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Excess PV dumping resistor at the DC side of grid tied inverters

Alex Van den Bossche[1] and Kamran Hafeez[2]

[1] Electrical Energy Laboratory, Ghent University EELAB UGENT
Technologiepark 131, 9052 Ghent Belgium
[2] Electrical Engineering Department COMSATS University Islamabad Pakistan

Abstract.

The tendency today is oversizing the PV peak power compared to the inverter power. It makes sense in northern cloudy countries, but the question arises if something can be done with the excess power, mainly in summer? The harvesting of unused power can be made at low cost by using a dump resistor. It results in another type of "PV characteristic", where the current gets lower at higher voltage, but it remains stable. A possible application is weed killing by hot water and to replace chemicals as glyphosate. The proposed method is tested with a Perturb and Observe (P&O) MPPT algorithm to verify the results using MATLAB.

Key words. DC-AC converter, Excess PV, Glyphosate, Maximum Power Point Tracking (MPPT), Photovoltaic.

1. Introduction

A solar photovoltaic (PV) system consists of PV modules connected with a maximum power tracking controller, DC-DC converter and finally an inverter to support the alternating current loads as shown in Fig.1 [1].The overall aim is to maintain higher efficiency, lower cost and better regulation [2].

Today, there is a tendency to choose the peak kW of PV panels much higher than the kVA. It makes sense, as when the sun shines there is anyhow "enough" but it could overload the grid. Grid tied inverters cost also in kVA rating and have a shorter life expectancy than PV panels. Oversizing PV peak power makes an economic sense, but this also means that some excess power is not used. Making hydrogen could be a nice idea, but it means that quite expensive apparatus is purchased that operates only in one season, a few hours/year, so in general not cost effective. In DC, with batteries, dump resistors are known and help to recuperate energy in heating when the battery is fully charged [3]. Operating aircons would be nice but not realistic for powering from the DC side of a inverter. In more northern countries, the summer winter difference is huge and almost no aircon is needed. Most of grid tied inverters will also not like choppers at the input, as it could interfere with their MPPT (Maximum Power Point Tracking). However, after a trial, it seems that they can accept a fixed resistor at the DC-side, which also not adds to the EMC problem, and is rarely turned on or off. In warm countries, the dry season needs aircon, other seasons might use power dumping and weed killing. For wind energy, various dump loads are quite common and are usually located at the generator side or DC link or grid side. [4,5]. However, wind turbines are usually not close to houses, so the dump load is less useful for domestic use.

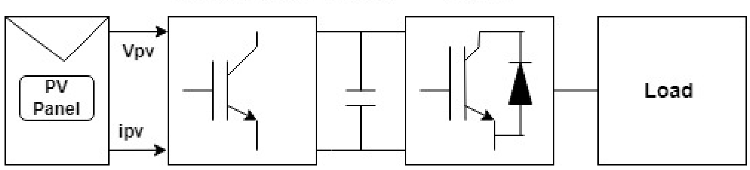


Fig.1.Solar PV system

2. Operation Principle

When the voltage at the DC side is >5% above the MPP, it is clear that the inverter is at its maximum grid power and does not use all available PV power. So, adding a dump resistor at the DC side could be considered. That added power resistor at the considered voltage should draw a significant lower power than the injected power. If not, the PV string will operate at a too low voltage after turning on the resistor. Adding a dump resistor at the input seems a possibility, but for what can it be used? It means in fact looking at heat which can be used in summer. To set things strongly, it was tried out with 3 strings in parallel (of each 6 panels in series), some 4900Wp PV, on a 1kVA inverter. The inverter takes anyhow only the power it can handle. However, care should be taken to avoid a wrong polarization at it can damage the boost converter in the inverter (do the first trial close to sunset). The practical effect is that inverter remains stable if a dump resistor is put at the DC side. The reason is that the “cheating” creates a new voltage current characteristic, but which still resembles to a PV characteristic (Fig 2). Parasitic capacitances remain the same, parasitic inductances as well, and no disturbing switching happens. The practical value of the dump resistor is about 35.5 ohm (1500W at 230V). The basic circuit is simple, see Fig. 3.

However, care should be taken, as what one thinks is resistor, might hide a thermal switch. Those switches are not made for DC and will arc even at 50Vdc. So, ‘normal’ sanitary hot water heaters are not possible. The good news is that normal plugs and wall sockets do resist to DC, as standards were made in the time that DC grids existed. Connection means should be made at least in an different colour, not to mix up. However, some specific loads can use simple resistors.

A. *Possible applications*

Often the PV kWp is oversized compared to the kVA of the inverter. The prime idea here, is to harvest the excess energy at low cost, and make a good use of it. One could think of room heating in winter, which could be OK in warm countries that normally need aircon. However, in northern countries the sun normally does not deliver excess power in winter, so only intermediate seasons are of interest. In warm countries, a sanitary or sink boiler could be considered, but in Northern countries it will not operate for the major part of the year. A sanitary boiler use might have safety problems, such as arcing in the thermostat due to DC switching, also the back-up overtemperature safety switch may have similar problems. The normal thermostat function can easily be replaced by a transistor, but the back-up function would need a galvanic separation, difficult to obtain in power electronics. A set of separate PV panels are better for sanitary boilers, used in pulsed DC [6].

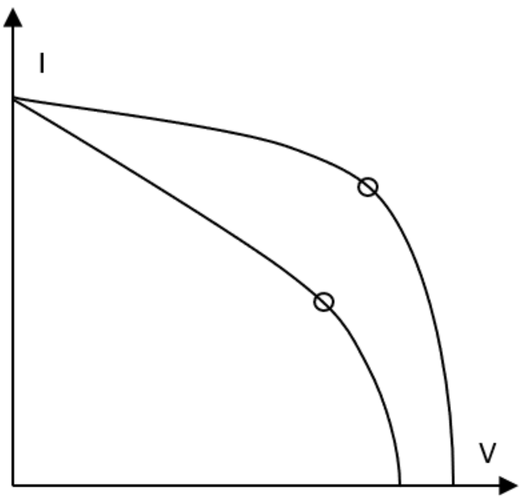


Fig. 2. Original PV and PV with parallel resistor. Maximum power points in circles

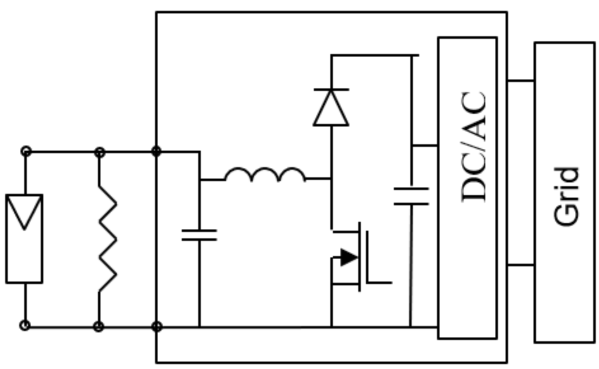


Fig. 3: Basic circuit

So applications were searched, are mainly use heating in summer. Such an application is using the dump resistor to heat water for weed killing, where often fossil fuels are used now. It is a quite common technique in Finland, The Netherlands, and UK. [7]. LPG gas bottles or gasoil is used to heat the water. In fact, the energy transition needs avoiding fossil fuels where it is possible.

Other uses are summer-winter storage of hot water. [8]

Thermal processes such as distilling (renewable) fuels might be considered as well. If the resistor would be chopped at the input of an inverter, there is a big chance that the inverter will not operate properly, as it interferes with the MPPT.

B. Adapting a water boiler for weed killing

In summer, on a sunny day 80 litres of boiling water are easily produced in that way, sing rain water). In fact, there is no problem of switching DC in power electronics. A sensor towards a transistor switch can do the job. The thermal sensor should be put at the outlet of the original hot water pipe (long pipe) as it has normally a low temperature.

A useful application of that kind was heating a boiler for weed killing, using a refurbished sanitary boiler (Fig.4), put on wheelbarrow wheels. The brown grass between the cobblestones was treated, an atelier at the back.

The thermostat has been removed as it would be destroyed at switching off a DC current, also we want to obtain 95-100°C, which is beyond the normal used temperature for thermostats. The hot water pipe was left open so there is no pressure build-up, it would anyhow take days to boil out, and if it does the resistor is damaged, but as it is used outside, no home fire risk. The original cold pipe (short pipe) is used to tap boiling water, and also to fill water with a garden hose for a new batch (normally with rain water). In summer, on a sunny day 80 litres of boiling water are easily produced in that way. In fact, the resistor parallel to the PV panels is rarely switched with hysteresis, only of too high or too low, see Fig. 5. Hysteresis control on PV characteristic. A sensor towards a transistor switch can do the job. It is possible to operate it by hand on a sunny day where the power is not going many times up and down. However an automatic control is better. To heat 80 Liters from 15°C to 100 needs about 8 kWh. The estimated kWh price is lower than the injection price of the kWh as it is mainly an energy which would not have the possibility to inject in the grid and it does allows to downsize the grid tied inverter. Nowadays the injected kWh in Flanders is lower than 0.03€/kWh, whereas the purchased kWh is rather 10 times more expensive. The method avoids anyhow to take power from the grid. Moreover, it avoids unhealthy smoke (and noise) of burning green weed by LPG or other fossil fuels as it is often done. One square meter needs between 1 and 5 litres of boiling water, depending on the amount of weed. Sparse grass is about 1, short grass between cobblestones 3, and longer gras 5 litres/m^2, applied on dry soil. Keeping a distance of 0.1m to vegetables, crops and flowers may be sufficient, which is small compared other methods.

Even without looking at the toxicity of glyphosate and its surrogates, the cost of such chemicals is still relevant. Hot water even works for glyphosate resistant plants. However, there is a limitation, as at high altitude, e.g. 3000 m, the water boils at 90°C. Another drawback is that is less effective on dandelions, because of their deep roots. The same happens for Miscanthus types.

C. Operating with hysteresis

Switching DC may be a problem for thermostats using contacts, but is no problem for power electronics, as it can be done even a millions of time a second. However, it the resistor is often switched, it will interfere with the boost converter, the MPPT, Maximum Power Point Tracker, and last but not least create an EMC problem. Here a really slow control is better. To set things strongly, it was tried it out with 3 strings in parallel (of each 6 panels in series) some 4900Wp PV on a 1kVA inverter. The inverter takes anyhow only the power it can handle. The quite unexpected effect is that inverter remains stable if a dump resistor is put at the DC side. The reason is that it creates a new voltage current characteristic but which still resembles to a PV characteristic.

The practical value of the dump resistor is about 35.5 ohm (1500W at 230V) Fig 4.

Fig. 4: A dump resistor for weed killing

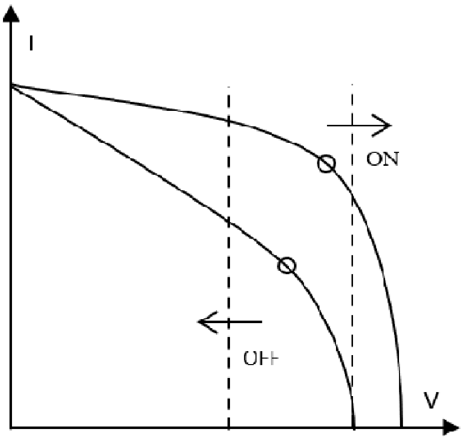


Fig. 5. Hysteresis control on PV characteristic.

D. Simulation of the behaviour

One of the questions is if the MPPT would remain stable. In principle it makes a "new" PV characteristic, but can normal MPPT algorithms be compatible? A quite common algorithm is tried out: Perturbation and Observation (P&O). In the P&O method to track MPP of PV module, a small perturbation is introduced to check the power changes in it [8,9]. If the same power is observed, the same voltage is kept. If output power increases, the same process is continued otherwise perturbation is reversed. To summarize, the PV module voltage is increased or decreased to check whether the power is increased or decreased. When an increase in voltage leads to an increase in power, this means the operating point of the PV module is on the left of the MPP otherwise the operating point is on the right of MPP as shown in Fig.6

A simulation is made using 3 series modules (instead of 6 in the real case), accordingly an optimal voltage around of 90 V is obtained. Figure 7 shows the case without a parallel resistor, normal case. Parallel strings 1 and series connected modules per string= 3, cells per module 60. PV power tracked 750W.

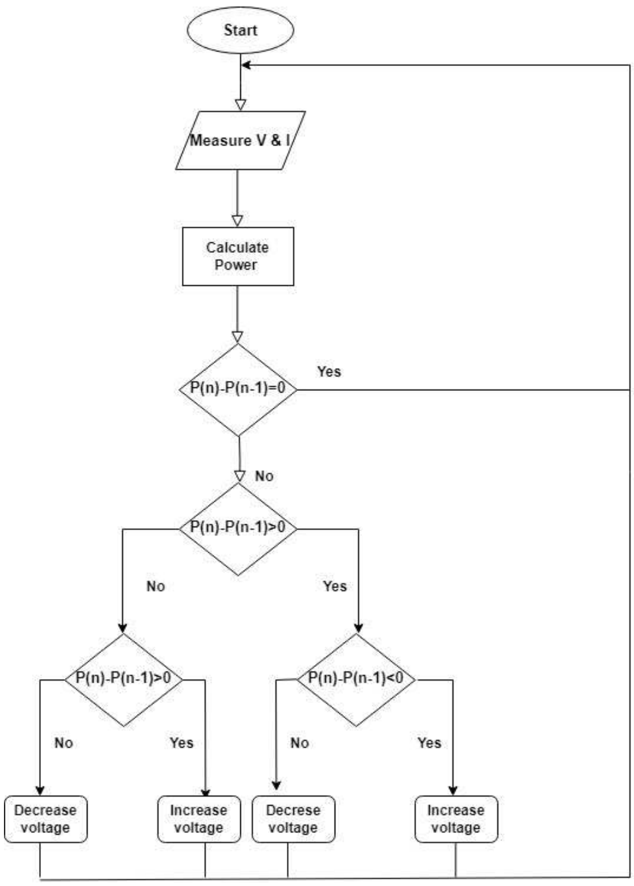
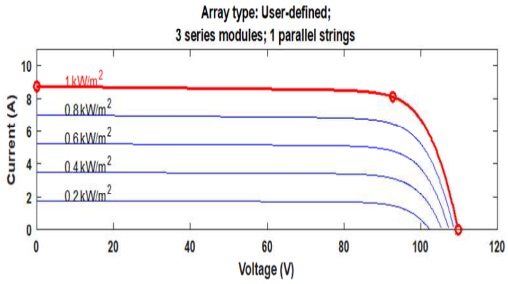
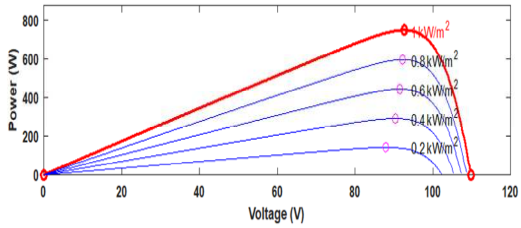


Fig.6. MPPT P&O Algorithm



a)



b)

Fig. 7(a-b). Simulation of 3 panels in series, one string in parallel, normal case: Voltage/current and Voltage/Power

Figure 8 shows the corresponding MPPT transient at turn-on.

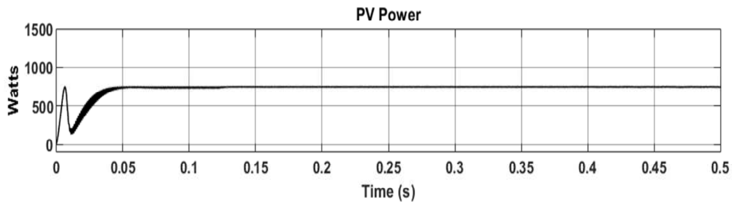
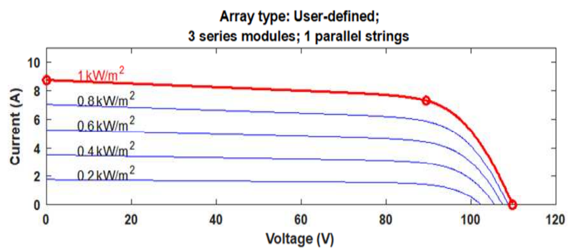


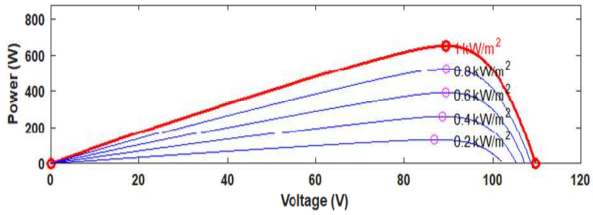
Fig. 8. Behaviour of a MPPT in the normal case.

In Figure 9, a parallel resistor of 30 ohm is added. It means that about 270W is deviated to the resistor. It can be observed that the MPPT operates at a slightly lower voltage so deviates away from the optimal point, but still 720 watts is drawn from the PV, but 450 W is going to the inverter. So it means that the inverter can be sized smaller and a part of the PV power can go directly to the resistor.

The power curve at the PV remains the same, but the power at the inverter is reduced.



a)



b)

Fig. 9(a-b). Simulation of 3 panels in series, one string in parallel, 30 ohm in parallel: Voltage/current and Voltage/Power

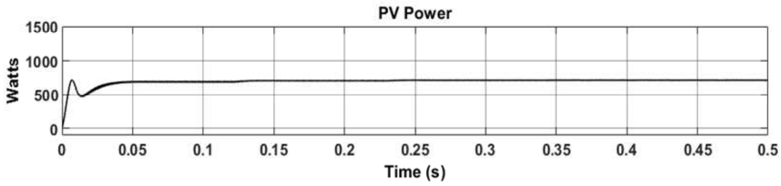


Fig 10: Behaviour of a MPPT with a 30 ohm parallel resistor.

Figure 10 shows that a MPPT can cope with the scheme with the resistor. If looked carefully, it stabilizes at a slightly lower voltage. This is as the MPPT tries to remove a part of the resistor power. It is also better damped than figure 7, the MPPT behaves more stable, the reason is that the maximum power is less peaked as evident from Table.1.

Table 1.

PV power	Watts
Normal	750
Proposed	745

The conclusion of the simulation is that a slightly different operating point is obtained, but can be stable, so it confirms the experiment. It is not surprising as PV panels may have different slopes in V-I characteristic and partial shadowing deviates also from a “normal” expected characteristic, hence the MPPT algorithms must be quite tolerant to changes in characteristic. So it is possible to harvest a part of oversized PV compared with the kVA of the inverter.

E. Cost effectiveness

In the “classic way”, when treating about 500m^2 of cobblestones with chemicals, two times per year it has a cost of about 60€ each time, so 120€/year. In its present state the proposed set-up used a recycled boiler, some plumbery, a silicone tube based shutter, which resists well to the temperature, two wheelbarrow wheels, a digital thermometer and a hysteresis control. The price of injected PV in Flanders in summer for a variable tariff for digital meters was typically around 0.03€/kWh. If a maximum of two times at 5 litres/m^2 is used, that surface would take 500kWh, or 15€/year, at a cost of “non-injected” energy. But the system uses energy which was even not converted to AC, so, even lower valued and uses smaller sized inverters. There is no risk to take energy from the grid, when a cloud passes over. So, the return on investment is less than 2 years for a “handyman”. Another important aspect is keeping the environment ‘cleaner’.

E. Upscaling the principle

Large PV farms could use it as well, while dumping for municipality weed killing, or summer-winter storage for district heating. In a few places, seasonal large hot water storage is already used, for example at Dronninglund, Denmark, 60 000 m^3[8], mainly fed by wind energy and solar thermal collectors, but why not partly be heated by local solar excess PV? The grid connection would then be rather sized on cloudy weather. It can also be combined with agrivoltaics, where there is also a need for weed control. In regions of Pakistan, mainly the lower cost compared to larger grid tied inverters is interesting, PV is booming there. Also remote grid places with stand-alone generators should not be overpowered by PV, so a significant lower connection power, compared to the PV peak power may be of interest.

4. Conclusion

Although the proposed circuit is simple, it could help to harvest excess PV power even before it is converted by a grid tied inverter, so using the often oversized PV kWp compared to the inverter kVA and avoid grid overloading. It also reduces the required investment in inverter power. Inverters seem to remain stable if a well-chosen dump resistor is put at the DC-side, but the system could be designed on purpose for it. For sanitary water it would ask to change the thermostat and the safety protections, and it is needed the year round so less suited. One of the applications where excess power could be used in summer, is weed killing by hot water. It avoids chemicals and unhealthy smoke of burning green weed, also applications in horticulture could be considered while using agrivoltaics.

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