« EMR AND INVERSION-BASED CONTROL OF RENEWABLE ENERGY SYSTEMS »

Prof. Alain BOUSCAYROL, Dr. Philippe DELARUE, Dr. Walter LHOMME
L2EP, University Lille1, MEGEVH network,
Alain.Bouscayrol@univ-lille1.fr
1. **Wind Energy Conversion System**
   - Studied System
   - EMR of the WECS
   - Inversion-based control of the WECS

2. **PhotoVoltaic Conversion System**
   - Studied System
   - EMR of the PV system
   - Inversion-based control of the PV system
Wind Energy Conversion System

A. Bouscayrol, X. Guillaud
(University of Lille 1, France)

R. Teodorescu
(University of Aalborg, Denmark)
Chosen WECS for variable speed and variable frequency:
a squirrel cage IM and two VSI

Technical requirements: provide the maximum active power $P$ and control the reactive power $Q$
\[ F_{\text{blade}} = \frac{1}{2} \rho S V_{\text{wind}}^2 \]

\[ F_{\text{tang}} = C_T(\lambda) F_{\text{blade}} \]

\[ \begin{align*}
T_{\text{blade}} &= R_{\text{blade}} F_{\text{tang}} \\
V_{\text{blade}} &= R_{\text{blade}} \Omega_{\text{shaft}}
\end{align*} \]

\[ \lambda = \frac{V_{\text{blade}}}{V_{\text{wind}}} = \frac{R_{\text{blade}} \Omega_{\text{shaft}}}{V_{\text{wind}}} \]

\[ C_T = f(\lambda) \]
EMR and Renewable Energy Systems

- EMR of the mechanical powertrain -

\[ J_1 \frac{d}{dt} \Omega_{ls} + f \Omega_{ls} = T_{blade} - T_1 \]

\[ \begin{align*}
T_1 &= k_{gear} T_2 \\
\Omega_{hs} &= k_{gear} \Omega_{ls}
\end{align*} \]

\[ J_2 \frac{d}{dt} \Omega_{hs} + f_2 \Omega_{hs} = T_2 - T_{im} \]
Element association?

1. permutation

2. merging \( J_{eq} = J_1 + \frac{J_2}{k^2} \)

Equivalent power train
Modelling simplifications:

\[
\begin{align*}
\phi_r &= k_1 i_{sd} \\
T_{im} &= k_2 \phi_r i_{sq}
\end{align*}
\]
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- EMR of the squirrel cage IM -

Simplified EMR

Coupling device

\[
\begin{align*}
\phi_r & \approx k_1 i_{sd} \\
T_{im} & \approx k_2 \phi_r i_{sq}
\end{align*}
\]

Stator windings in (d,q)

\[
\begin{align*}
\theta_{d/s} \\
\Omega_{gear} \\
T_{im} \\
\phi_r
\end{align*}
\]

Rotor windings in (d,q)

\[
\begin{align*}
u_{rotor} = 0
\end{align*}
\]

Park’s transformations

Squirrel cage

permutation of windings and transformation

concatenation of EM conversion and transformation
\[ s_{11} = \begin{cases} 1 \text{ (closed)} \\ 0 \text{ (open)} \end{cases} \]

\[ m_{\text{rect}} = \begin{bmatrix} s_{11} - s_{13} \\ s_{12} - s_{13} \end{bmatrix} \]

\[ \begin{cases} u_{\text{rect}} = m_{\text{rect}} u_{\text{cap}} \\ i_{\text{rect}} = m_{\text{rect}}^t i_{\text{im}} \end{cases} \]

\[ C \frac{d}{dt} u_{\text{cap}} = i_{\text{rect}} - i_{\text{inv}} \]
\[ L_1 \frac{d}{dt} i_1 + R_3 i_1 = u_{inv} - u_1 \]

\[ \begin{cases} u_2 = m_{trans} u_3 \\ i_3 = m_{trans} i_2 \end{cases} \]

\[ L_2 \frac{d}{dt} i_2 + R_3 i_2 = u_1 - u_2 \]

\[ L_3 \frac{d}{dt} i_3 + R_3 i_3 = u_3 - u_{grid} \]
Element association?

1. merging

2. permutation

3. merging

\[ L_{eq} = L_1 + L_2 + \frac{L_3}{m_{trans}^2} \]
objectives: active power $P$
reactive power $Q$

$$m_{rect} = \begin{bmatrix} m_{13} \\ m_{23} \end{bmatrix} \quad \Rightarrow \quad 2 \text{ freedom degrees}$$

constraints: capacitor voltage
machine flux

$$m_{inv} = \begin{bmatrix} m'_{13} \\ m'_{23} \end{bmatrix} \quad \Rightarrow \quad 2 \text{ freedom degrees}$$


MPPT = Maximum Power Point Tracking
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- MPPT strategy -

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« PHOTO-VOLTAIC CONVERSION SYSTEM »

Dr. W. Lhomme, Dr. P. Delarue, Prof. A. Bouscayrol,
(University of Lille 1, France)
Technical requirements: provide the maximum active power $P$. 
\( i_{pv} = f(u_c, T, G) \)

- **EMR of the PV System** -

\( \frac{d}{dt} u_C + \frac{u_C}{R_C} = i_{pv} - i_L \)

\( L \frac{d}{dt} i_L + R_L i_L = u_C - u_{bc} \)

\( u_{bat} = f(i_{bc}, OCV) \)

\( OCV = f(\text{SoC}) \)

\( \text{SoC} = f(i_{bc}, T) \)
Inversion-based control of the PV System

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