2016

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

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Recommended Citation

Esfandyari A., Świerc A., Norton B., Conlon M., McCormack S.J.: Campus Energy Testbed: Battery Energy Storage System (BESS) Based Photovoltaic Charging Station (PV-CS) For A Green University Transportation. *Orcas 2016: International Conference on Energy Conversion & Storage*. Friday Harbor, WA 2016

Funder: Technological University Dublin(DIT)

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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 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 maximize 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.

Table 1. PV-CS components TRNSYS TYPES

Components	TYPE	Variables Observed
Weather data / Solar Radiation	TYPE 15	Irradiance
PV panel	TYPE 94	Power
BESS	TYPE 47	Power , SOC
Charge Controller	TYPE 48	Energy Balancing
Load (Forcing Function)	TYPE 14	-
Unit Conversion	TYPE 57	-
Printer	TYPE 65	-
Online plotter	TYPE 25	-

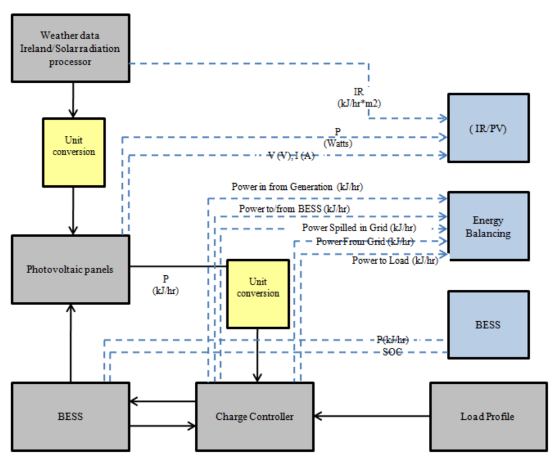

Figure 1. PV-CS flow-diagram in TRNSYS

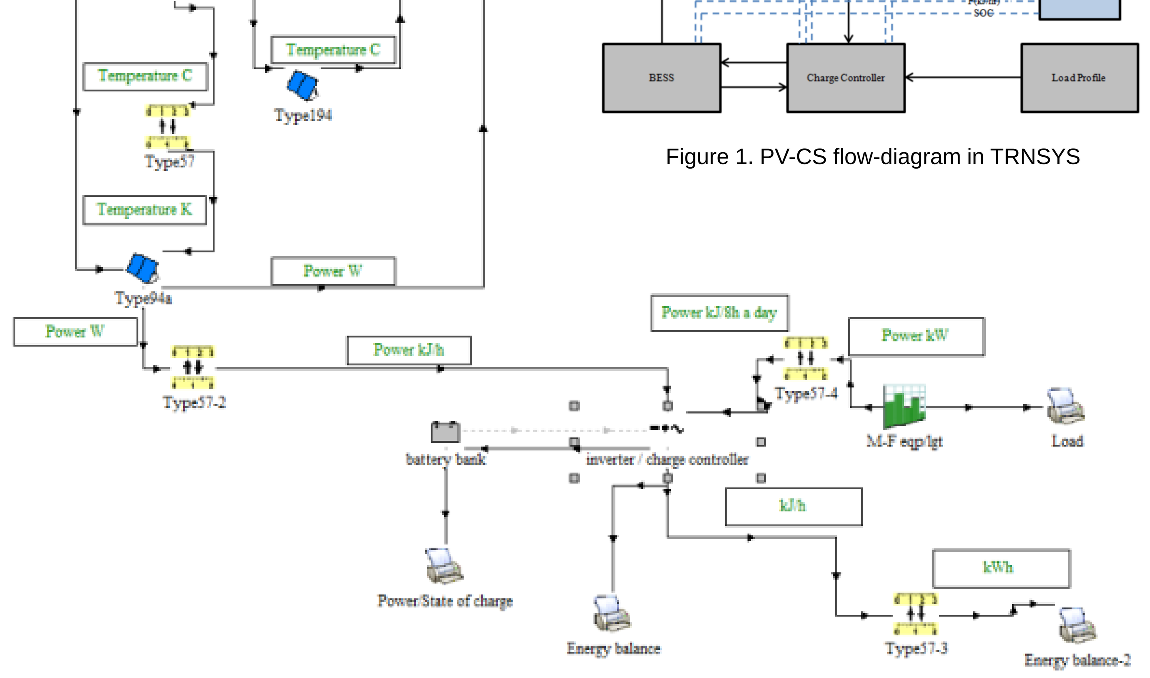

Figure 2. PV-CS TRNSYS model with all in-built components

ENERGY MANAGEMENT

- The energy flow parameters were calculated according to the steps summarised in Figure 3.

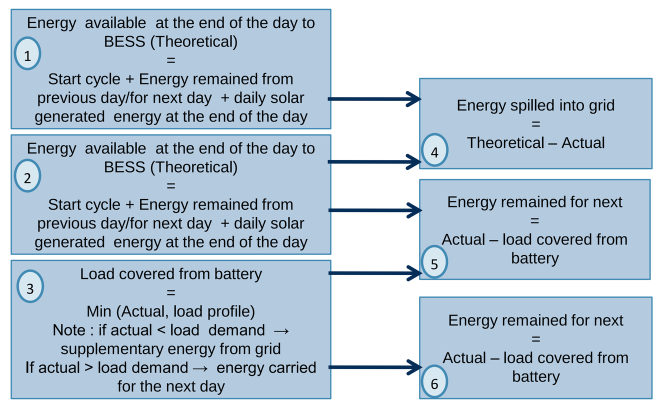

Figure 3. Logical flow diagram for energy control management

- 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).

Table 2. Load iteration factor and BESS capacity tuning

Load iteration	100% - 80% - 60% - 40% - 20%
BESS tuning	7kWh - 14 kWh - 21 kWh

RESULTS

- The SPP for all analyzed BESS/load configurations is gathered in Table 3.

Table 3. SPP scenario comparison for BESS sizing for all BESS/load configurations

System	SPP		
	7 kWh	14 kWh	21 kWh
100%	18.22	18.36	20.59
80%	18.22	19.17	21.62
60%	18.22	20.76	22.91
40%	18.89	21.72	24.62
20%	20.47	23.63	26.86

- 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.

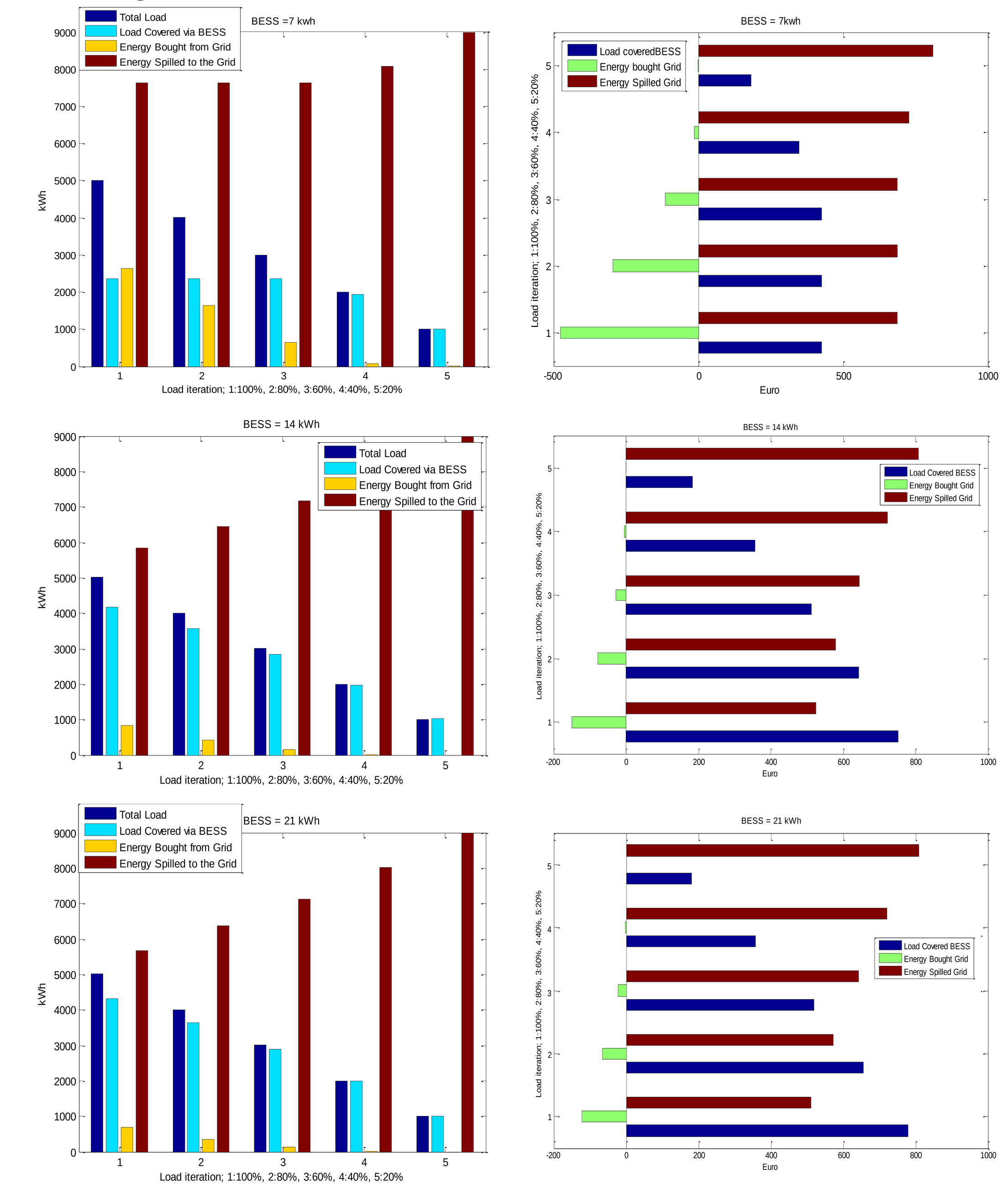

Figure 4. Load iteration for 1-3 units of 7 kWh BESS and corresponding cash and energy flows

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.

PV-CS TESTBED COMPONENTS

- The details of PV and Balance of System (BoS) components integrated as part of PV-CS is as following:

- 10.5 kWp PV array
  - (42 modules of 250 Wp)
  - Area: 68.3 m²
  - Angle: 10°
  - Orientation: SE (135°)

Figure 5. PV array of 42 modules located on a roof

- Sunny Boy Inverters
- Sunny Island
- Sunny Remote Control
- BESS
  - LG RESU 6.4 kWh
  + 1 unit extension 3.2 kWh
- Protection Elements
  - (fuses and emergency switch boards)

Figure 6. System components

- Sunny Energy Home Manger

- Figure 7 illustrates of energy outcomes for a solar sufficient day in Summer.
- The results are extracted from the web-portal, via established control and communication of Energy Manager.
- The signals are categorised into various energy categories, i.e., displayed by a distinct colour.

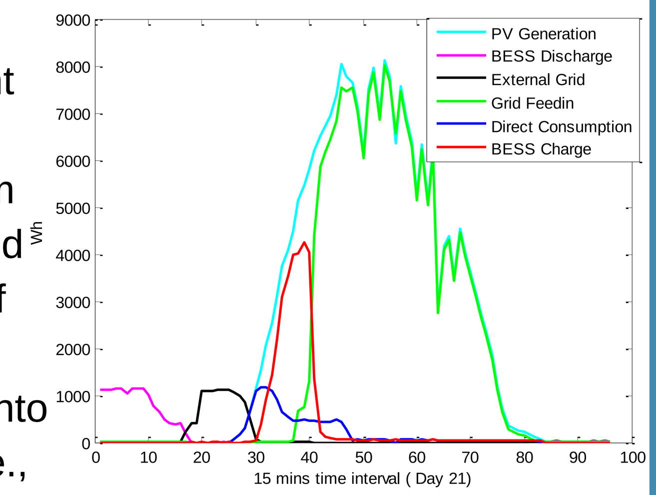

Figure 7. Energy Flow signals obtained from EM controller

FUTURE WORK

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

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

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