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Campus Energy Testbed: Battery Energy Storage System (BESS) Based Photovoltaic Charging Station (PV-CS) For A Green University Transportation

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ABSTRACT
With the trends encouraged by governments and political parties to increase the adoption of Renewable Energy Sources (RES): solar energy, and in particular photovoltaics (PV), is poised as an excellent candidate to offset the energy requirements of charging stations (PV-CS) for Electric Vehicles (BEV). This work presents a 10.5 kW Transient System Simulation (TRNSYS) model of a university campus PV-CS to determine sizing as well as wide to determine the best operating strategies for a Battery Energy Storage System (BESS). The economical optimization model is formulated via theoretical approach adopting the Simple Payback Period (SPP) indicator. The optimization takes into account the campus transportation load profile while BESS is used to attain the shortest SPP gain. The results, from both theoretical as well as simulation approach, reveal that leveraging the campus BEVs charging via BESS based PV-CS scheme has the potential to reduce the energy demand from the grid, and to maximise self-consumption efficiency.

OBJECTIVE
- Develop a 10.5 kW Transient System Simulation (TRNSYS) model of a university campus PV-CS
- Determine the size and the best operating strategies for a Battery Energy Storage System (BESS)
- Perform economical optimization via theoretical approach adopting the Simple Payback Period (SPP) indicator
- Give recommendations for the real system components

MODELLING PROCEDURE
The PV-CS model was developed to replicate the experimentally proposed model in [1].
- The model was created in TRNSYS through the connection of selected components, called TYPES, (Table 1) and their input-output mapping.
- The flow diagram for the model and utilised components are shown in Figure 1.
- Furthermore, completed PV-CS TRNSYS model with all in built components (TYPES) is illustrated in Figure 2.

ENERGY MANAGEMENT
The energy flow parameters were calculated according to the steps summarised in Figure 3.
- To assess the feasibility of investment, parameters are further monetised using the economic model hence, adopting the system capital cost along with time variant energy tariff rates.
- It was assumed that the excess energy is fed back into the grid, and exploited for other campus loads.
- The energy balancing optimization adopted the Simple Payback Period (SPP) method in order to investigate the acquired positive gain by BESS unit. The SPP time for regaining project investment was expressed in years.
- The key variables for tuning the BESS capacity were load profile and size of BESS. This was selected accordingly to the specification of newly launched Lithium-Ion Tesla Powerwall batteries (Table 2).

RESULTS
The SPP for all analysed BESS/load configurations is gathered in Table 3.
- The values for 7 kWh and 14 kWh BESS are in the same range.
- As the result of campus expanding load and available BESS unit, a capacity that falls between 7-14 kWh would be reasonable.

REPRESENTATIVE BESS CAPACITY
Figure 4 summarise energy balancing parameters and corresponding cash flows for the 3 cases when 1-3 units of 7 kWh BESS were incorporated as part of PV-CS installation. Daily load value was iterated and total load demands, load coverage from BESS, purchased and spilled energy from and to the grid were observed.

DISCUSSION
Leveraging the campus BEVs charging via BESS based PV-CS scheme has the potential to reduce the emission levels at the generation point.
- To embrace the full potential of PV-CS green generation, it would be beneficial to incorporate additional auxiliary campus loads as part of the overall system demand.
- This could potentially lead to increase in system self-consumption and reduction of energy procurement from the grid.

FUTURE WORK
- Clarification of energy flow and control management
- System monitoring: charge/discharge cycles, electrical/thermal characteristics

REFERENCES: Esfandyari, A. et al., The Battery Energy Storage System (BESS) Design Option for On-Campus Photovoltaic Charging Station (PV-CS), Smart World Congress (SWC2015), Daegu, South Korea.

ACKNOWLEDGEMENTS: The authors would like to acknowledge Fersenam scholarship (DIT), Grangegorman Development Agency, Dublin Institute of Technology, and Trinity College Dublin for all the support and co-Basis.

Table 1: PV-CS components TRNSYS TYPES

<table>
<thead>
<tr>
<th>Component</th>
<th>TRNSYS</th>
<th>Model Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV panel</td>
<td>TRNSYS</td>
<td>Solar panels with installed capacity of 10 kW each.</td>
</tr>
<tr>
<td>BESS</td>
<td>TRNSYS</td>
<td>Power, BESS capacity of 14 kWh.</td>
</tr>
<tr>
<td>Charge Controller</td>
<td>TRNSYS</td>
<td>Energy Balancing, battery capacity is 14 kWh based on initial sizing.</td>
</tr>
<tr>
<td>Load Feeding Network</td>
<td>TRNSYS</td>
<td>Load Feeding Network, battery capacity is 14 kWh based on initial sizing.</td>
</tr>
<tr>
<td>Unit Governor</td>
<td>TRNSYS</td>
<td>Unit Governor, battery capacity is 14 kWh based on initial sizing.</td>
</tr>
<tr>
<td>Meter</td>
<td>TRNSYS</td>
<td>Meter, battery capacity is 14 kWh based on initial sizing.</td>
</tr>
<tr>
<td>Drive plate</td>
<td>TRNSYS</td>
<td>Drive plate, battery capacity is 14 kWh based on initial sizing.</td>
</tr>
</tbody>
</table>

Table 2: Load iteration factor and BESS capacity tuning

<table>
<thead>
<tr>
<th>Load Level (%)</th>
<th>Load iteration factor</th>
<th>BESS capacity (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>+ 1 unit</td>
<td>14</td>
</tr>
<tr>
<td>90</td>
<td>+ 1 unit</td>
<td>14</td>
</tr>
<tr>
<td>80</td>
<td>+ 1 unit</td>
<td>14</td>
</tr>
<tr>
<td>70</td>
<td>+ 1 unit</td>
<td>14</td>
</tr>
<tr>
<td>60</td>
<td>+ 1 unit</td>
<td>14</td>
</tr>
<tr>
<td>50</td>
<td>+ 1 unit</td>
<td>14</td>
</tr>
<tr>
<td>40</td>
<td>+ 1 unit</td>
<td>14</td>
</tr>
<tr>
<td>30</td>
<td>+ 1 unit</td>
<td>14</td>
</tr>
<tr>
<td>20</td>
<td>+ 1 unit</td>
<td>14</td>
</tr>
</tbody>
</table>

Table 3: SPP and LCT for different load configurations

<table>
<thead>
<tr>
<th>Load Level (%)</th>
<th>System configuration</th>
<th>Load iteration</th>
<th>SPP</th>
<th>LCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>System configuration</td>
<td>+ 1 unit</td>
<td>240</td>
<td>24</td>
</tr>
<tr>
<td>90</td>
<td>System configuration</td>
<td>+ 1 unit</td>
<td>240</td>
<td>24</td>
</tr>
<tr>
<td>80</td>
<td>System configuration</td>
<td>+ 1 unit</td>
<td>240</td>
<td>24</td>
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<tr>
<td>70</td>
<td>System configuration</td>
<td>+ 1 unit</td>
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<td>60</td>
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<td>+ 1 unit</td>
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<td>System configuration</td>
<td>+ 1 unit</td>
<td>240</td>
<td>24</td>
</tr>
<tr>
<td>20</td>
<td>System configuration</td>
<td>+ 1 unit</td>
<td>240</td>
<td>24</td>
</tr>
</tbody>
</table>

Figure 4: Load iteration for 1-3 units of 7 kWh BESS and corresponded load and energy follow signals.

Figure 5: SPPs and LCTs for different load configurations.

Figure 6: Load iteration for 1-3 units of 7 kWh BESS and corresponding load and energy flow signals.

Figure 7: SPPs and LCTs for different load configurations.

Figure 8: System components.

Figure 9: PV array of 65 modules located on a roof.

Figure 10: System components.

Figure 11: System components.

Figure 12: System components.