EMR AND INVERSION-BASED CONTROL OF AN ELECTRIC VEHICLE

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“EMR AND INVERSION-BASED CONTROL OF AN ELECTRIC VEHICLE”

- Presentation Outline -

EMR’13, Lille, Sept. 2013

Introduction
System Modeling Using EMR
Inversion-Based Control Structure
Simulation Results
Conclusions
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- Introduction -

Real system

Dynamical model

Representation

model objective

organization

prediction

assumptions

no assumption

assumptions

limited validity range

valuable properties

behavior study

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« SYSTEM MODELING USING EMR »
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- System Modeling Using EMR -

common variable $v_{bat}$

\[ i_{tot} = i_{cha} + i_{chf} \]
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- System Modeling Using EMR -

\[
\begin{align*}
\mathbf{u}_{\text{cha}} &= \mathbf{m}_{\text{cha}} \mathbf{u}_{\text{bat}} \\
\mathbf{i}_{\text{cha}} &= \mathbf{m}_{\text{cha}} \mathbf{i}_a \\
\mathbf{u}_{\text{chf}} &= \mathbf{m}_{\text{chf}} \mathbf{u}_{\text{bat}} \\
\mathbf{i}_{\text{chf}} &= \mathbf{m}_{\text{chf}} \mathbf{i}_f
\end{align*}
\]
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- System Modeling Using EMR -

\[ u_{cha} - e_a = r_a i_a + L_a \frac{di_a}{dt} \]
\[ u_{chf} - e_f = r_f i_f + L_f \frac{di_f}{dt} \]

without saturation of the DC machine
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- System Modeling Using EMR -
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- System Modeling Using EMR -

battery connexion choppers DC machine Trans- wheels

\[ F_{\text{tran}} = \frac{k_{\text{red}}}{R_{\text{wh}}} T_{em} \]
\[ \Omega_{em} = \frac{k_{\text{red}}}{R_{\text{wh}}} v_{ev} \]

neither the contact law nor curving road
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- System Modeling Using EMR -
\[ F_{res} \approx F_{air} + F_{slope} \]
\[ F_{air} = \frac{1}{2} \rho_{air} S_{front} C_x v_e^2 \]
\[ F_{slope} = Mg \sin(\alpha) \]
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- System Modeling Using EMR -
« INVERSION BASED CONTROL STRUCTURE »
Step 1: Energetic Macroscopic Representation (EMR) of system

ES \quad \Rightarrow \quad \text{battery} \quad \text{connexion} \quad \text{choppers} \quad \text{DC machine} \quad \text{Trans- wheels} \quad \text{chassis} \quad \text{environ.}

\begin{align*}
\text{batter}y & \quad \text{connexion} \\
& \quad \text{choppers} \\
& \quad \text{DC machine} \\
& \quad \text{Trans- wheels} \\
& \quad \text{chassis} \\
& \quad \text{environ.}
\end{align*}
Step 2: Objectives, constraints and tuning variables of system

-1 objective: control of $v_{ev}$
-1 constraint: field current of DC machine
-2 tuning variables: $m_{cha}$ and $m_{chf}$
Step 3: According to the objective, Choose tuning chains
Step 4: By inversion of tuning chains, obtain control chains

- Inversion Based Control -
Step 5: Maximum Control Structure

Conversion Element

Accumulation Element

Coupling Element
Step 5: Maximum Control Structure

Conversion Element

Accumulation Element

Coupling Element
Step 5: Maximum Control Structure
Step 5: Maximum Control Structure

- Inversion Based Control -

```
| battery | connexion | choppers | DC machine | Trans-wheels | chassis | environ |
                  |           |          |            |             |        |          |
```

```
T_{em} \quad \frac{k_{red}}{R_{wh}} \quad F_{tran} \\
\Omega_{em} \quad \frac{k_{red}}{R_{wh}} \quad v_{ev} \\
T_{em_{ref}} \quad \frac{R_{wh}}{k_{red}} \quad F_{tran_{ref}} \\
```

```
F_{tran} = \frac{k_{red}}{R_{wh}} T_{em} \\
\Omega_{em} = \frac{k_{red}}{R_{wh}} v_{ev} \\
```

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Step 5: Maximum Control Structure

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- Inversion Based Control -

Introduction  Modeling Using EMR  Control Structure  Simulation Results  Conclusions
Step 5: Maximum Control Structure
Step 5: Maximum Control Structure
Step 5: Maximum Control Structure
**Step 5: Maximum Control Structure - STRATEGY**

- **battery** → **connexion** → **choppers** → **DC machine** → **Trans-wheels** → **chassis** → **environ.**

**Diagram:**
- **ES** to **MS**
- **u_{bat}** → **i_{cha}** → **u_{chf}** → **i_f**
- **T_{em}** → **F_{tran}** → **v_{ev}**
- **m_{cha}** → **m_{cha_ref}**
- **m_{chf}** → **m_{chf_ref}**
- **Field weakening...**

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**Introduction** | **Modeling Using EMR** | **Control Structure** | **Simulation Results** | **Conclusions**
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- Inversion Based Control -

Step 6: Practical Control Structure

Field weakening…
Step 6: Practical Control Structure

Field weakening...
Step 7: Application in the real system
System Response to a Velocity Profile

a) vehicle velocity. b) Modulating signal.

Armature current evolution.
Summary of the Proposal

- Step 1: Establish the system model using EMR.
- Step 2: Analyze the system model: objectives, constraints, tuning variables of system, etc.
- Step 3: According to objectives, choose tuning chains.
- Step 4: Inverse the modeling through the tuning chains to obtain the Maximum Control Structure.
- Step 5: Strategy.
- Step 6: Simplify the Maximum Control Structure to achieve a Practical Control Structure.
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