Comparison of AC, DC, and AC/DC Bus Configurations for PV Hybrid Systems

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Michael M. D. Ross
RER Renewable Energy Research

Dave Turcotte, Sophie Roussin & Marc-André Fry
CETC-Varennes, Natural Resources Canada

RER Renewable Energy Research
2180 Valois Ave • Montréal • Québec • H1W 3M5 • www.RERinfo.ca
Acknowledgements

- Photovoltaic and Hybrid Systems Group, CETC-Varennes (Natural Resources Canada)

- Panel on Energy Research and Development (PERD)
AC/DC bus configuration is typical in Canada

- PV <-> battery connection is DC
- Genset can supply loads directly
AC bus is being promoted in Europe

- Module or string inverters at array
- Modularity and flexibility—can just add more modules
- But two conversion stages between array and battery
DC bus on the horizon?

- DC output of genset permits variable speed operation, leading to decreased fuel consumption under part load
- Genset output directly to load must pass through inverter
Gabler and Wiemken (1998) Study

- Compared AC bus and AC/DC bus for one hybrid system in Freiburg, Germany using simulation

- “In spite of the additional transforming processes, the AC coupled system is not far away in performance”

- Solar fraction and performance ratio are only 6% lower than with AC/DC bus
Gabler and Wiemken (1998) Study

- Do not include MPPT for AC/DC bus system

- Who cares about solar fraction and performance ratio?
  - Genset fuel consumption is what counts
PVToolbox Simulation Study

- Recreated Gabler and Wiemken results with good accuracy

- When AC/DC bus system includes MPPT, fuel consumption of AC bus system is around 19% higher

- When rectifier efficiency improved to match efficiency of inverter, fuel consumption of AC bus system is around 12% higher
Sensitivity to Load Profile, Size of Array

- Conclusions insensitive to diurnal or seasonal variation in load profile
- Apply over entire range of array-to-load ratios

![Graph showing sensitivity to load profile and size of array](chart.png)
Comparison with DC bus system: Electricity

- Extended simulations to include DC bus and DC loads
- Results for electricity required from genset:

<table>
<thead>
<tr>
<th></th>
<th>AC/DC Bus</th>
<th>AC Bus</th>
<th>DC Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total=100</td>
<td>Total=100</td>
<td>% Diff</td>
</tr>
<tr>
<td>Baseline</td>
<td>39.7</td>
<td>44.6</td>
<td>12.3%</td>
</tr>
<tr>
<td>No equalisation</td>
<td>36.2</td>
<td>41.3</td>
<td>14.1%</td>
</tr>
<tr>
<td>5.1 kW AC load</td>
<td>41.1</td>
<td>47.4</td>
<td>15.3%</td>
</tr>
<tr>
<td>AC &amp; DC loads</td>
<td>38.0</td>
<td>44.7</td>
<td>17.7%</td>
</tr>
<tr>
<td>DC loads</td>
<td>36.0</td>
<td>42.5</td>
<td>18.2%</td>
</tr>
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</table>
Comparison with DC bus system: Fuel

- Results for fuel consumed by genset:

<table>
<thead>
<tr>
<th></th>
<th>AC/DC Bus</th>
<th>AC Bus</th>
<th>DC Bus</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>l diesel</td>
<td>l diesel</td>
<td>% Diff</td>
</tr>
<tr>
<td>Baseline</td>
<td>844</td>
<td>935</td>
<td>10.8%</td>
</tr>
<tr>
<td>No equalisation</td>
<td>675</td>
<td>769</td>
<td>13.9%</td>
</tr>
<tr>
<td>5.1 kW AC load</td>
<td>869</td>
<td>987</td>
<td>13.6%</td>
</tr>
<tr>
<td>AC &amp; DC loads</td>
<td>814</td>
<td>938</td>
<td>15.2%</td>
</tr>
<tr>
<td>DC loads</td>
<td>776</td>
<td>899</td>
<td>15.9%</td>
</tr>
</tbody>
</table>
This overestimates benefit of DC bus

- DC bus system will not, in reality, achieve this level of improvement
  - Ideal variable speed genset was used; real variable gensets do not have zero fuel consumption at zero load
  - 8 hour monthly equalisation is probably longer than is necessary

- Dispatch strategy that avoids part-load operation of genset may permit AC/DC bus system to match DC bus system performance
Conclusions

- AC/DC bus configuration in common usage is just fine
- AC bus system requires 10 to 18% more fuel than AC/DC bus configuration
- DC bus system with ideal genset and very frequent equalisation consumes 10 to 14% less fuel than AC/DC bus configuration
  - Real gensets far from ideal
  - Smarter dispatch that avoids genset part load operation closes gap