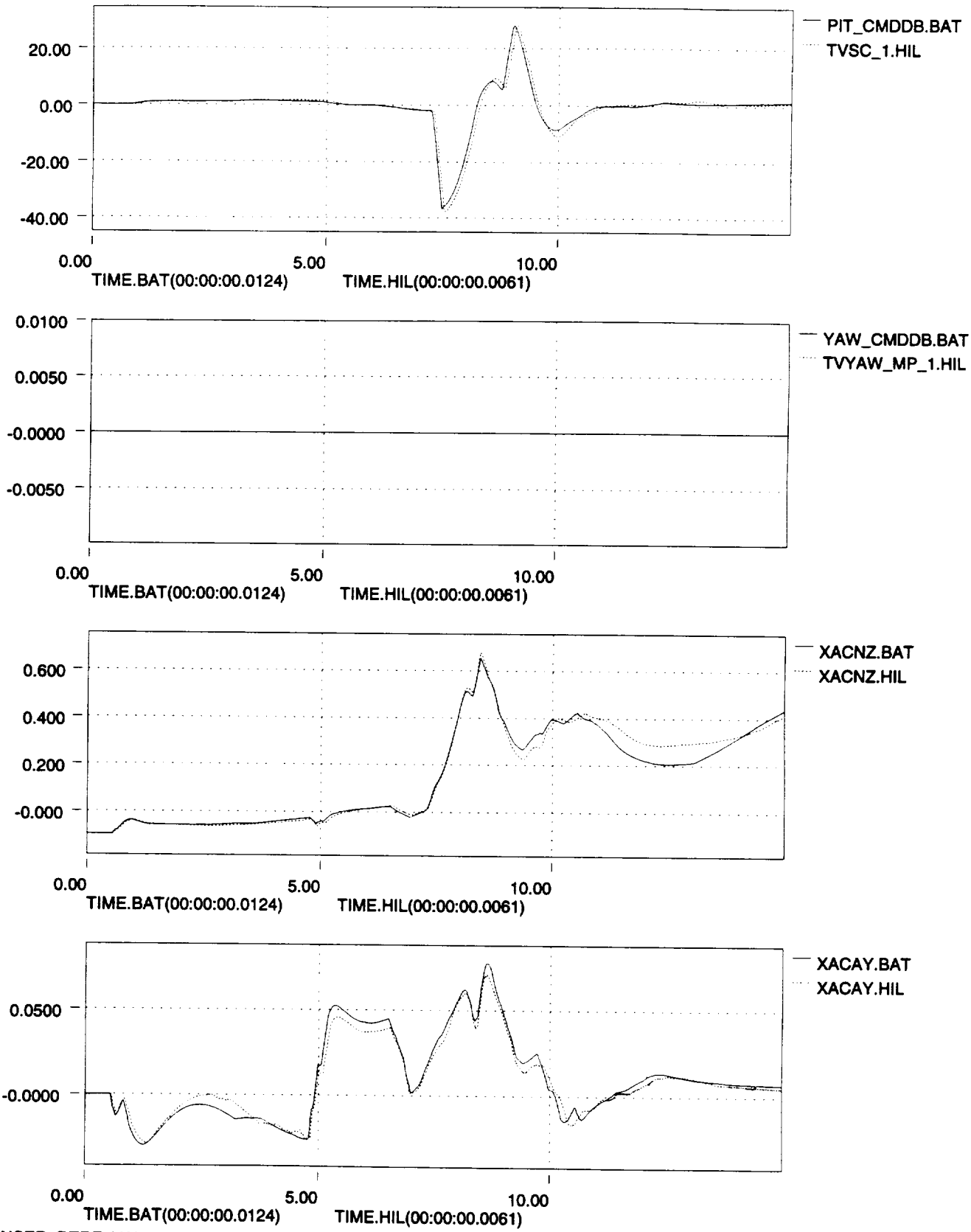

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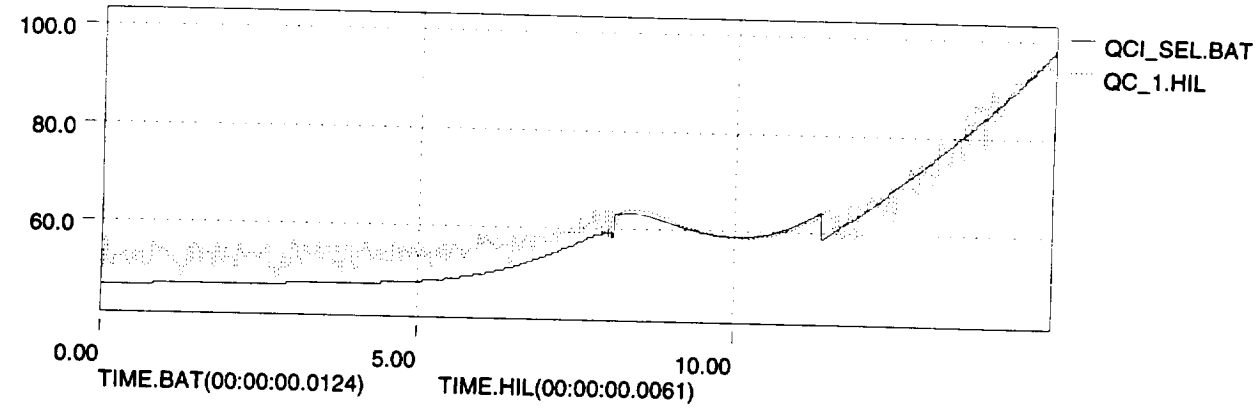

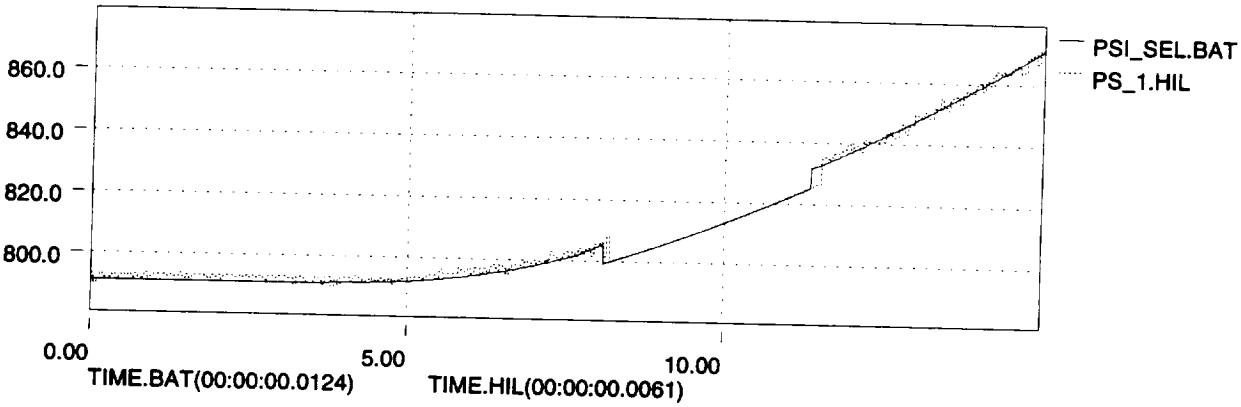

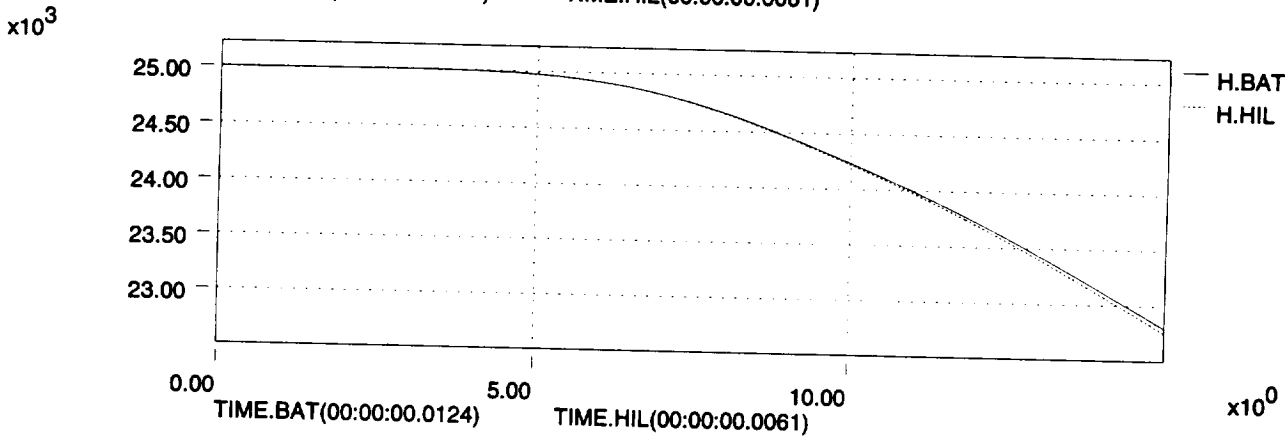

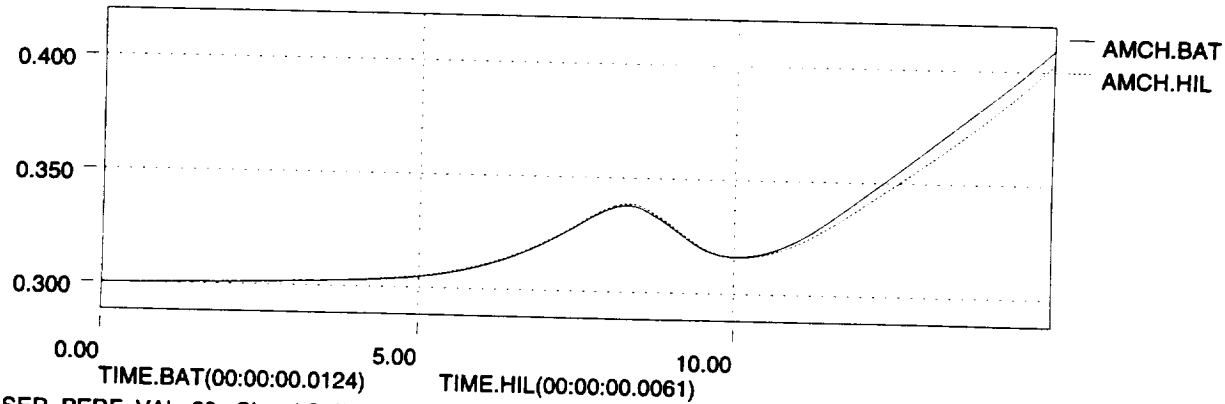

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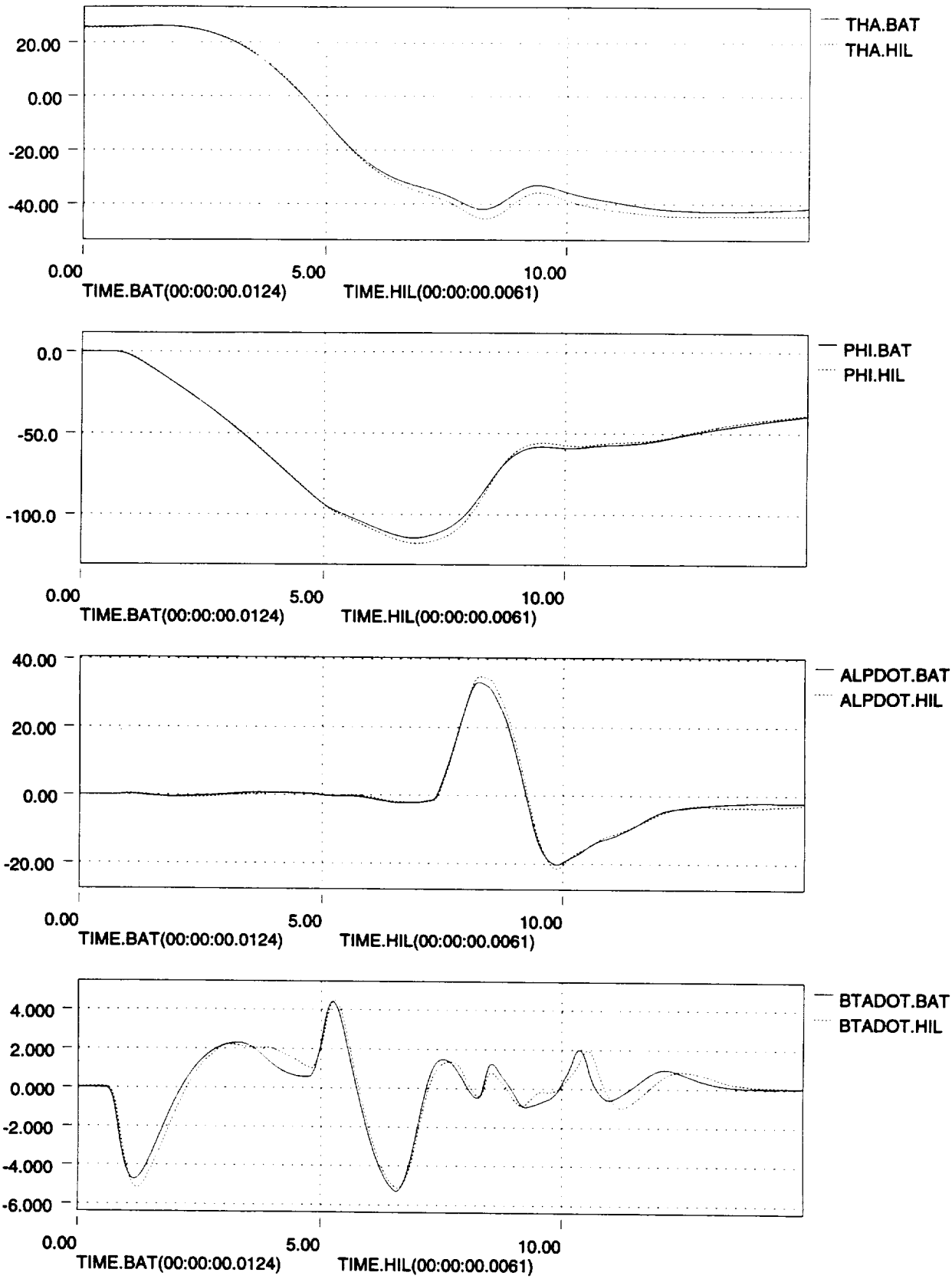

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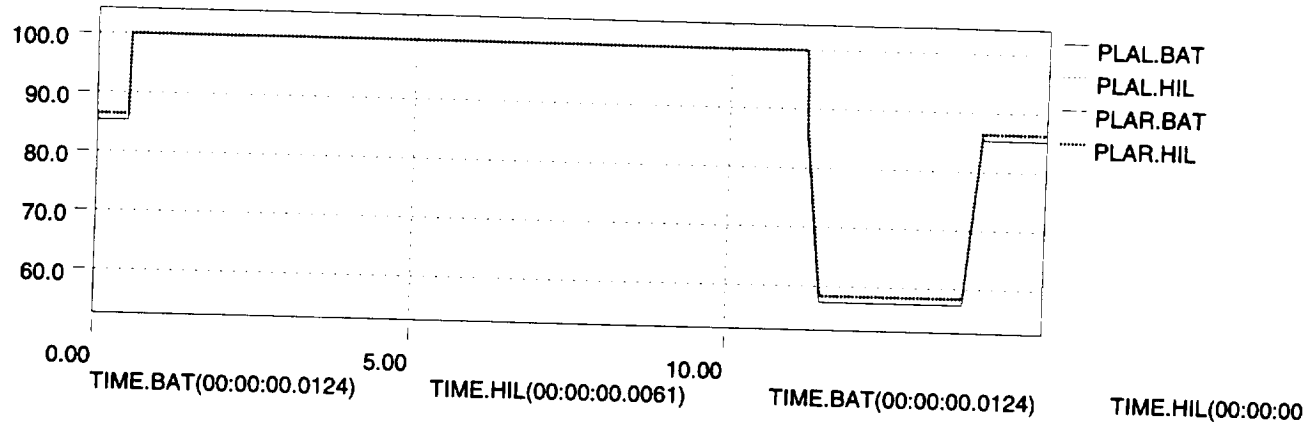

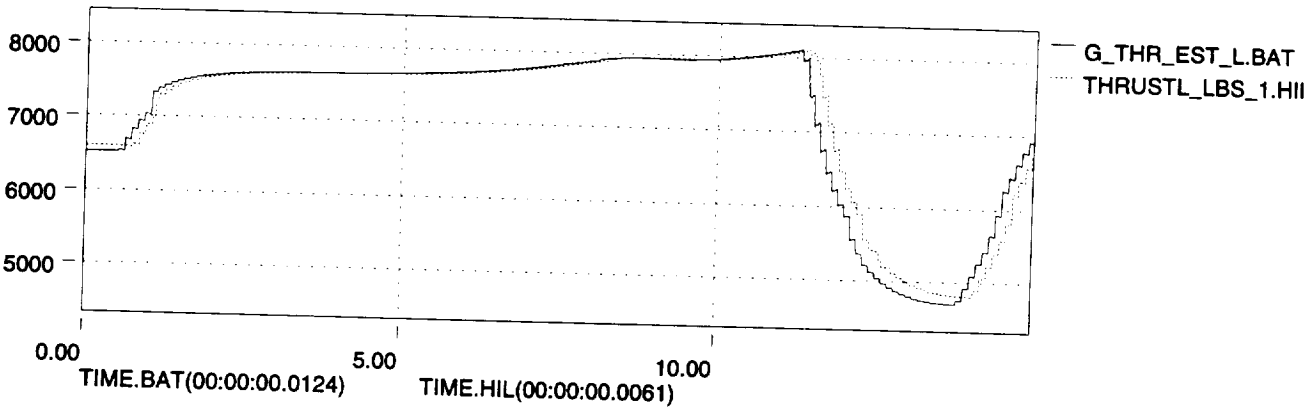

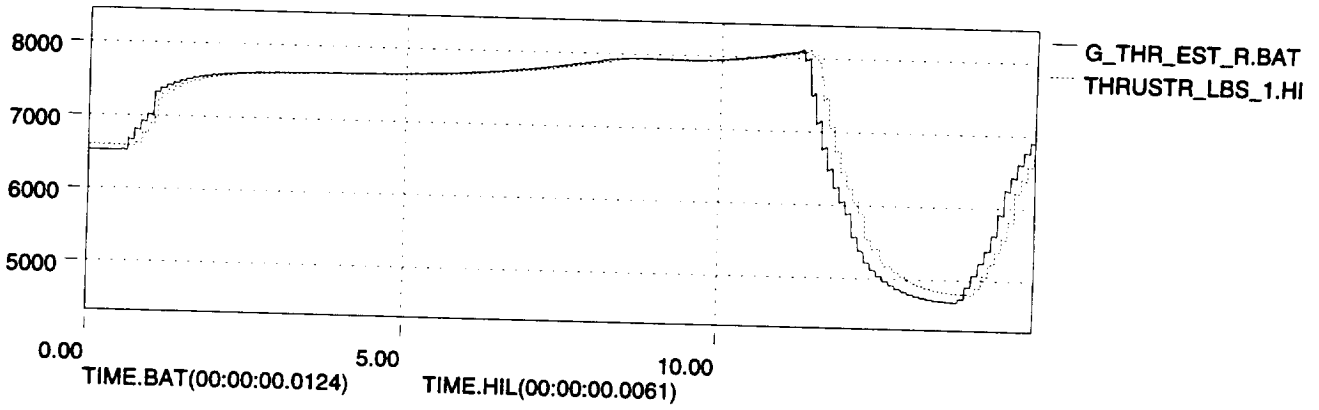

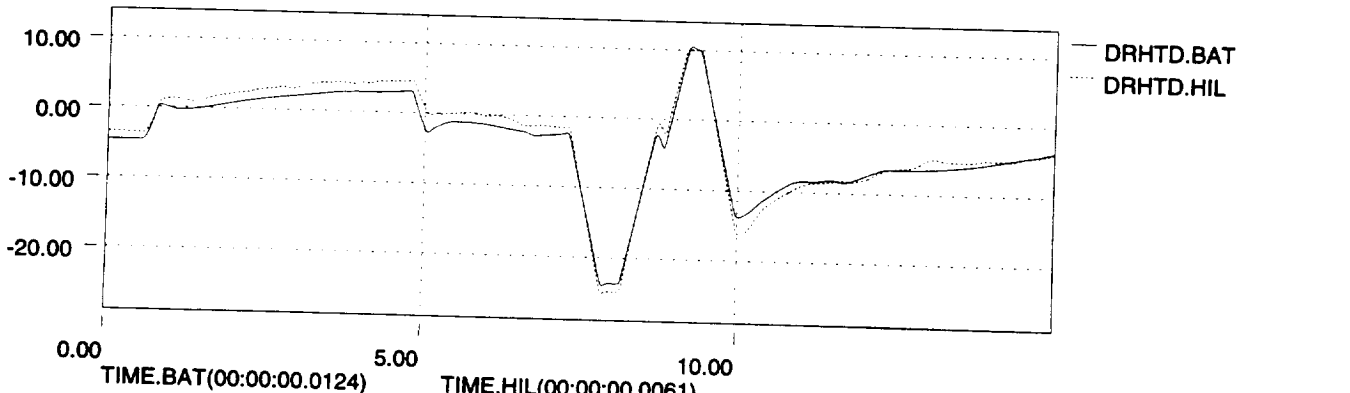

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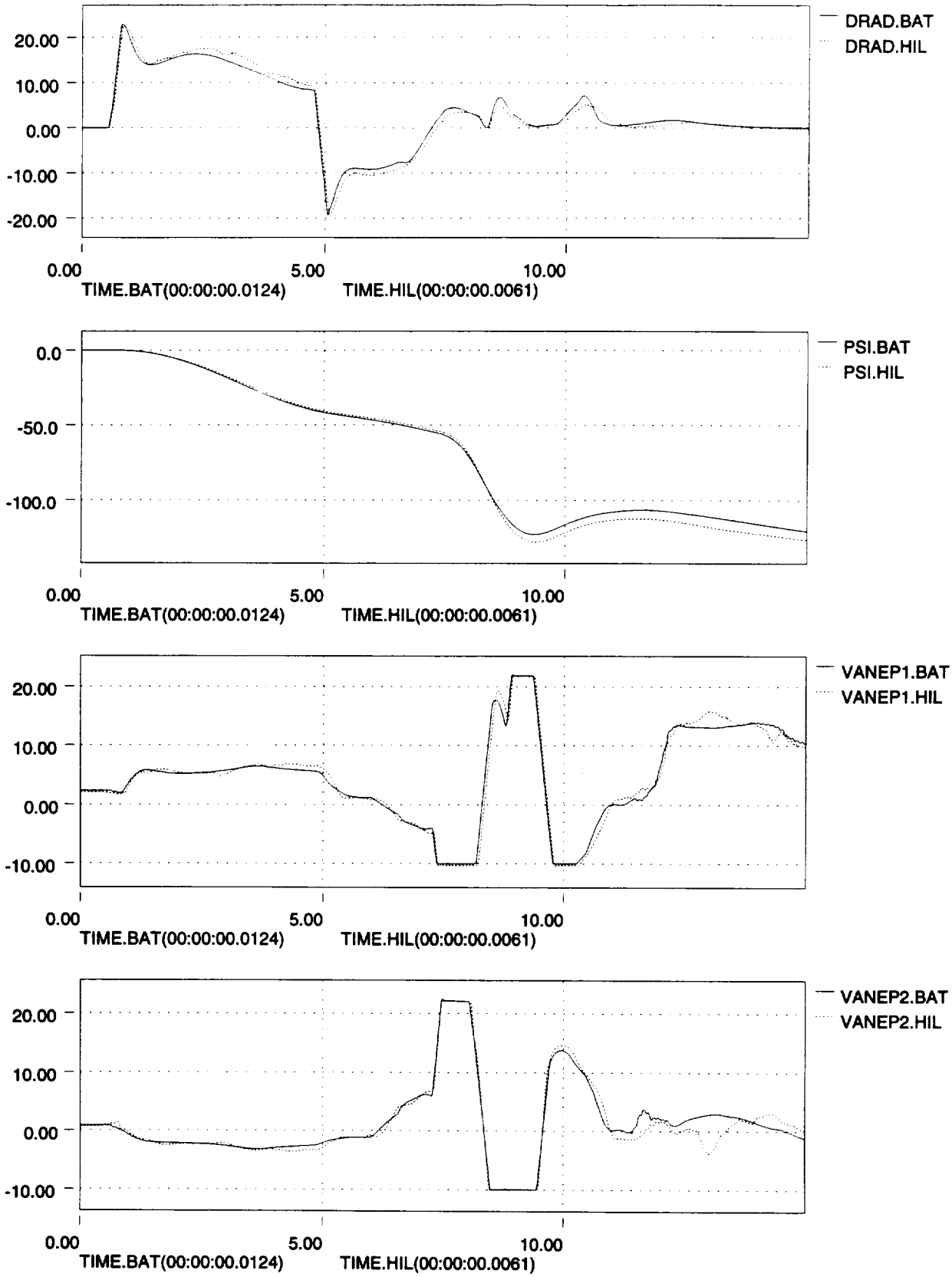

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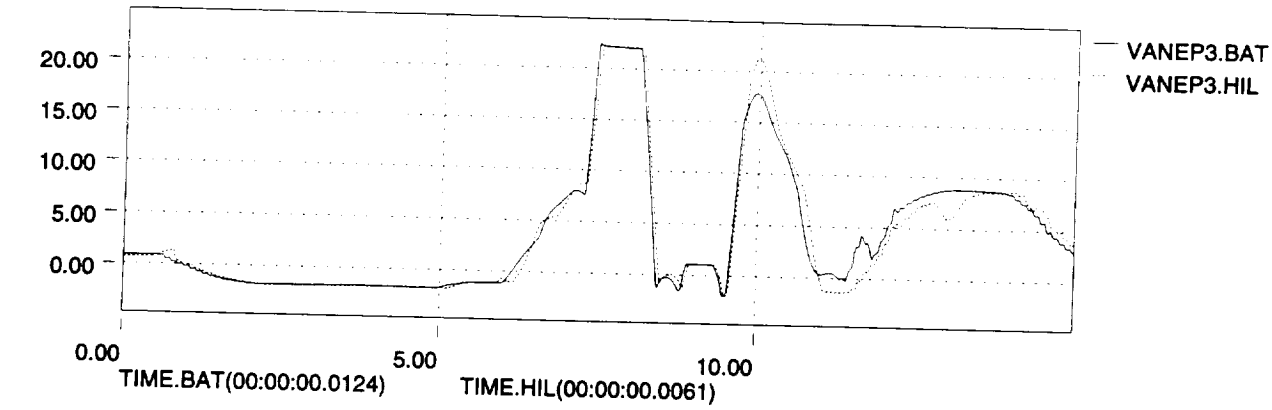

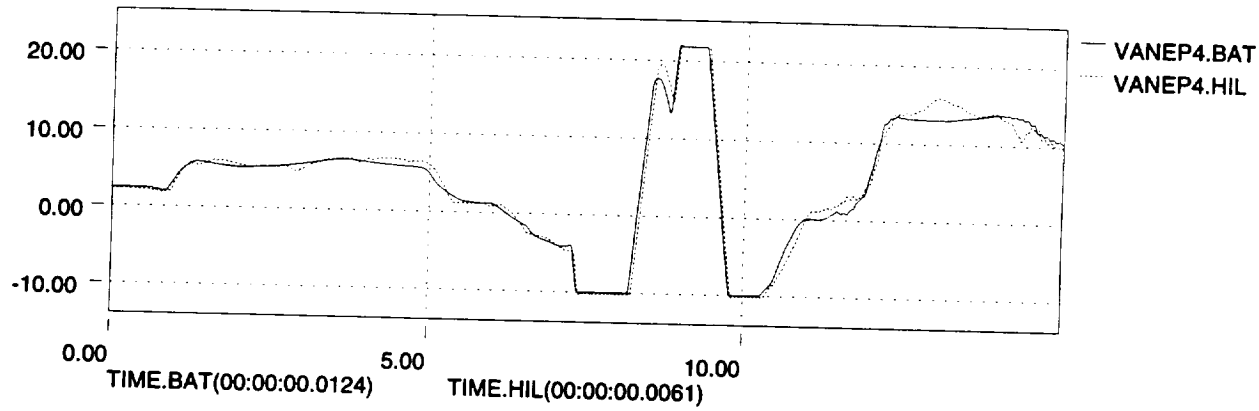

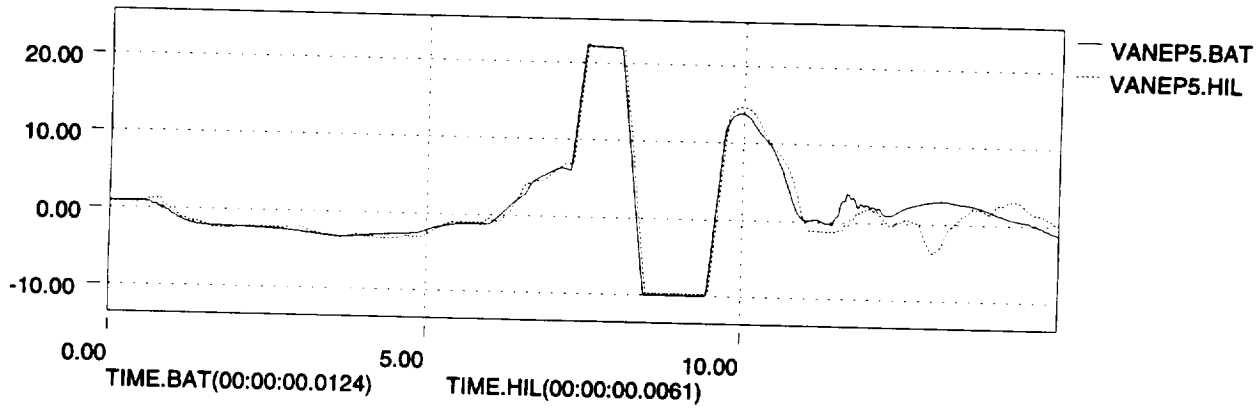

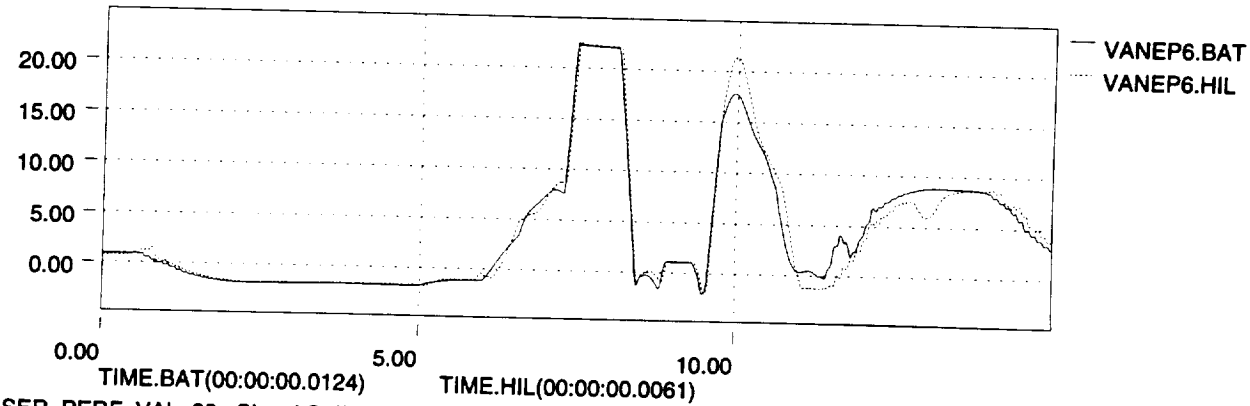

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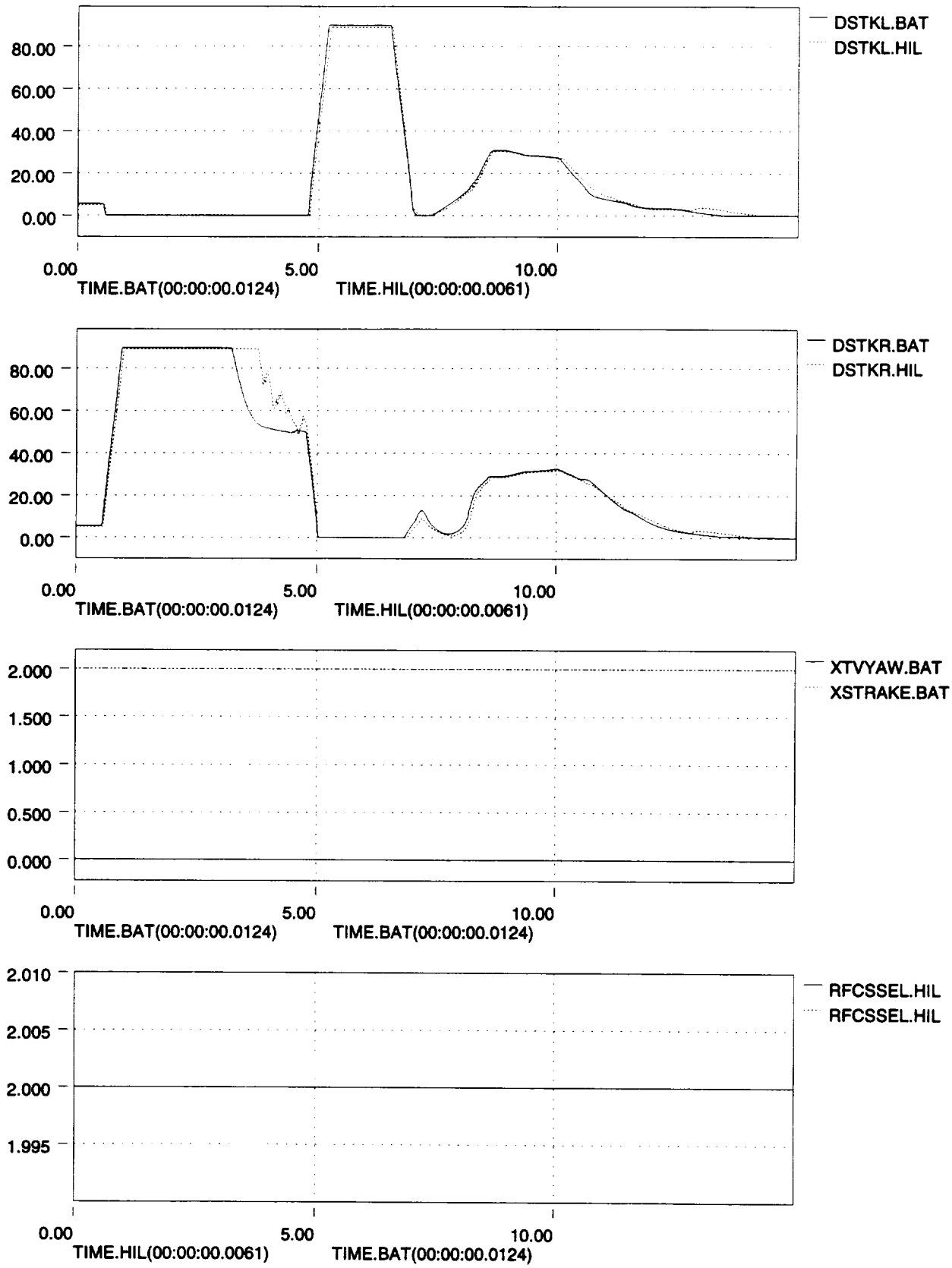

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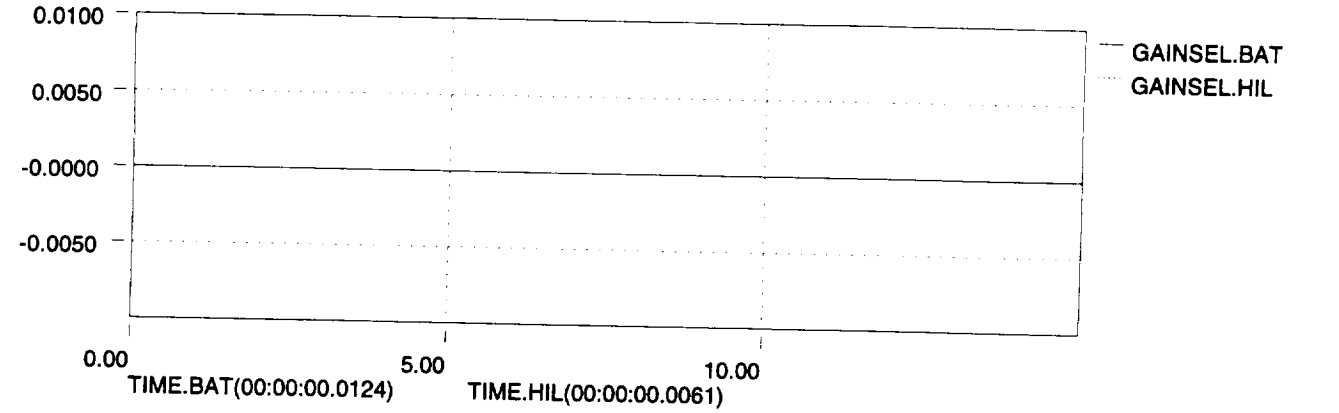

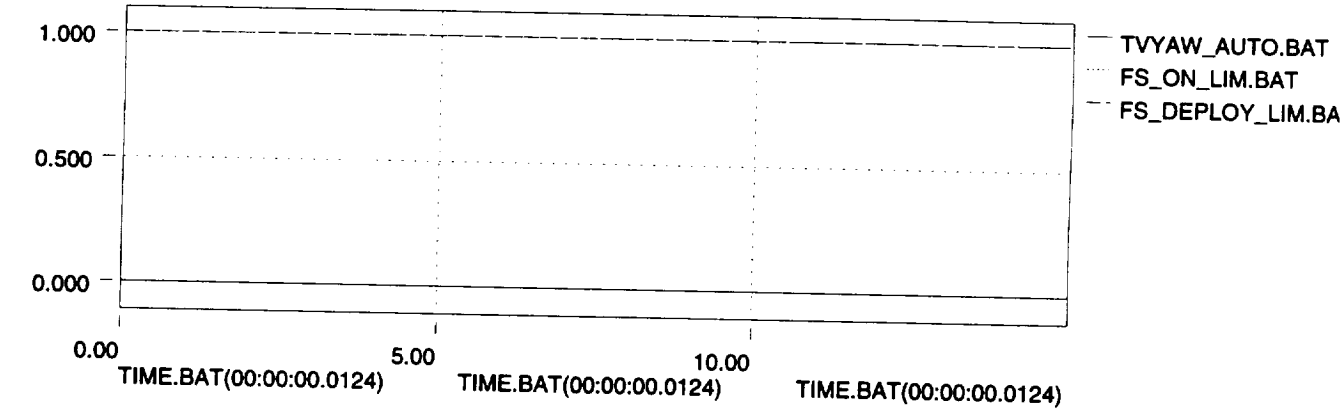

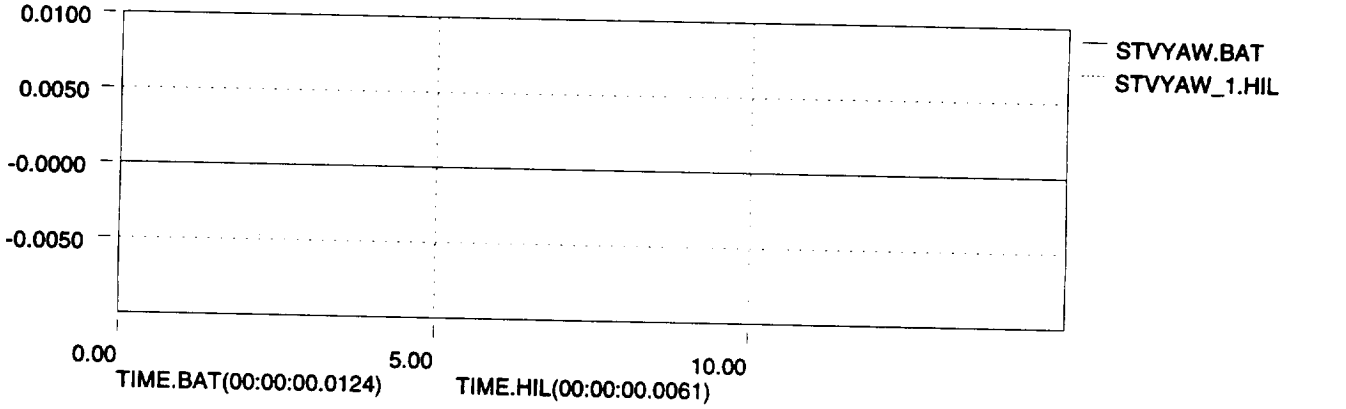

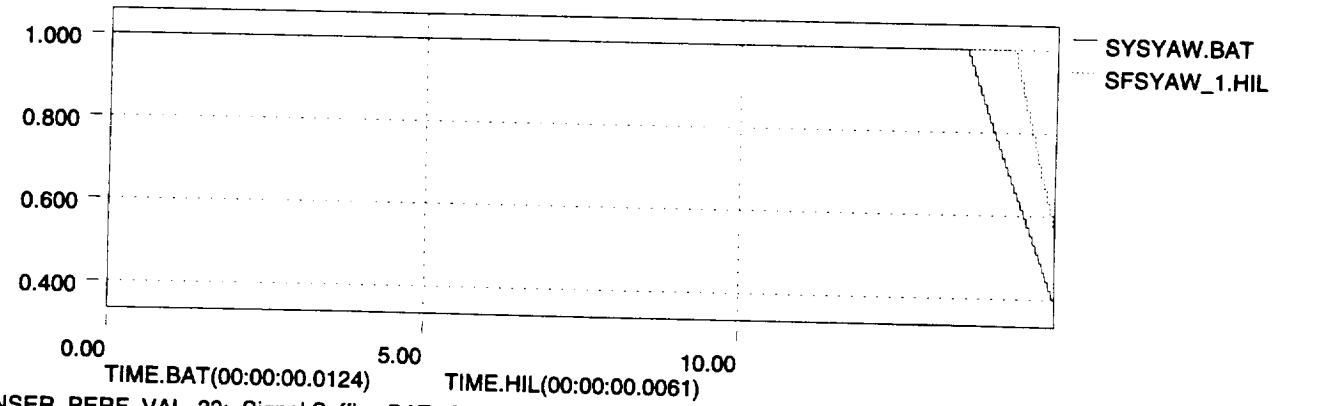

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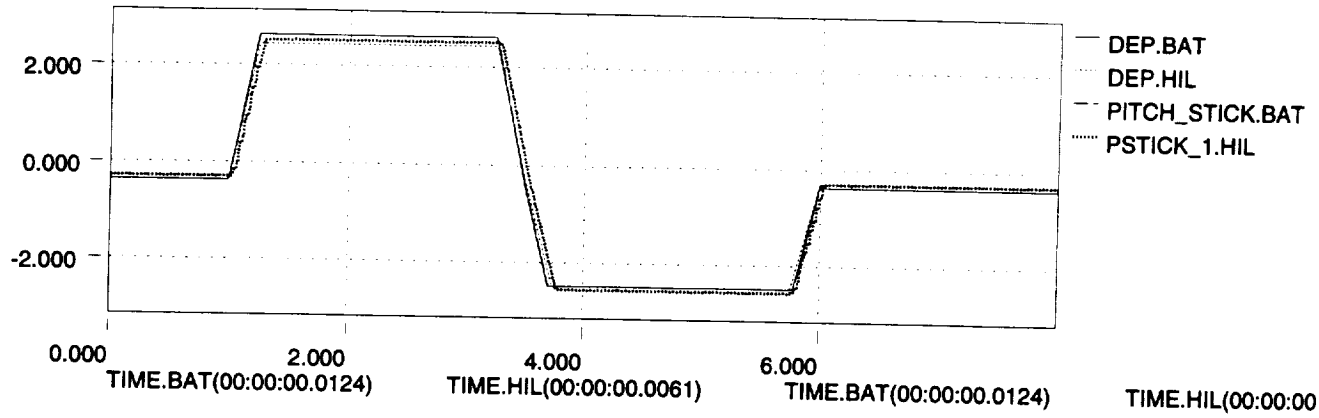

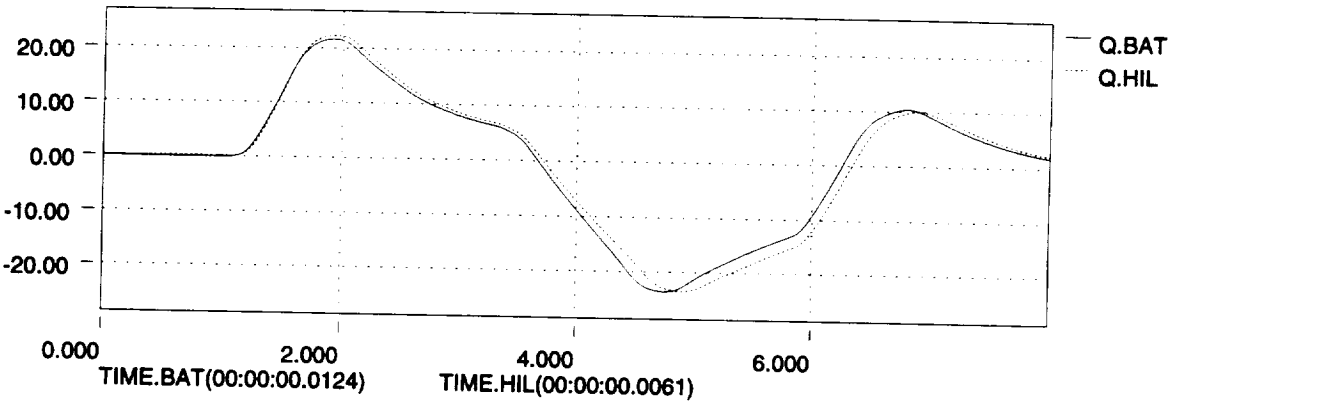

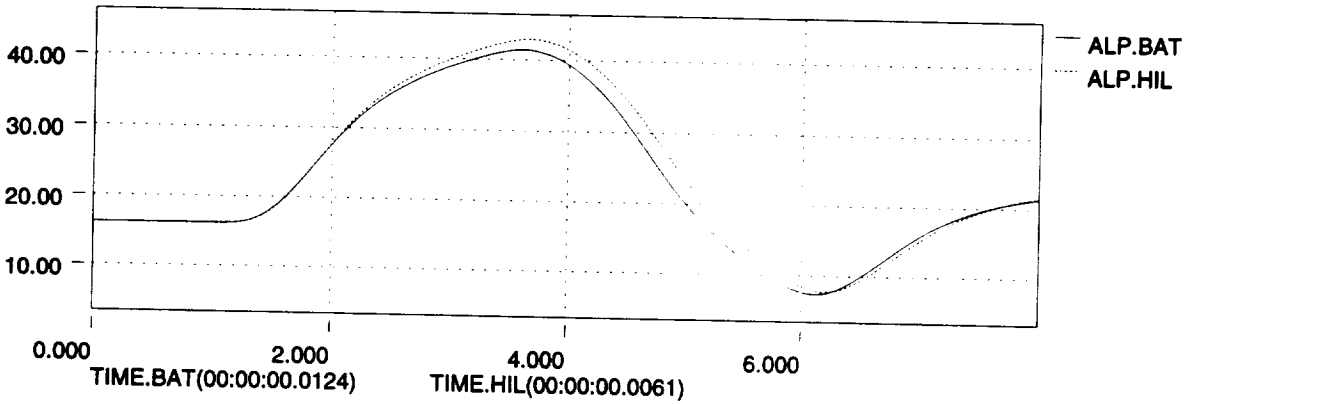

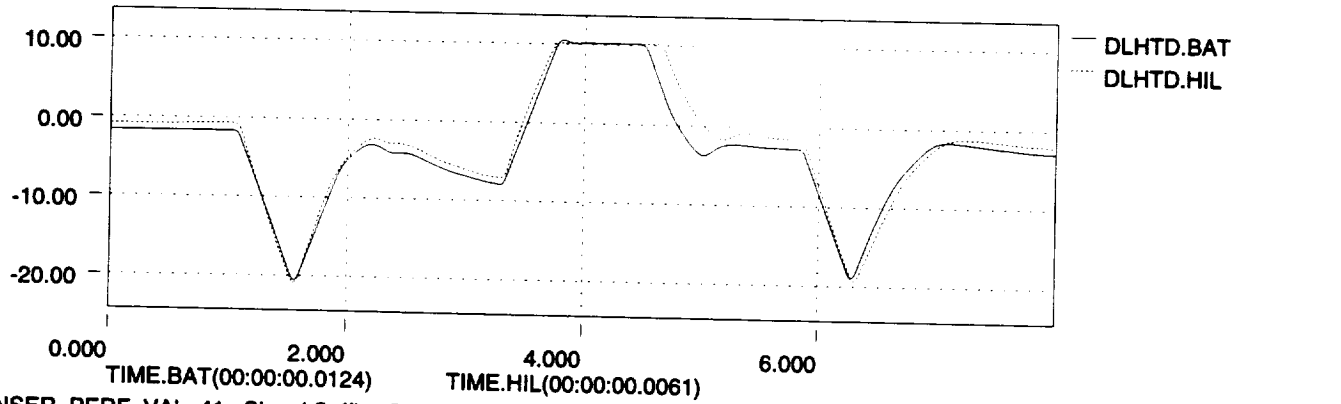

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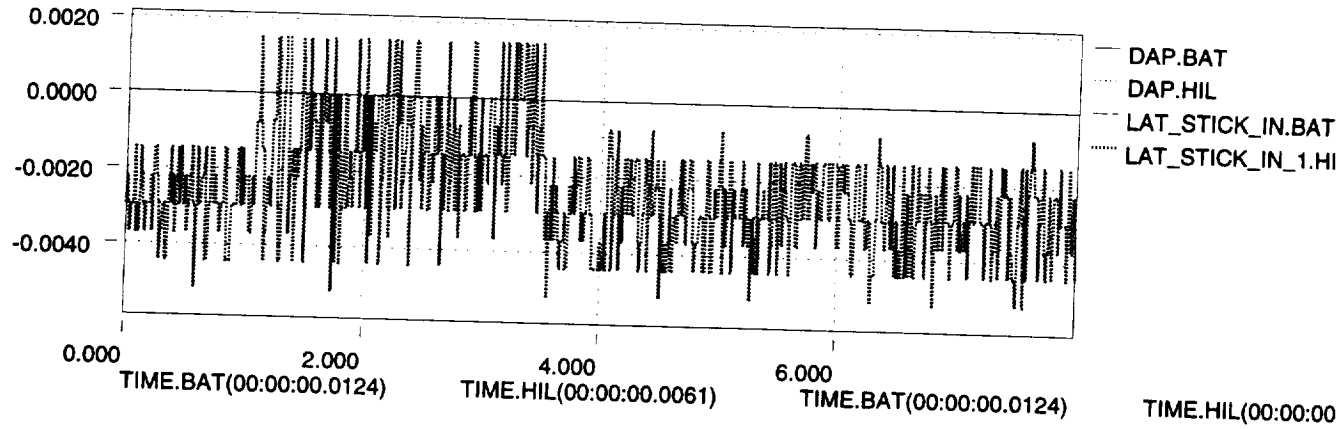

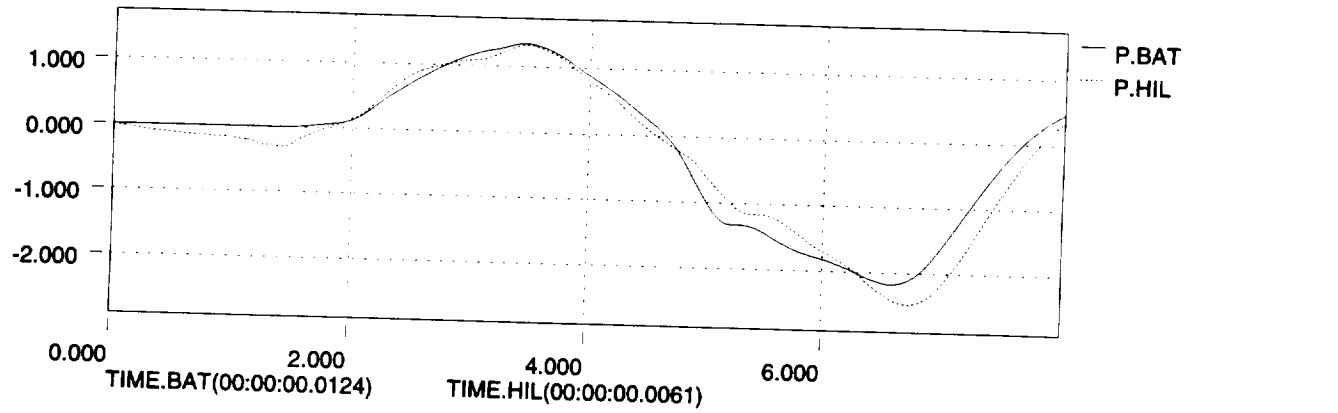

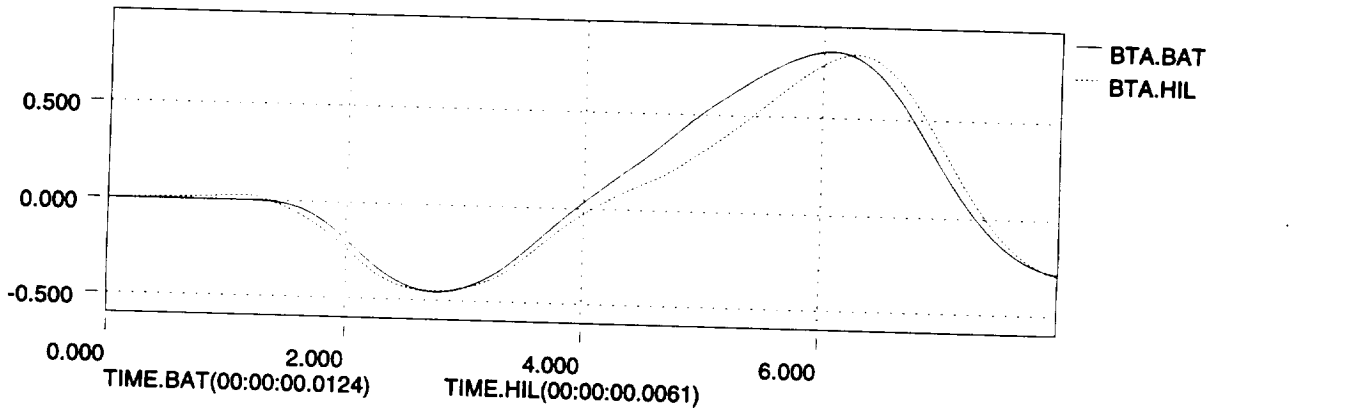

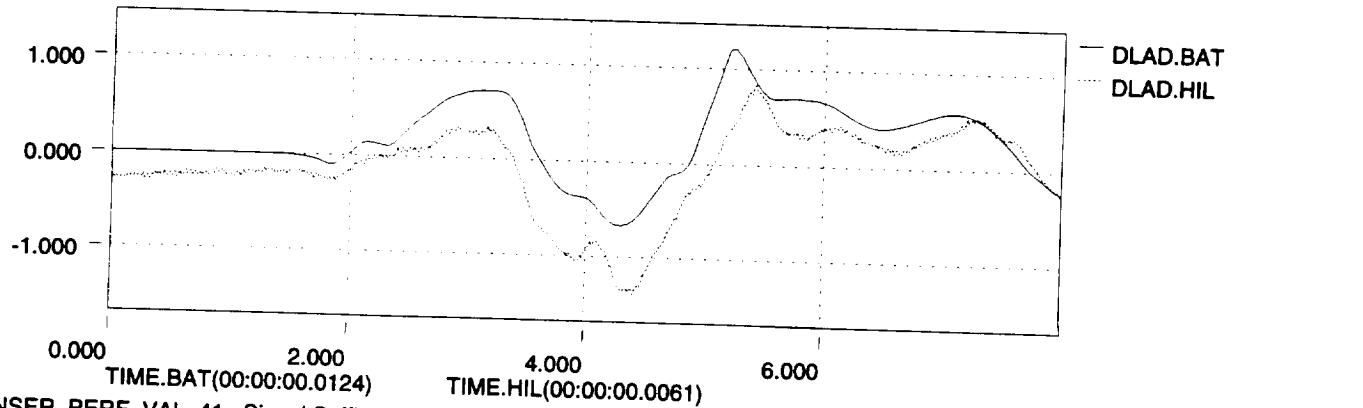

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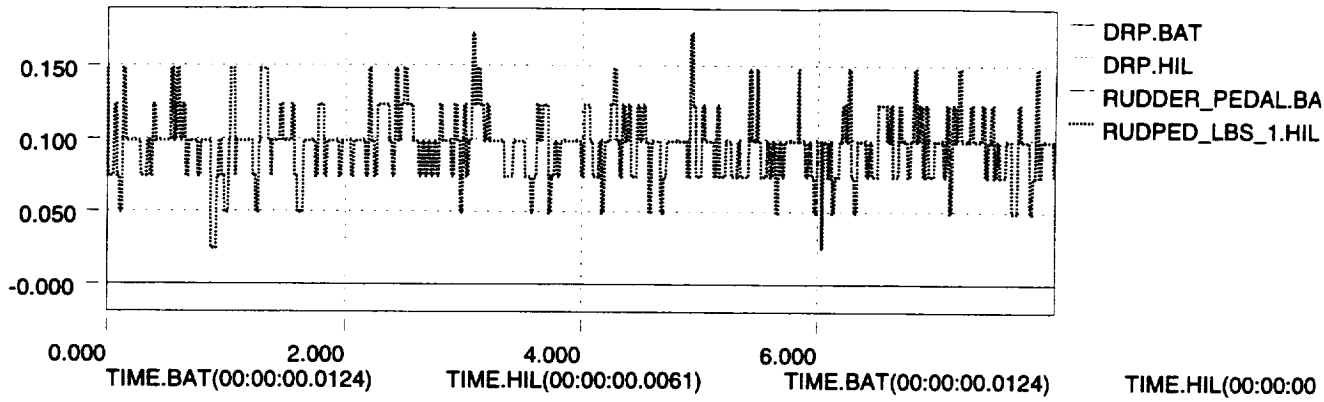

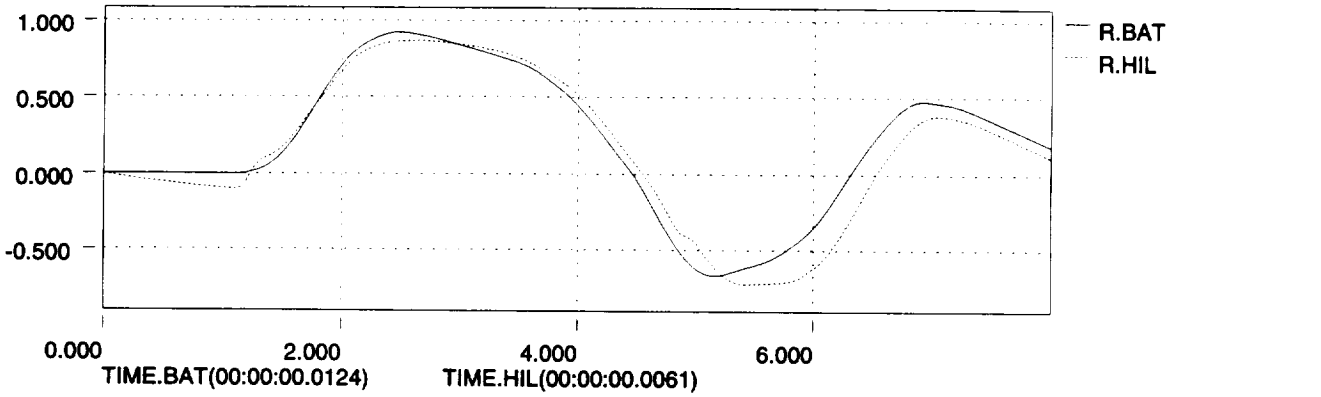

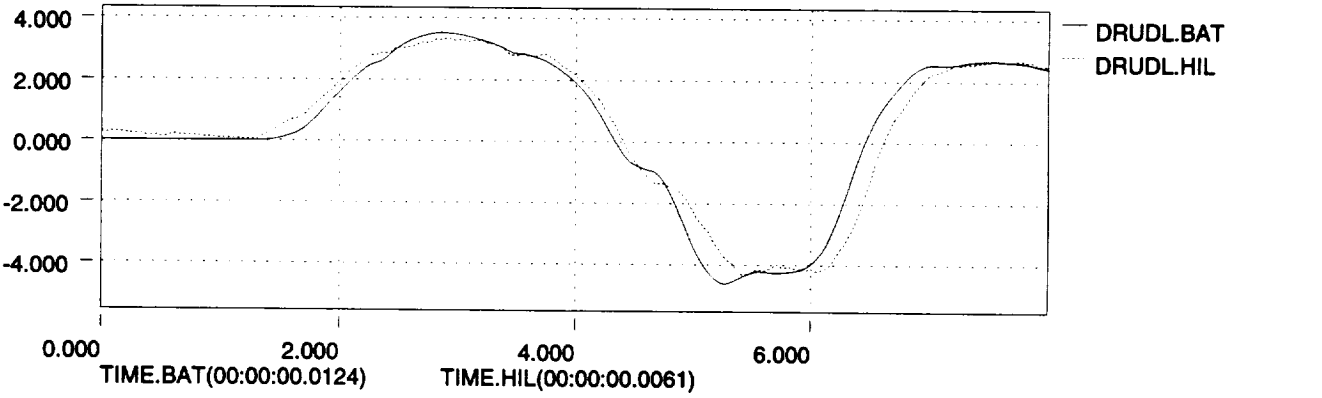

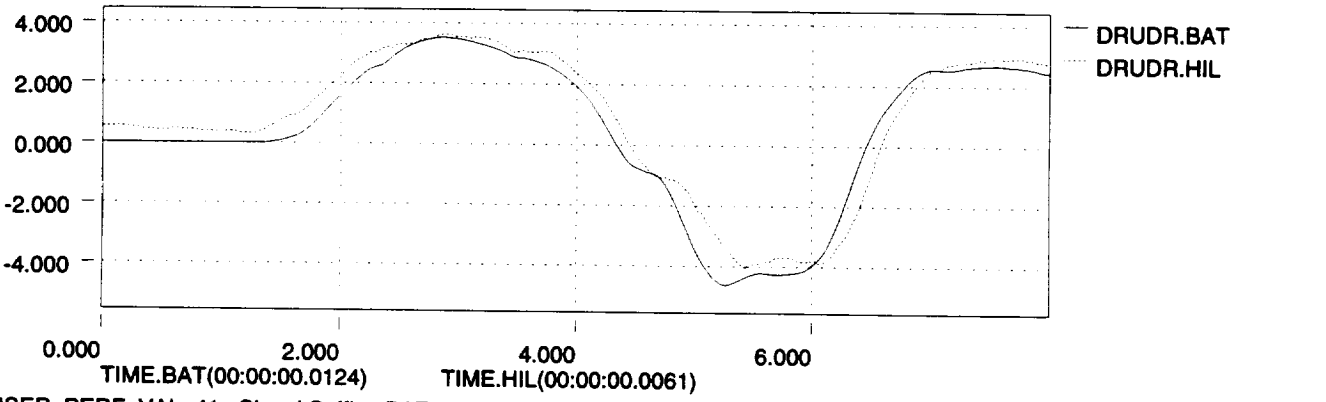

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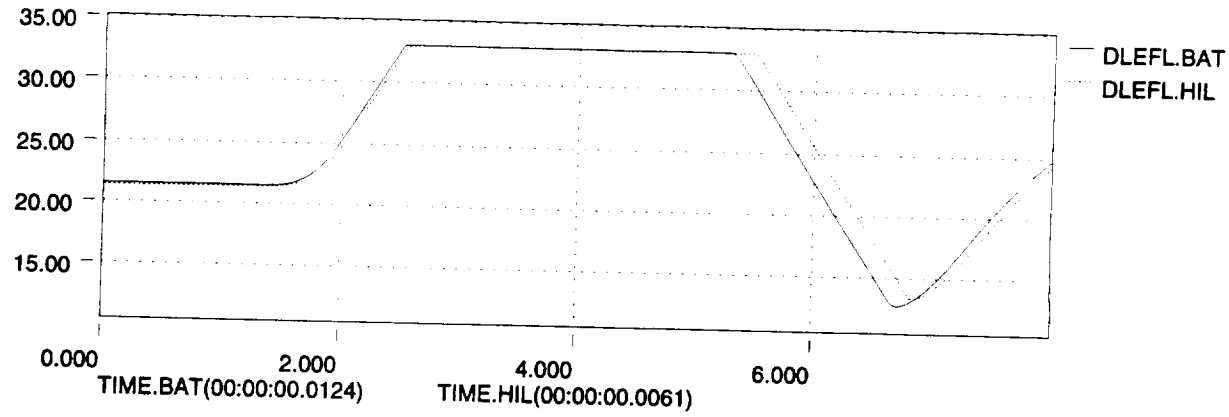

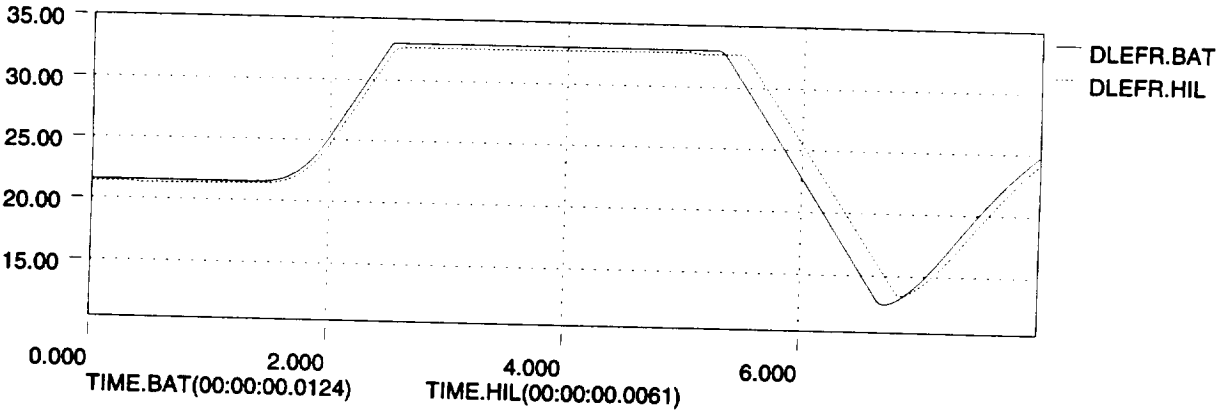

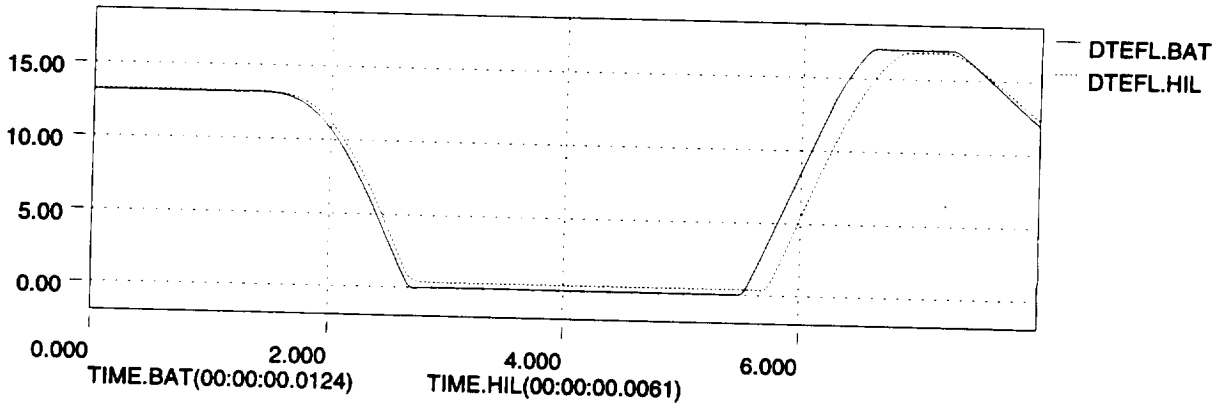

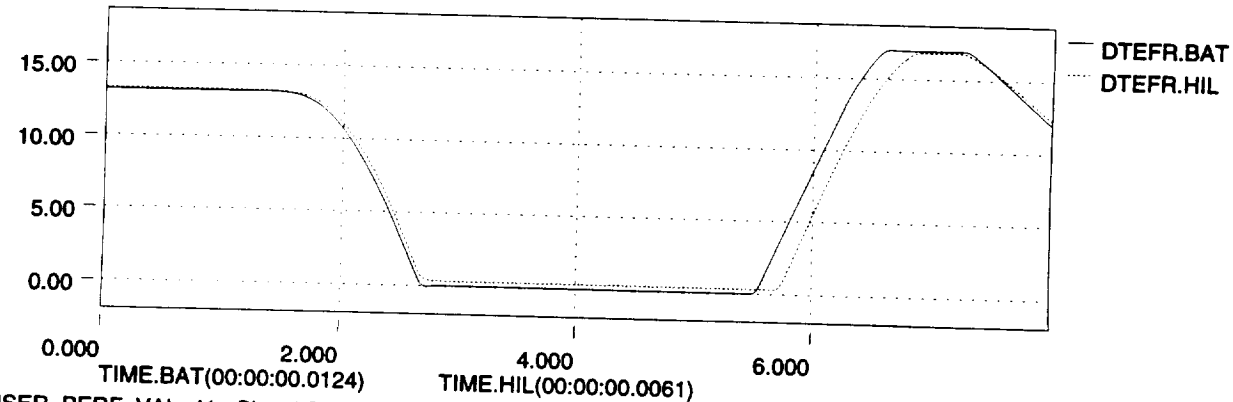

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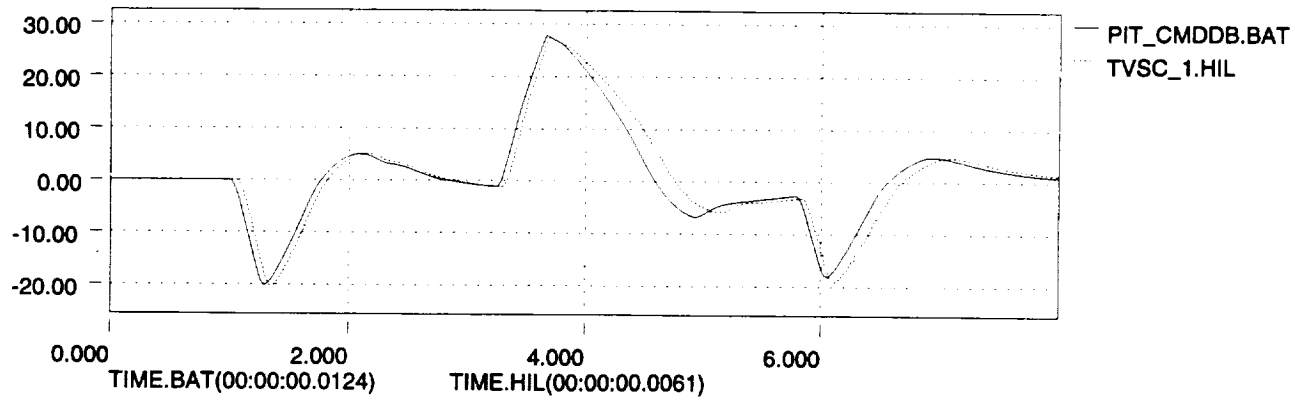

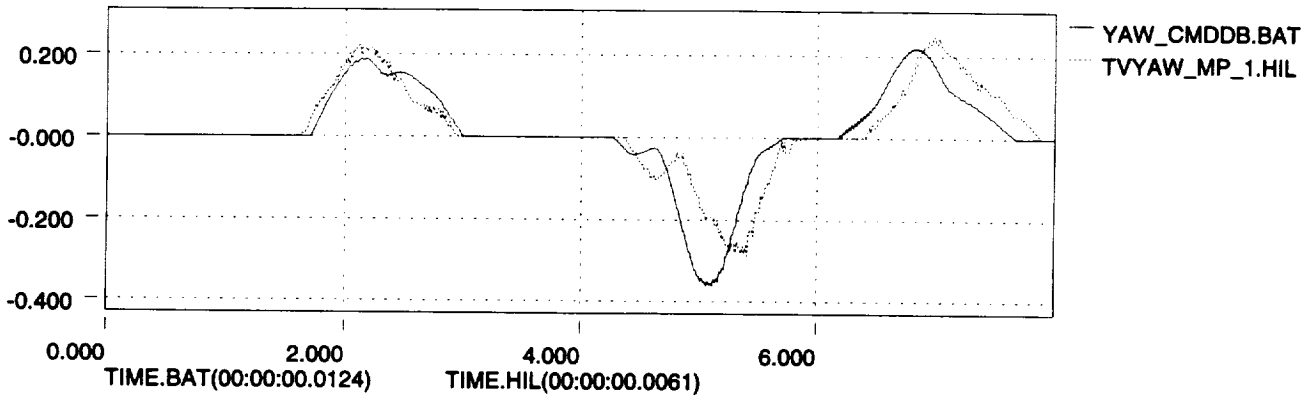

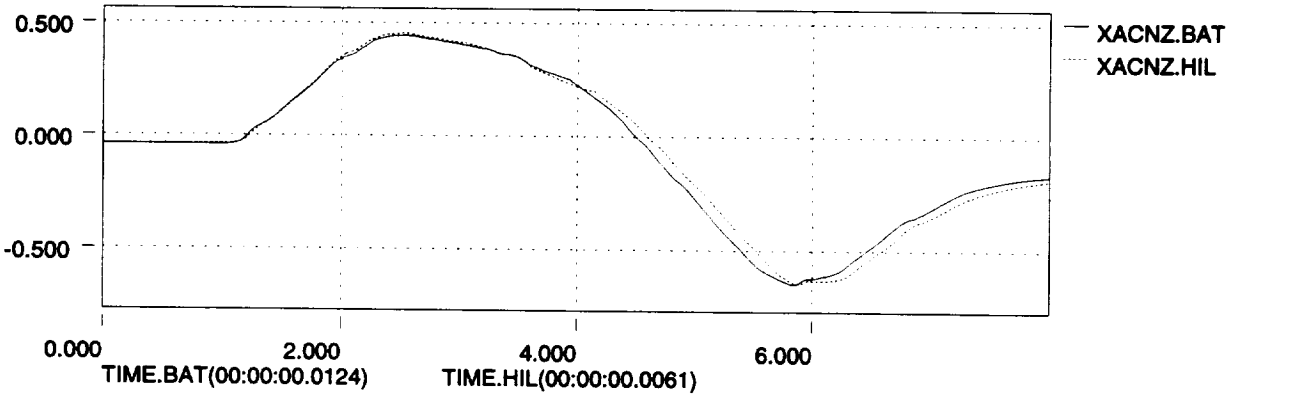

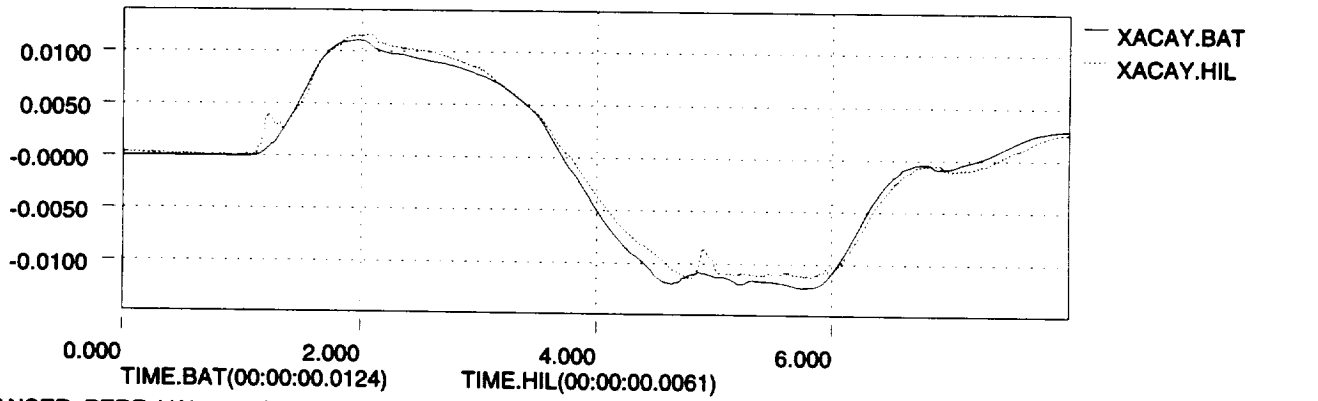

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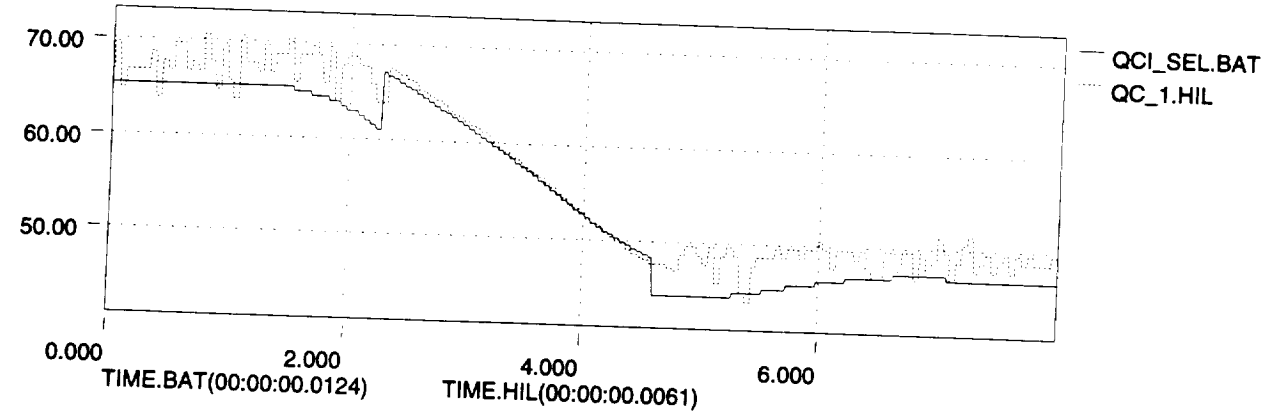

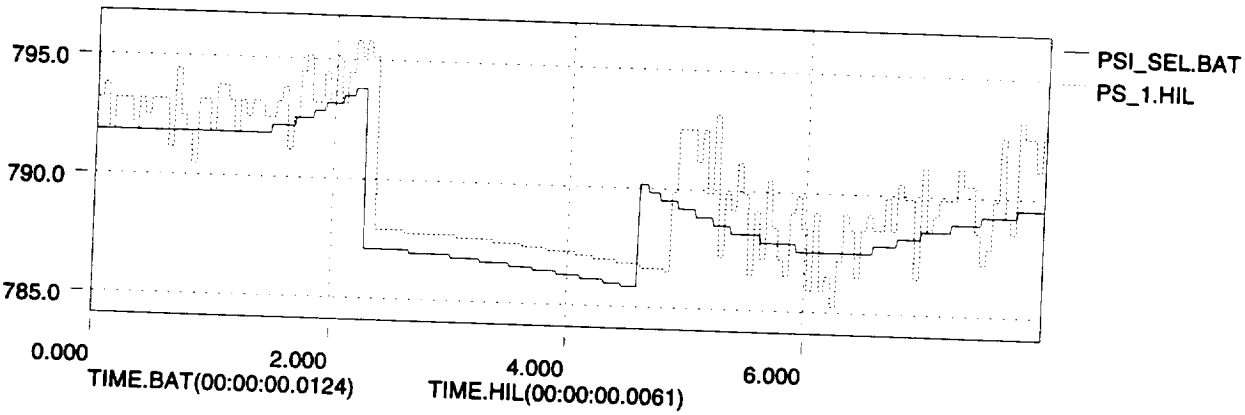

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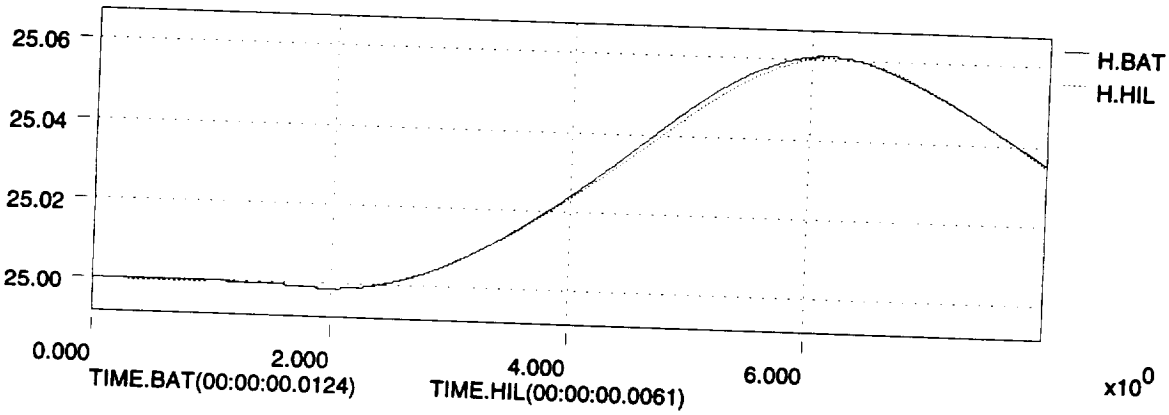

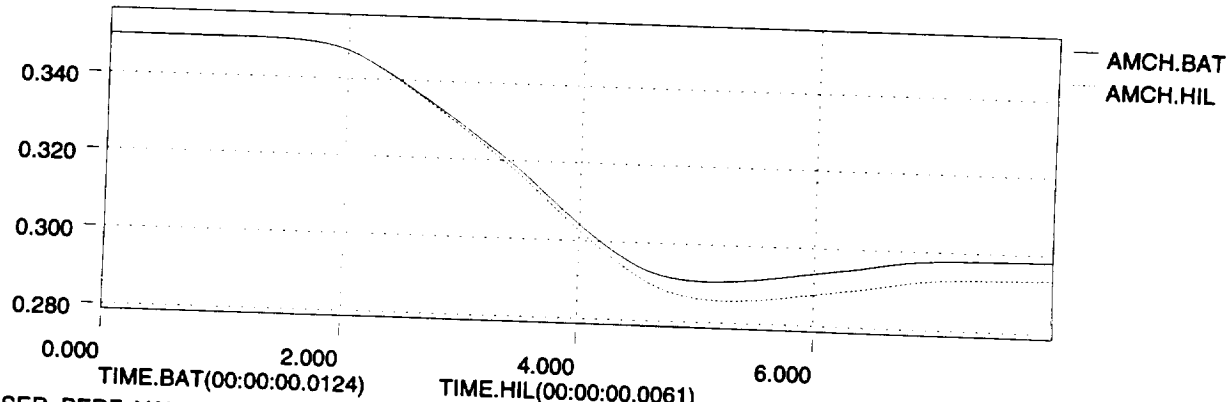

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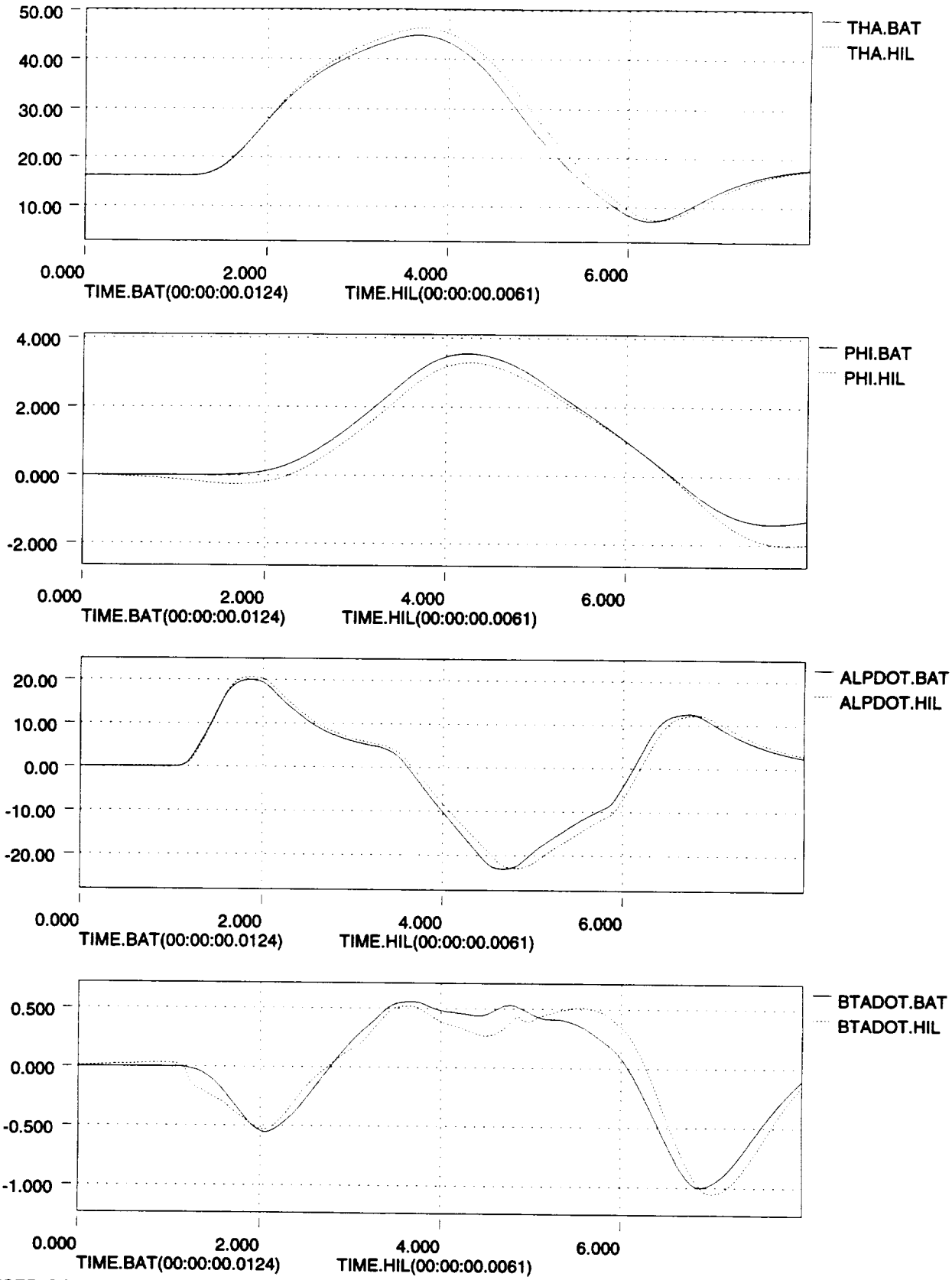

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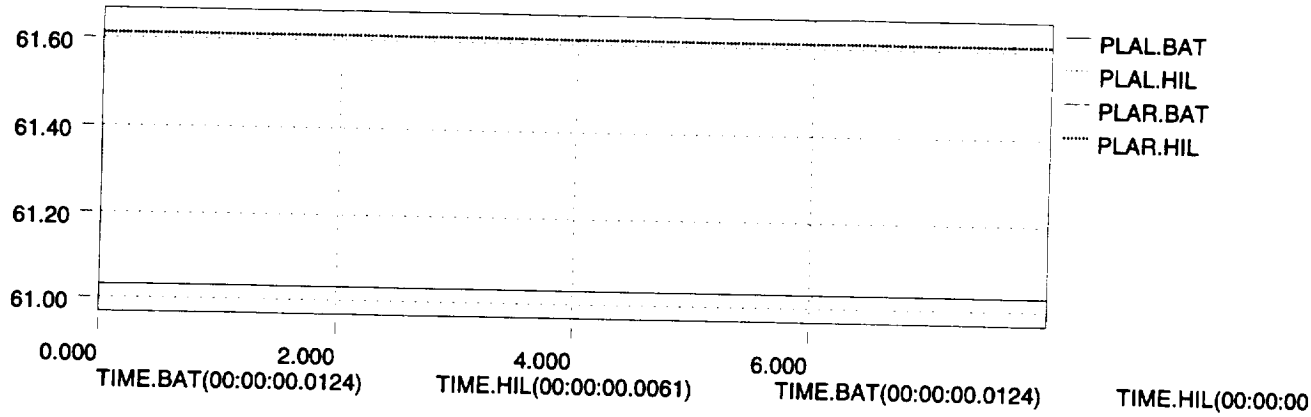

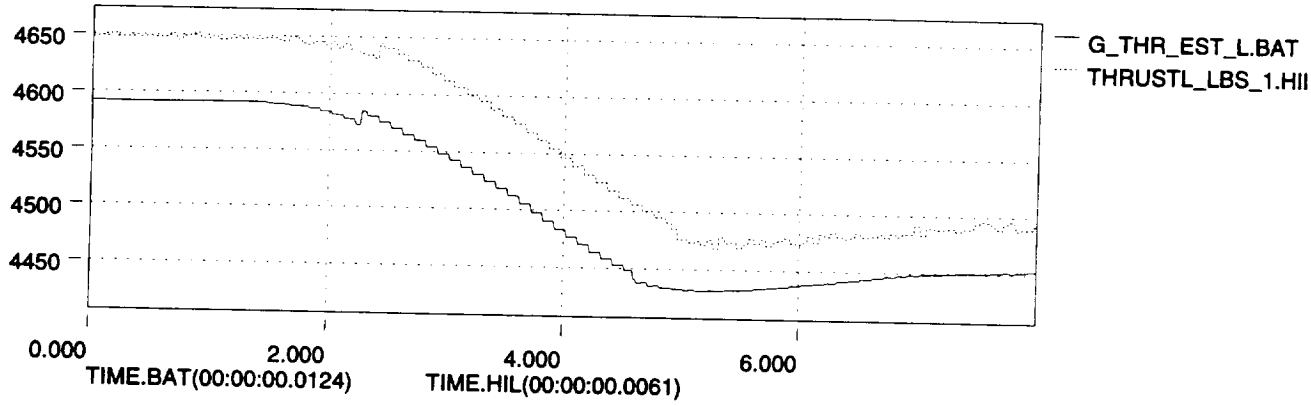

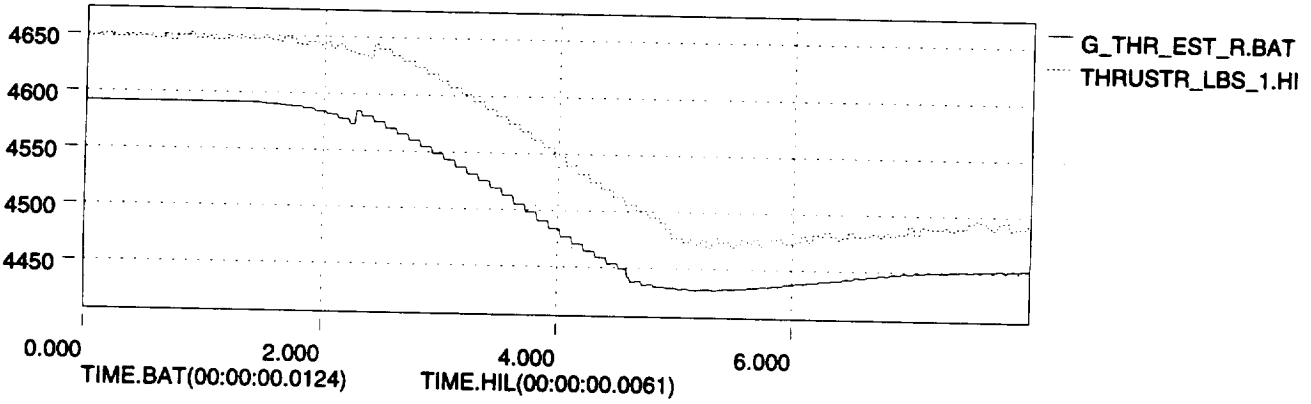

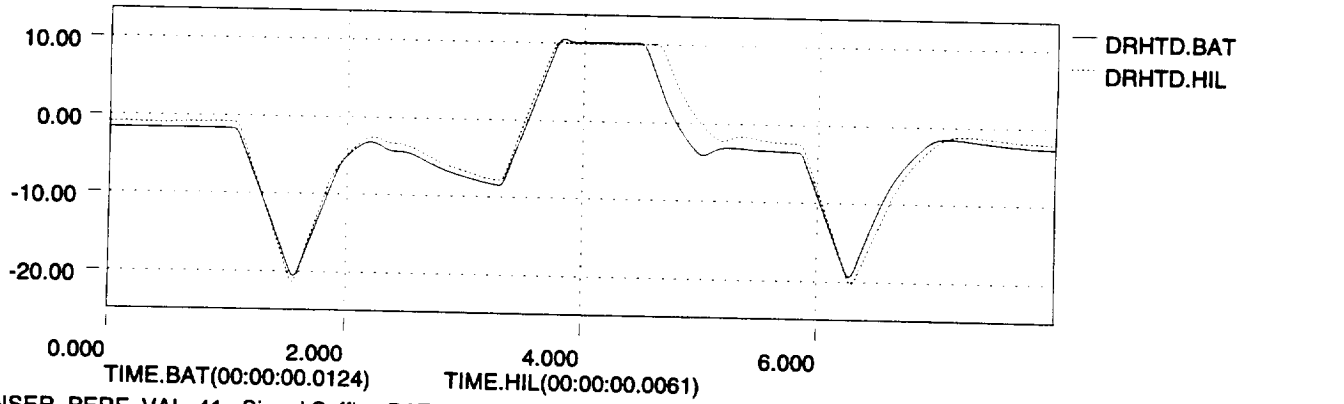

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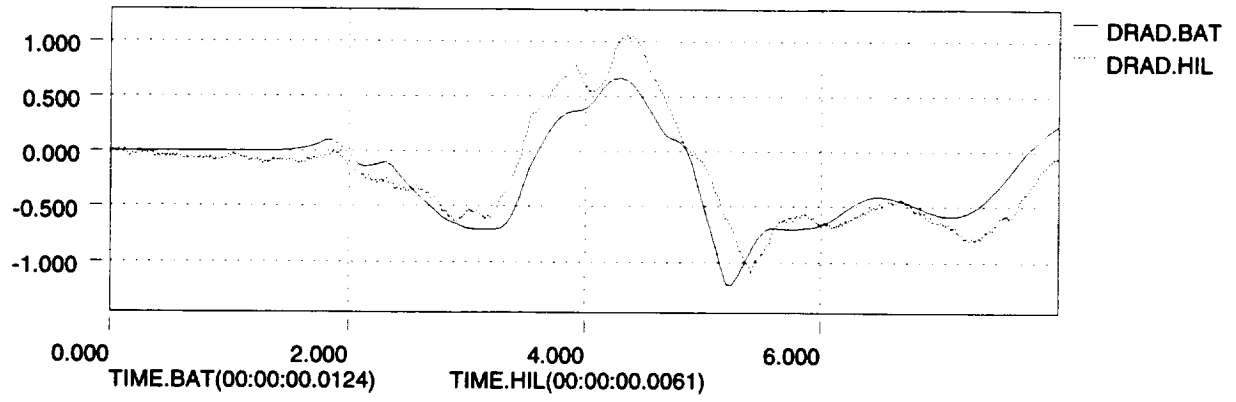

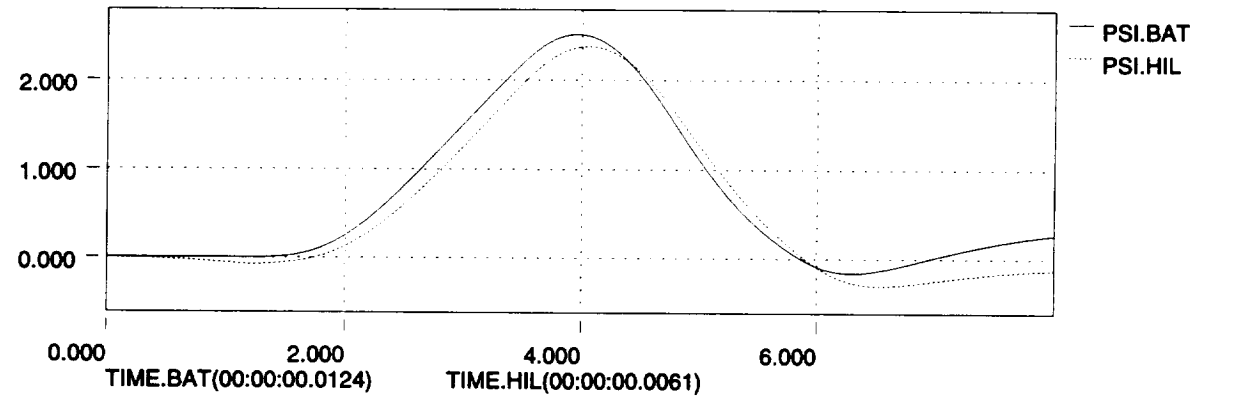

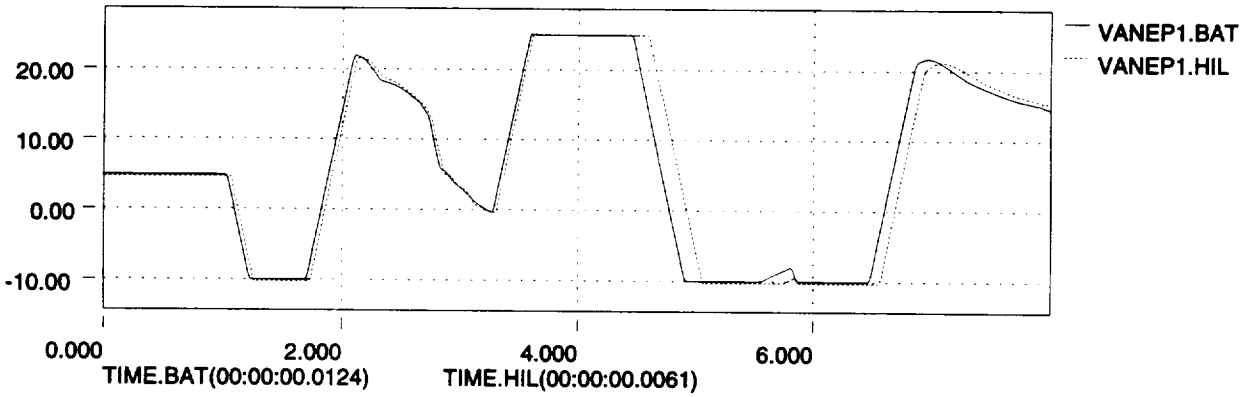

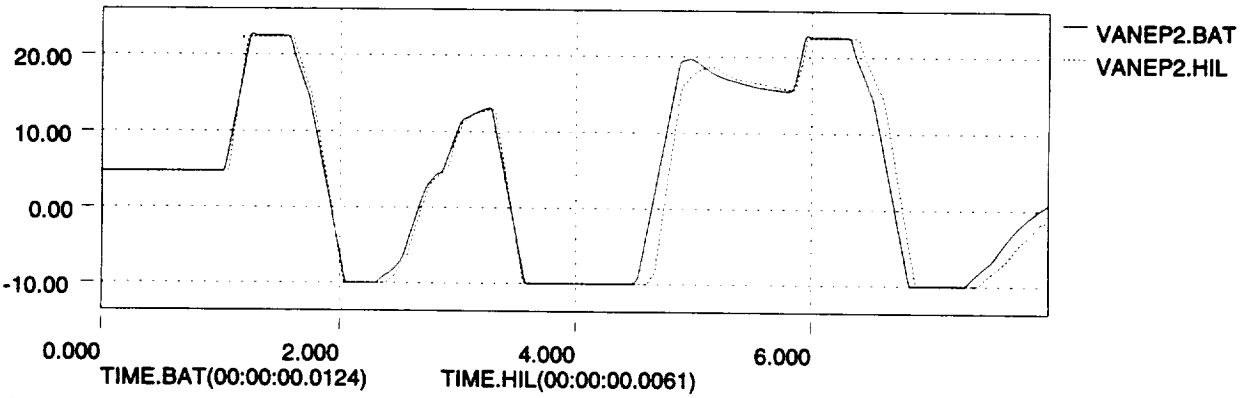

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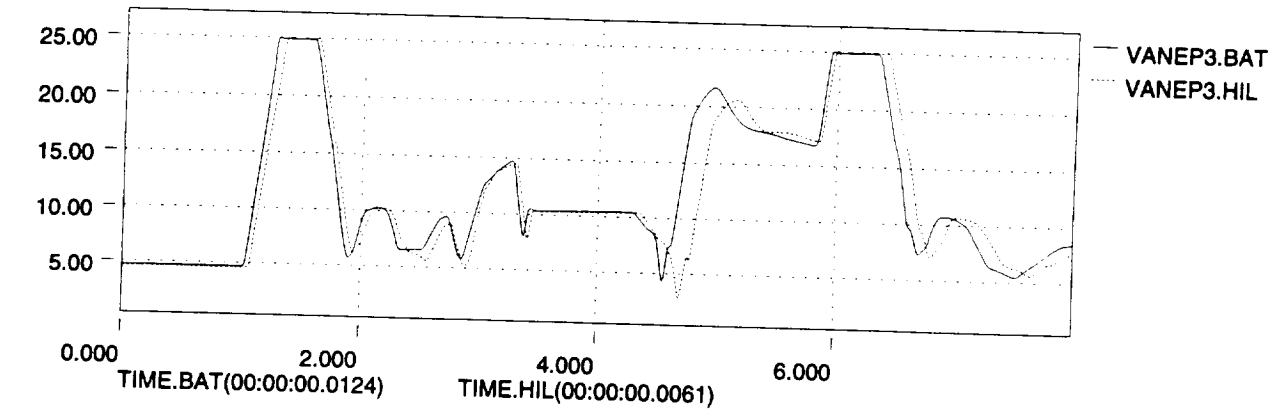

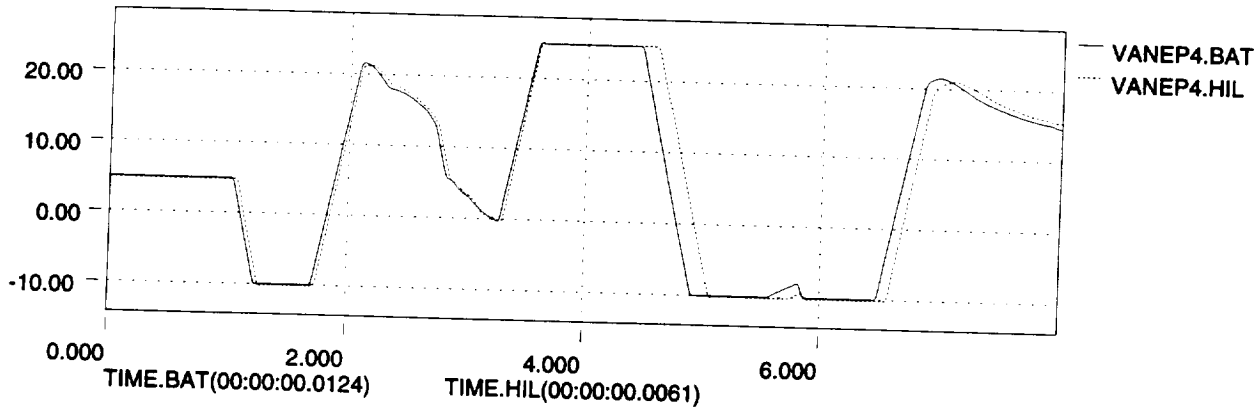

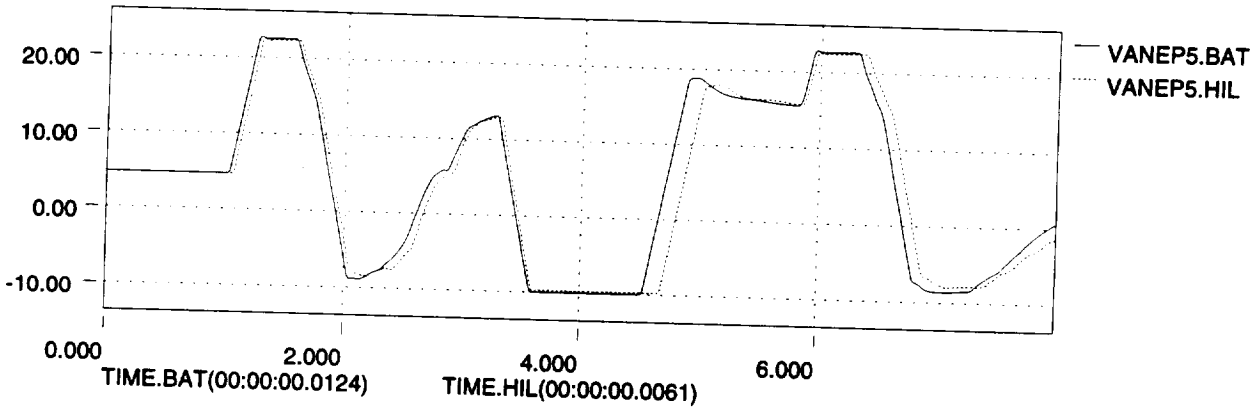

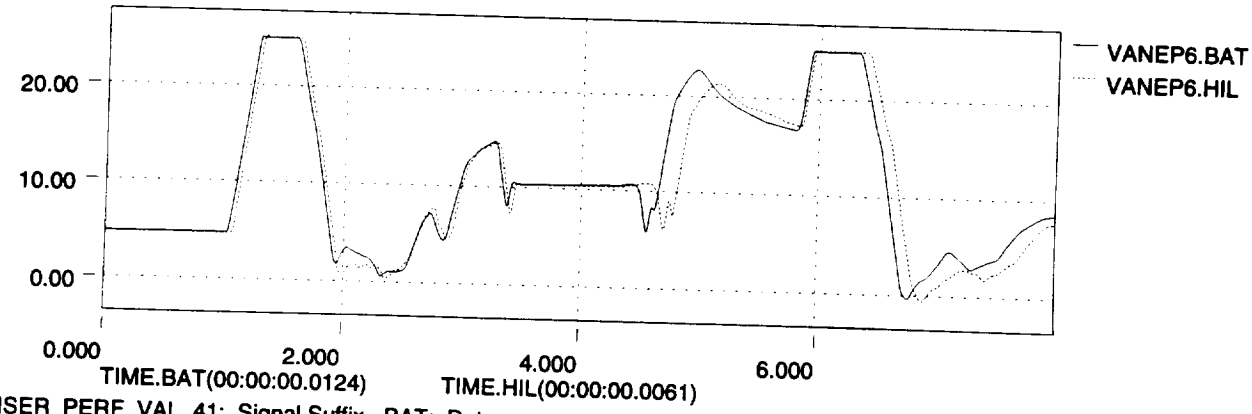

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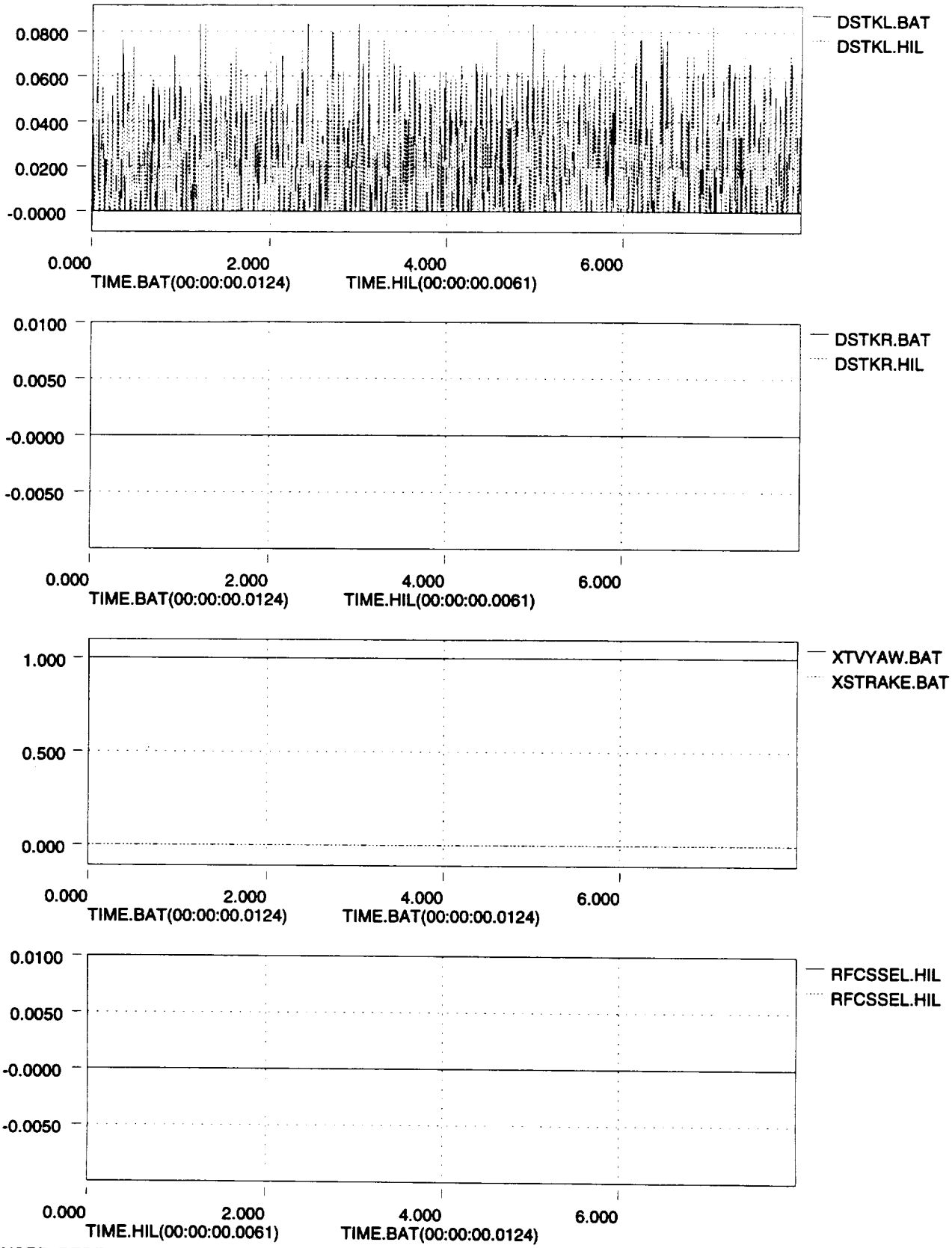

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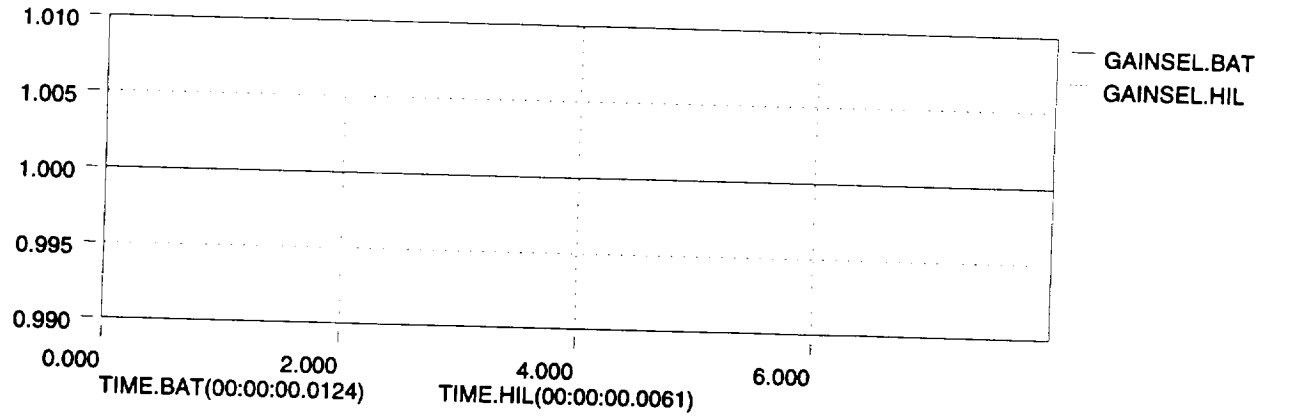

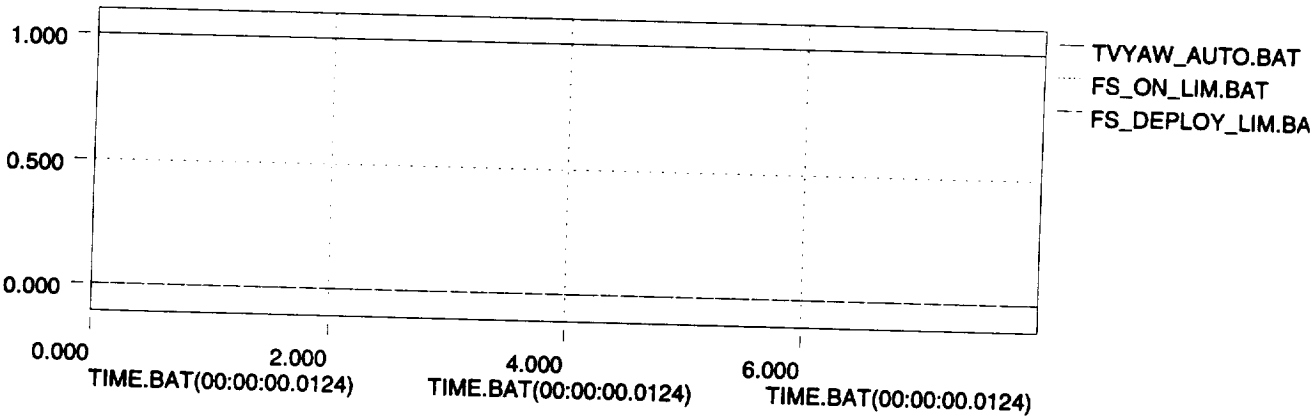

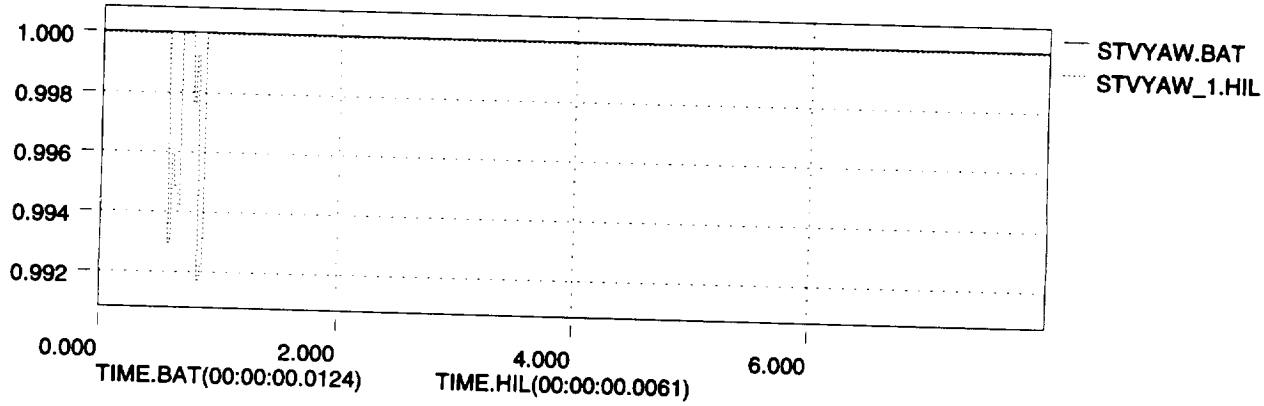

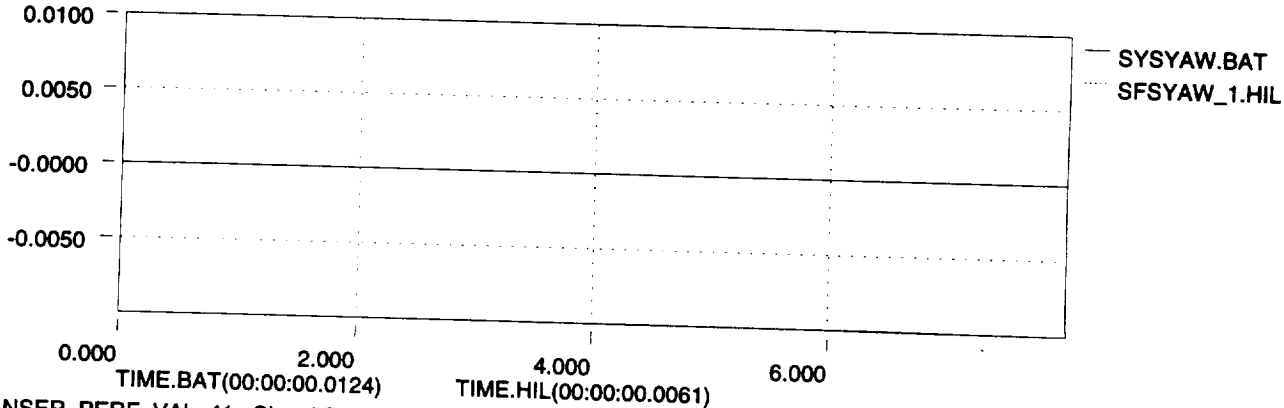

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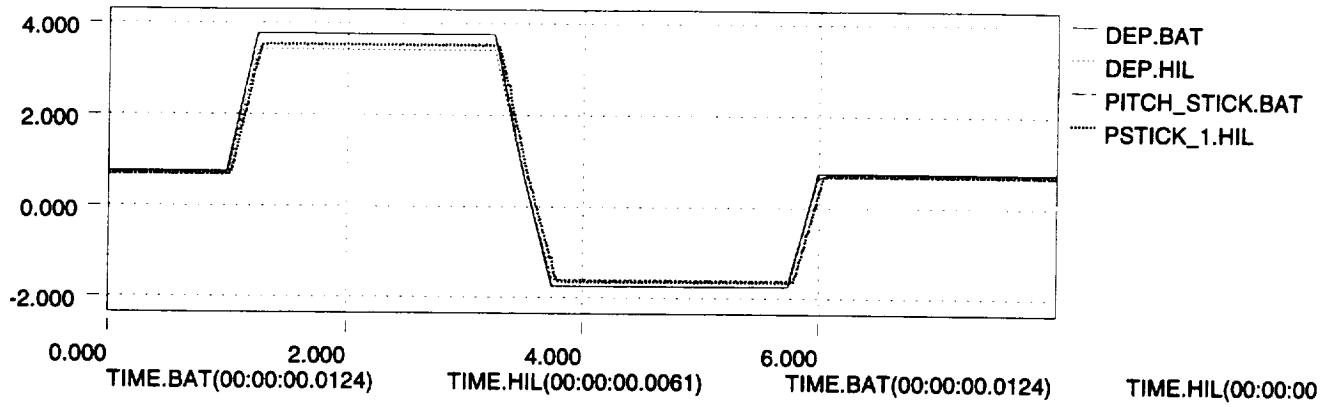

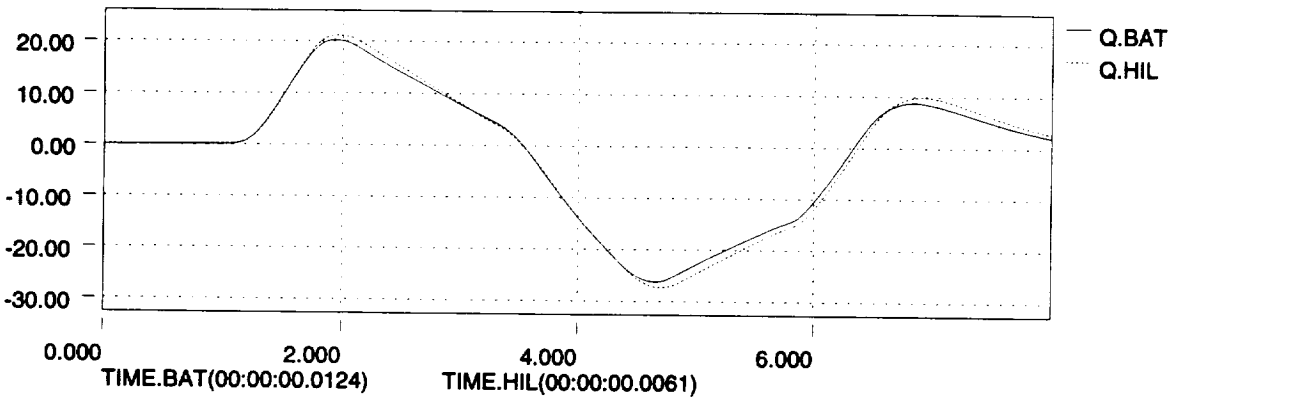

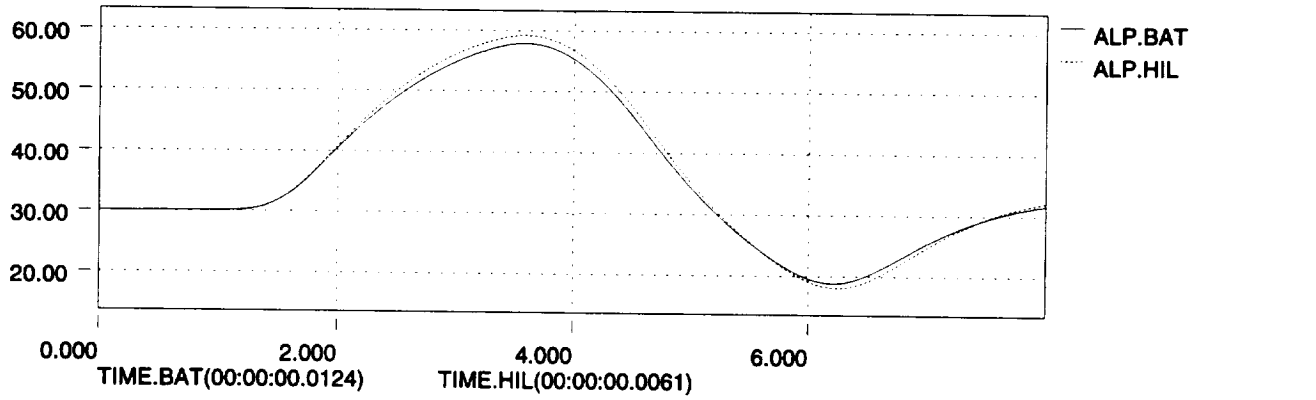

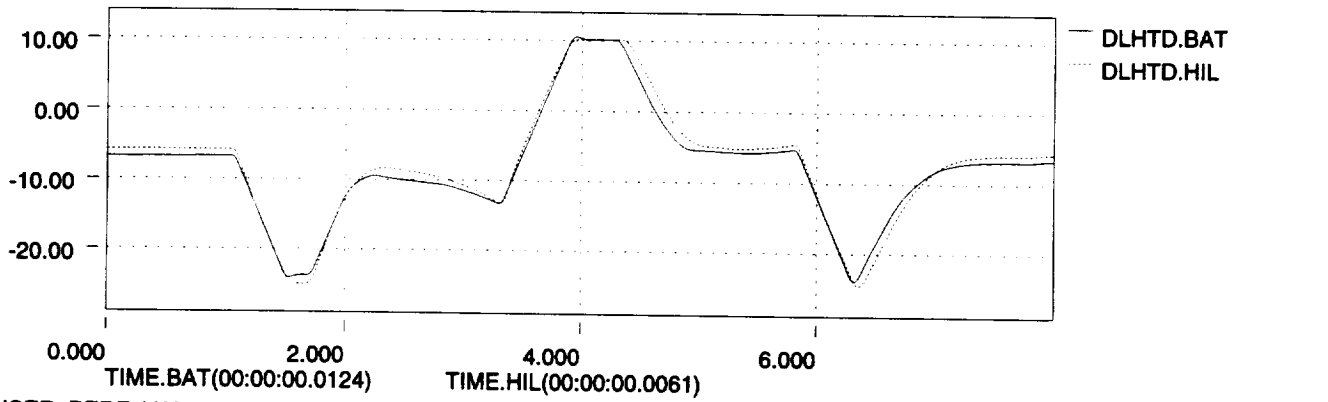

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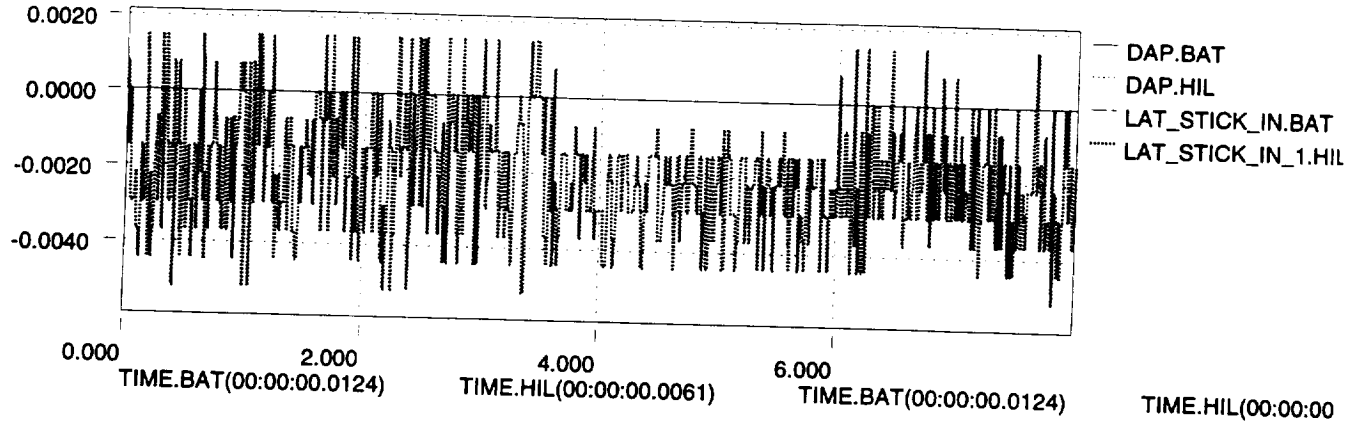

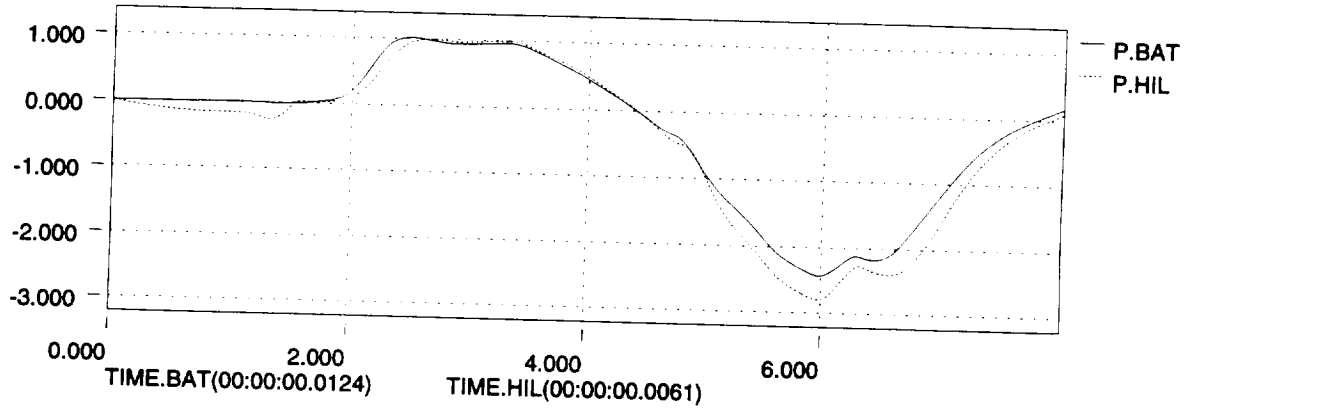

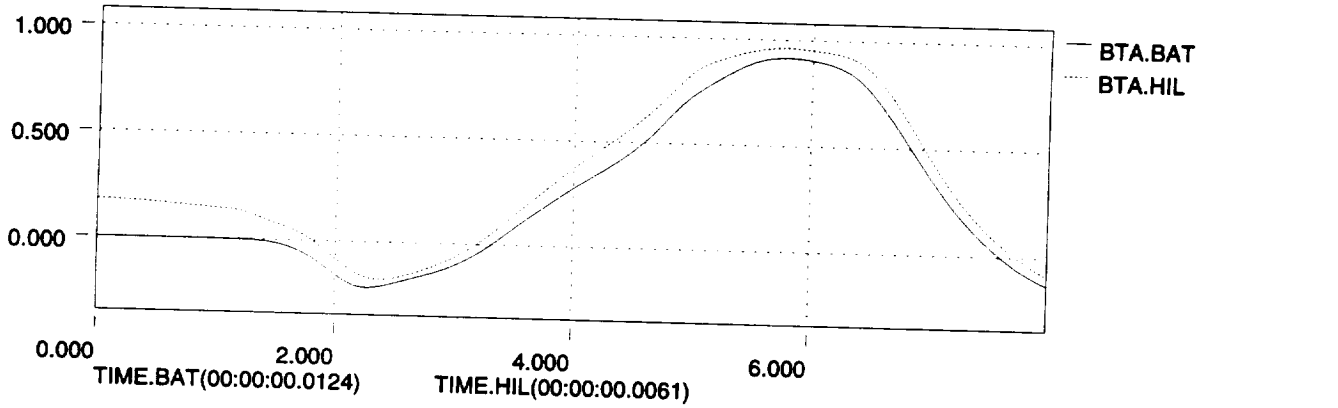

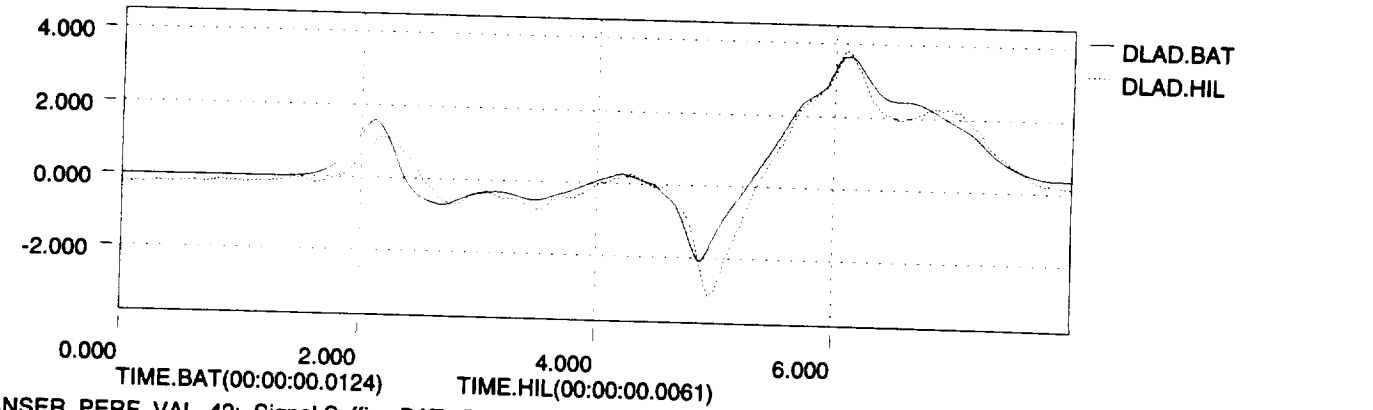

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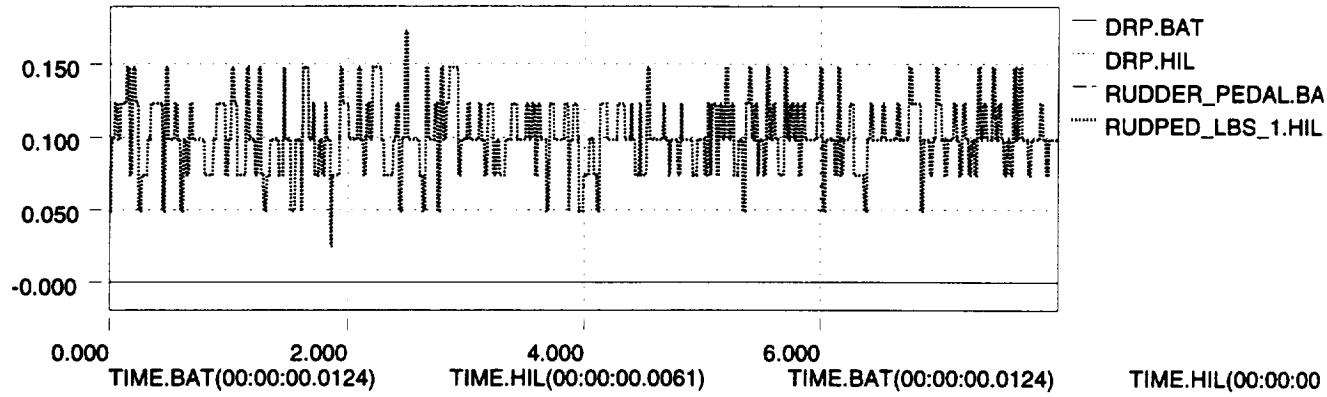

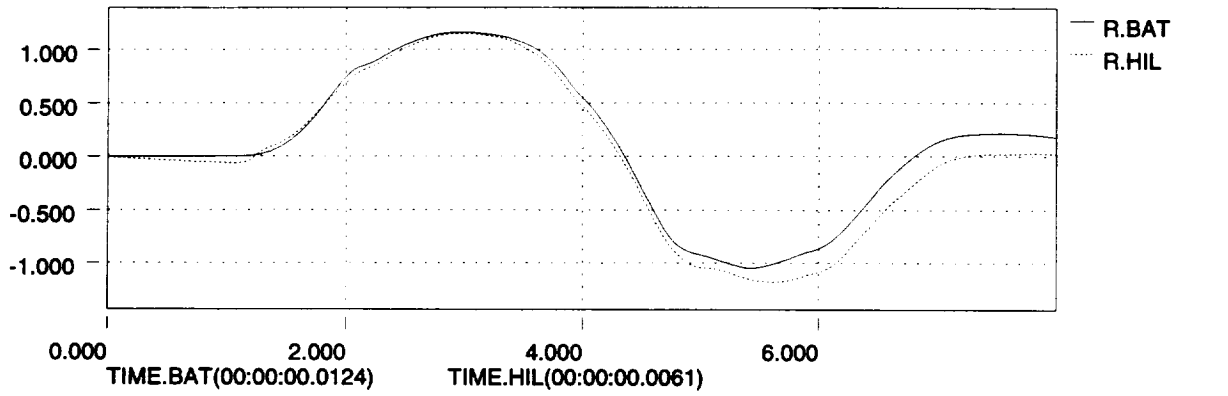

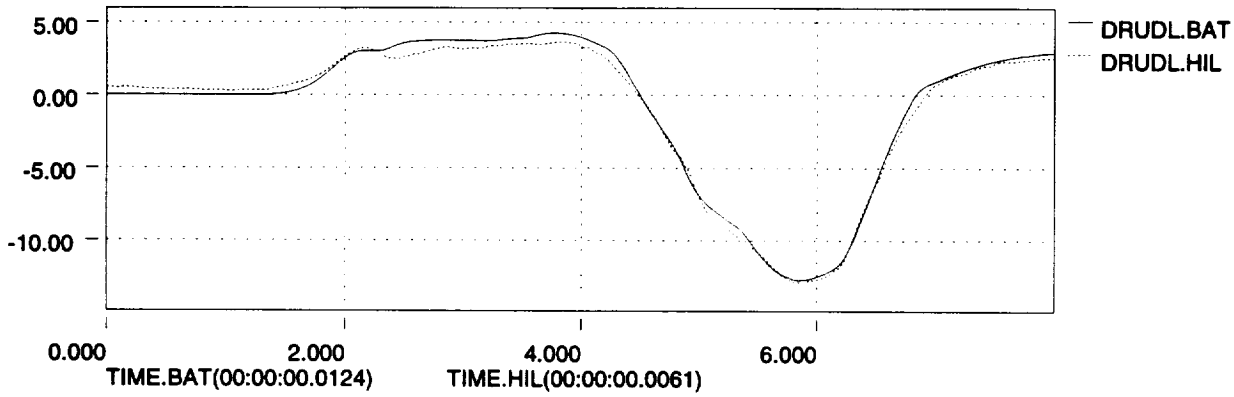

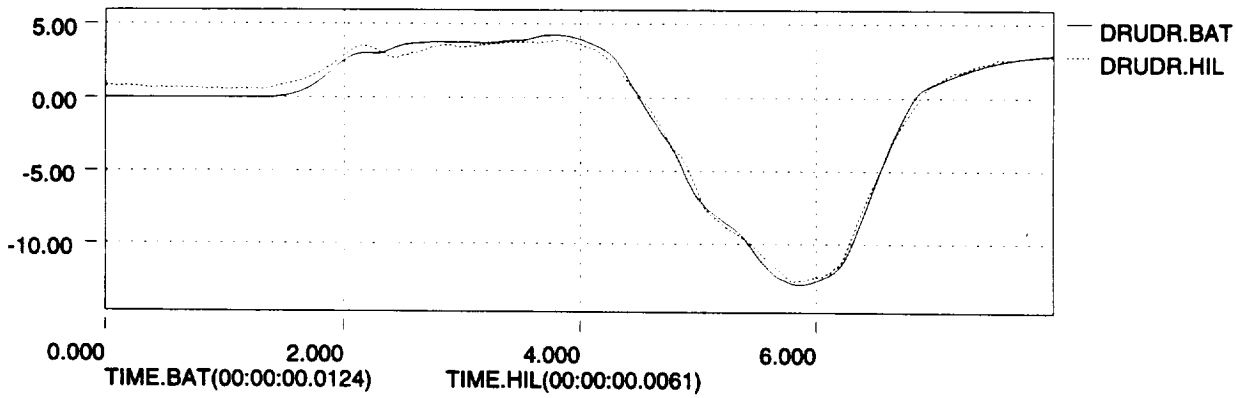

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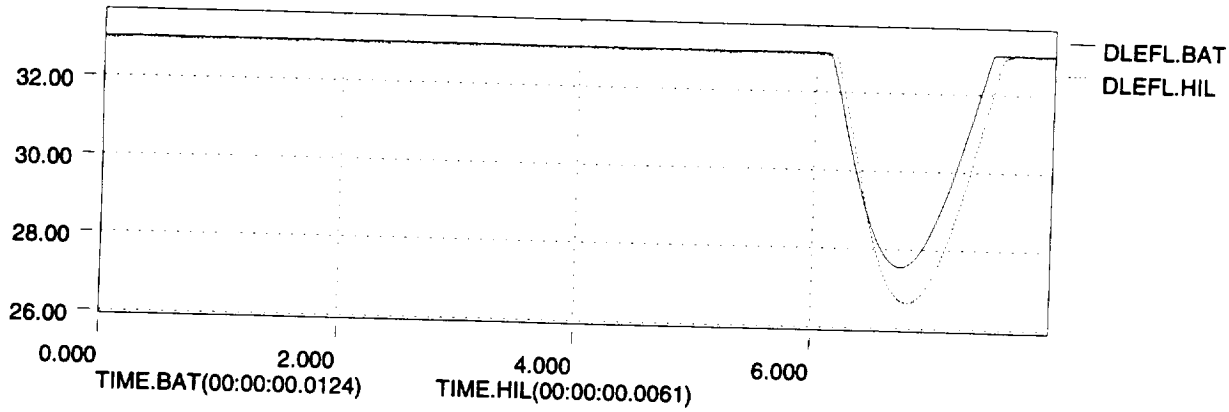

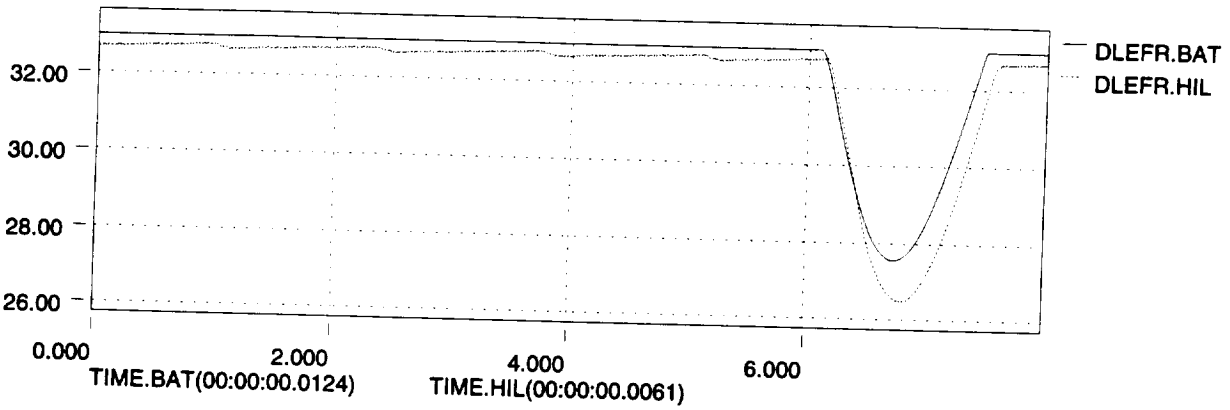

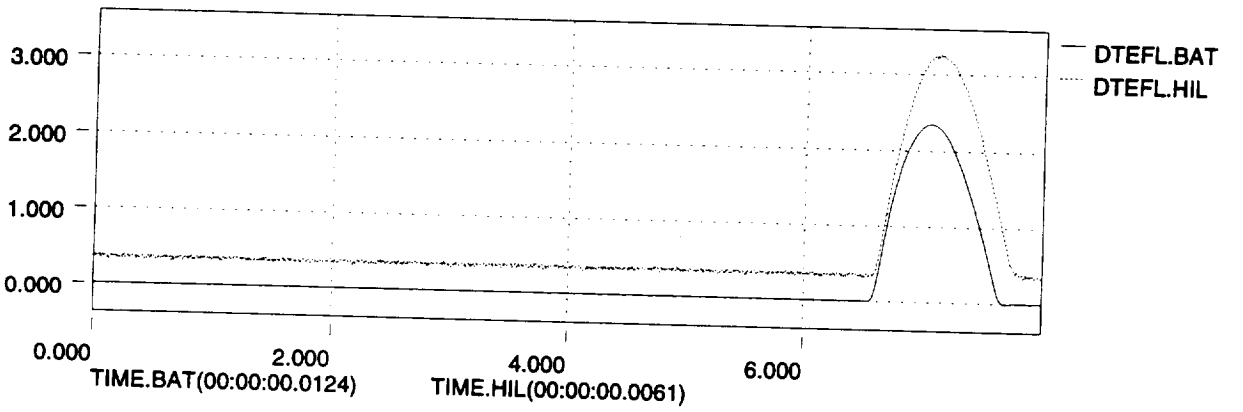

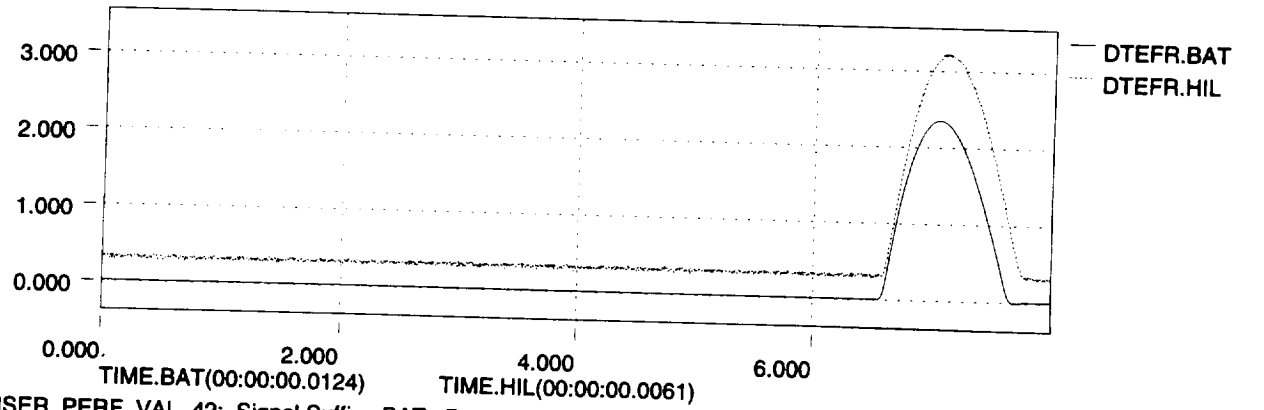

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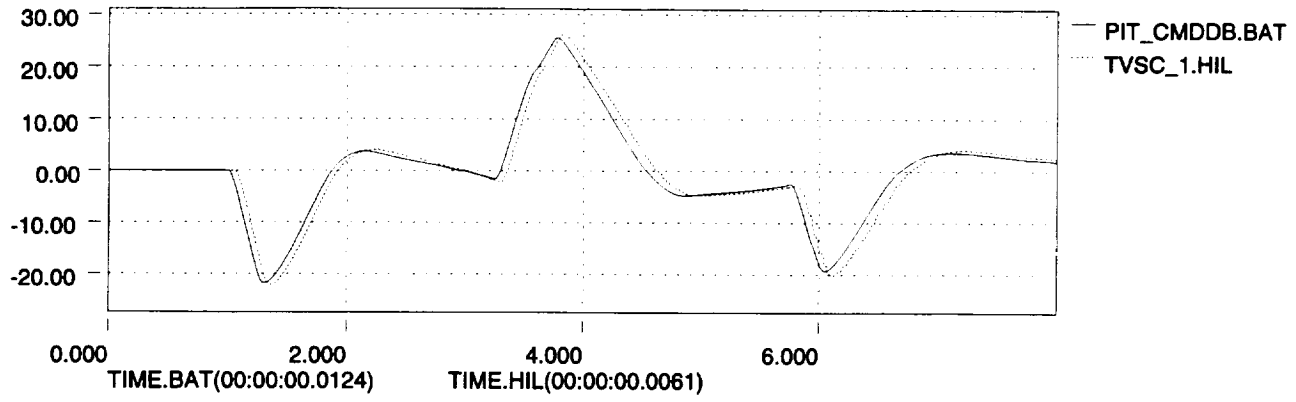

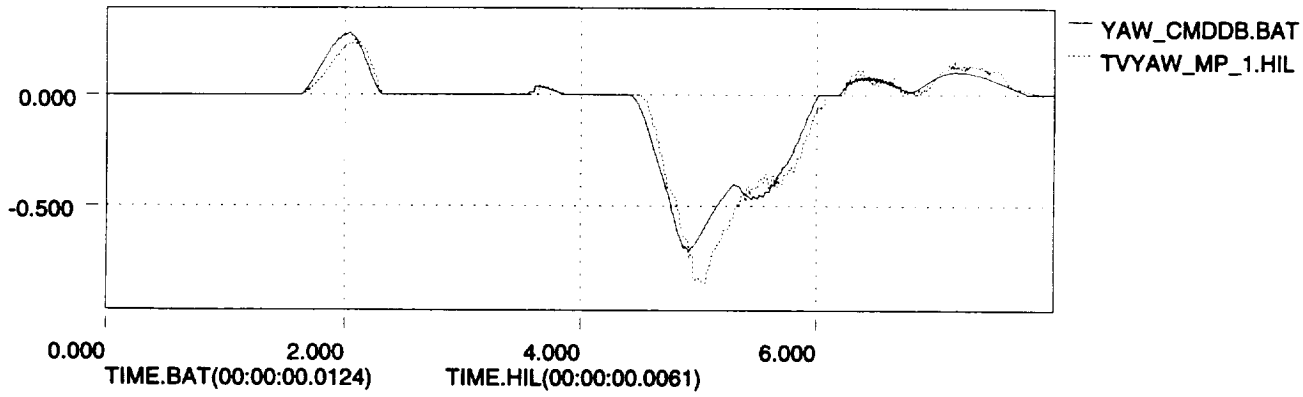

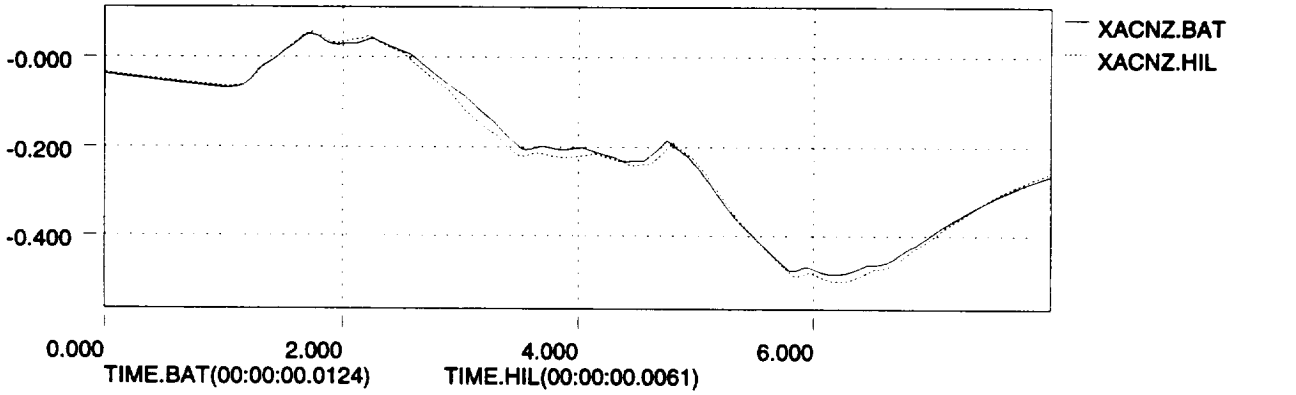

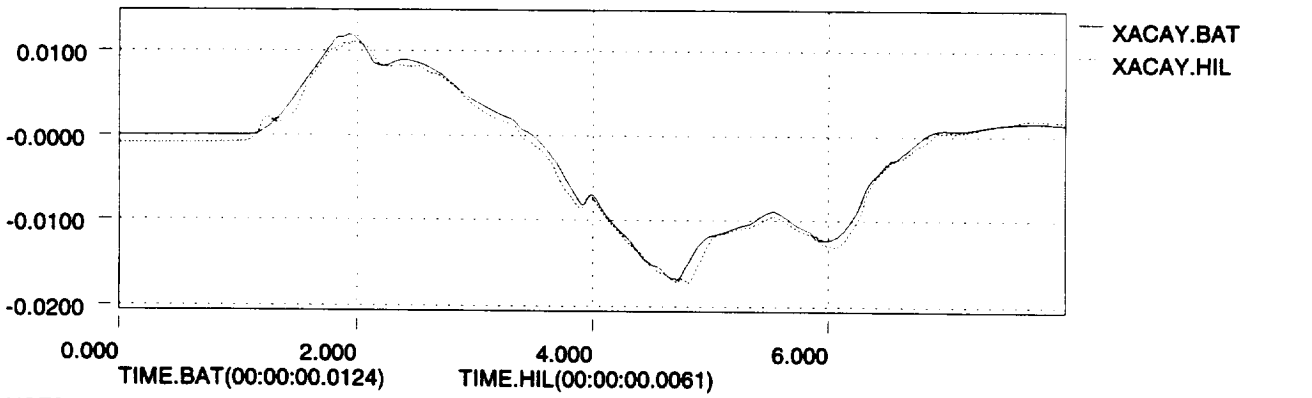

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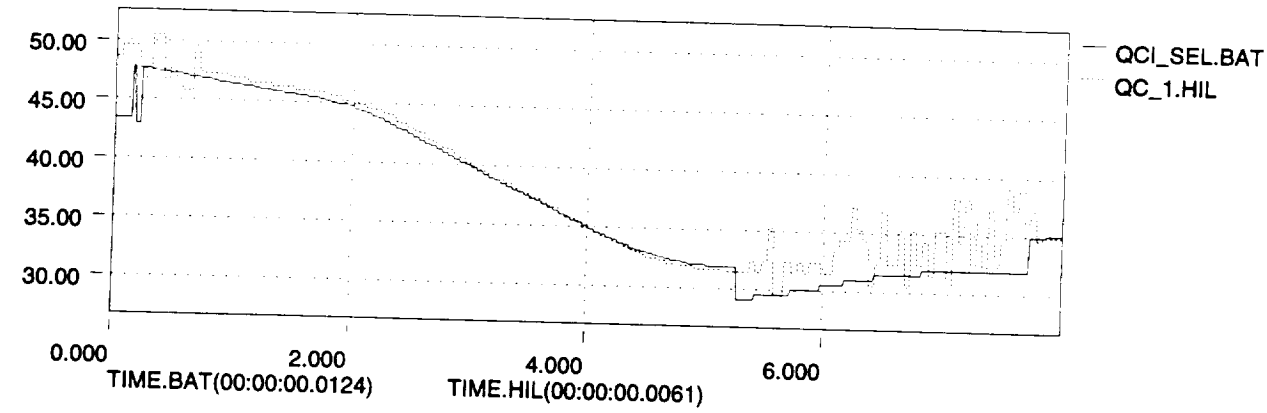

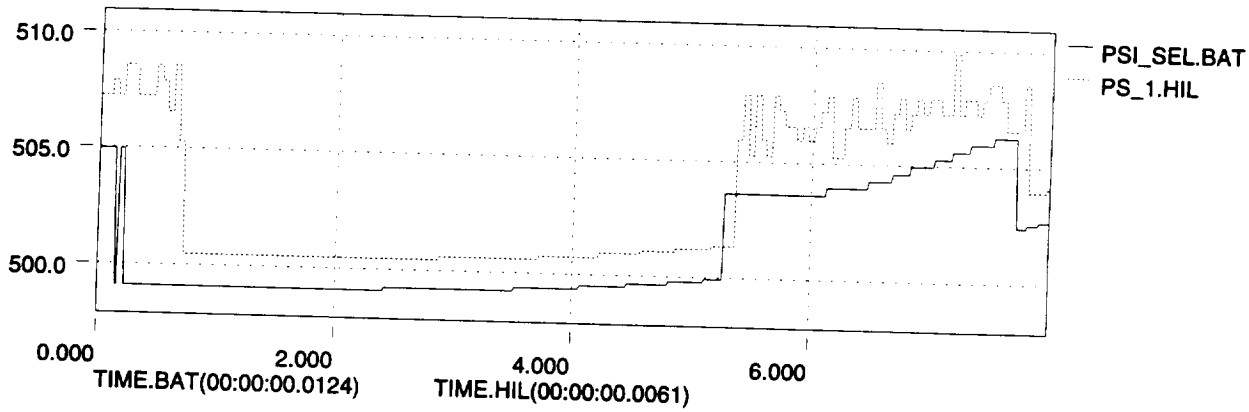

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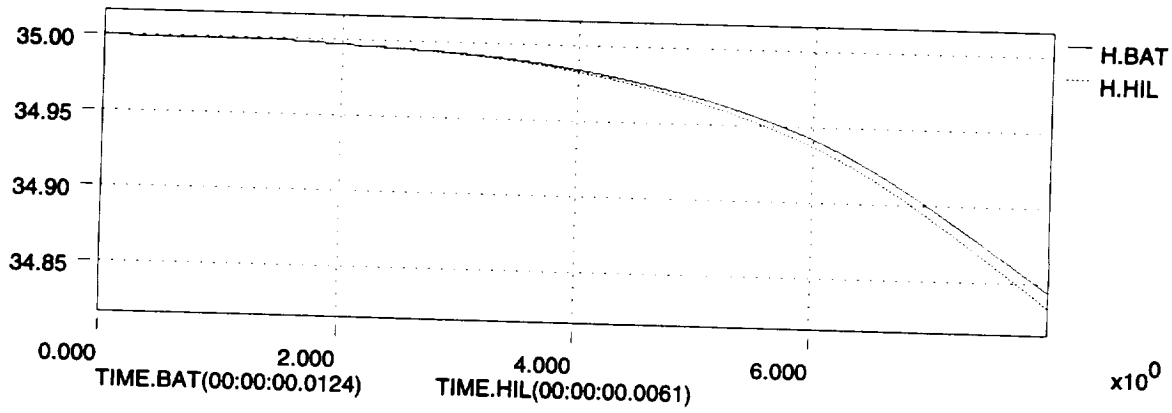

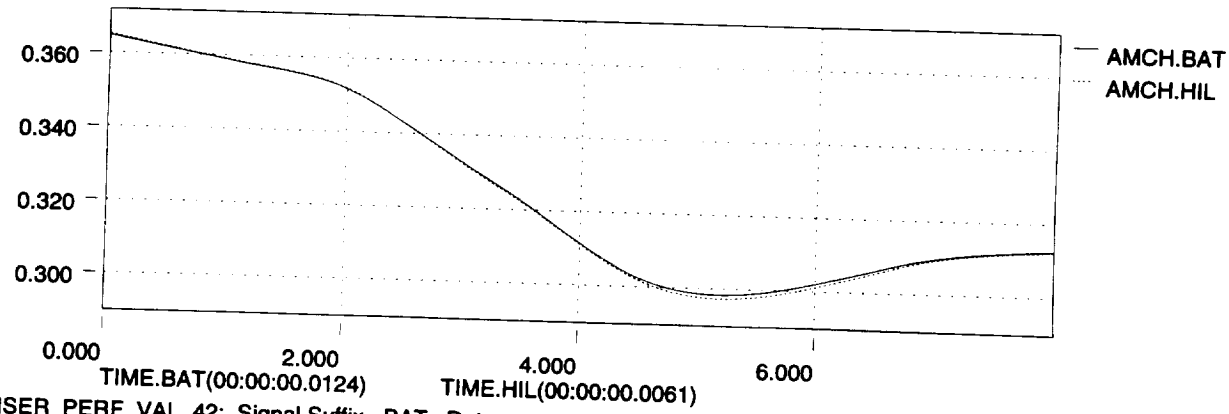

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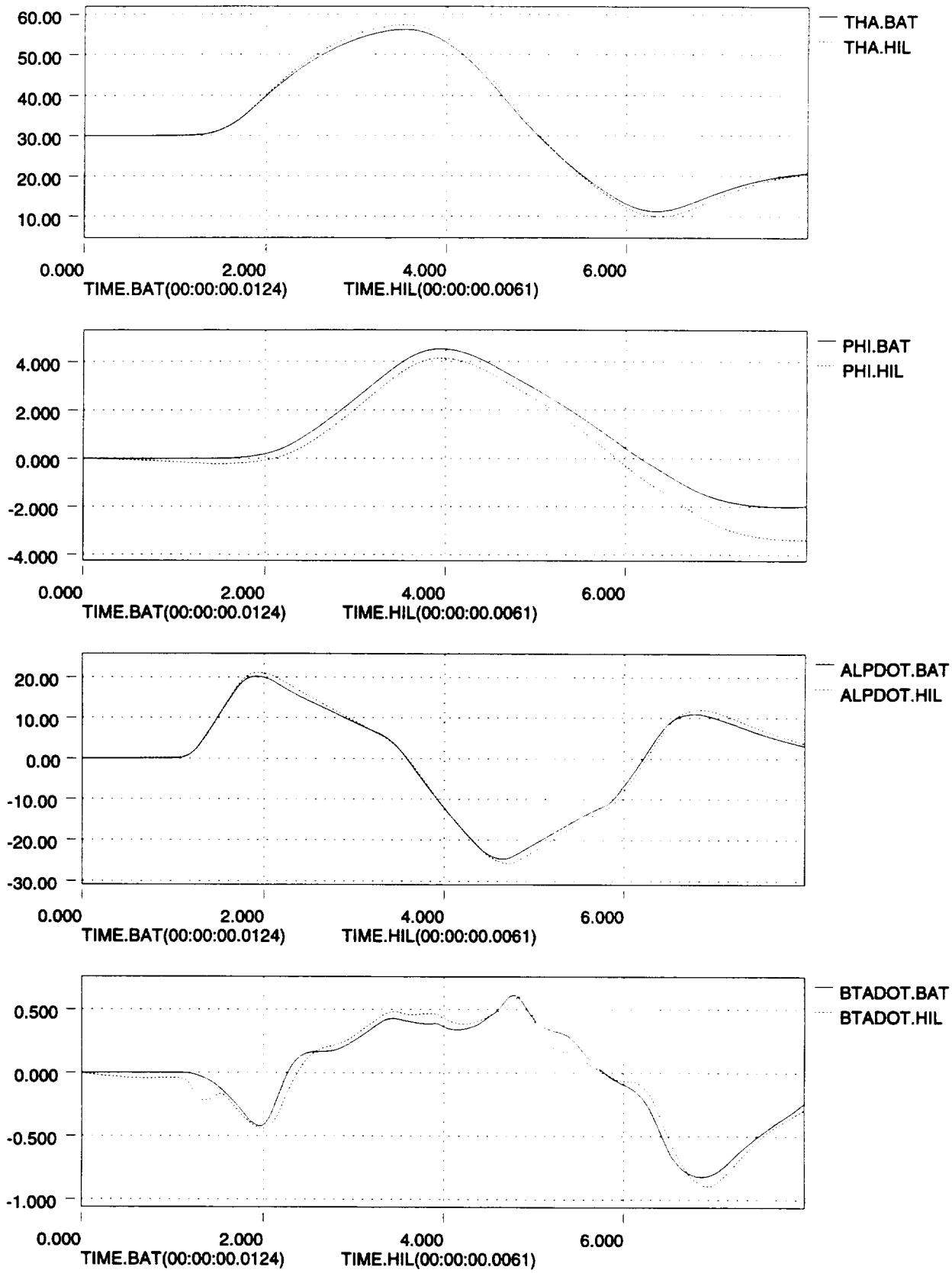

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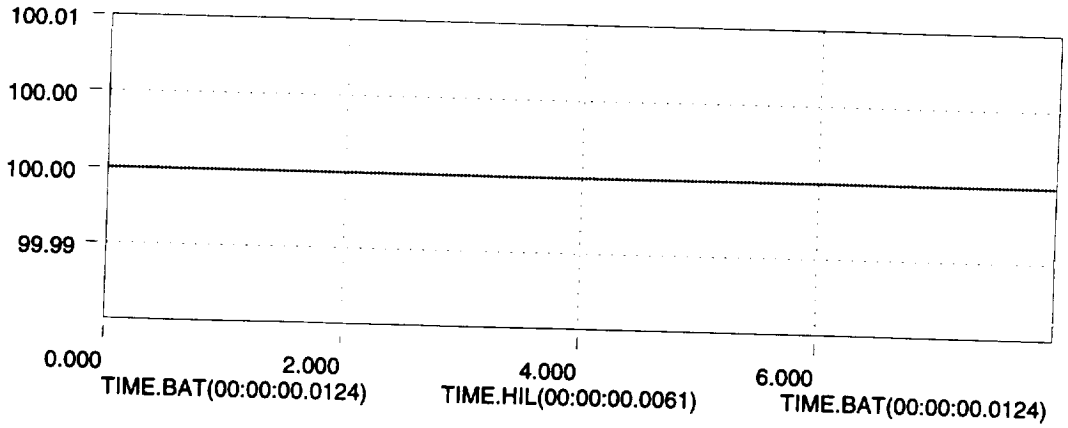

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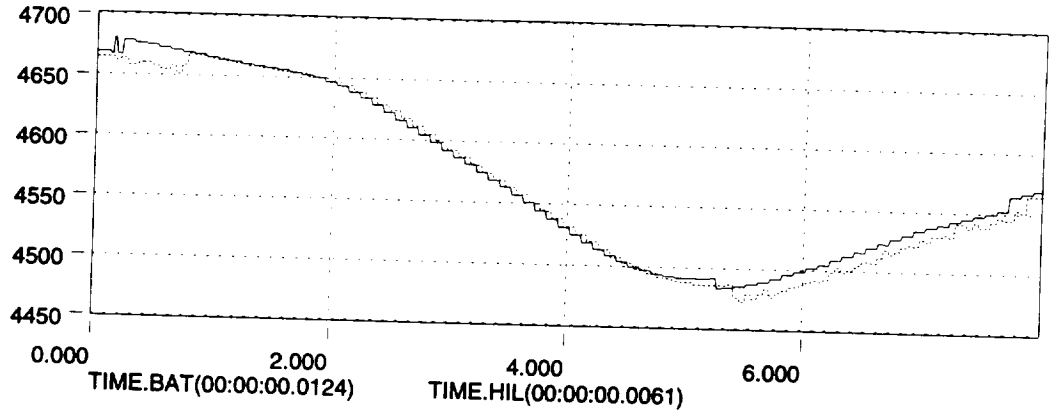

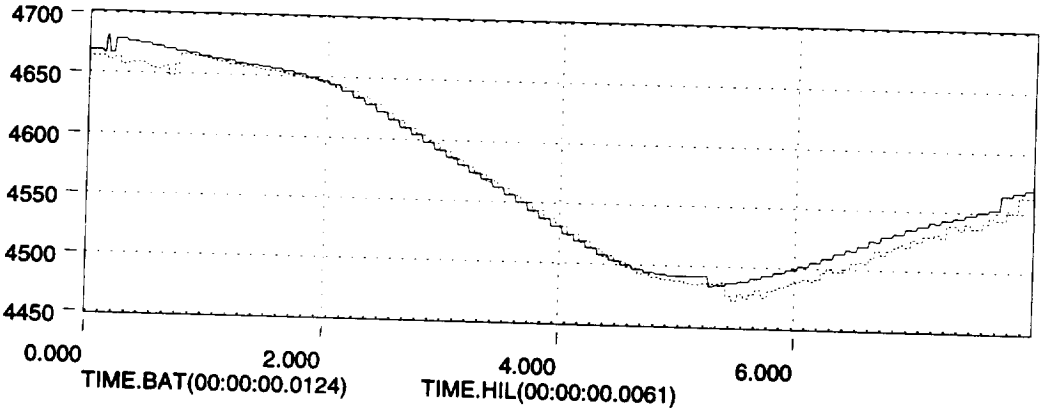

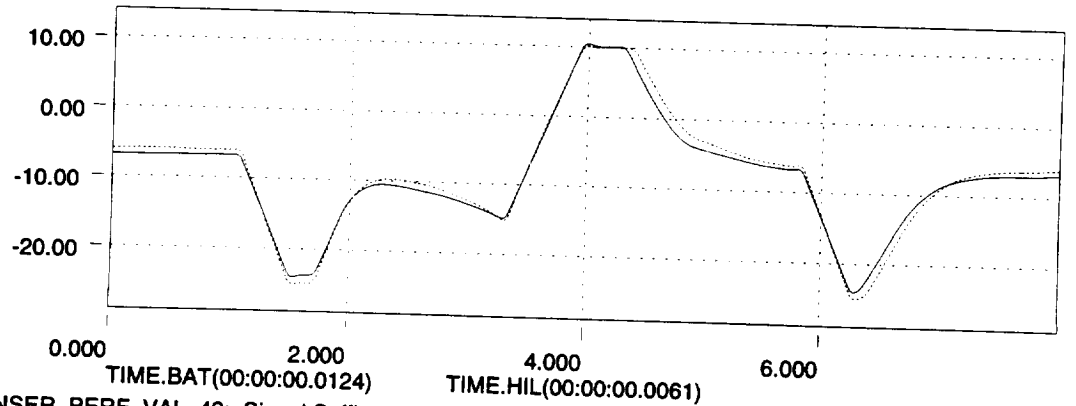

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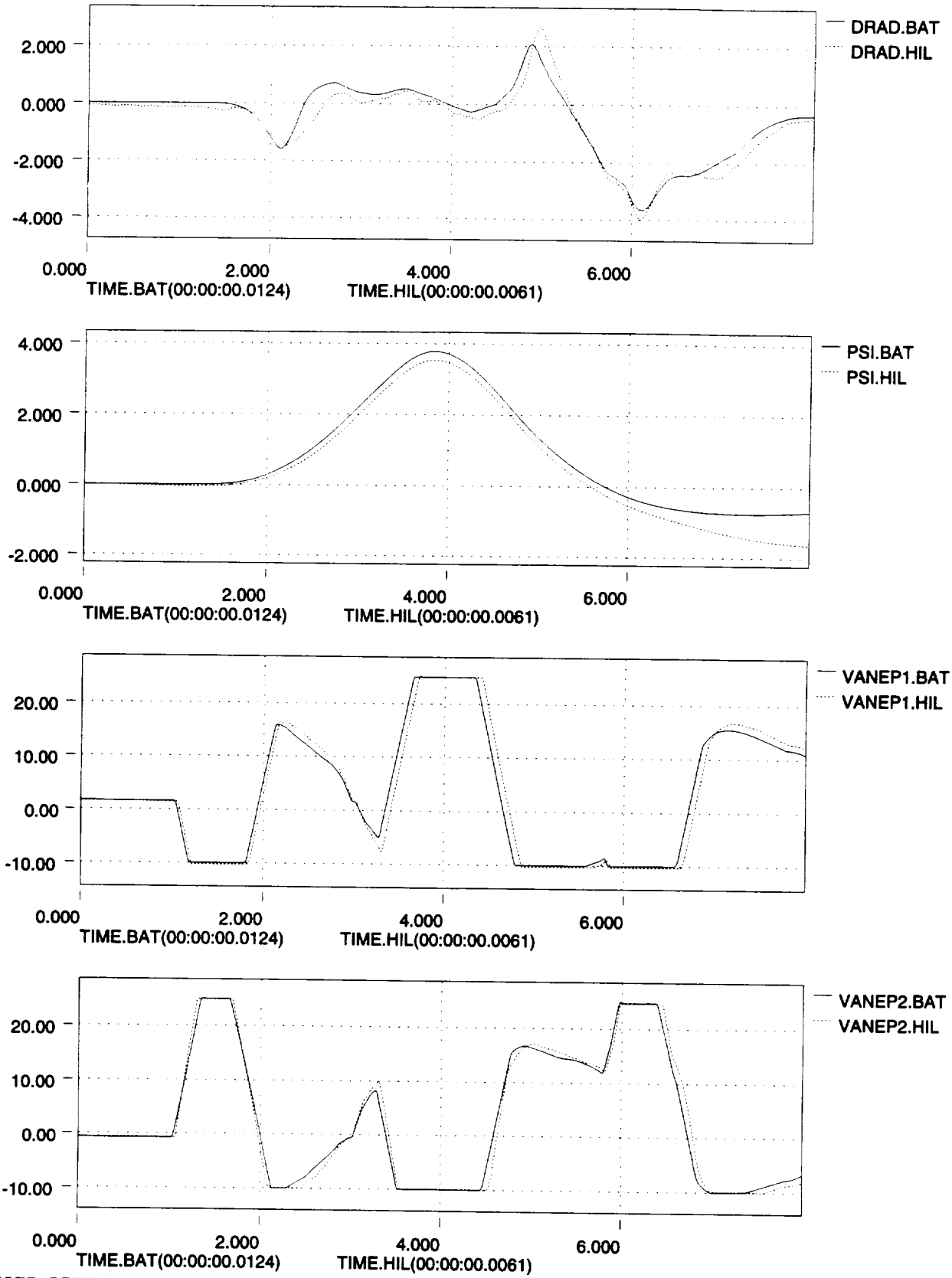

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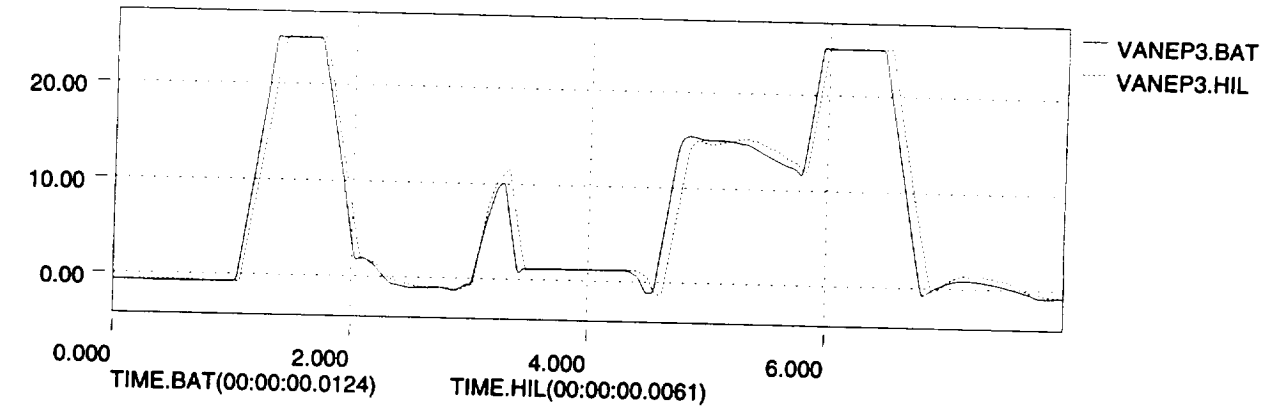

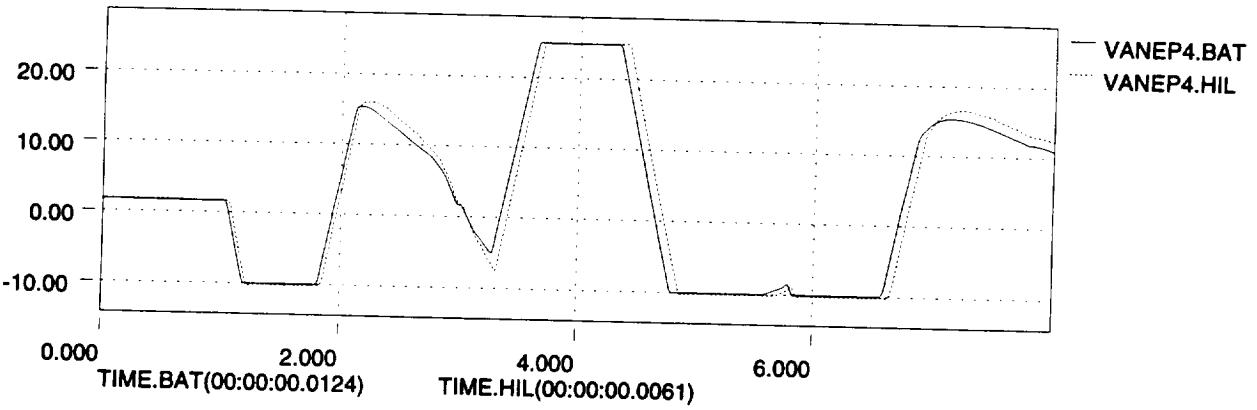

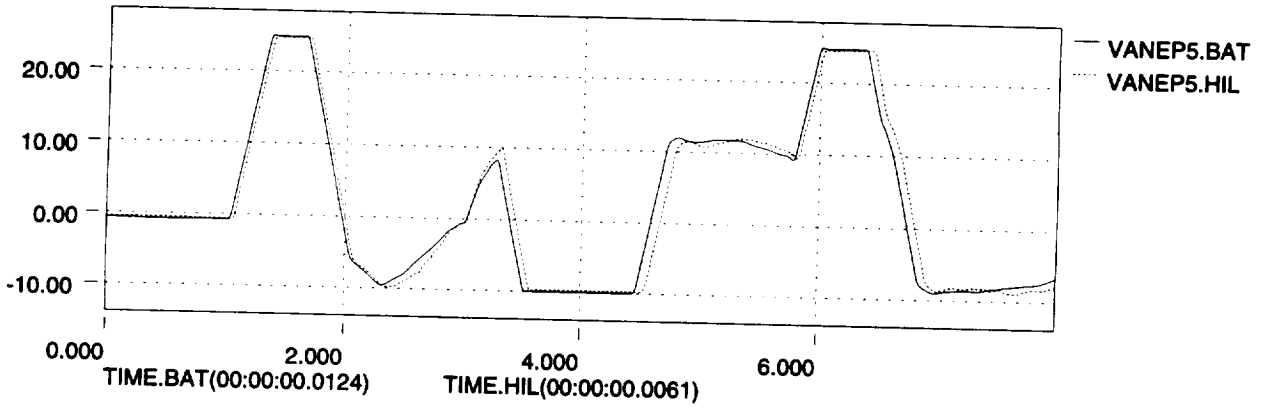

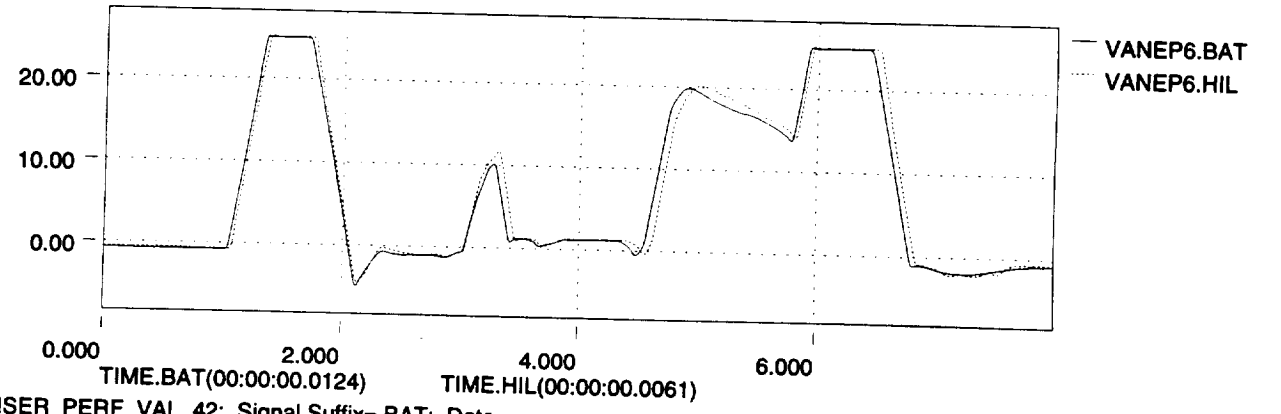

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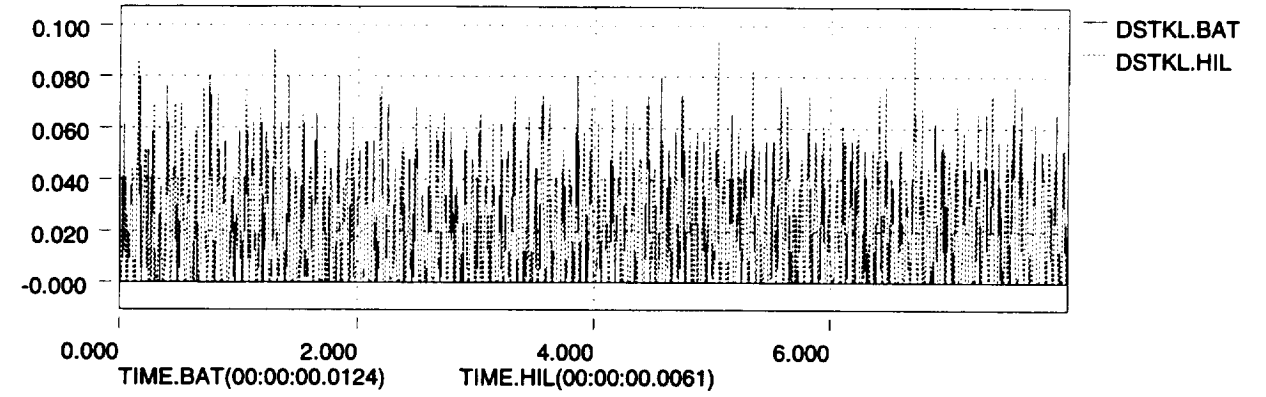

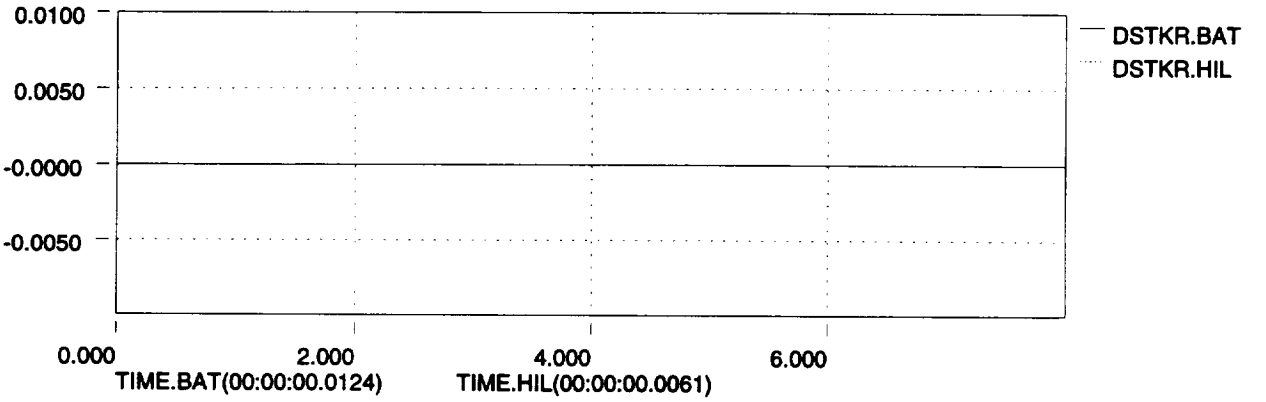

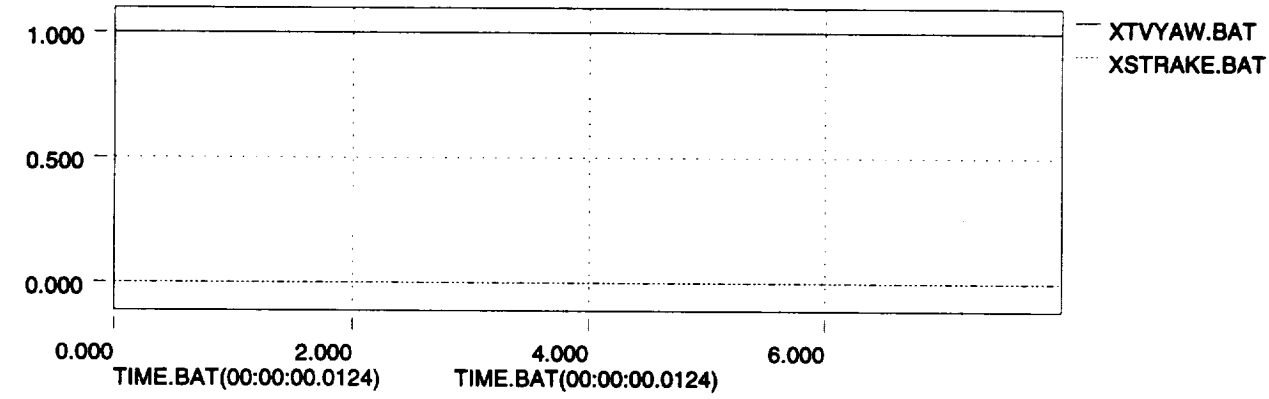

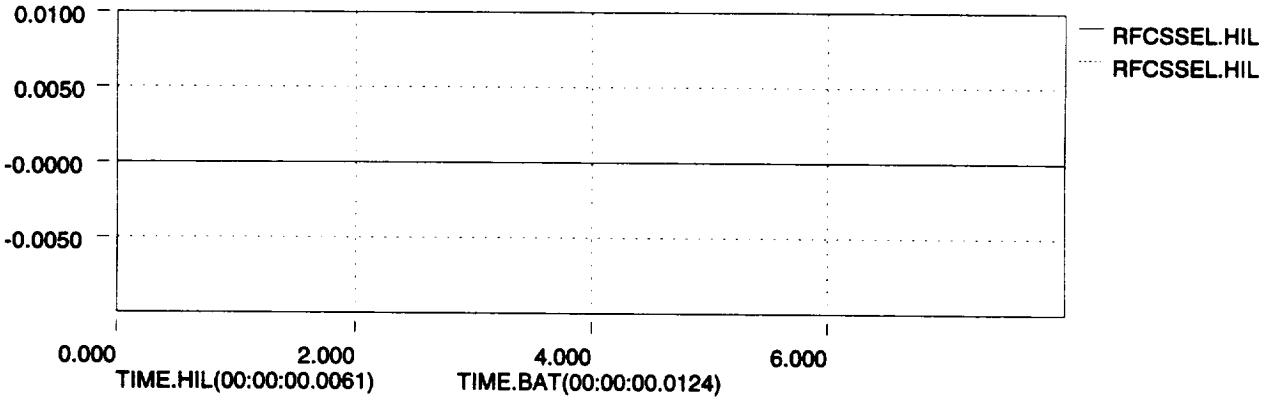

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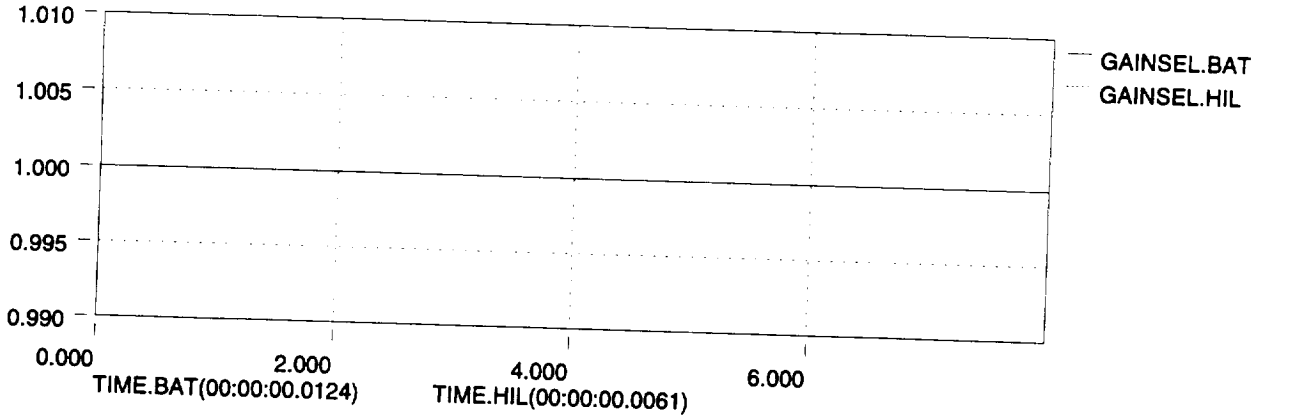

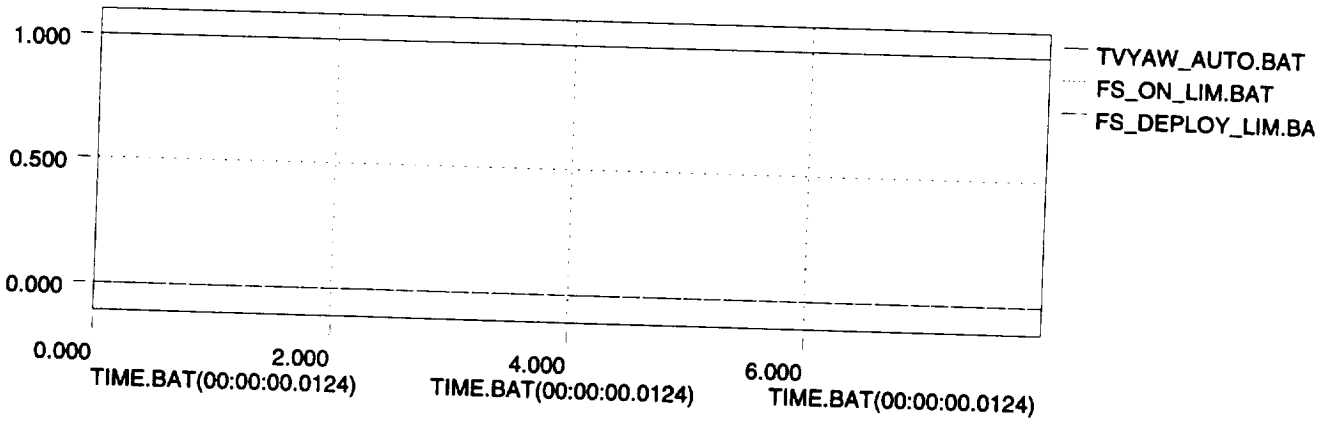

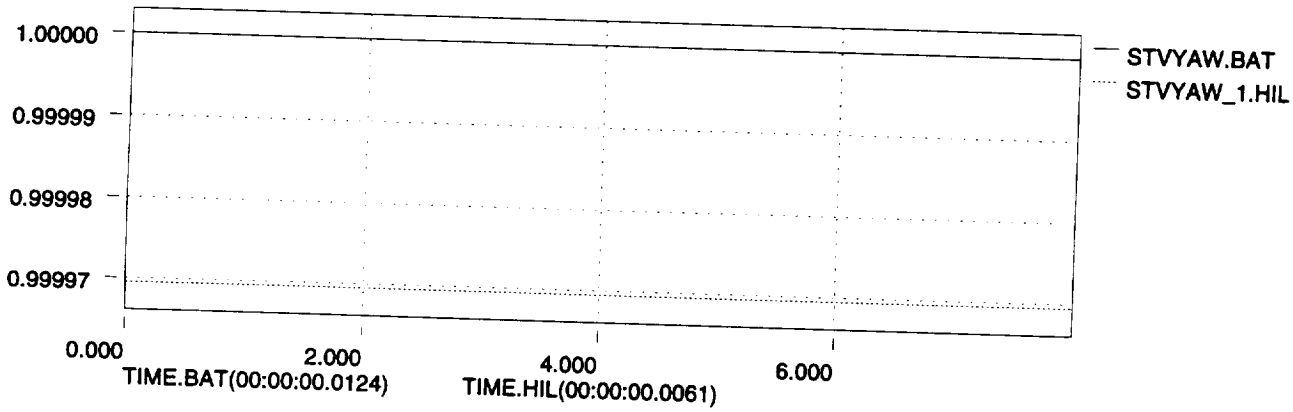

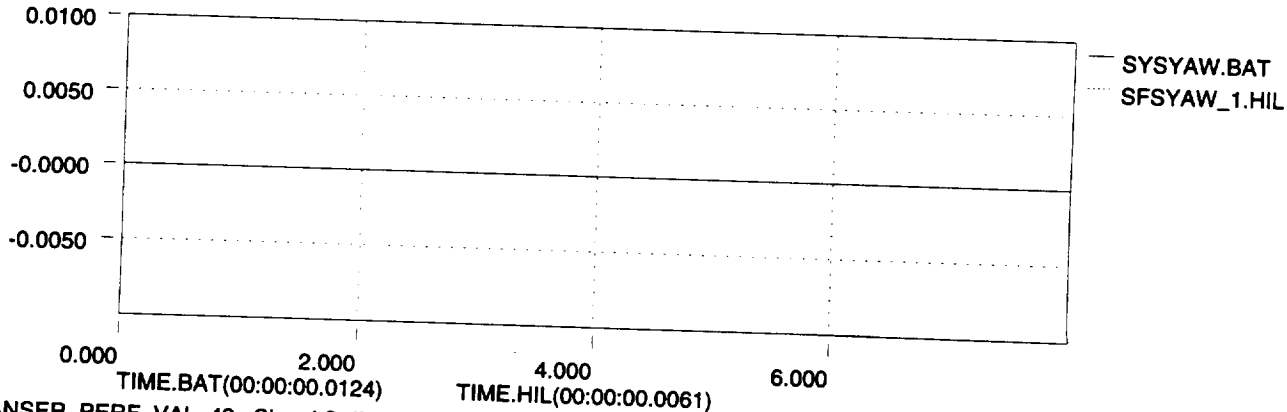

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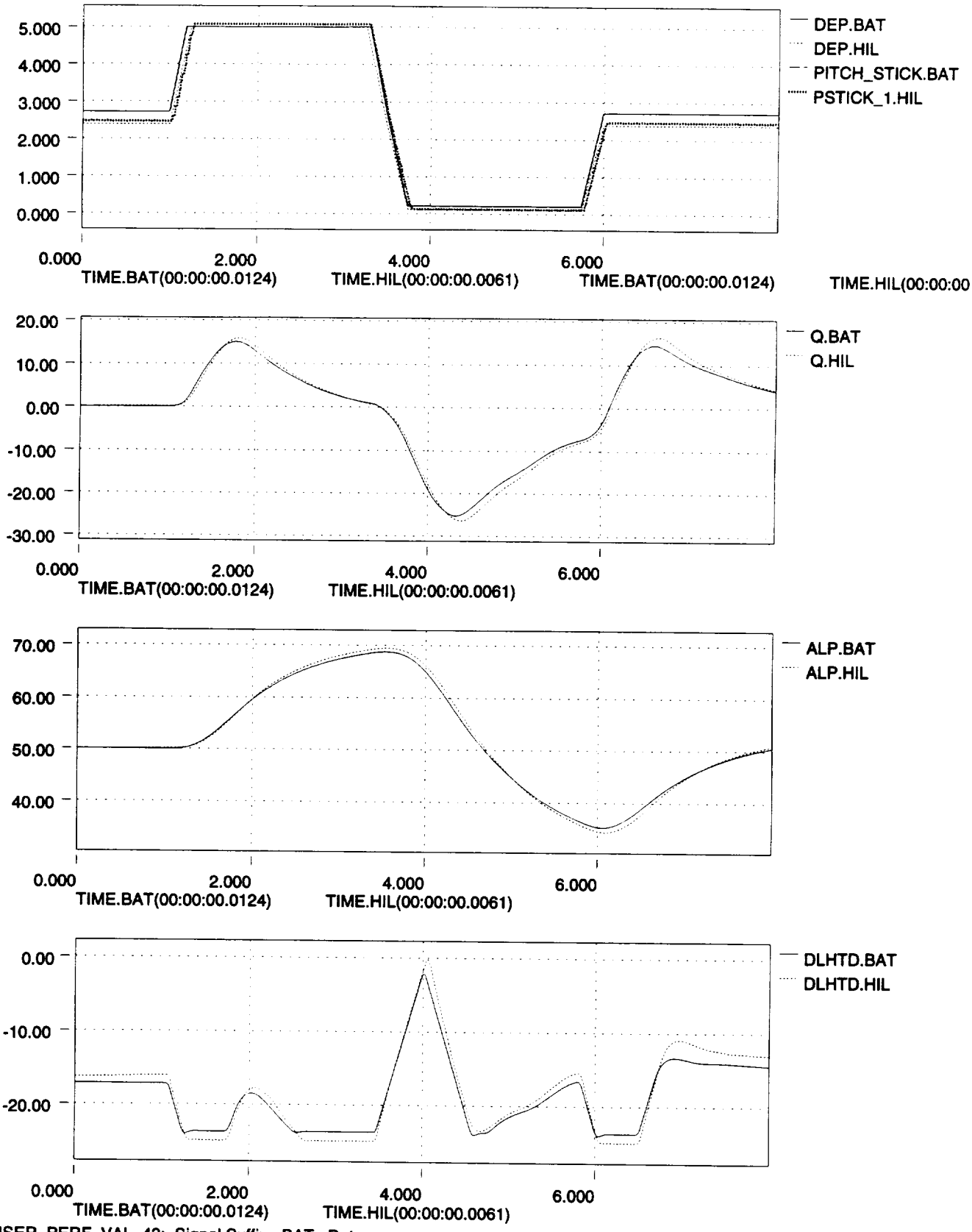

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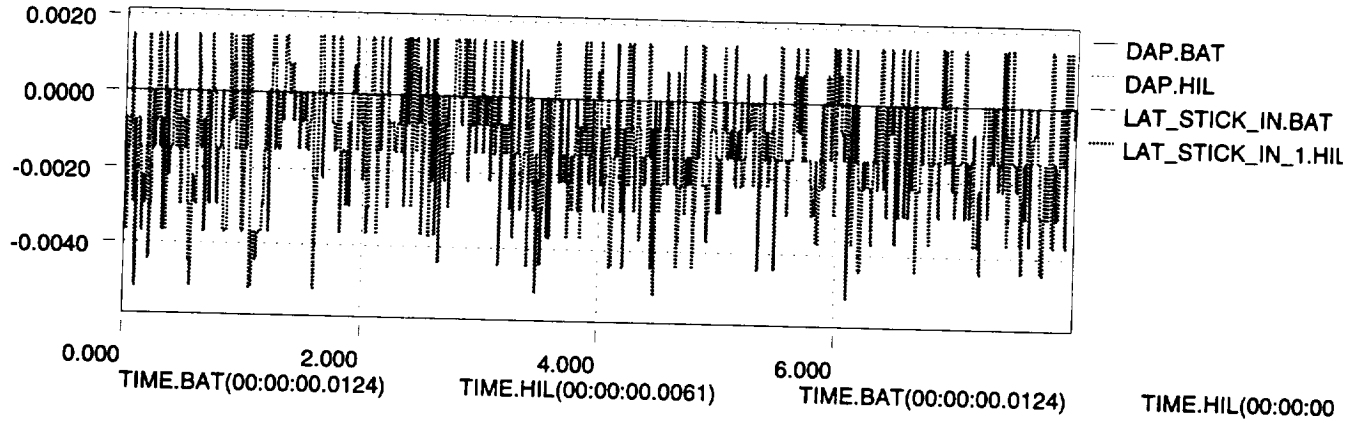

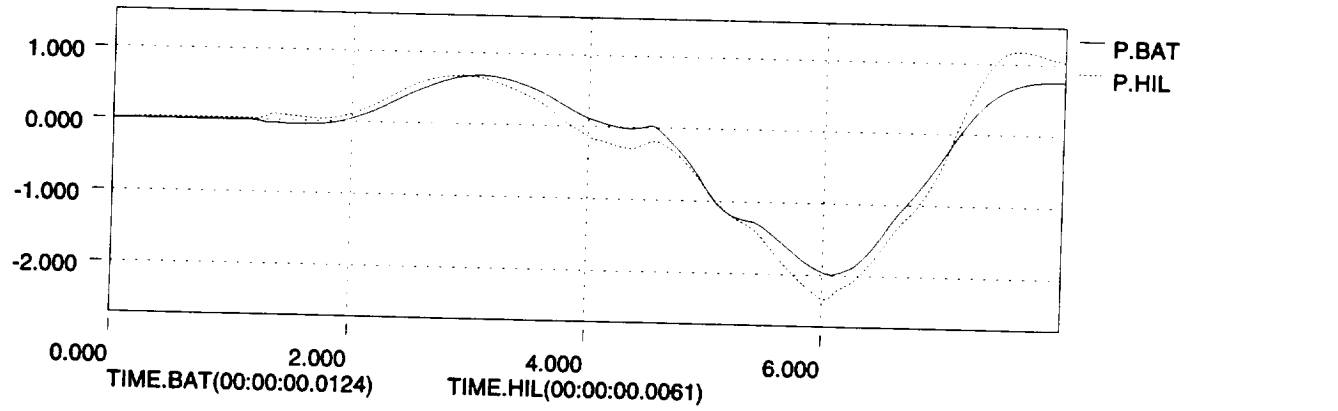

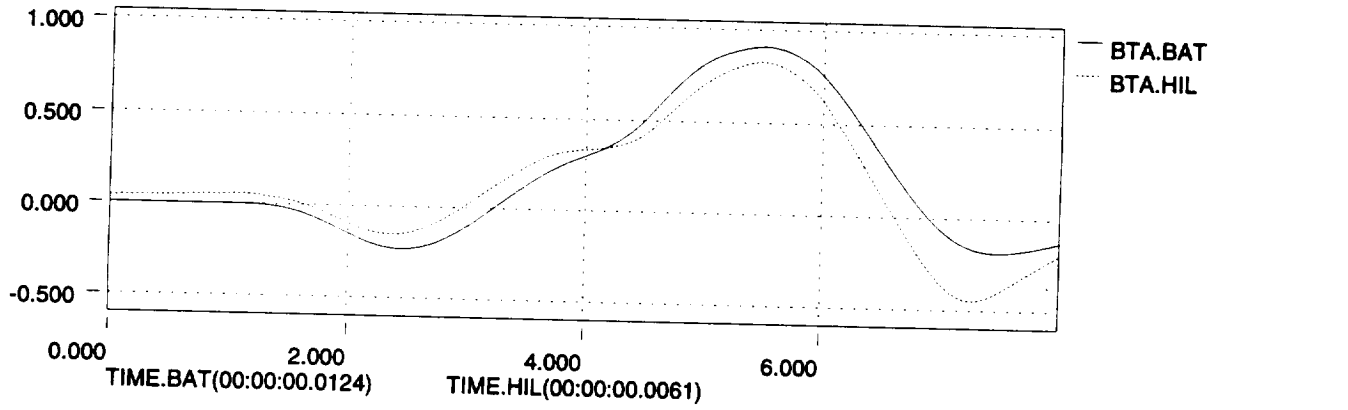

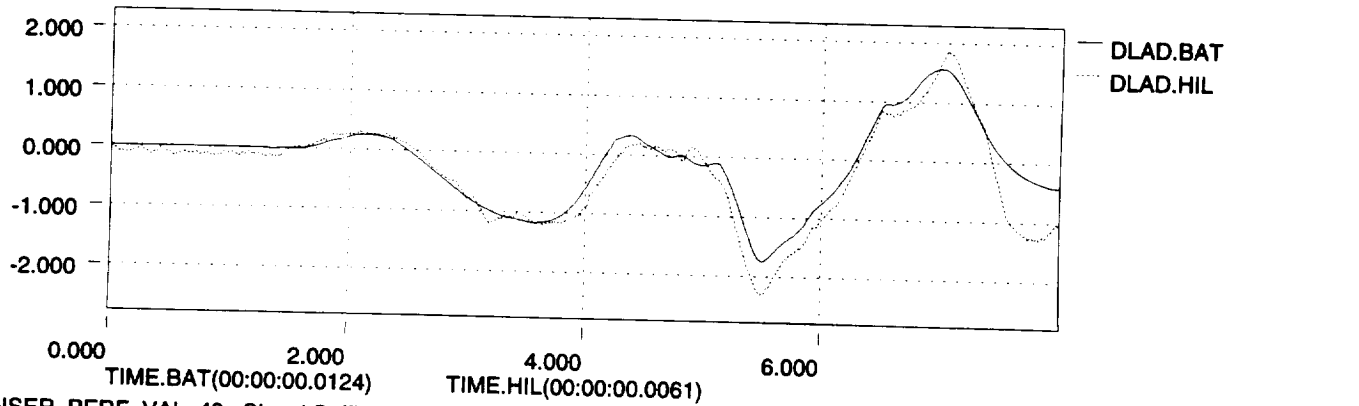

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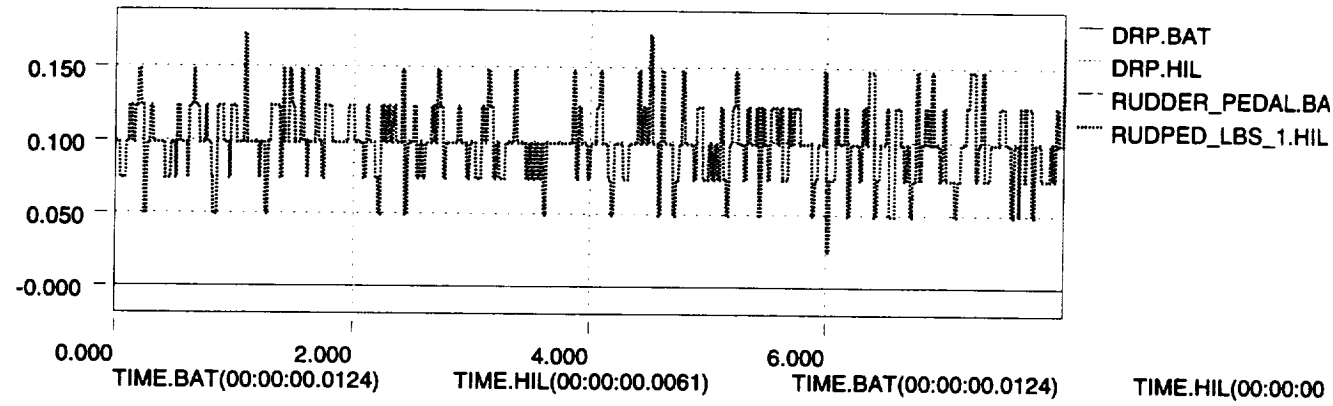

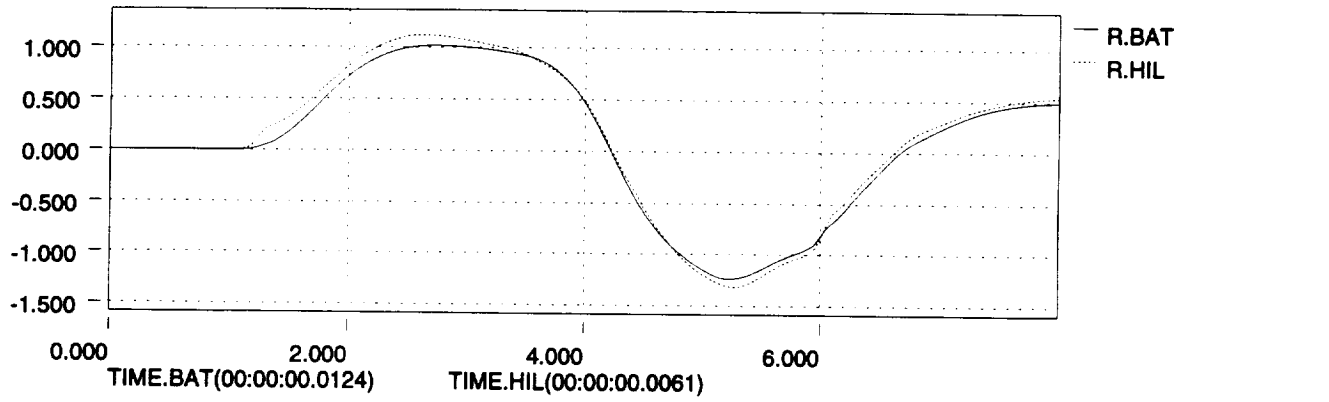

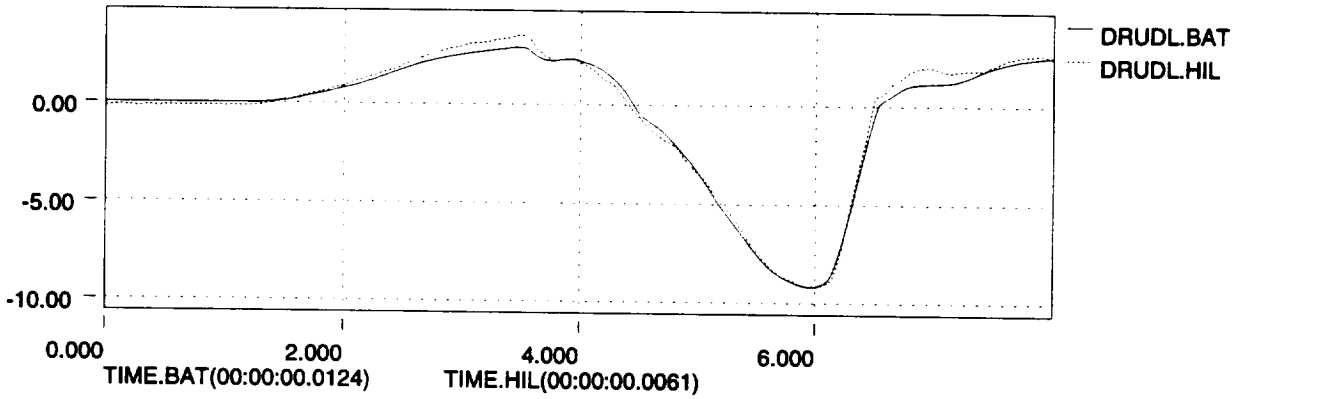

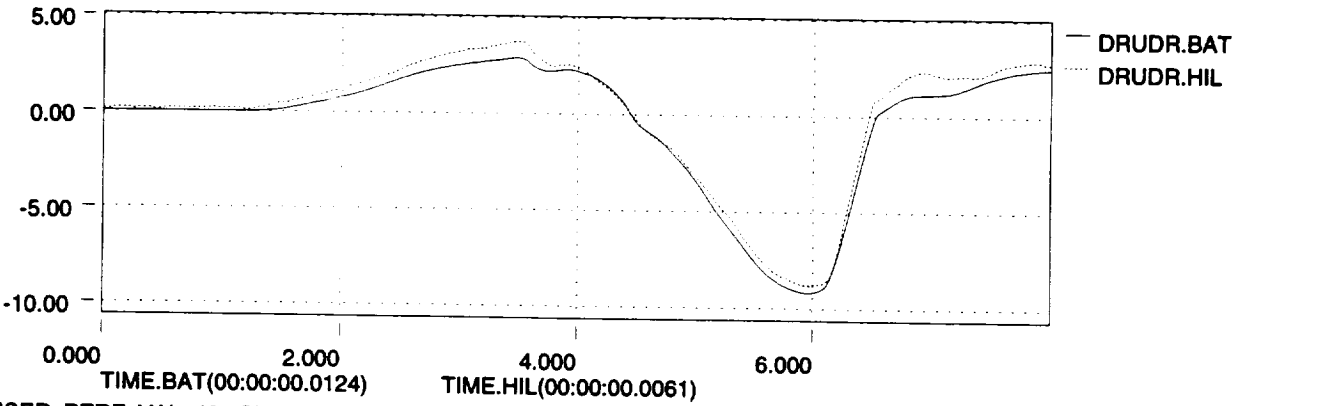

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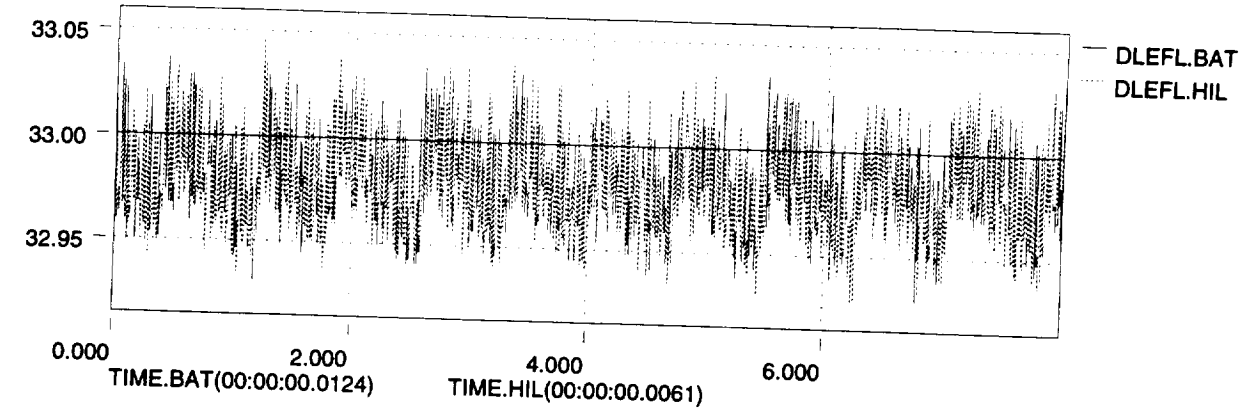

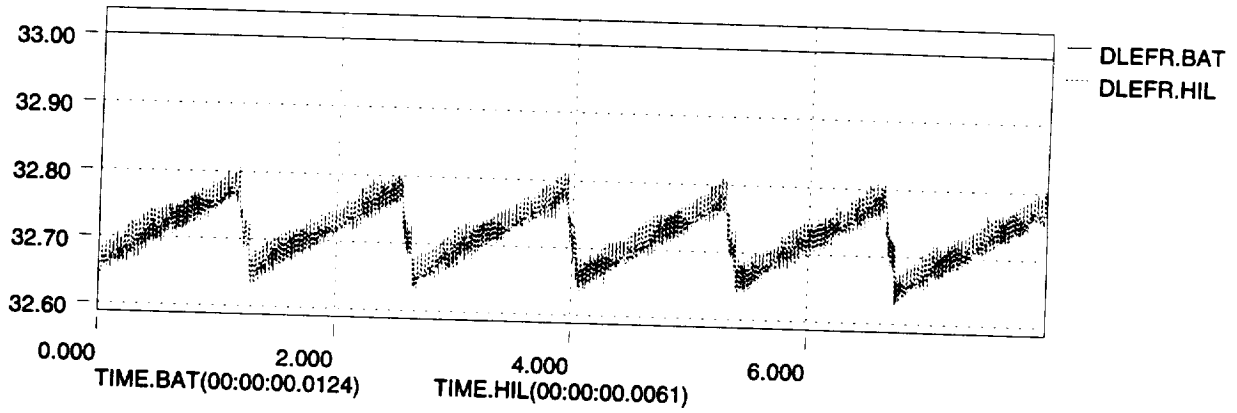

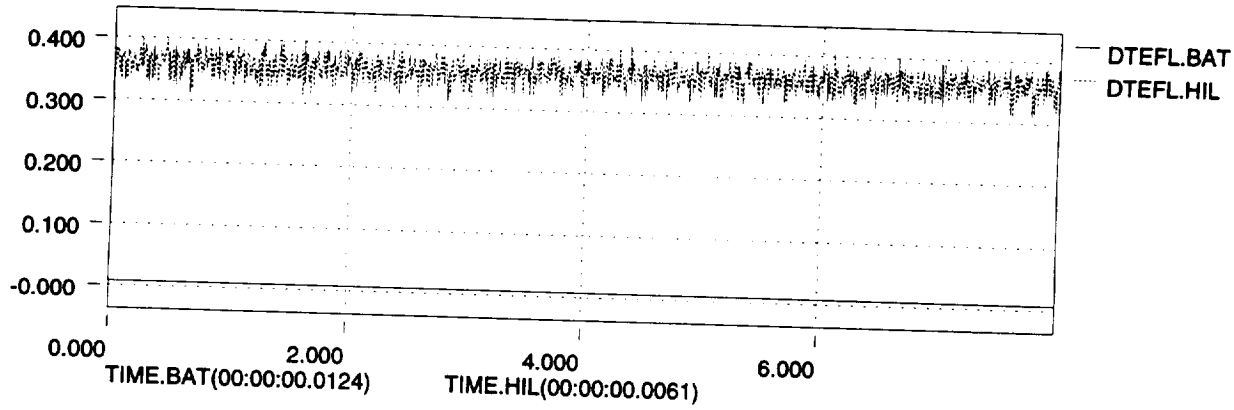

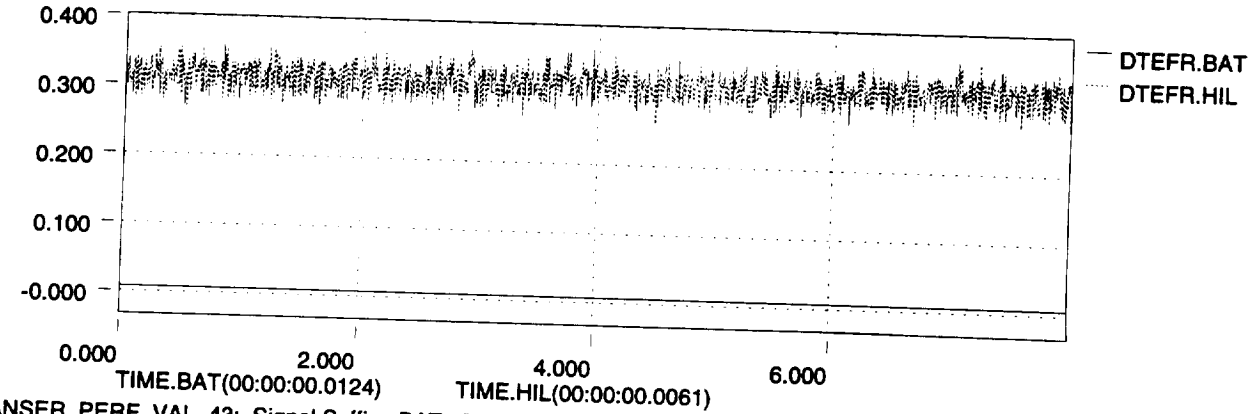

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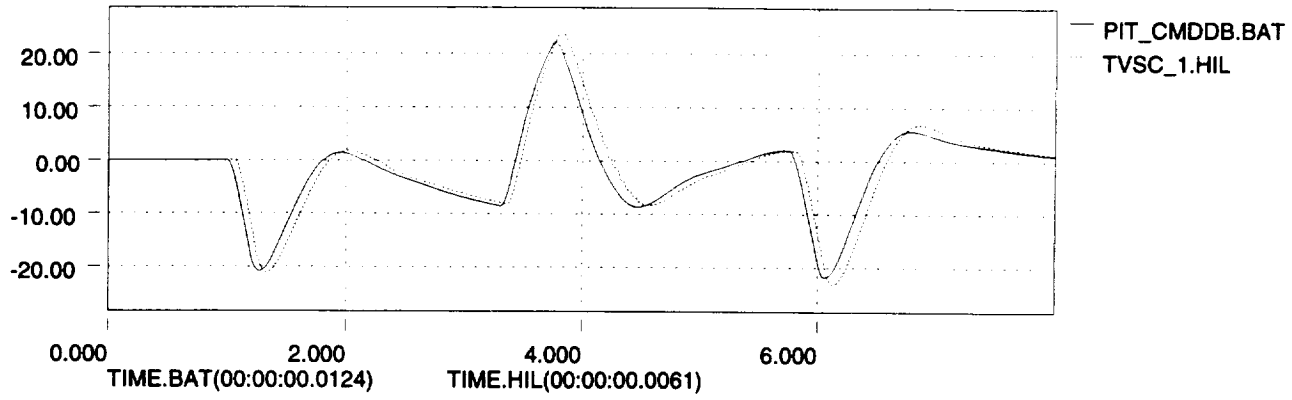

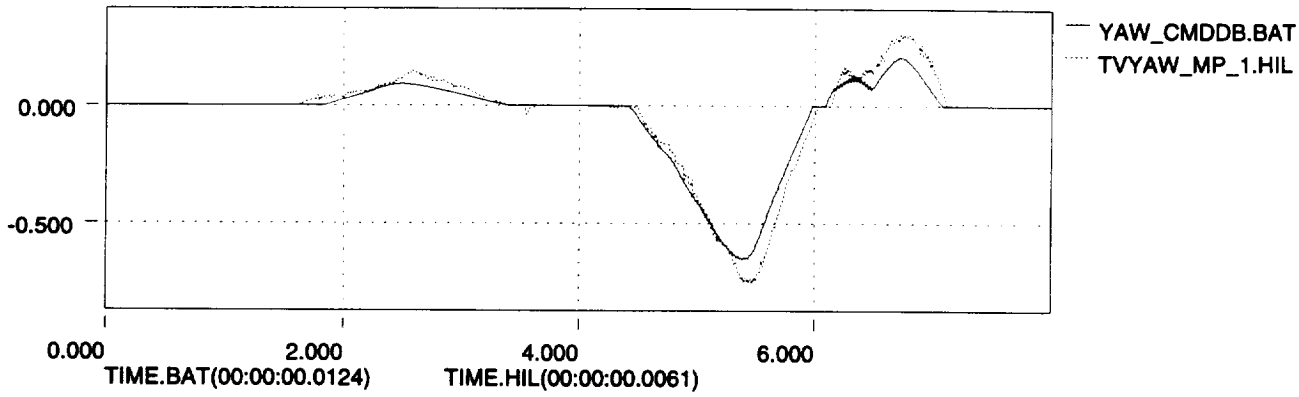

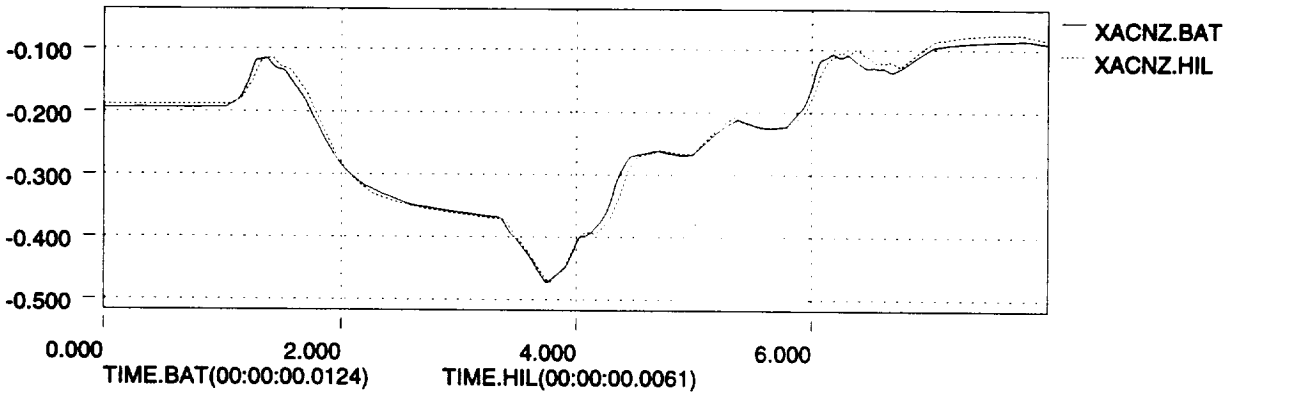

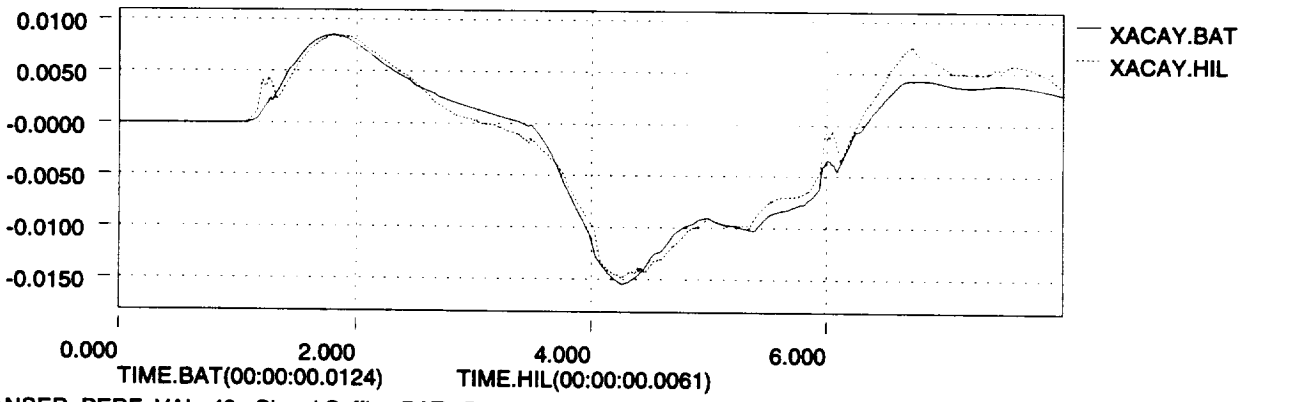

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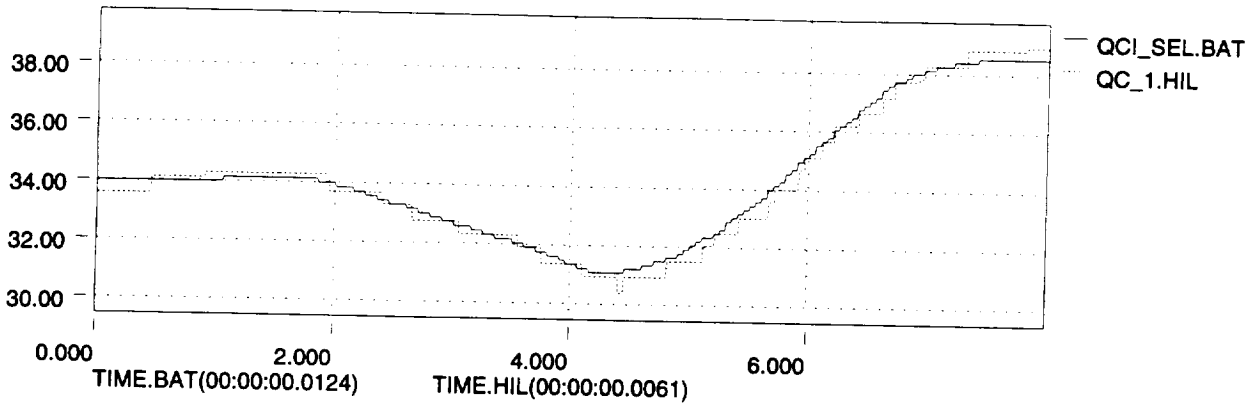

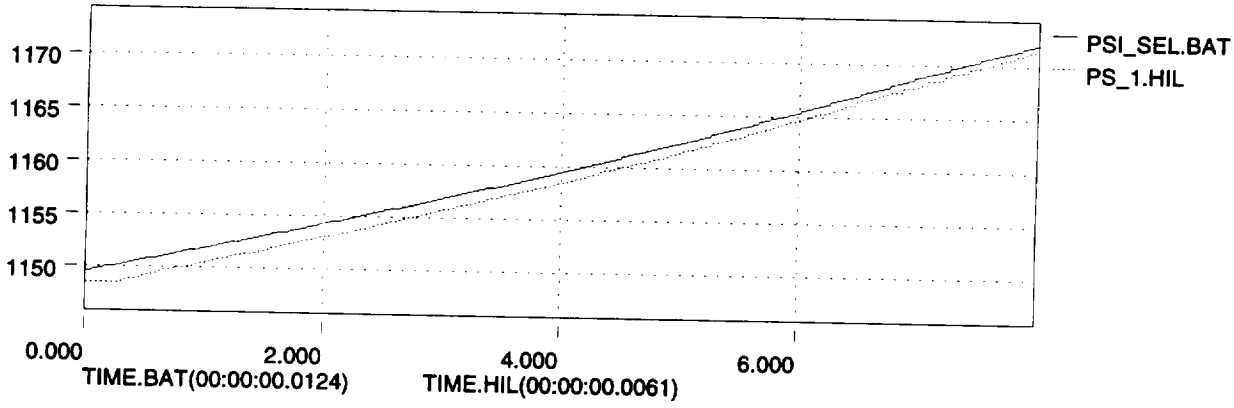

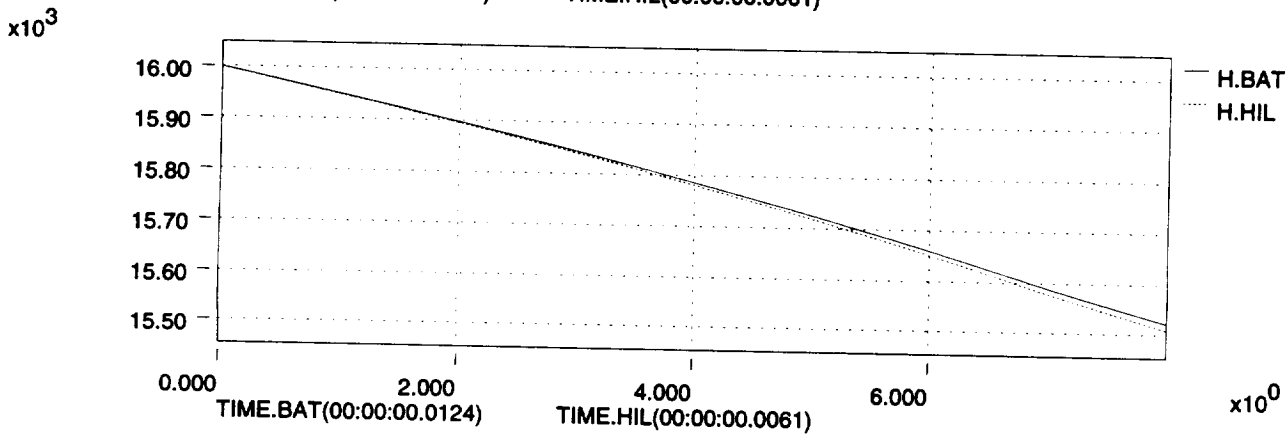

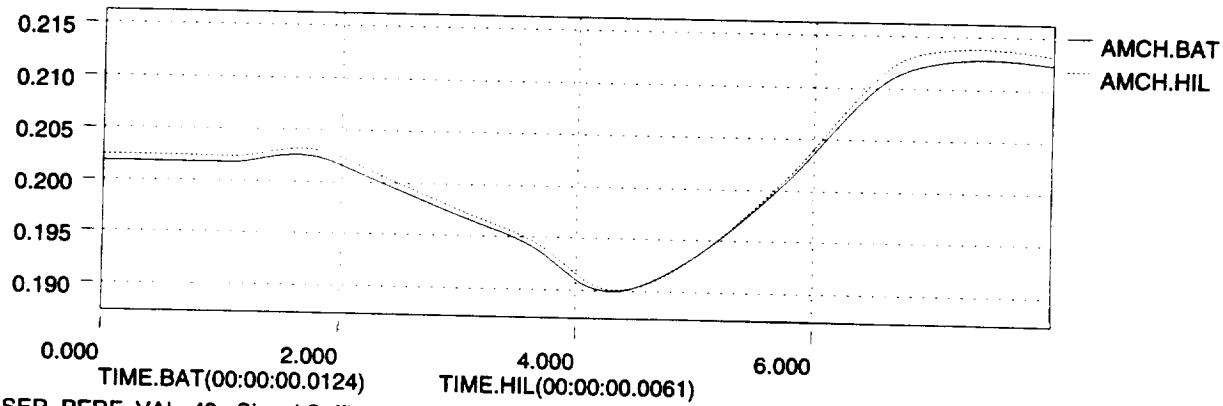

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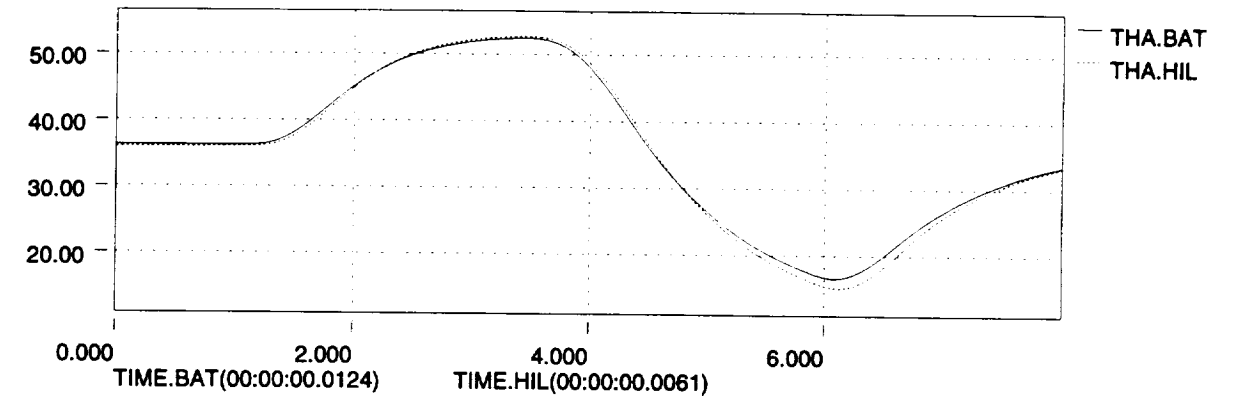

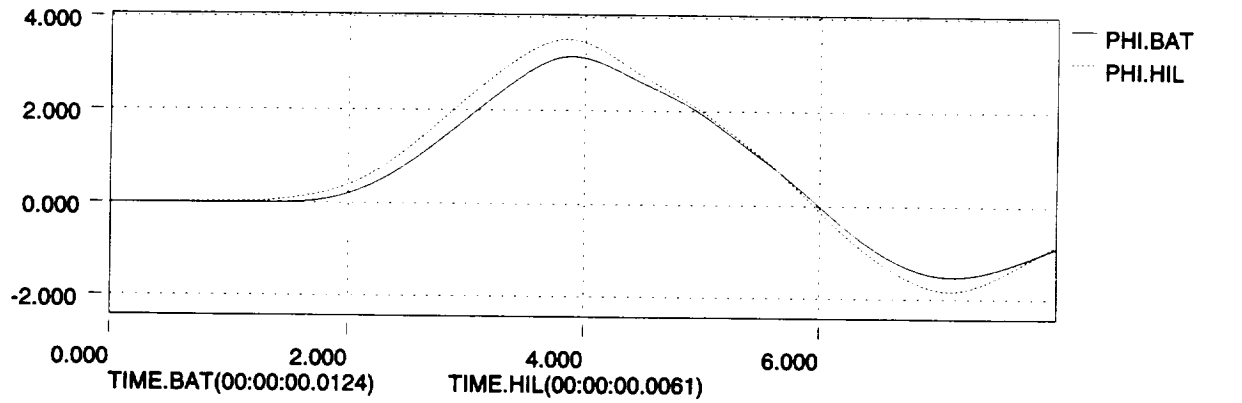

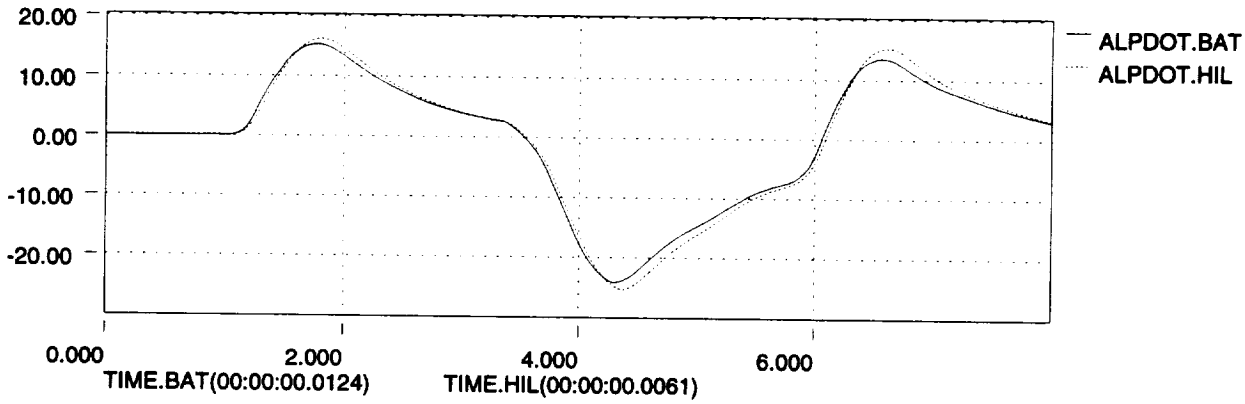

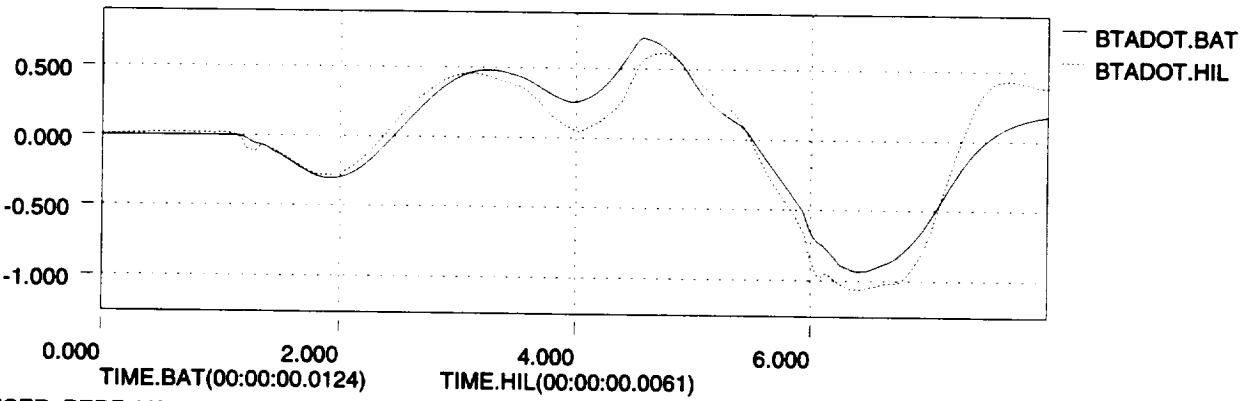

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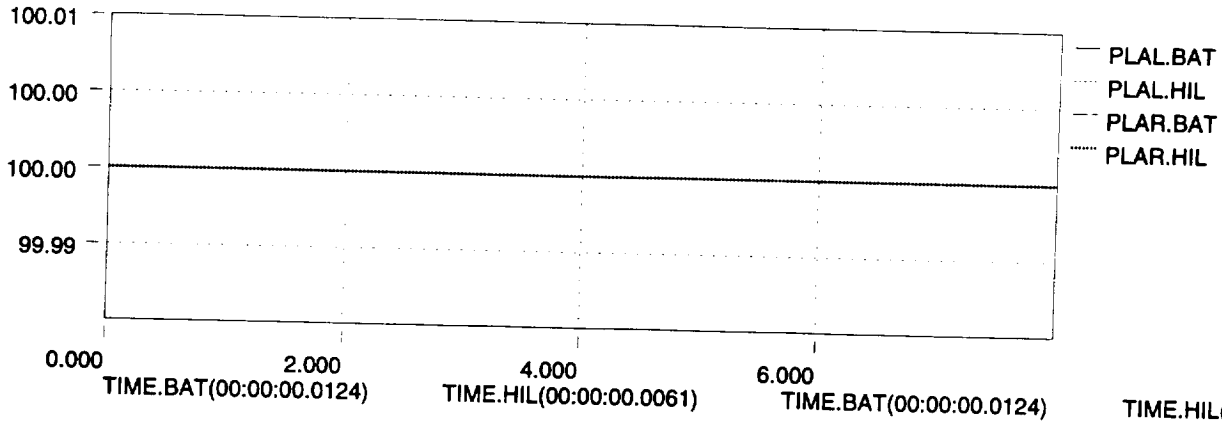

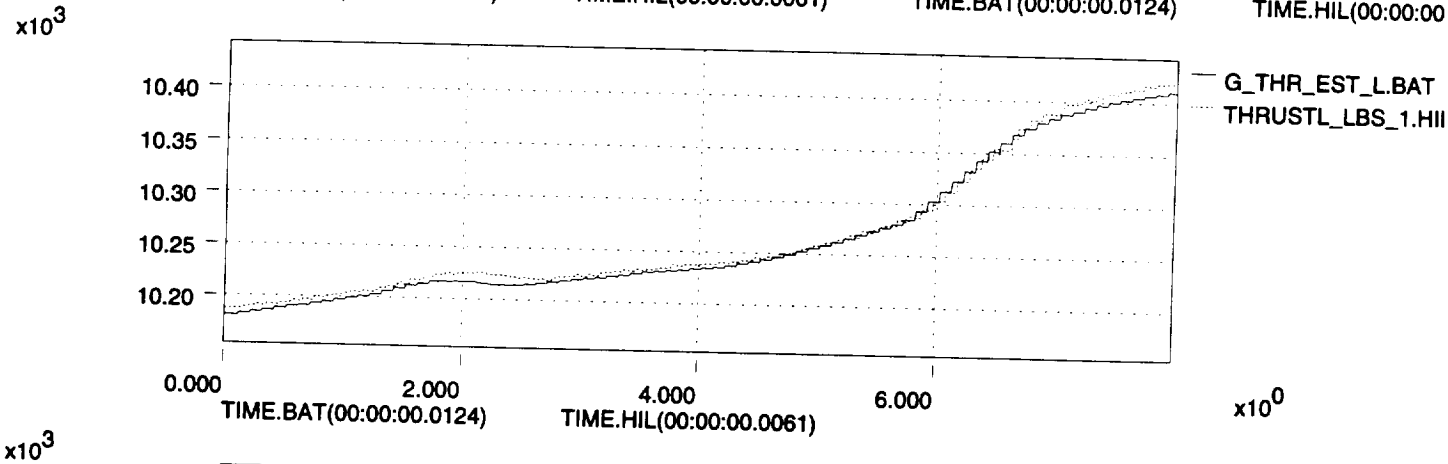

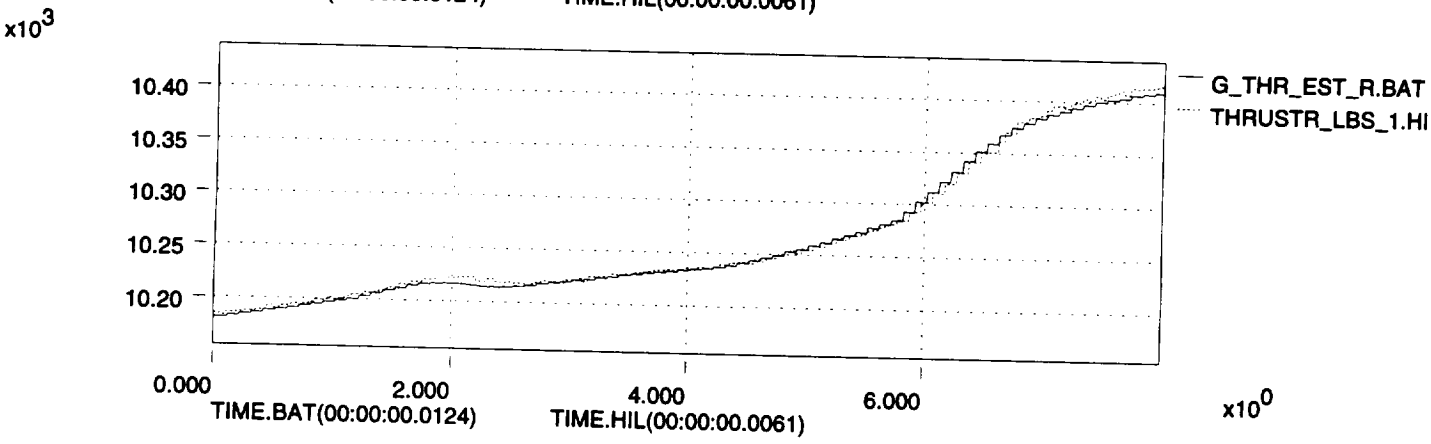

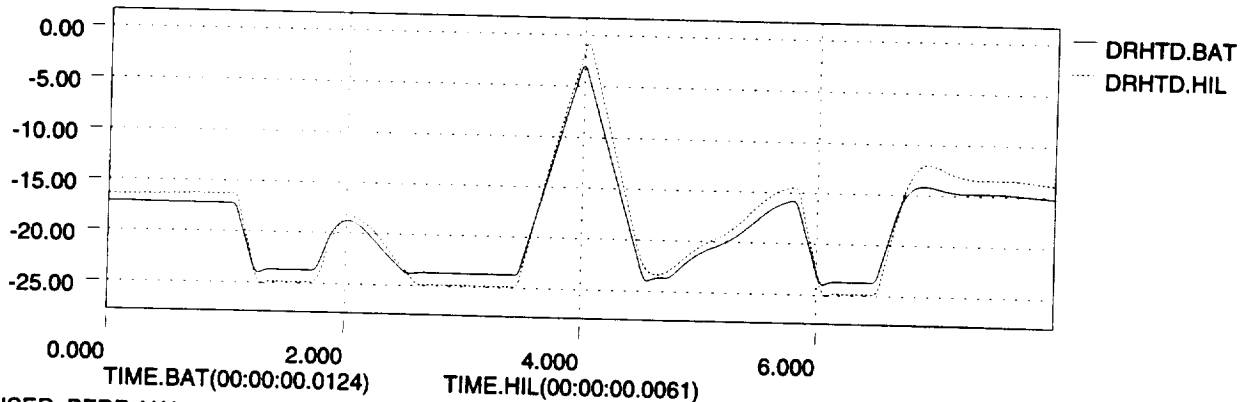

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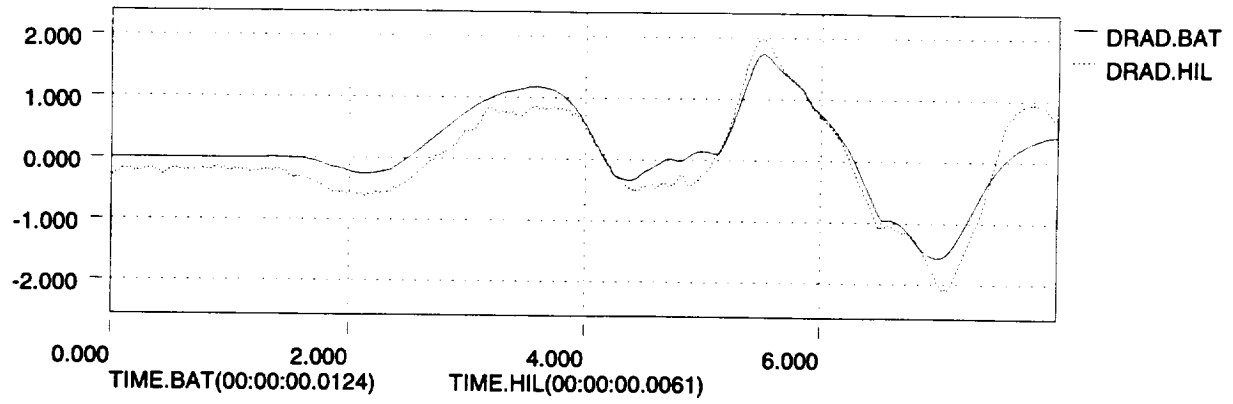

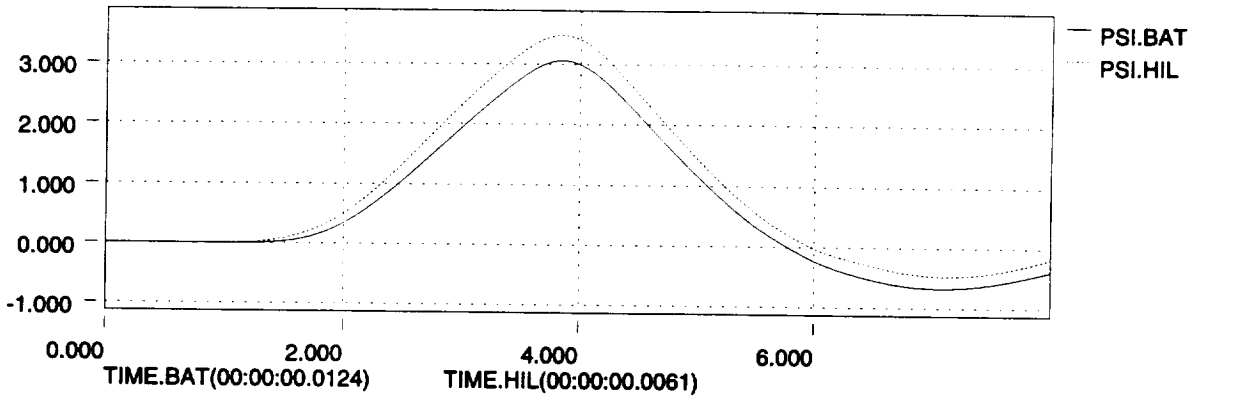

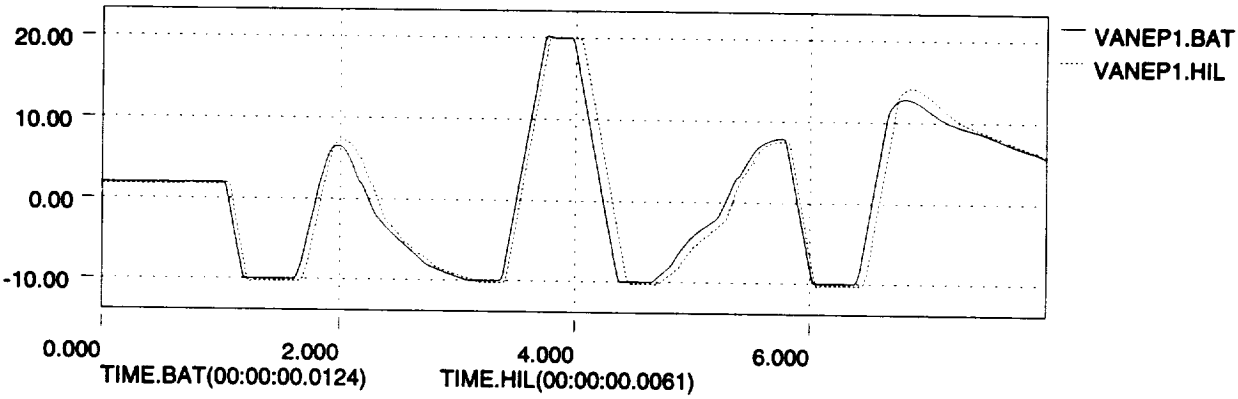

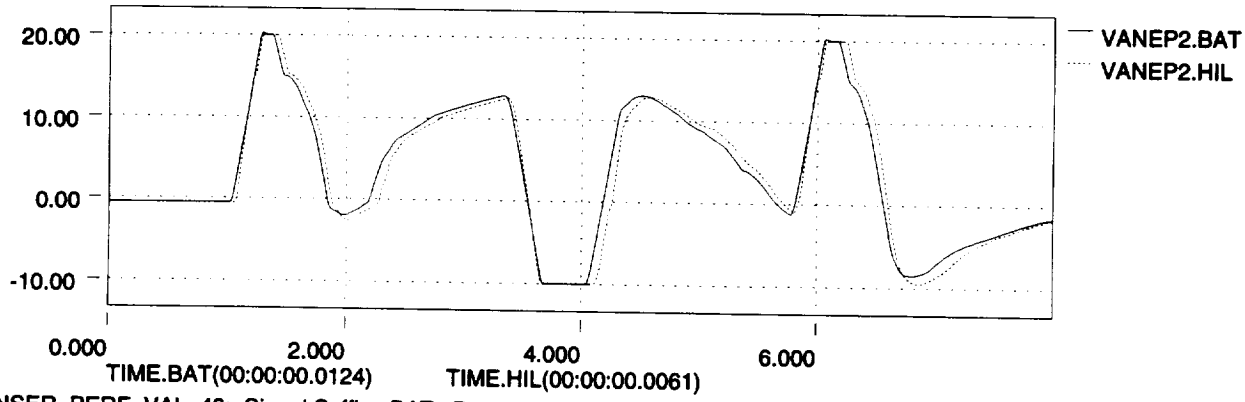

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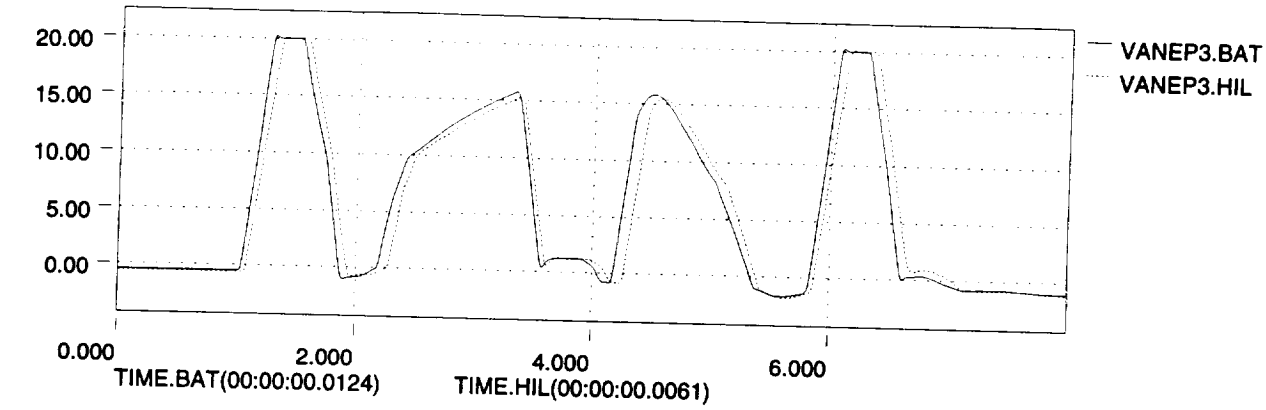

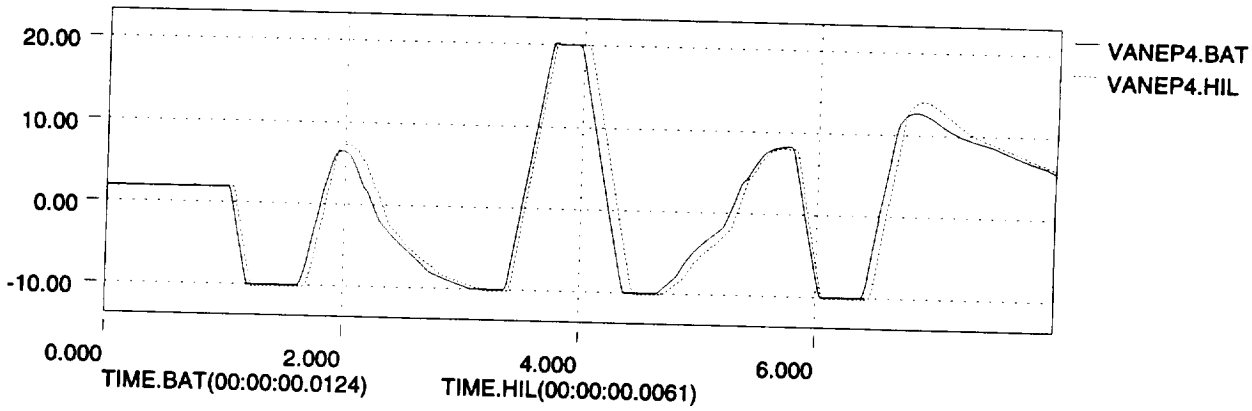

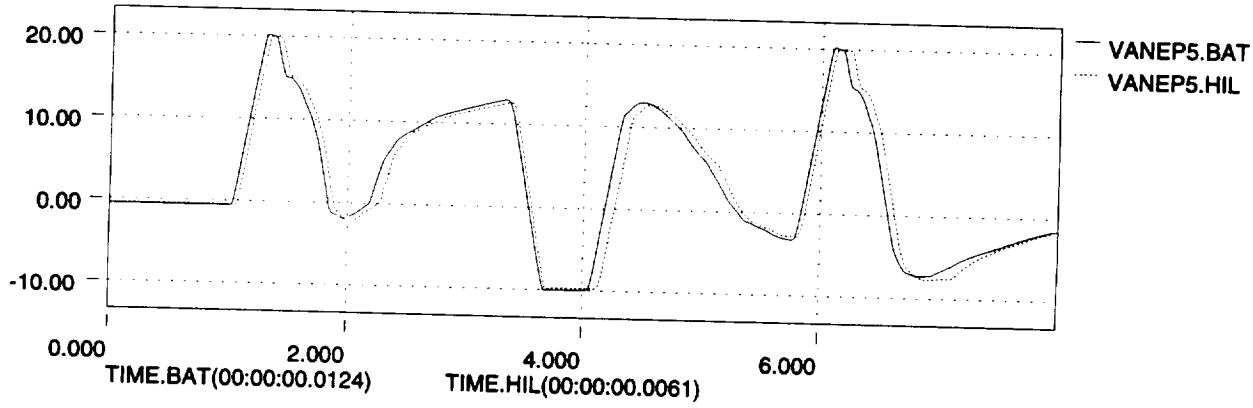

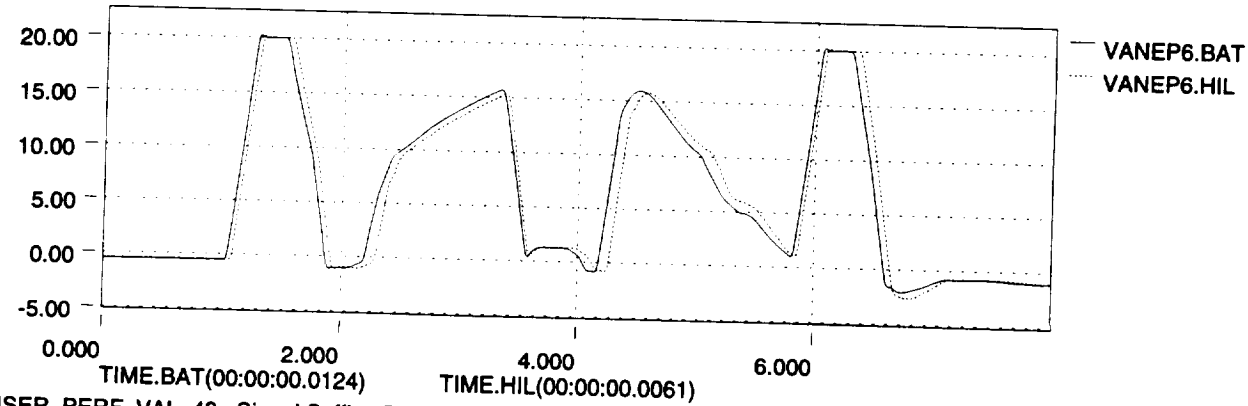

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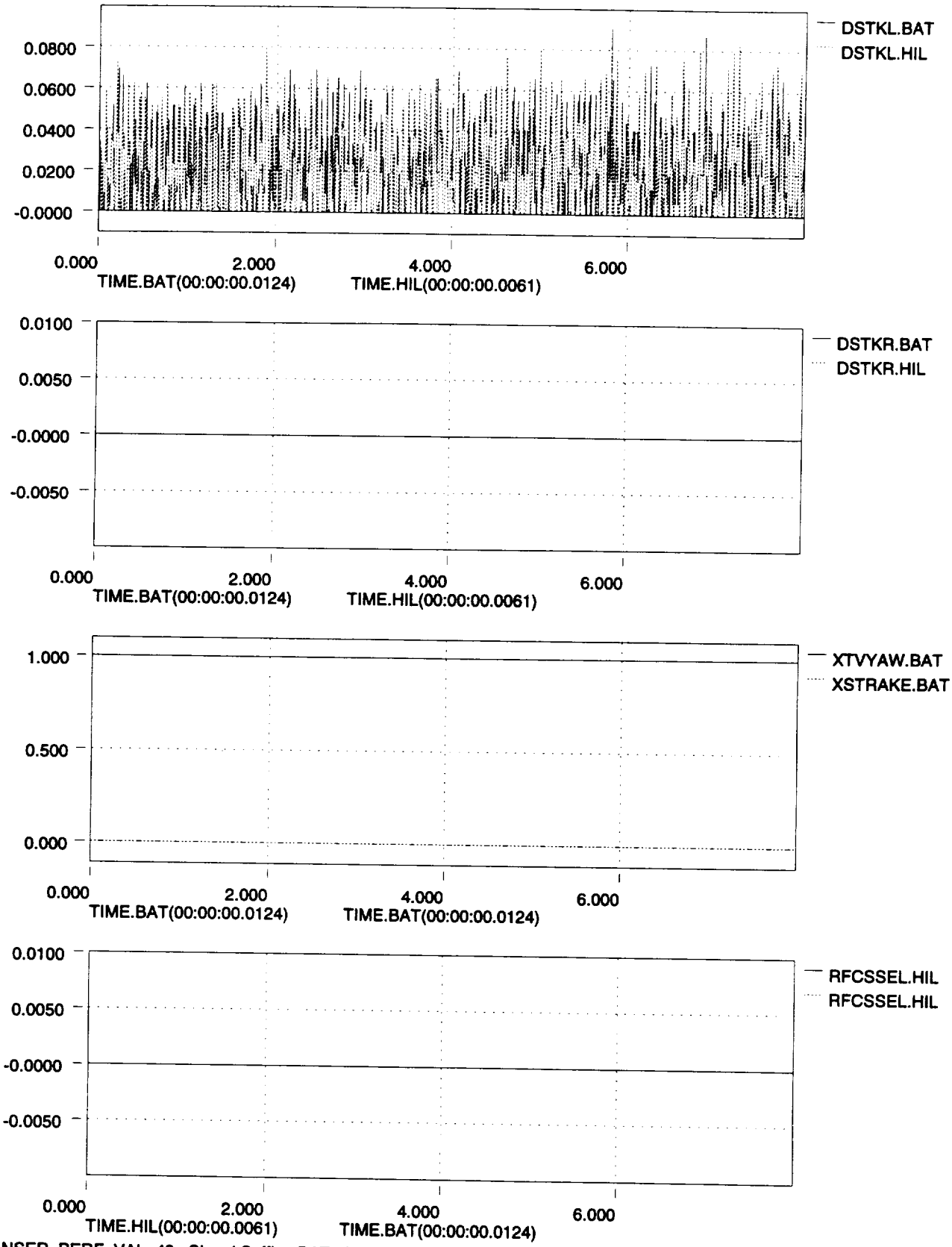

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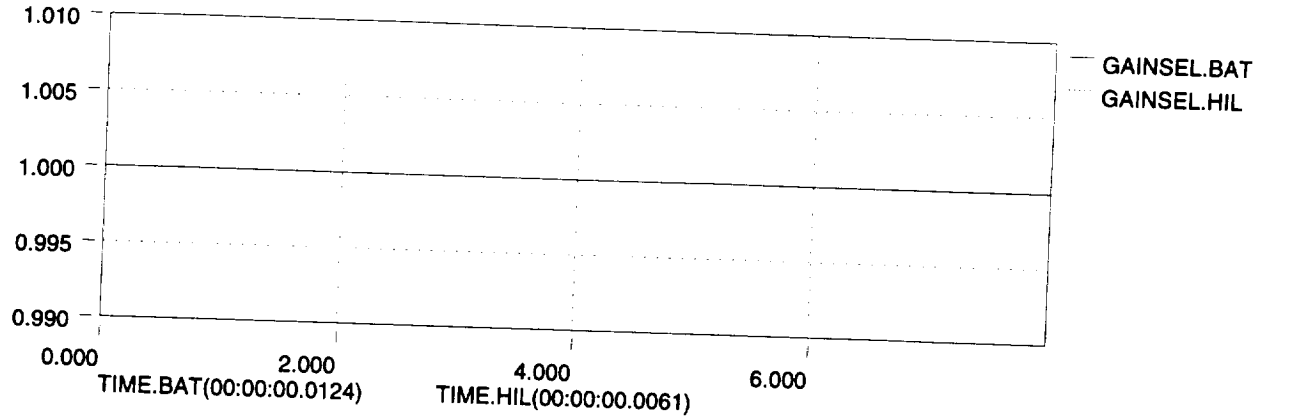

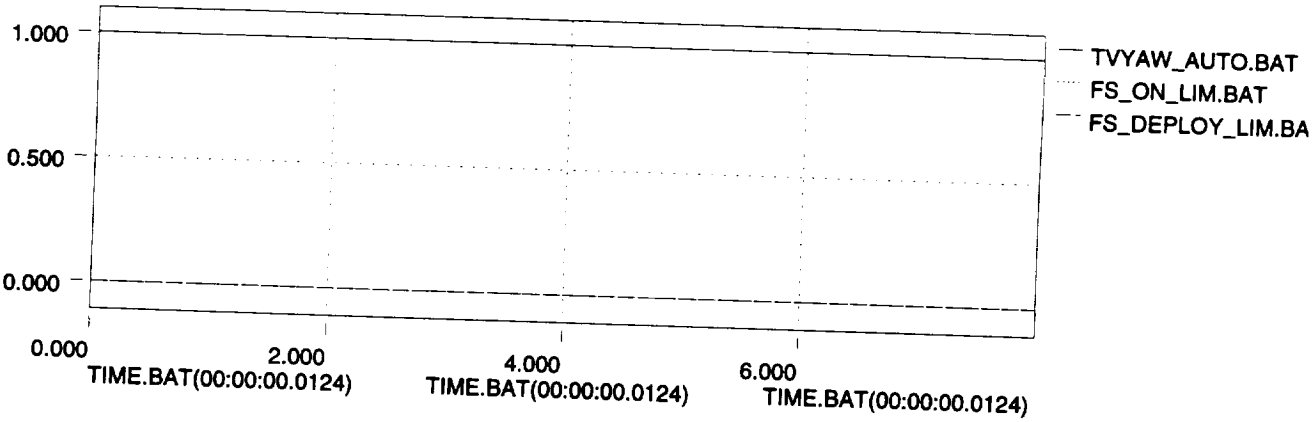

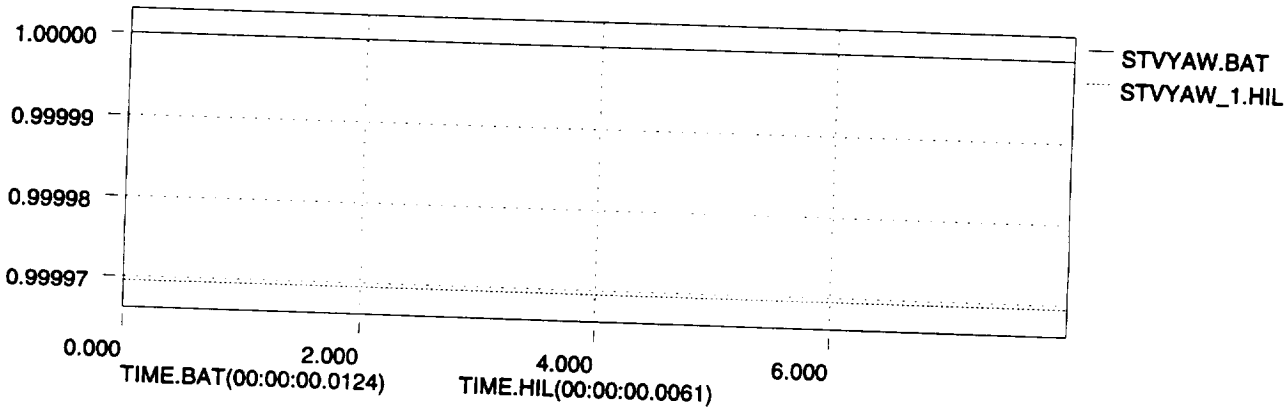

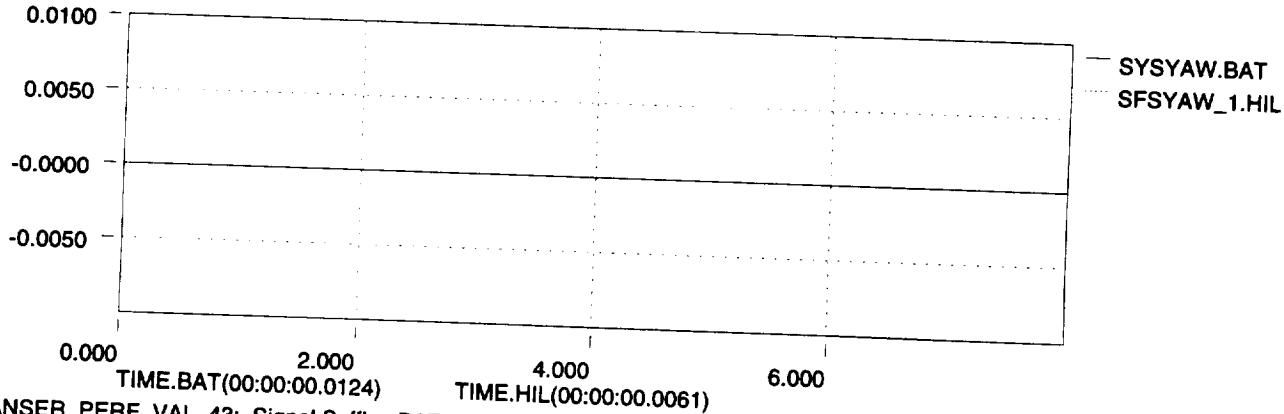

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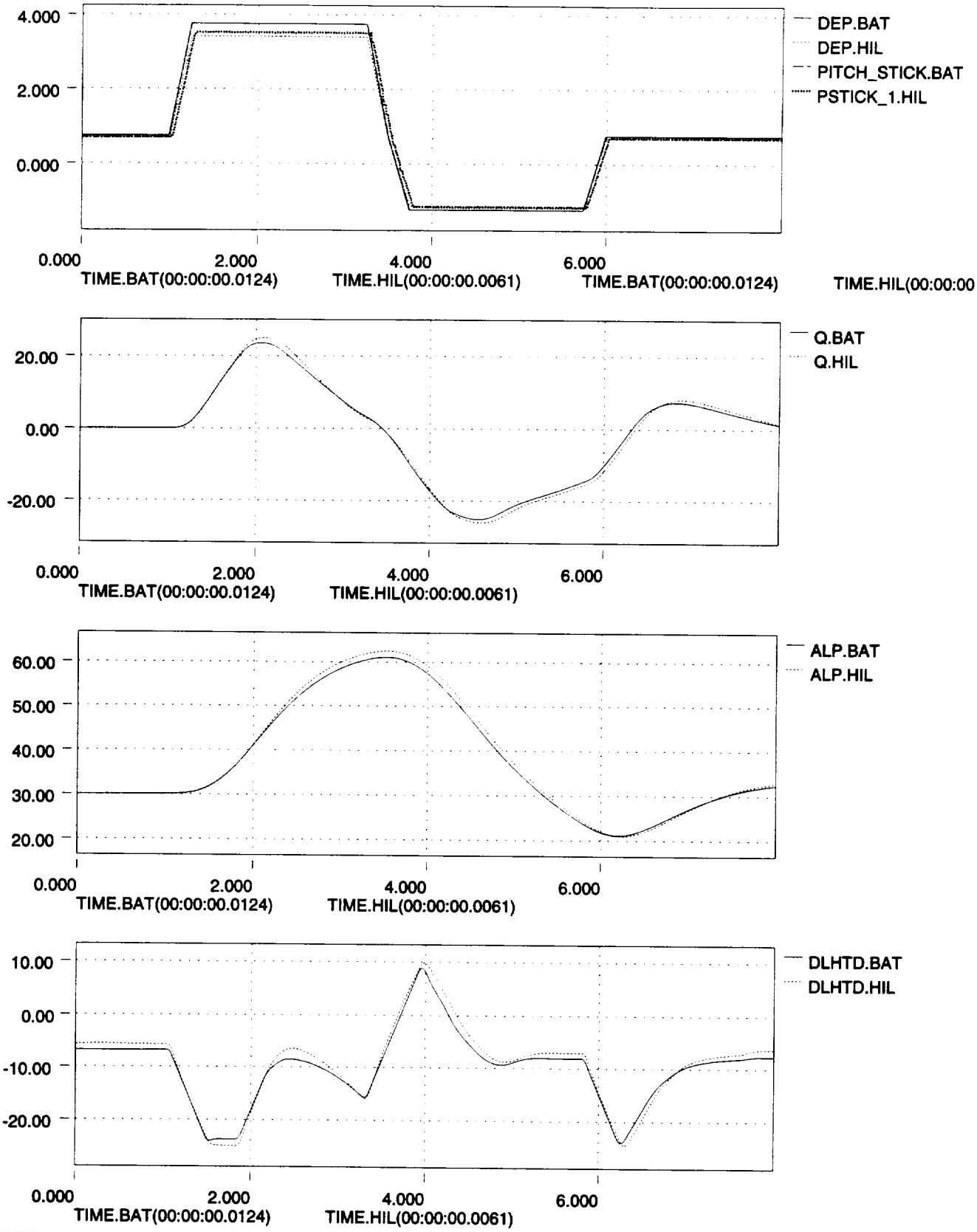

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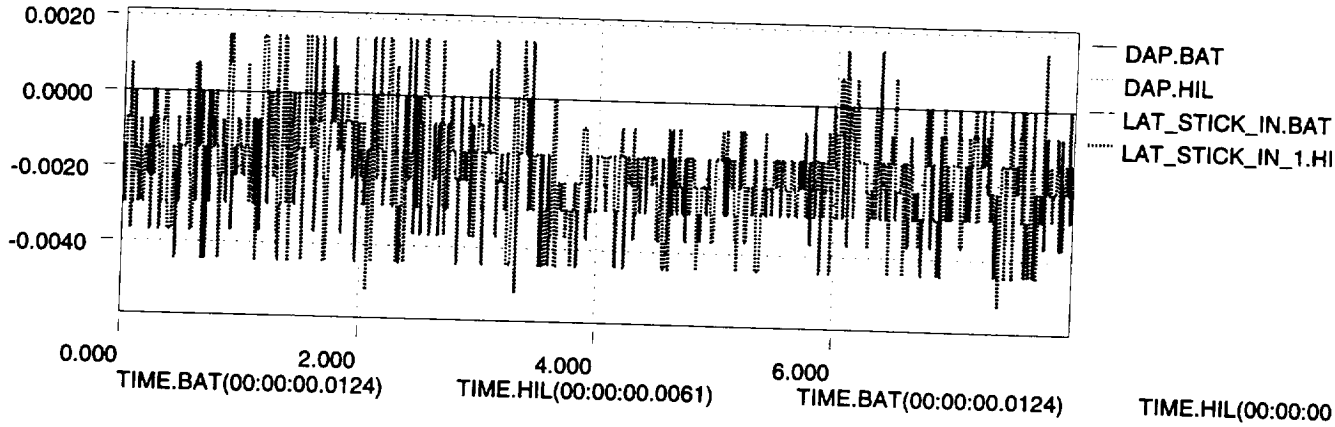

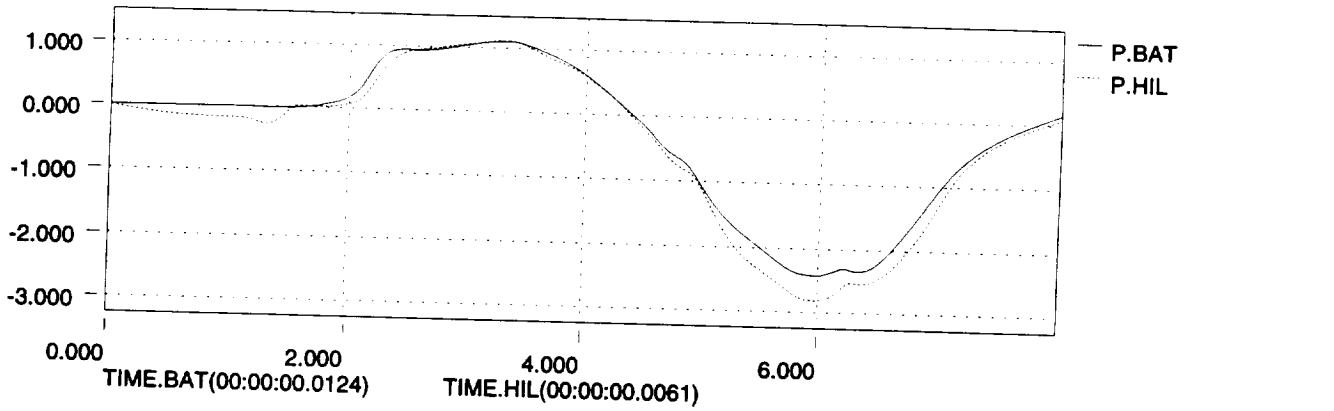

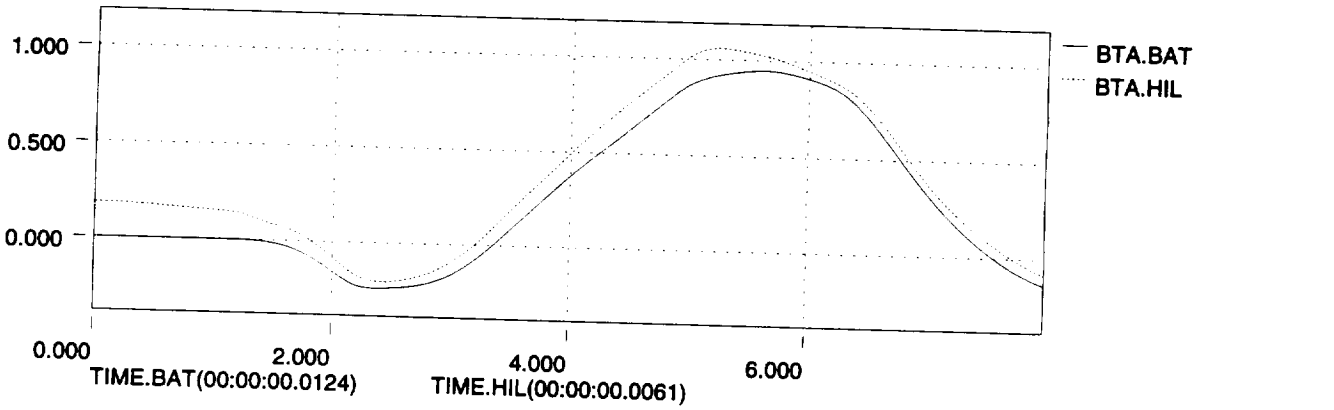

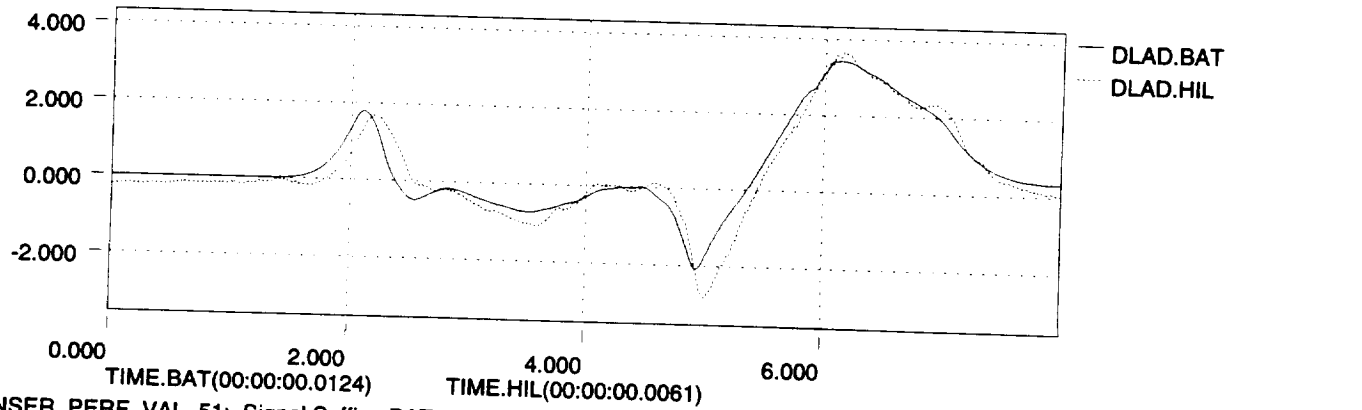

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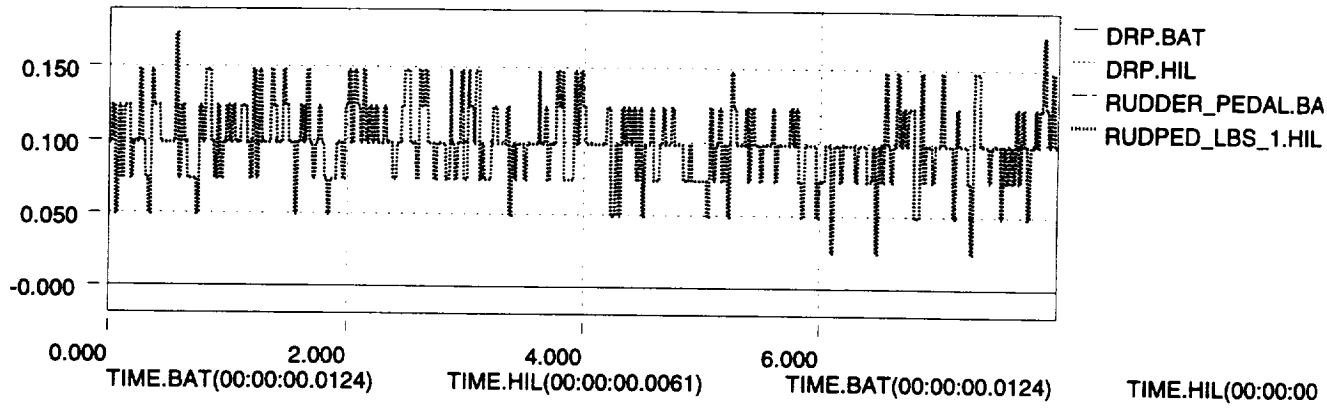

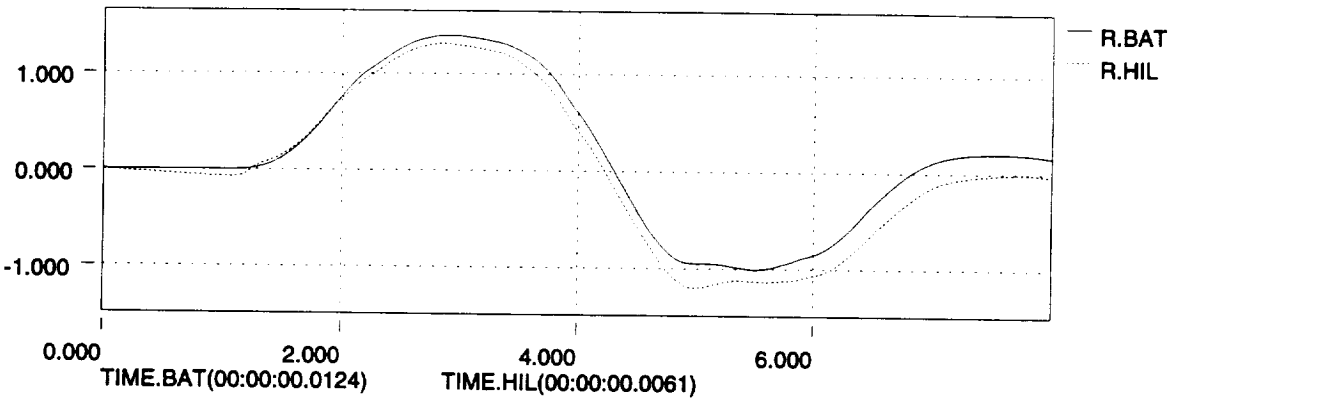

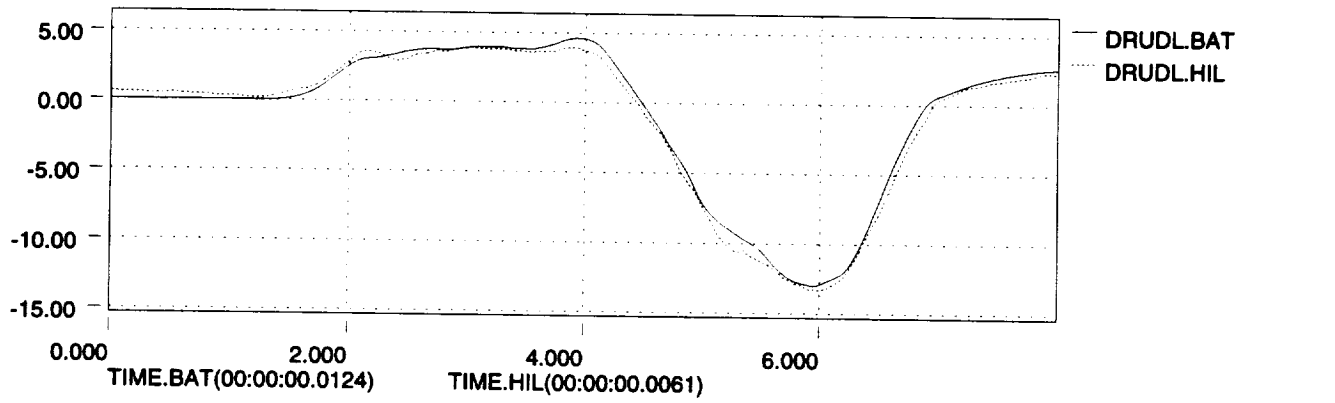

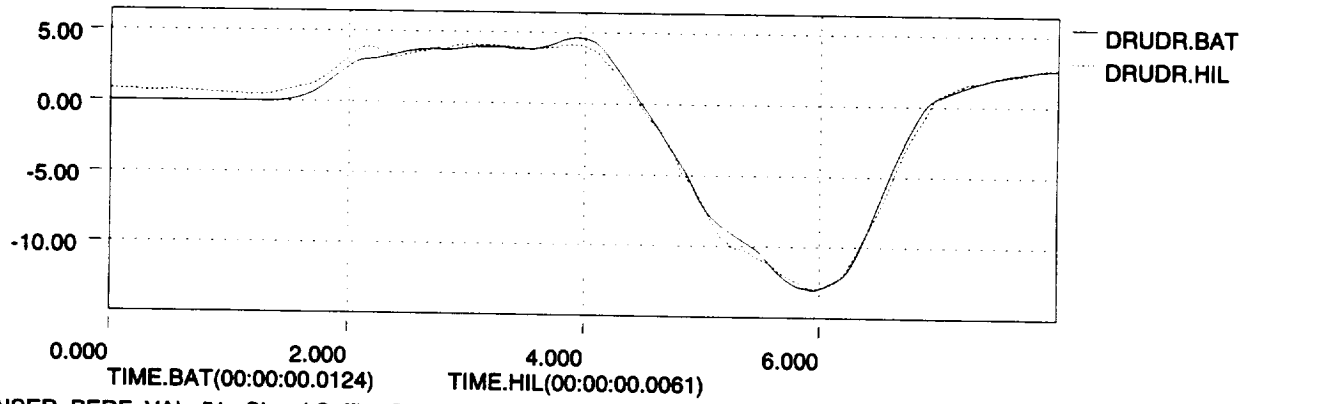

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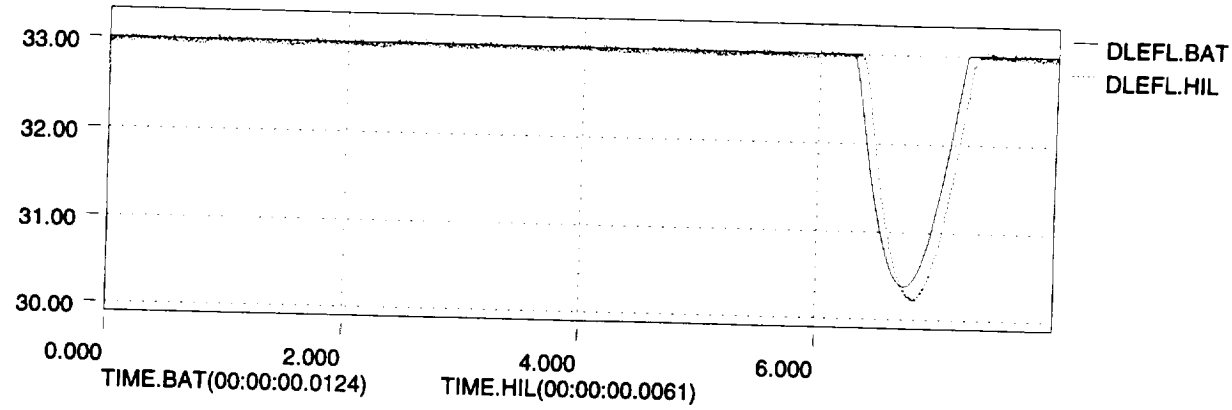

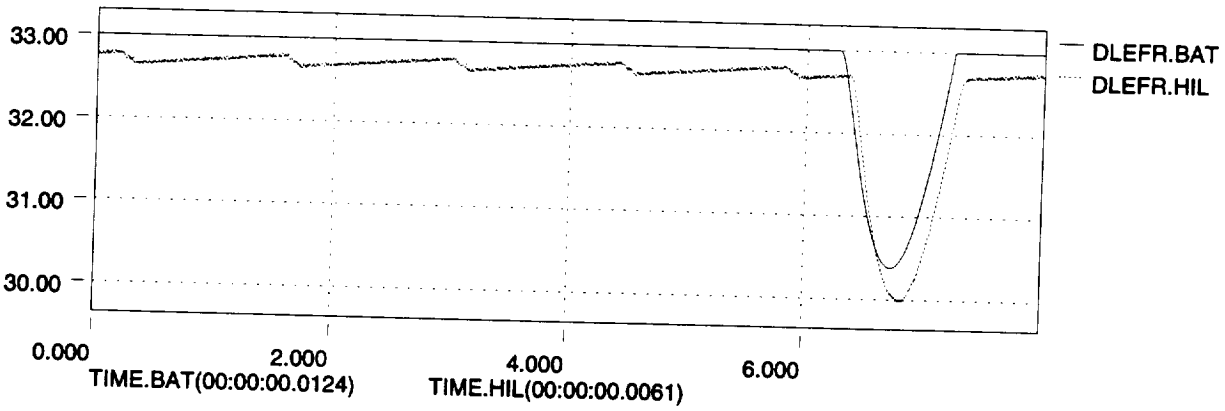

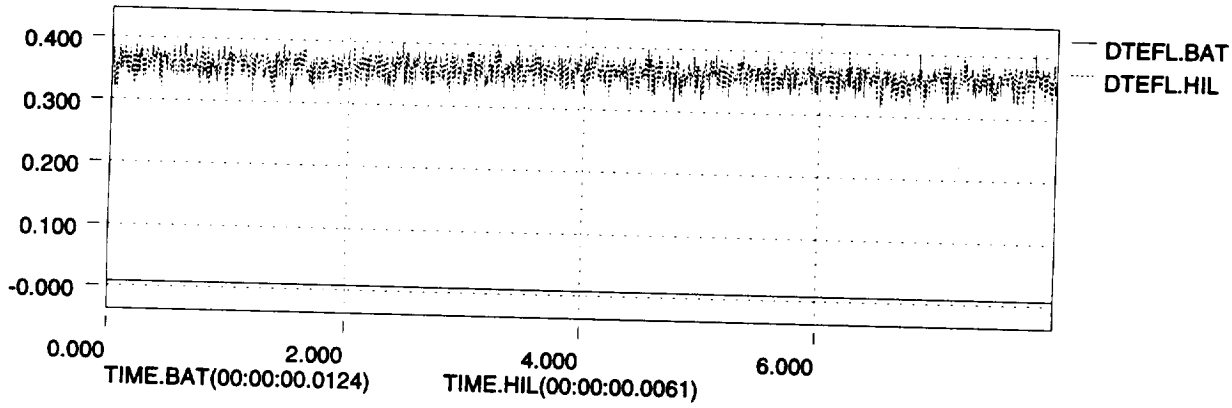

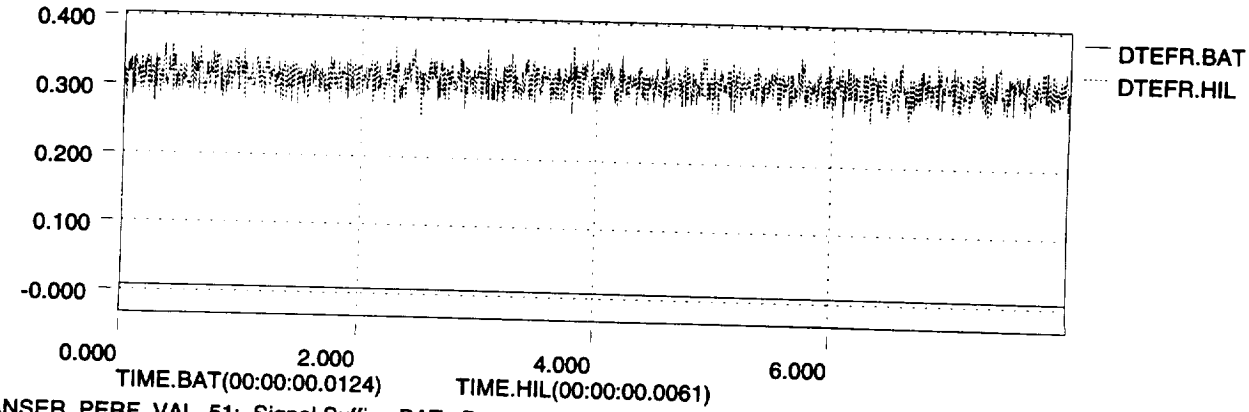

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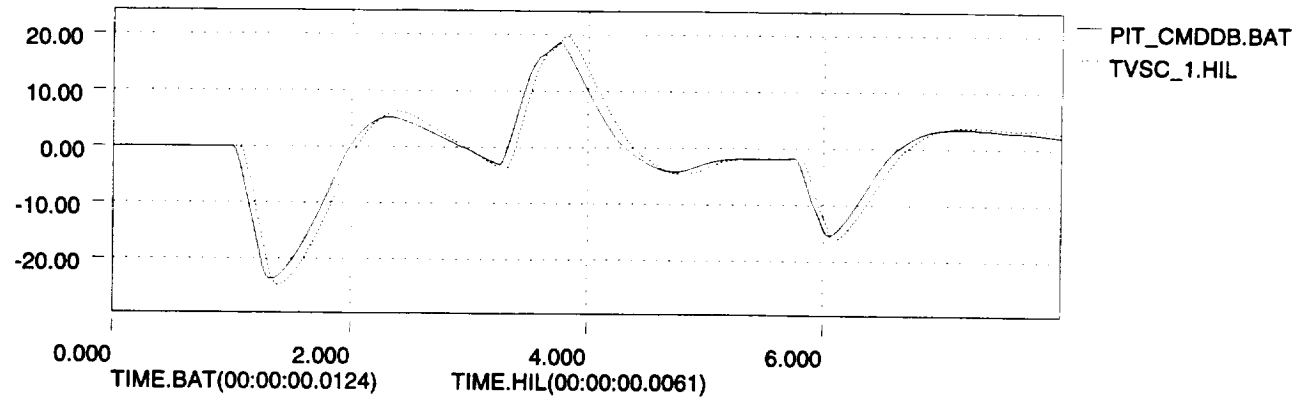

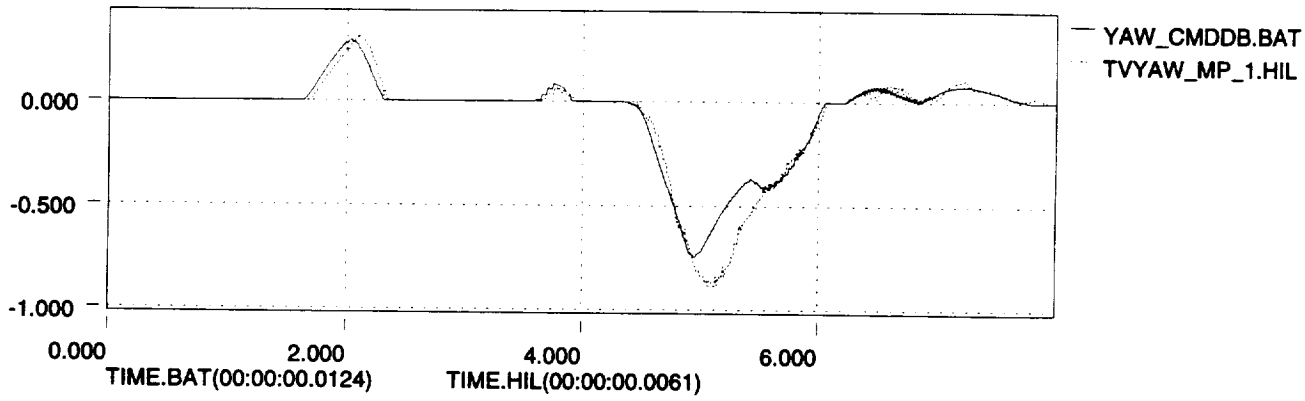

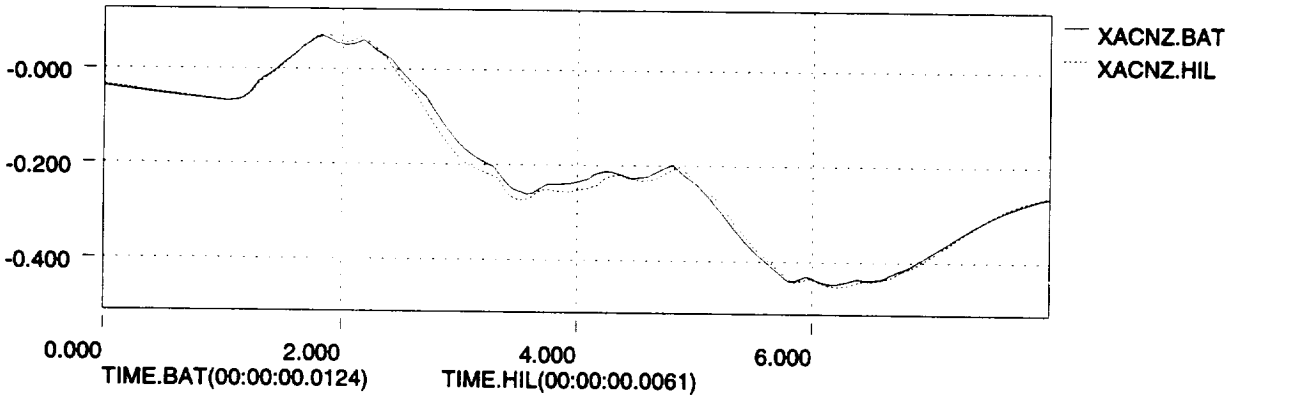

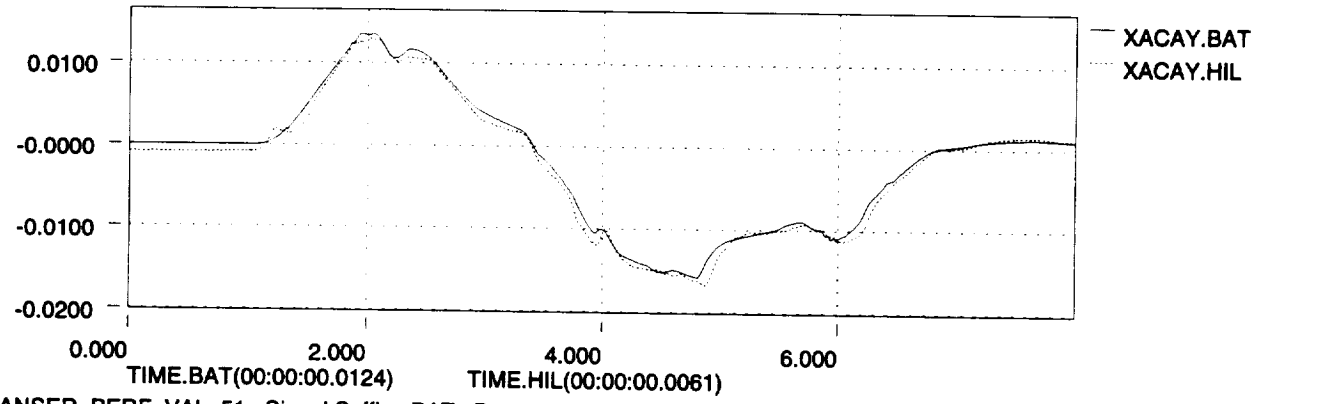

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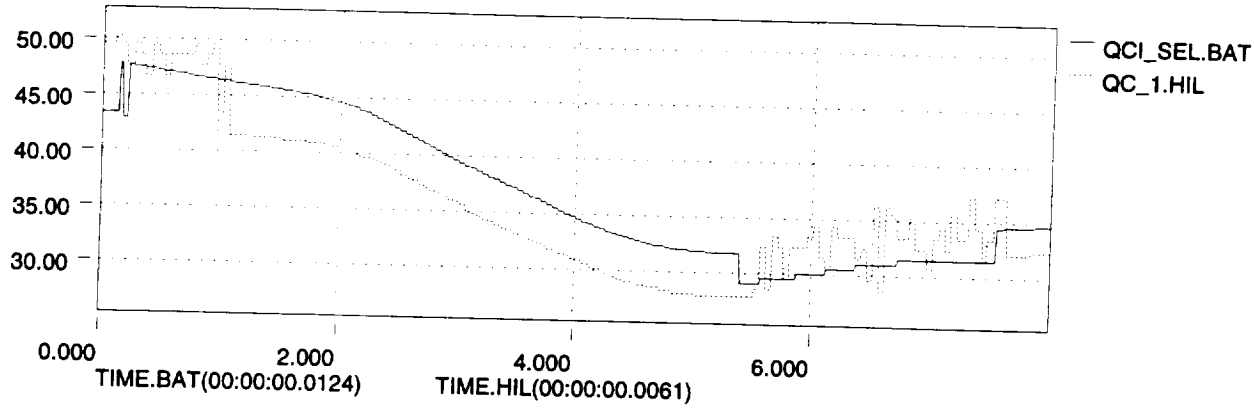

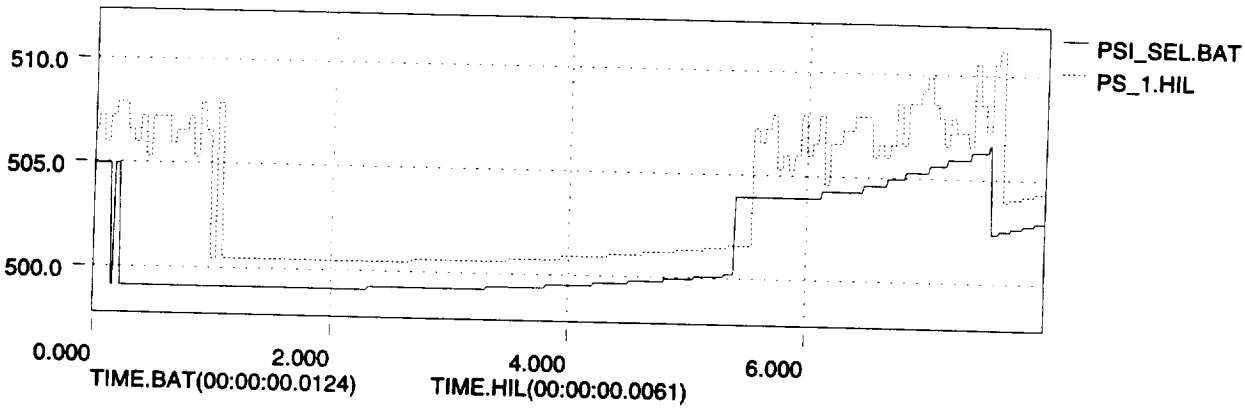

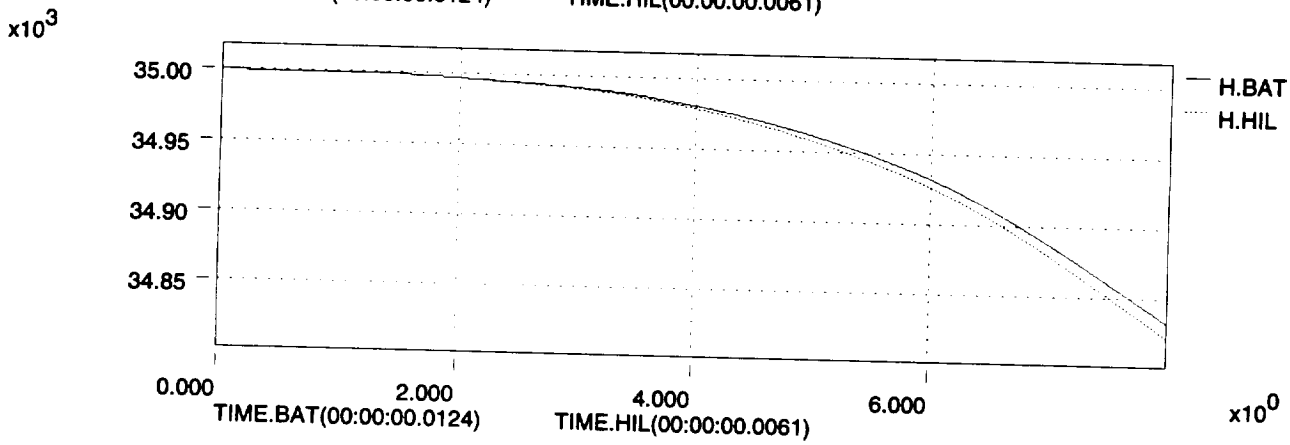

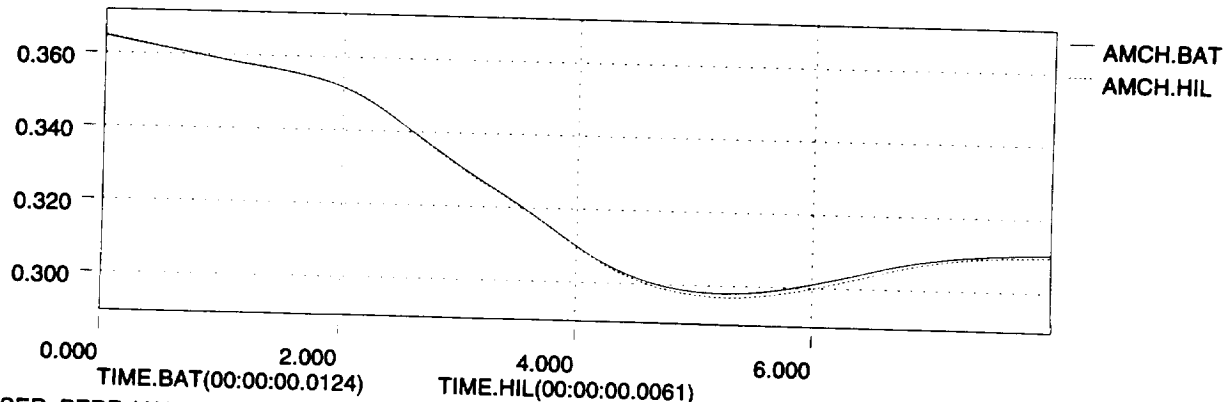

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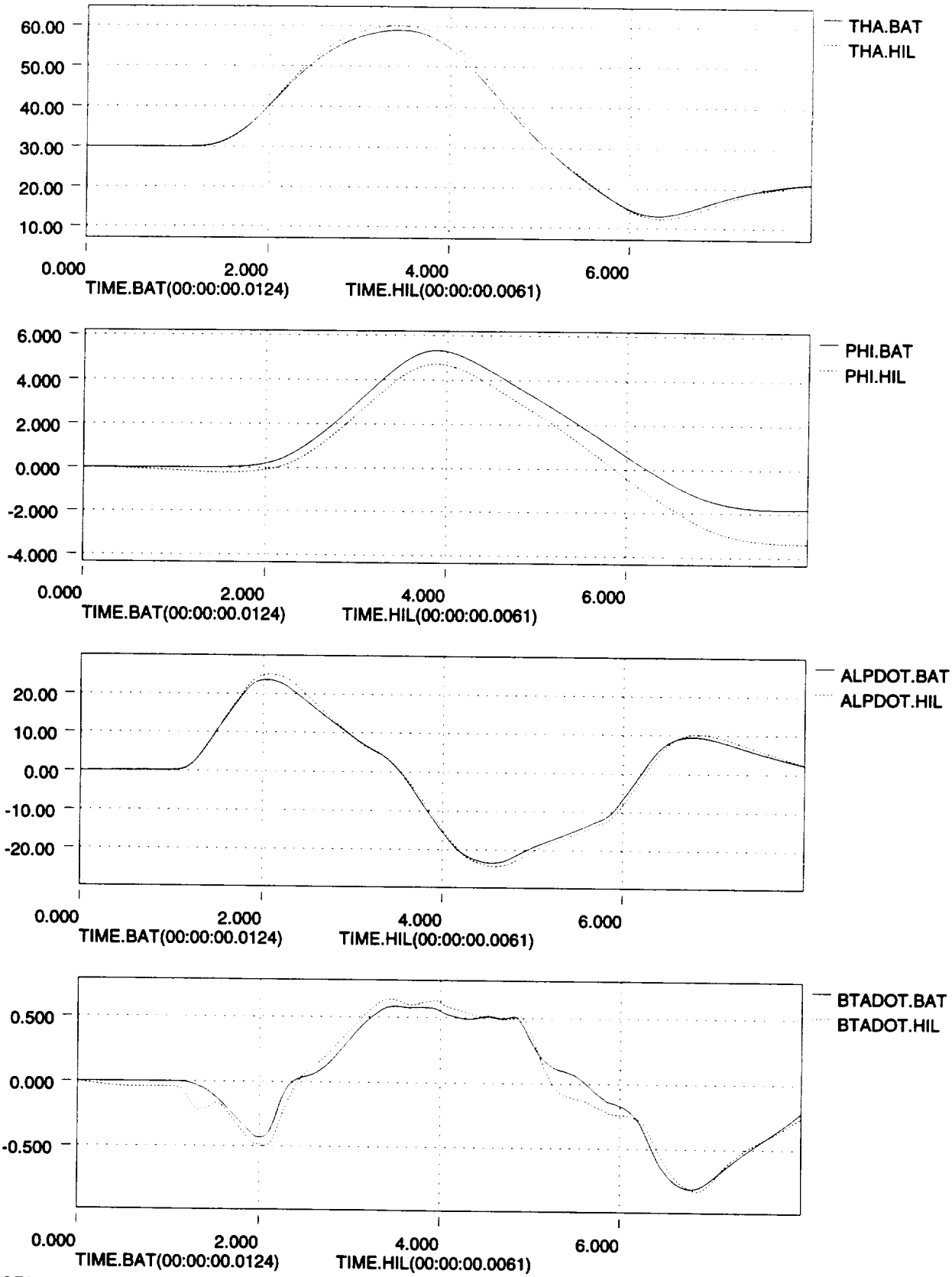

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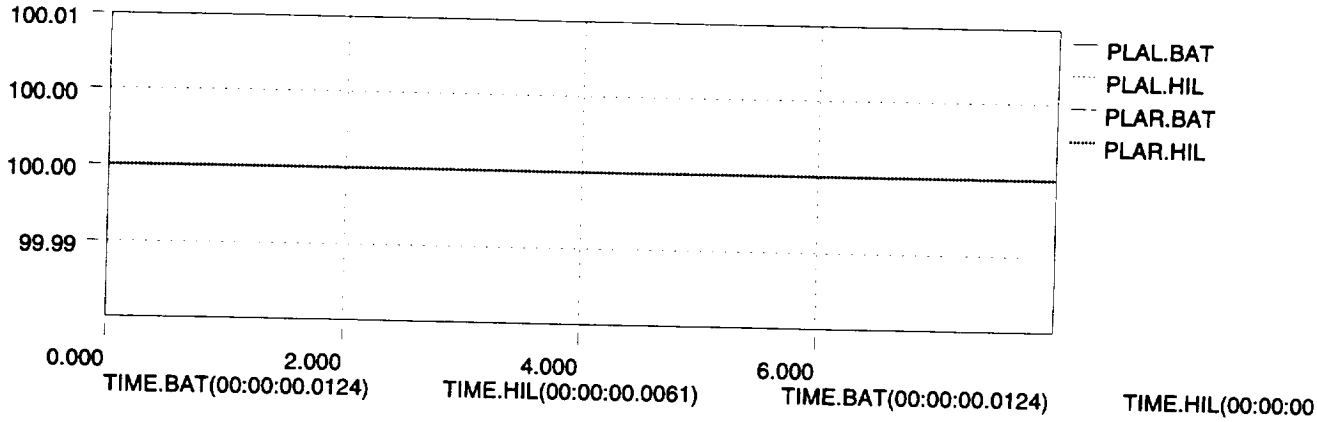

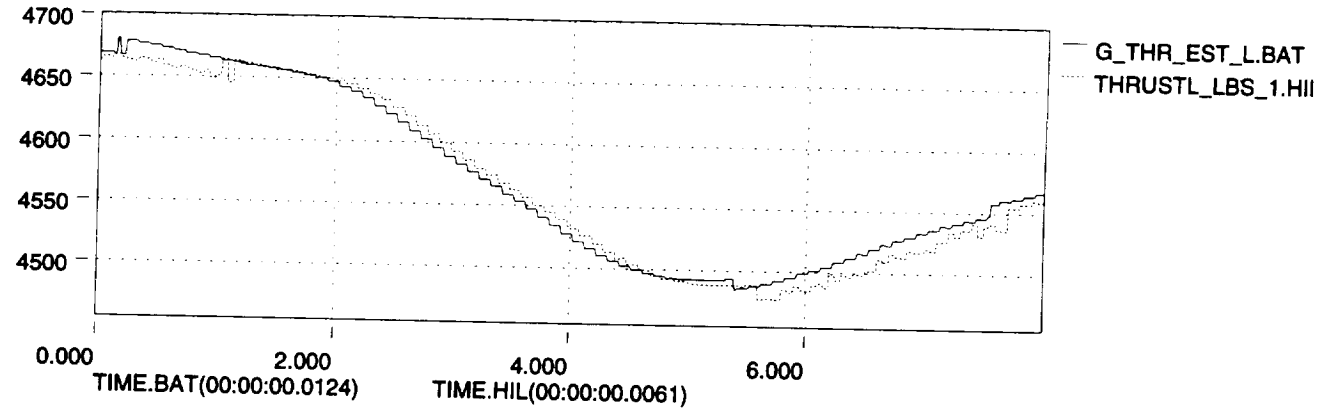

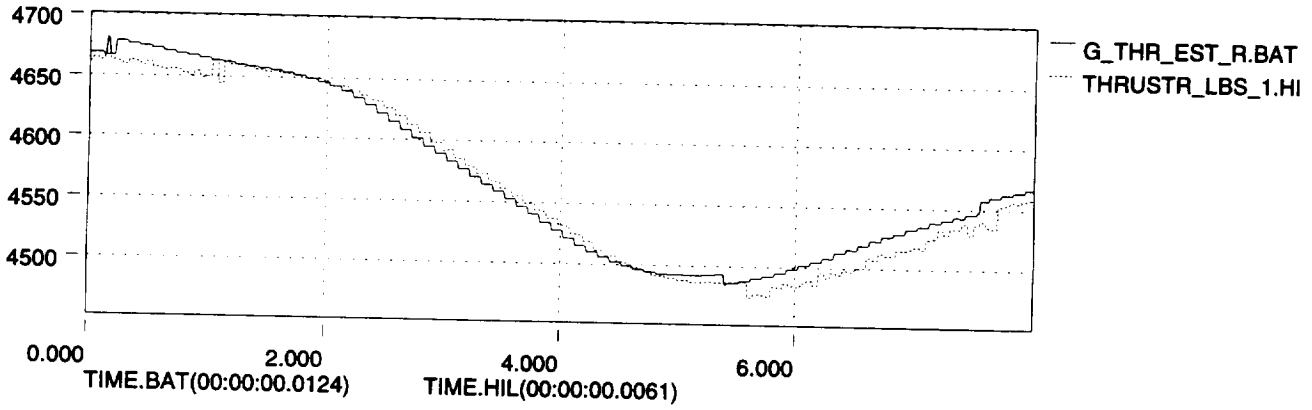

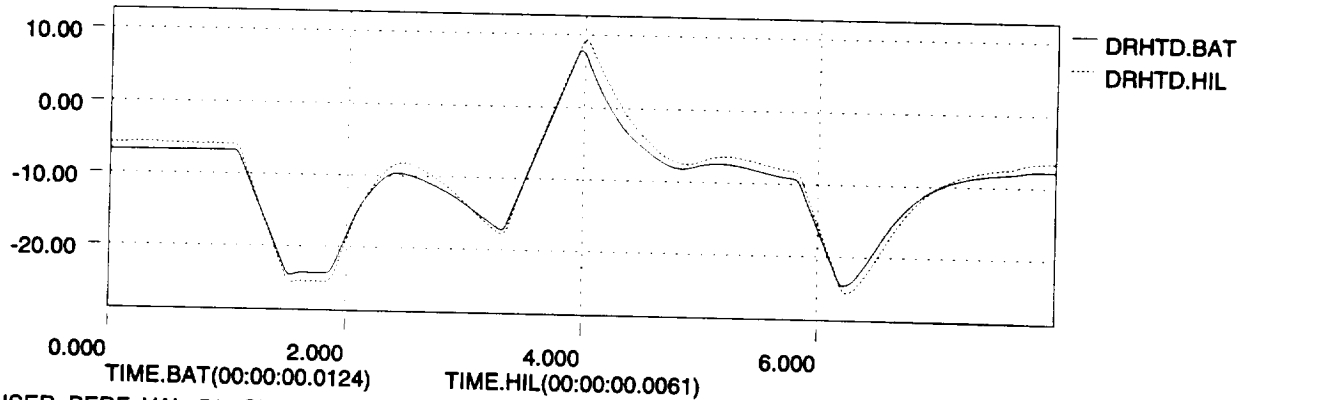

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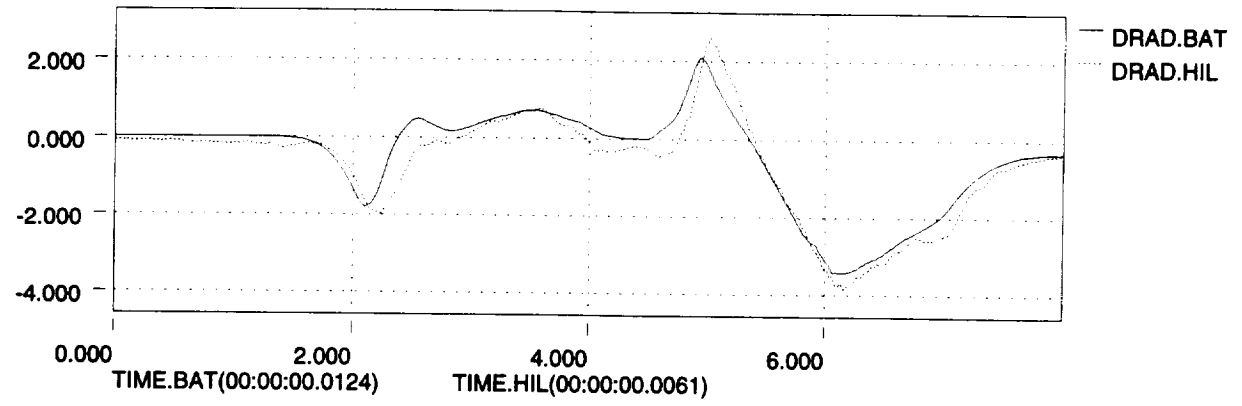

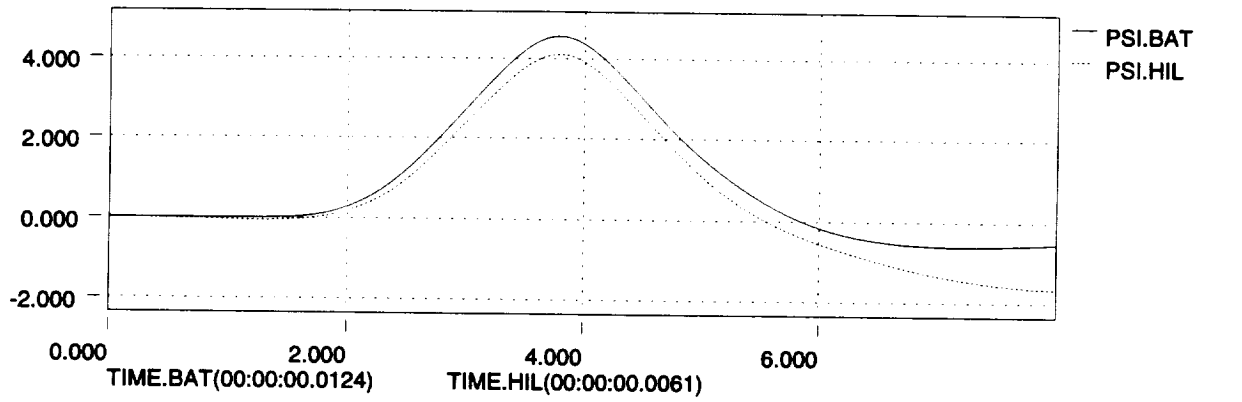

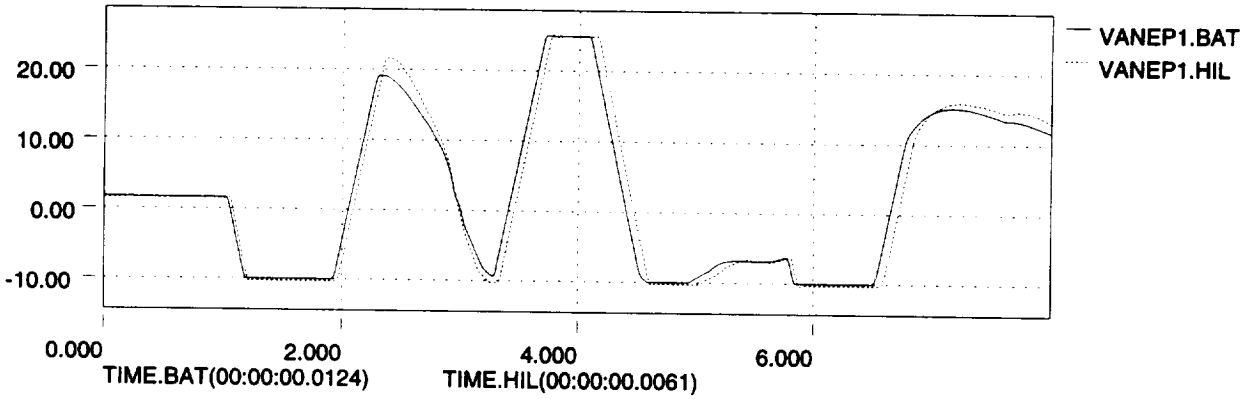

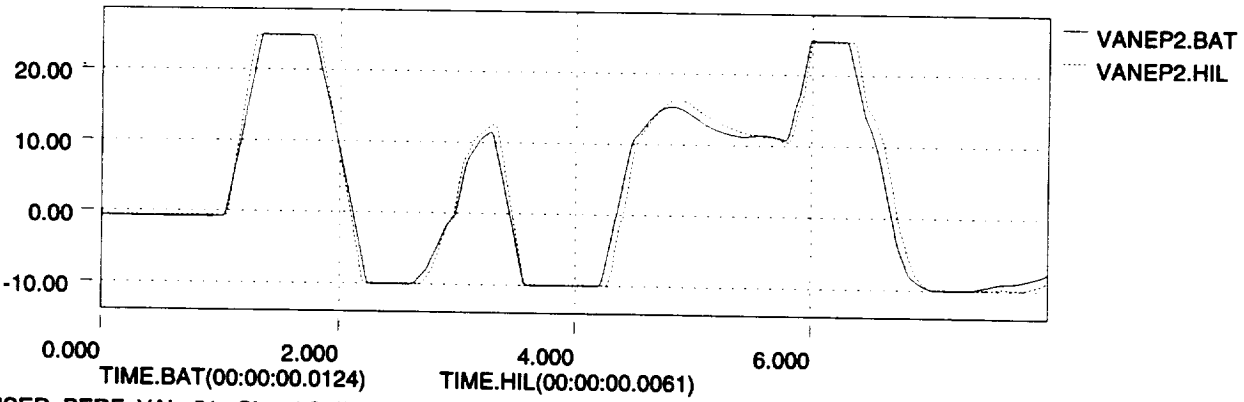

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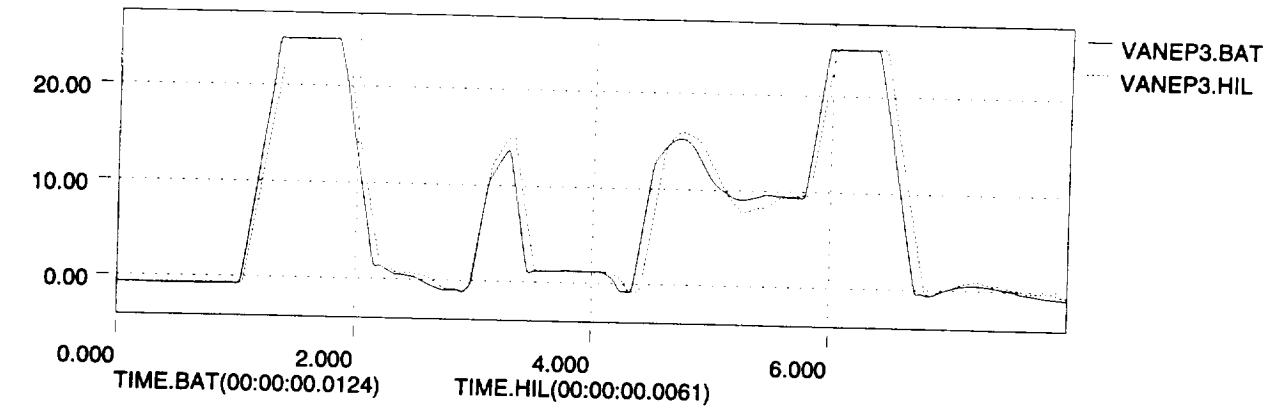

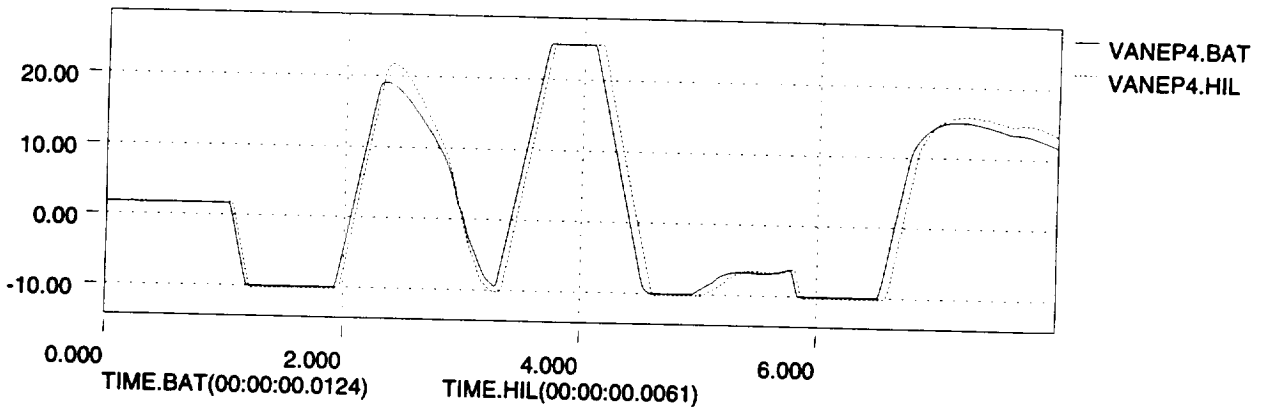

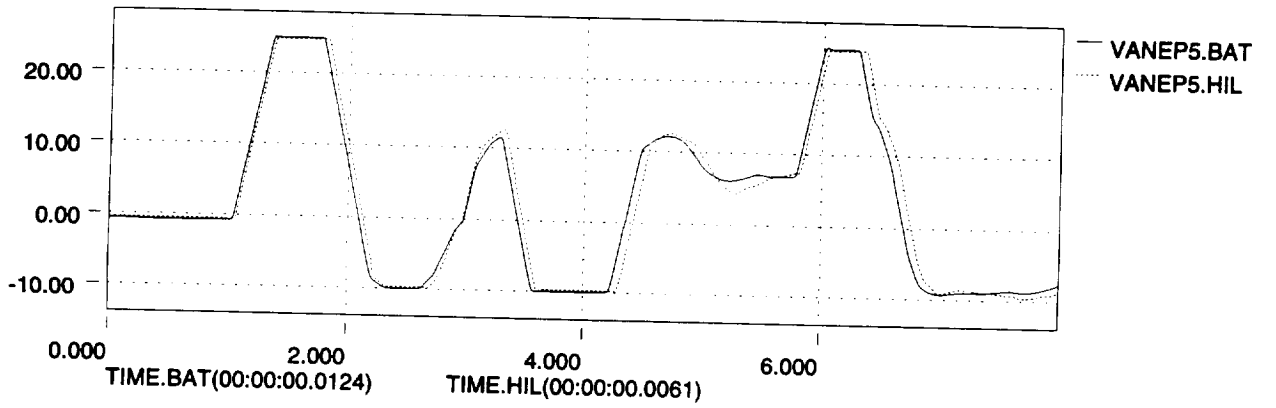

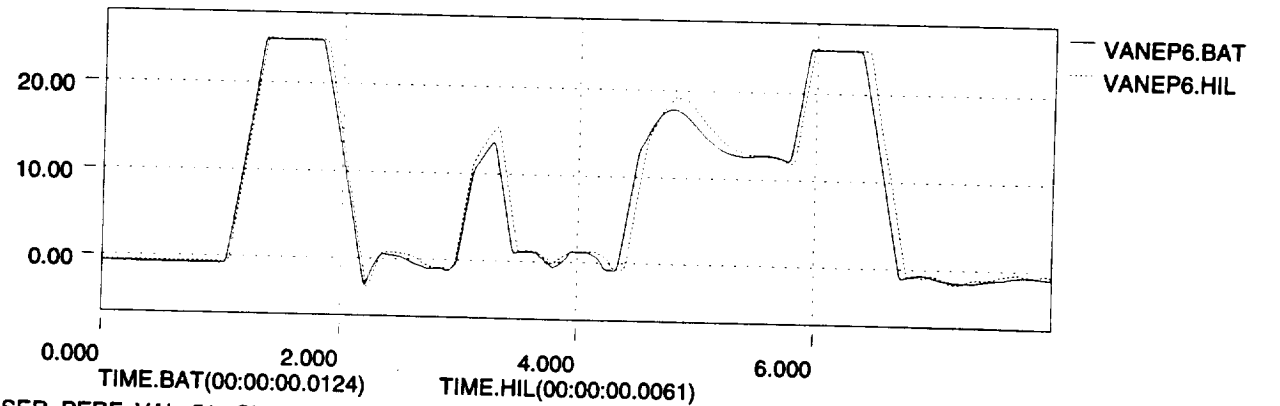

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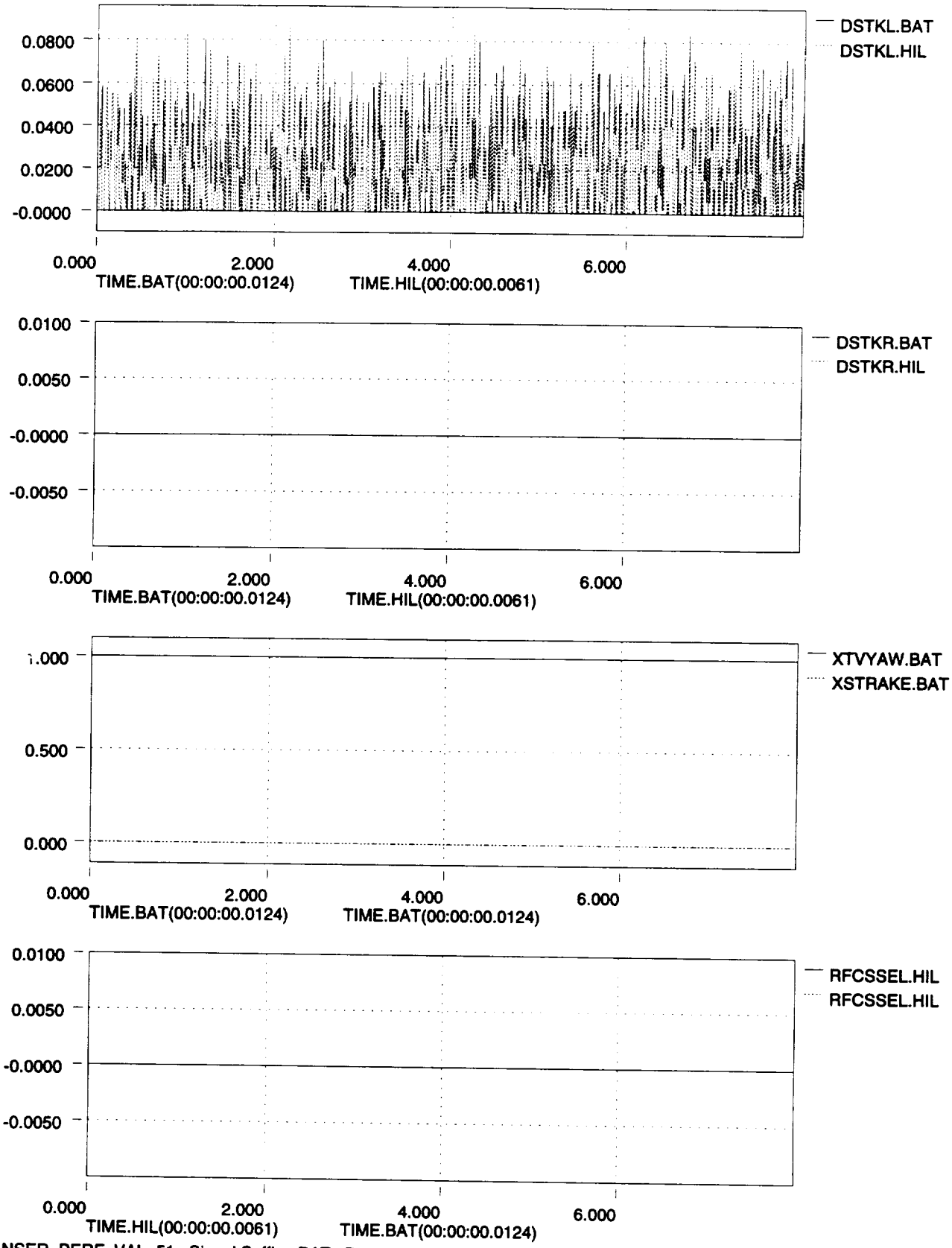

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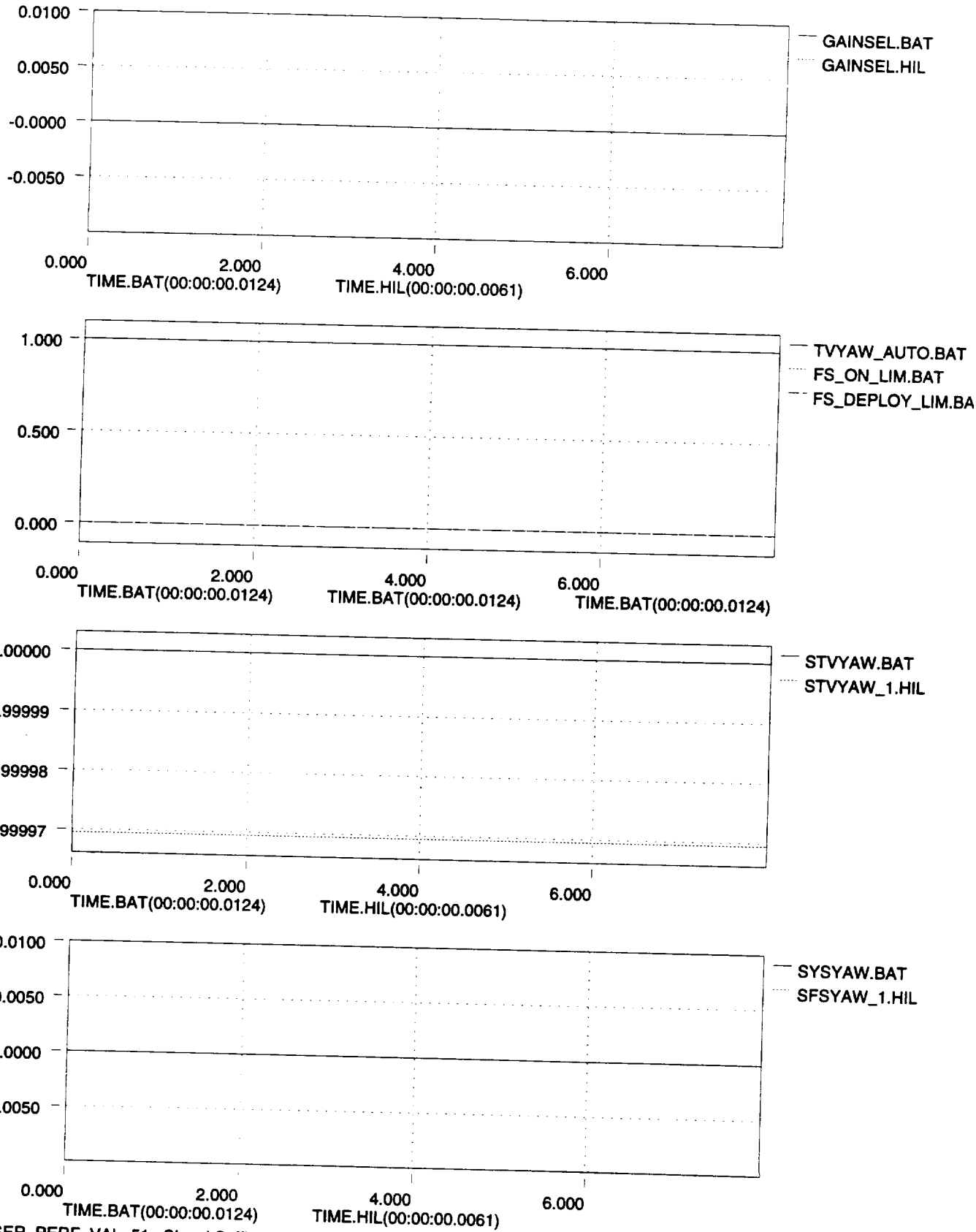

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The Actuated Nose Strakes for Enhanced Rolling (ANSER) Control Laws were modified as a result of Phase III F/A-18 High Alpha Research Vehicle (HARV) flight testing. The control law modifications for the next software release were designated version 152.0. The Ada implementation was tested in the Hardware-In-the-Loop (HIL) simulation and results were compared to those obtained with the NASA Langley batch Fortran implementation of the control laws which are considered the "truth model." This report documents the performance validation test results between these implementations for ANSER control law version 152.0.

14. SUBJECT TERMS
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