International Conference on Renewable Energies and Power Quality (ICREPQ'14)
Cordoba (Spain), 8th to 10th April, 2014

*Renewable Energy and Power Quality Journal* (RE&PQJ)

ISSN 2172-038 X, No.12, April 2014

# The shift from „grid-tie" to partly „off-grid"

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**Abstract.** This paper deals with that basic economy grounds which support to shift from „grid-tie" to partly „off-grid" photovoltaic (PV) systems. By using our own written VBA Simulation to predict the size of energy storage capacity and to support our basic assumption.

### Keywords

Partly off-grid PV system, energy storage simulation

## 1. Introduction

It is well known that the underestimated household PV systems changed the way of the European electricity generation. The question is that how we can regulate and plan the effects of the upcoming boom in the case of the partly off-grid systems.
The fundamental reason behind the ongoing shift from „grid-tie" to „off-grid" PV systems is that basic economics, which is mostly powered by the continuously widening gap between the PV feed-in prices and the household electricity prices[1],[2]. In this paper the „off-grid" term means that the PV systems are only virtually in off-gird work, because these are connected to the low voltage network (sol called "the grid"); therefore, the only sense of the partly connected off-grid system is the minimization of the energy consumption from the grid, which leads to saving.

## 2. Economic prediction

Germany is one of the leading countries in PV systems installation and it has a really high price of household electricity and a fast decreasing PV feed-in tariff which is a good combination for such a systems. Therefore, it is chosen to show the following prediction.

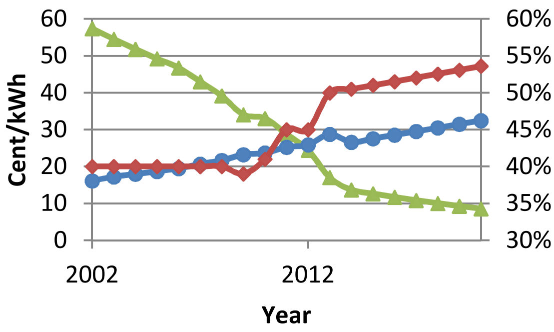


Figure 1,German (blue) household and (green) PV feed in tariff prices, Part of taxes and subsidizations in the German electricity price (red)

Today the gap between the household electricity price and feed in tariff price is approximately15 euro cents. Using regression analysis for the German household electricity price and a yearly 7,5% decreasing in feed-in tariff, the gap is likely to be widened to 24 cents by 2020 in a moderate scenario.
This gap between the PV feed-in tariff and the household electricity price is significantly narrower

in other European states; however, the trend is the same as in Germany. Although, they have not reached the tipping point yet or if they did, then the gap is too narrow.

## 3. The structure of the energy storage simulation

As it is well known that the determination of the adequate size of the electricity storage is going to be more important in the future to support the shift from „grid-tie" to the partly „off-grid" PV electricity generation. It leads us to the conclusion that there will be a need for such an adequate PV electricity storage optimization method program. In our work we created a macro program based on Visual Basic, which helps us to set a wide range of weather conditions and custom parameters to get as suitable prediction for irradiation as possible. One of them is the albedo which can significantly influence the irradiation level on the PV array. The albedo represents the reflection of solar radiation on the nearby objects and it varies between urban and rural areas a lot. The typical urban albedo value is approximately 0,16. Furthermore, the temperature distribution plays another important role in the simulation by affecting the PV cell temperature which changes the efficiency of the PV modules. The temperature of the PV cell can be calculated with the Eq.1. [3]

$$T_c = T_a + \frac{T_{NOCT} - 20}{0{,}8\, kw/m^2} \times I(t)$$

Figure 2, Equation of the temperature of the PV cell [4]

The cell temperature is also important which has a strong effect on the efficiency of the PV modules as well as on the inverter [4]. To create a real temperature distribution, we have chosen the double cosine model which it is calculated by using the mean temperature of a given day and the exact hour of the hottest and coldest hour [5]. In this simulation the weather modification parameter is constant, because in such a short term this index cannot be predicted.

Additionally, there is an option to select the suitable type of the PV module, inverter and set the right number of the modules. The program chooses the selected PV module matrix which is the function of the solar irradiation and the cell temperature, the inverters matrix is the function of the DC power and the outside temperature. The DC power of the PV modules is corrected by average 5% wiring and dust losses [6]

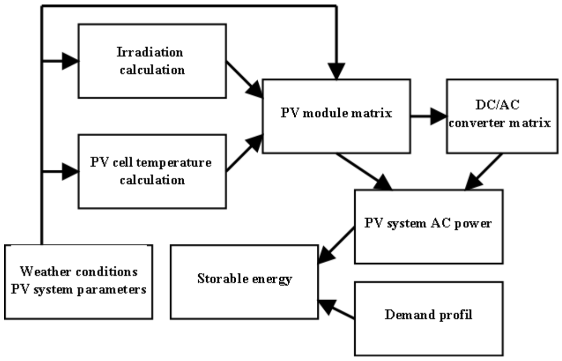


Figure 3, Process diagram of the simulation

## 4. Simulation results

As a matter of fact, the first thing that should be defined is that in what season the optimization should be run. Obviously, if the simulation took place in summer, then the energy storage would be oversized and in winter it would be undersized. It leads us to the conclusion that the optimal size of the energy storage capacity should be defined in spring or in autumn, because it covers the most part of the year in case of storable PV energy.

To create the summary of the daily energy consumption we have to assume an average daily consumption. In this scenario we used an average daily energy demand chart of a yearly 4000 kWh consuming household [7].

We have done a simulation on a 3,34 kWp PV system in Budapest on 21 of March. The daily production (Fig.4), and the temperature of the PV cell (Fig. 5) were registered during the simulation

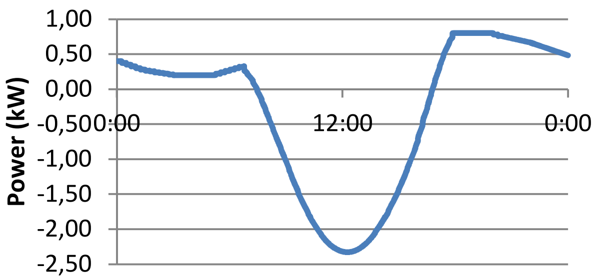


Figure 4. Daily energy consumption/production of 3.34kWp PV system in Budapest on 21 of March

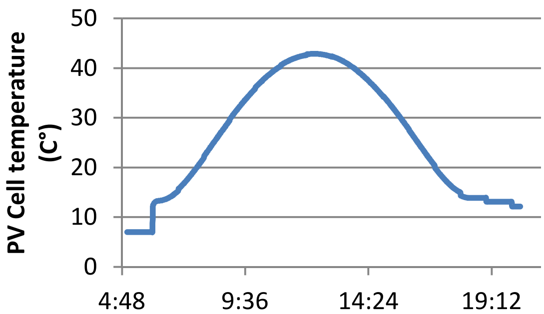


Figure 5. PV cell temperature in C°

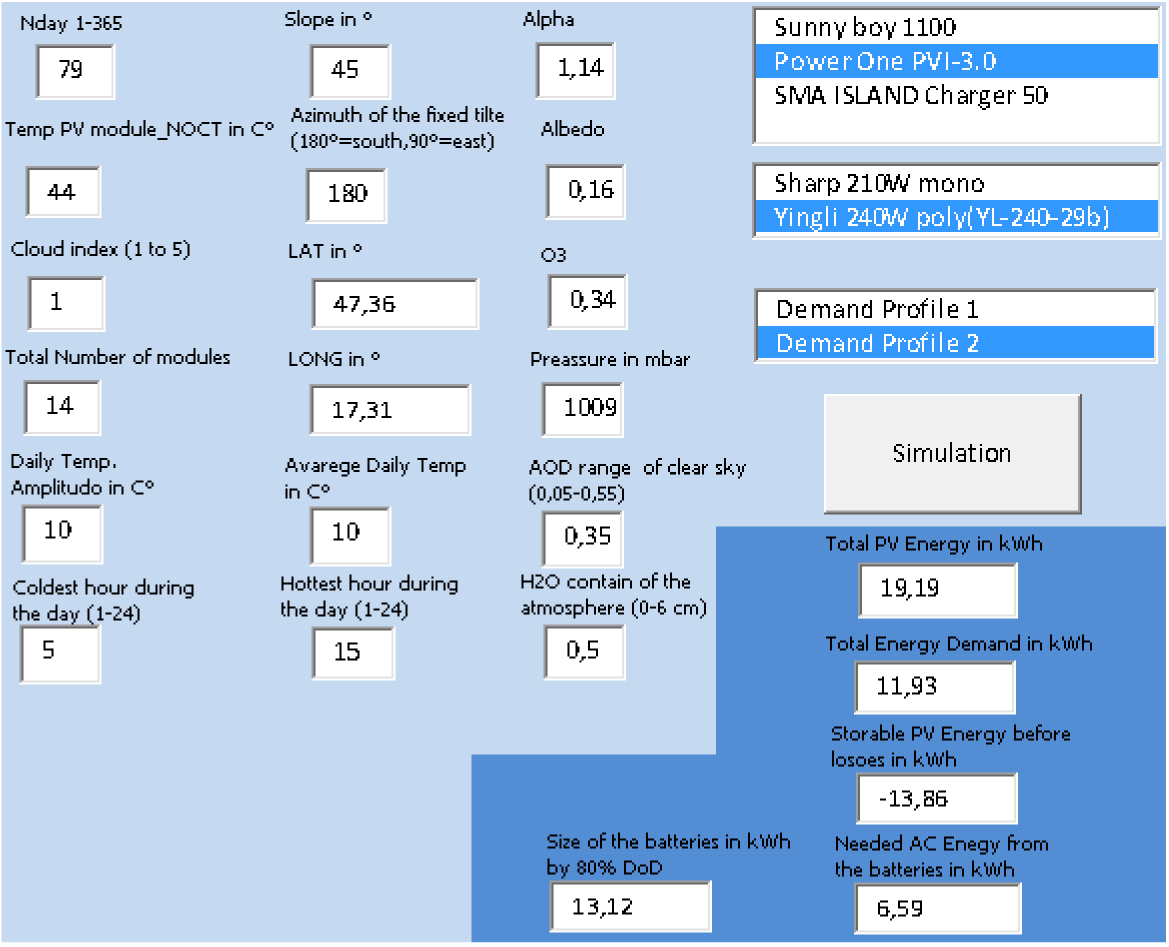

Figure 6. Simulation parameters and results

The user interface of the simulation program is shown on Fig. 6. The adjustable parameters are the followings:

- Nday: On what day the simulation will run
- Temp PV module_ NOCT: It is the nominal operating in PV cell temperature in C°
- Cloud index: Value one represents no power decrease and value five represent a 80% power decrease caused by clouding
- Alpha: Alpha is a parameter in the Angstrom's turbidity formula which is the function of the aerosol size. For most natural atmospheres Alpha is between 0,8 and 1,8
- Albedo: It shows that how much of the incoming irradiation the nearby objects reflect
- O3:Ozon absorbs ultra viola radiation, therefore, it has a significant effect on the irradiation, especially in cities where there are high smog levels
- AOD: Aerosol Optical Depth stands for the air practical content
- The inverter and the PV module can be chosen, the program will load the chosen matrix
- Demand profile can be adjusted according to how much energy the consumer uses

According to the simulation results, the needed capacity of the energy storage would be 13,12 kWh and it stores (13,12/(0,95*0,85*0,8)) 8,47 kWh of "AC" energy, but it still higher than the needed storable energy which covers the consumption (6,59kWh) of the chosen day (21th of March) [8]. (It is important to know that the average PB-acid battery energy efficiency is 85% for charging/discharging and the average DC/AC conversion efficiency is 95 %, also taking into consideration the 80% DoD level.)
Taking into consideration all of mentioned simulation result then a good guess would be 14 kWh to the size of the energy storage capacity.

## 5. Payback time calculation

As we mentioned that the partly "off-grid" shift is only powered by the price difference between the PV feed in tariff and the household electricity price. To support our basic assumption, there will be a simple payback time calculation.

The average retail price of one kWh deep cycle lead-acid battery cost is around 125 Euro and its life cycle life is around 1000 Cycle at 80% DoD[8].It means that in the whole lifetime of the partly "off-grid" system there will be need for two more battery swaps.(Taking into consideration the estimated battery capacity which has 30% over capacity.)

The average retail price of a 3 kW battery charger is 2000 Euro. The yearly income is calculated by number of days and the saved "AC" energy multiplied by the gap between the feed in tariff and the household electricity price. As the matter of fact, the payback time calculation takes into account a 2% of inflation rate which is used to calculate the net present value (NPV) price of batteries. Furthermore, I made a prediction to widening price gap (5%) based on our former economic analysis.

TABLE I. - Payback time calculation in case of PV feed in tariff is available

| | **Cost (Euro)** |
|---|---|
| 14 kWh battery | 1750 |
| NPV 1st battery swap | 1650 |
| NPV 2nd battery swap | 1550 |
| Battery charger 3kw | 2000 |
| Installation | 250 |
| **Total cost** | **7200** |
| | **Income (Euro)** |
| Yearly | 360 |
| Inflation | 2% |
| Yearly price gap widening | 5% |
| **Payback time (years)** | **15,75** |

The calculation shows that the payback time would be around 15-16 years, but if everything goes as it is predicted, then the payback time might decrease to around 10 years until 2020. It is important to know that actual PV feed- in tariff price was used in the payback time calculation.

However, if there is a slightly major bigger PV system (10-40 kWp) [2], then only the 90% of PV energy is paid in the feed in system and 10% of the PV energy generation could be stored optionally. It leads to the fact that in such a case the payback time is shorter.

TABLE II. - Payback time calculation in case of PV feed in tariff is not available

| | **Cost (Euro)** |
|---|---|
| **Total cost** | **7200** |
| | **Income (Euro)** |
| Yearly | 695 |
| Inflation | 2% |
| Yearly price gap widening | 5% |
| **Payback time (years)** | **8,24** |

When, there is no 100% feed in opportunity for a PV system, then a partly "off-grid" system is rentable investment.

## 6. Conclusion

As a conclusion, the European regulators must act fast to create a proper regulations to the partly „off-grid" battery chargers, before they spread all over Europe.

If the payback time fewer than 10 years, then it could be a huge jump in the investment volume. The perfect regulation in the case of the „off-grid" charger controller would be that the charger completely satisfies the night peak and the morning peak load as well, but if it is not set properly, then it will release all of it charge at night when the grid load is low. Furthermore, the battery charger must qualify for all of the IEC standards.

Indeed, we think that there should be further studies about the optimal discharging profile. We would suggest that the discharge at night should stop, when the battery capacity reaches a certain level of SoC, but to be the precious it should be the function of the battery capacity. Therefore, the morning peak load could be decreased without having any effects on the consumer habits, or the rent ability of the investment.

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