Modelling of Standalone PV-Wind-Battery Hybrid Systems Using Physics-based Battery Models

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Past, present and forecast of the world’s energy needs up to 2050*

Top ten electricity consuming countries**

*Larcher and Tarascon, Nature Chemistry 2015;7:19-29
**IEA Report
INTRODUCTION  

CO$_2$ emission challenge

World gross electricity production by source*

CO$_2$ emissions from fuel combustion in Asia*  

**IEA Report
• Weather dependant
• Quantity and quality of electricity generated
• Unpredictable and inconsistent
• Large capital cost
• Resource location

Figure: Renewables energy resources
Figure: Schematic of a proposed hybrid system
Physics-based models are more accurate than equivalent circuit based models (ECMs)*


Figure: Process map for numerical simulation

Li-ION BATTERY MODELLING

Figure: Battery models Vs computational demands

- A pseudo-two-dimensional* LiB model & it’s discretization using finite volume method**

*Ramadesigan et al., JES, 2012;159(3):R31-R45
*M. Doyle et al., JES,1993;140(6):1526–1533
**M. Torchio et al., JES, 2016;163(7):A1192–A1205
MODELLING OF STANDALONE PV-WIND-BATTERY HYBRID SYSTEMS

POWER BY PV & WIND TURBINE

PV Modelling

- Single-diode equivalent circuit-based model of a PV cell
- DAE-based MPPT* algorithm is implemented**

\[
I(t) = I_{PV}(t) - I_0 \left[ \exp \left( \frac{V(t) + R_S I(t)}{V_{th} a} \right) - 1 \right] - \frac{V(t) + R_S I(t)}{R_P}
\]

\[
I(t) = I_0 \left( 1 - \frac{R_S I(t)}{V(t)} \right) \exp \left( \frac{V(t) + R_S I(t)}{V_{th} a} \right) \frac{1 - R_L I(t)}{V(t)}
\]

Wind Turbine Modelling

- The output power produced by the wind turbine

\[
P_{wind}(t) = \frac{1}{2} \rho A V_w(t)^3 C_p \eta_{inv} \eta_{mech}
\]

\[
P_{wind}(t) = \begin{cases} 
0, & V_w(t) < V_{ci} \\
P_{wind}(t), & V_{ci}(t) \leq V_w(t) \leq V_r \\
P_{rated}, & V_r \leq V_w(t) \leq V_{co} \\
0, & V_{co} < V_w(t)
\end{cases}
\]

**M. Bonkile and V. Ramadesigan, J. Energy Storage, 2019, 23:258 – 268
*S.B.Lee et al., JES, 2017, 164(11):E3026–E3034

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RESULTS

- A remote site at Wardha circle of Nagpur region (20.7453° N, 78.6022° E), located in India
- MATLAB®/SIMULINK environment

Figure: (a) Hourly average of solar irradiation and wind speed profile; (b) Hourly load variations profile
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RESULTS

Figure: (a) Power-Voltage graph for the single-diode equivalent circuit model; (b) Hourly power generated by PV panels; (c) Hourly power generated by wind turbines; (d) Battery SOC & power
Figure: (a) Power supplied by wind turbines and BES during no sunshine hours; (b) Battery charging during sunshine hours
Physics-based battery model representing the transport and kinetic processes inside the LiB is implemented instead of the typically used ECM.