MACRO PLANNING OF PHOTOVOLTAIC CAPACITY: MATCHING ORIENTATION AND TILT ANGLES TO LOAD PROFILES IN ABSENCE OF FREE MARKETS

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Overview

Traditionally the optimum setup for grid-connected PV installations has been understood as to be defined by the tilt and azimuth angle that would maximize the installation's annual electricity output. This understanding was fostered by previously high PV system prices and feed-in tariffs that would reward PV electricity generation indiscriminately, i.e. without differentiating the tariffs according to demand and thus the true value of the electricity at the time of generation. However, PV system prices have fallen tremendously in recent years, and in regions of high PV electricity shares the focus has changed towards grid integration issues and market effects. As pointed out in previous studies, the chosen orientation and especially tilt angle of PV systems could potentially be influenced by policy makers to reach particular goals (Weissenbacher 2012, 2013). Lower-than-optimum tilt angles decrease annual electricity output by single percentage points only, while increasing the yearly output per area occupied by the system by double digit percentage points (as spacing requirements to avoid cross-shading are reduced). Such strategy would thus increase the renewable energy share that can be achieved in a given area, which would for instance be relevant in insular or urban settings, or generally wherever population densities are high and electricity generation close to the point of consumption is desired. In addition, lower panel angles shift output towards summer months, which may well be beneficial in warm climates where summer load peaks due to cooling requirements fully or nearly coincide with PV peak output, thus potentially reducing the high generation costs associated with meeting such peak demand through fossil electricity. The purpose of this study is to further investigate and quantify the effects of variation of PV setups in this context.

Methods

We analyzed the readings from about 900 residential electricity meters in a single Maltese village. These 15-minute readings for the year 2013 were used to create a residential standard load profile that was compared to the overall national load profile for 2013 that was made available in one-hour increments. We compared the overall and domestic load profiles to real generation data of PV installation during 2013. In turn the output of PV installations with varying tilt and orientation angles was modeled, and the model outcome compared to actual PV output for available tilt and orientation settings. We are modeling PV output curves for various setups to compare them to the demand profile to estimate which combination of tilt and orientation variety, at which overall capacity, would best match the demand profile. The results are then associated with estimates of available residential and industrial rooftop area, and with projections of future electricity demand. We also take into account the implication of assumed minimum fossil electricity purchase requirements linked to the current Maltese power sector transition from heavy fuel oil to an LNG infrastructure financed by an Independent Power Producer, as described below.

Results

Preliminary results based on relatively large intervals in tilt and azimuth angles indicate that seasonal day-time load profile curves can well be matched through the combined output of adequately distributed PV setup variations. However, the annual PV system output is significantly reduced when a western orientation with steep tilt angle is chosen to match residential week-day evening peak demand. The requirements in terms of total PV capacity to approach the load profile curve depends strongly on the chosen capacity that will need to be purchased by the state utility from the Independent Power Producer. The base load (night time load) is about

160MW in Malta, while the new gas-fired power plant financed by a private consortium will have a capacity of 210MW.

Conclusions

Recent studies have argued that with an increasingly large penetration of photovoltaics in regions where electricity exchanges and spot markets exist, owners of PV installations (in absence of traditional feed-in tariffs) should in theory start adjusting the orientation of panels away from perfect south (in the northern hemisphere), and perhaps towards steeper tilt angles, to gain from higher spot market prices obtained when electricity demand is high, while supply from other PV installations is lower. To be sure, such studies concluded that PV penetration would have to be rather high for this market effect to set in (Hartner et al. 2014; Zipp and Lukits 2014). In Malta such study cannot be conducted based on spot market price comparisons, simply because such market does not exist. Due to a derogation, Enemalta, the state-owned utility and thus far sole significant electricity producer, remains in charge of electricity distribution as well. Any entity that would like to produce and sell electricity in Malta needs to sell to Enemalta rather than to the final consumer. On the other hand, a situation in which electricity generation and distribution is controlled by a central government that also owns industrial estates with vast empty rooftop space, careful planning may well include PV setup variations to optimize renewable energy integration and to minimize overall power sector costs. Management of PV penetration is especially relevant, as the revision of the National Renewable Energy Action plan will see a strong shift from wind power to photovoltaics. Apart from economic reasons (Weissenbacher, 2012), this shift will be necessary as wind power would be difficult to integrate under the new circumstances in which a private consortium is financing a shift from heavy fuel oil to LNG as the main fuel to generate electricity in Malta. The new private power plant of 210MW will likely deliver the base load of 160MW during the night and close to full capacity during daytime to allow the consortium to recover the investment. On the other hand, PV capacity in Malta experienced tremendous growth when system prices started to decrease. Less than 20 MWp worth of PV installations had been operational in Malta by the end of 2012, but over 55 MWp had been registered (including operating ones) by the end of 2013. This suggests that well over 60 MWp will be operational by the end of 2014, while figures of installations so far authorized in 2014 suggest that this growth is even accelerating. It will thus soon come to a situation where PV electricity may contribute large shares to total demand during mid-day, and the focus will shift towards renewable electricity integration rather than generation in Malta as well. Our modeling results should thus assist the planning of further PV growth to ensure optimal integration. Differentiated feed-in tariffs may well be used to incentivize orientation away from perfect south or lower tilt angles that would also be encouraged through high rooftop rents.

References

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