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Publication date
2017

Citation (APA)

Chandra Mouli, G. R., Van Der Meer, D., Bauer, P., Zeman, M., Schijffelen, J. H., van den Heuvel, M., & Kardolus, M. (2017). *Charging Electric Vehicles from Solar Energy: Integrated Converter and Charging Algorithms*. 1-2. Abstract from Energy-Open 2017, Enschede, Netherlands.

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Charging Electric Vehicles from Solar Energy: Integrated Converter and Charging Algorithms

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Keywords—Electric vehicles, PV system, EV charging, silicon carbide, smart charging, solar energy, MILP

I. INTRODUCTION

500 million electric vehicles (EVs) are expected to be on the roads by 2030 [1]. At the same time, the current electricity grid is largely powered by fossil fuels. When electric vehicles are charged from this grid, a large part of the emissions is merely moved from the vehicle to the power plant. Hence electric vehicles are only sustainable when charged from sustainable sources of electricity like solar [2]–[4]. There are several advantages for charging EVs from PV:

1. Reduced demand on the grid as the EV charging power is locally generated from PV [5]
2. EV battery can be used as an energy storage for the PV
3. Long parking time of EV paves way for implementing Vehicle-to-grid (V2G) technology
4. Reduced cost of EV charging and reduced impact of changes in feed-in-tariffs [6]

Currently, to charge EVs from PV is to use a PV inverter to feed PV power to the grid and to use an AC EV charger to charge the EV [7]. However this is not cost effective and efficient due to two reasons:

1. PV and EV are fundamentally DC by nature, hence exchanging power in AC leads to additional conversion steps and losses [4][3].
2. Two inverters would be needed, one each for the PV, EV

The paper presents the development of a highly efficient, modular, V2G-enabled smart charging station for electric vehicles that is powered by solar energy. The EV and PV are connected on DC rather than AC and uses a single inverter to AC. The paper focusses on the system design, power converter development and charging algorithms. The charging station is designed for use in workplaces to charge electric cars of the employees as they are parked during the day. Industrial sites and office buildings harbor a great potential for photovoltaic (PV) panels with their large, flat roofs.

II. SYSTEM DESIGN

Research has shown that there is sufficient solar insolation to charge EVs from a PV array in Netherlands [5]. Simulations based on data from the Dutch Meteorological Institute (KNMI) have shown that a 10kW PV array produces on average 30kWh/day, with 10kWh/day in winter and 50kWh/day in



Fig. 1. Design of solar powered bi-directional EV charging station

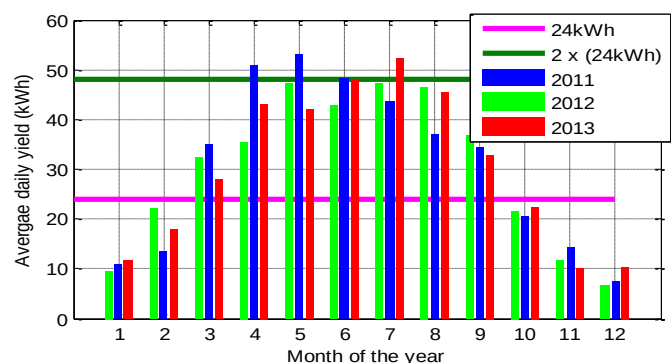


Fig. 2. Yield of 10kW PV system in Netherlands compared to Nissan Leaf EV

summer. This necessitates a grid connection to ensure reliable power supply, especially in winter. For 54% and 22% of the year, the daily yield is greater than 24kWh/day and 48kWh/day respectively (Fig. 2). 24kWh considered here corresponds to the battery capacity of a Nissan Leaf EV. The use of a local storage or a PV tracking system does not help in overcoming the seasonal variations in irradiance. However small sized storage of 10kWh helped in mitigating the day-day solar variations and reduced the grid energy exchange by 25%.

III. 10KW BI-DIRECTIONAL THREE-PORT CONVERTER

The optimal system architecture for EV charging from PV is an integrated three-port converter connected to the AC grid, as shown in Fig. 3 [8]. It has three sub-converters: a DC-DC converter for PV, a DC-DC isolated converter for EV and a DC-AC inverter to connect to the AC grid.

