Model-based Approach to Test and Validate the Performance of an Islanded Photovoltaic Plant using Simscape Power Systems

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Abstract: Photovoltaic (PV) system is considered as the most viable alternative source in renewable-based AC/DC microgrids. Addressing the key design challenges involved in the development and implementation of these systems requires simulation tools capable of not only modeling and analyzing the behavior of PV panels, but also the ability to combine them with the control algorithms to evaluate the system performance. In this work, we demonstrate the use of dynamic models in SimScape® Power Systems™ to model and test an islanded PV system with batteries and converters. These models are designed and simulated for different loading conditions and partial shading.

Introduction: Simscape® is a block diagram and model-based environment backed by MATLAB® Simulink as a foundational tool. Simscape® has multiple domains and advanced libraries that can be used to model a system at the component level such as shown in Fig. 1. It enables the system designer to schematically represent and simulate electrical systems like, in our case, a PV plant in an islanded microgrid with maximum power point tracking (MPPT) implemented.

Results: To feed an AC load of 5/10kW by fifty-six (56) panels PV array in islanded mode through an AC inverter, the model parameters are listed in Table-I, and the associated results are plotted in Fig. 2. For DC only system, as in Fig. 3, a 48V PV-based microgrid is simulated in partial shading and under heavy load conditions and the results are compared.

Conclusions: It is validated that desktop simulation can be used to model and test any kind of PV array in standalone microgrids in a controlled manner. The performance of PV panels to different loading conditions and irradiation including partial shading is observed. In addition to the desktop simulation for analysis, they can be transferred to a compatible real-time platform for hardware-in-the-loop (HIL) system to validate the practical behavior of the complex nature of PV systems.

Outlook: 1) To integrate second-life storage devices such as batteries and evaluate different energy management strategies to fulfill the load demand 2) To determine the impact of different PV faults.

Table-I: Modelling parameters of a fifty-six (56) panels PV array

No. of panels	PV output (V)	Inverter voltage (V_{rms})	Inverter type
56	~812V_{DC}	380V	3-phase
Parallel strings	V_{oc}	Inverter (V_{peak})	Load type
2	36.3V	520V	Resistive
Series panels	V_{mpp}	I_{load} (rms) @5kW	Solar irradiation
28	29V	~11A	1000W/m^2
P_{mpp} (max)	I_{mpp}	I_{load} (rms) @10kW	Test condition
213W	7.35A	21A	STC

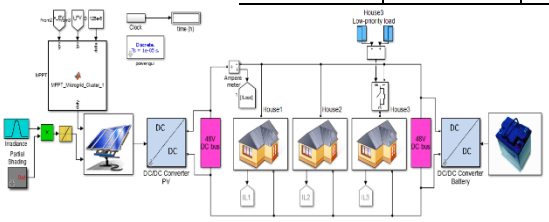

Fig.1. Simulation model of a PV-based DC microgrid using components in Simscape Power Systems Toolbox.

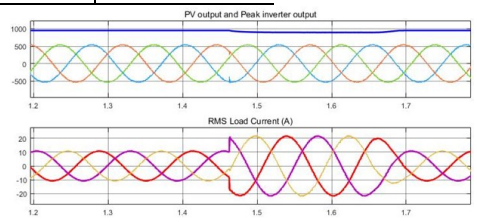

Fig.2. Simulated PV array consisting fifty-six (56) PV panels and total output voltage of 812V: The small dip in PV output is due to the inverter's loading from 5kW to 10kW.

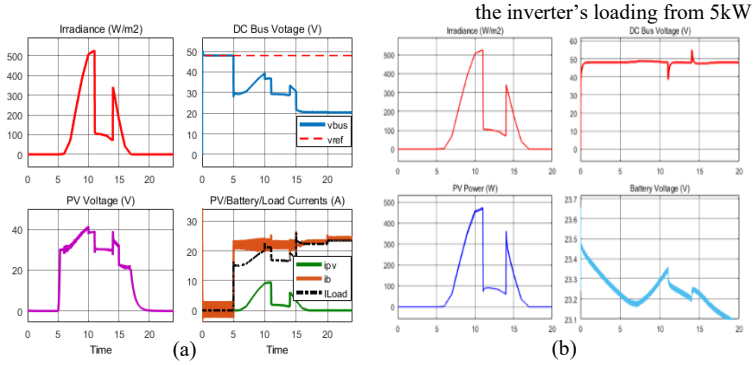

Fig. 3. (a) Simulated results of a 48V PV system with MPPT in the presence of partial shading and few heavy inductive loads. The PV array consists of 8 PV panels (02 parallel strings of 4 series connected 12V modules). The DC bus is modelled for 48V. The load is fed by the battery at a current discharge limit of 22A. The PV power is insufficient to fulfill the load demand, and the DC bus voltage collapses down to 20V after 15sec. (b) In light load condition, the DC bus is stable at 48V under MPPT, the battery can get charged from the excess PV power, and it gets slightly discharge to feed the load during the partial shading and no sunshine.