ELEKTROTEHNIŠKI VESTNIK 79(3): 141-147, 2012
ENGLISH EDITION

Overview on the solar photovoltaic power generation growth and forecasts updating

Stefano Quaia

University of Trieste, Department of Engineering and Architecture - DIA, Via Valerio 10, 34127 Trieste, Italy
E-mail: quaias@units.it

Abstract. As well known, 2020 is an important reference for the EU energy policy because of the targets set by the European Council agreement on the climate and energy package of December 2008 (the so-called "20-20-20"). In particular, by 2020 the EU is committed to increase to 20% of the total electricity production the share of renewable energy sources.
In 2010 the EV published the paper "Present and future limits for the PV generation growth", updated at the end of 2009, that aimed at pointing out the main factors that will limit solar photovoltaic (PV) penetration by 2020. Since then PV has, among all energy sources, the fastest growth, and has grown much faster than many had expected. This paper reports on the actual PV market and compares the forecasts on the PV growth and competitiveness made by 2009 with the most recent and accredited ones. Also, the paper reports and discusses the main effects that the current large PV penetration already has on the Italian electric power system.

Keywords: PV generation, PV market, electricity storage technologies.

1 INTRODUCTION

Forecasts are a singular exercise that generally can be made easily by everyone, but to hit upon them is, on the contrary, much more difficult. Fortunately, their accuracy can be verified only afterwards, in many cases after several years, which makes it harder to remember them.

In 2010 the EV published the paper "Present and future limits for the PV generation growth" [1], which aimed at pointing out the main factors that will limit PV penetration in the power generation mix by 2020, when the EU, according to the European Council agreement on the climate and energy package of December 2008 (the well known "20-20-20"), is committed to increase the share of renewable energy sources in its energy mix to 20%. The paper had been updated at the end of 2009. Since then, during about two and half years, PV electricity continued its very remarkable growth trend, in spite of the heavy financial and economic crisis and of the period of consolidation which the PV industry was enduring. As in the last several years, the PV market has again been growing faster than most people had expected both in Europe and worldwide.

Now, therefore, it is interesting to evaluate in hindsight the real evolution of the PV market – at the global, European and at some of the most significant national levels –, and compare the present forecasts for the PV growth by 2020 with those made in past by some of the most accredited national and international organizations.

With this aim, this paper reconsiders and updates some of the topics discussed in [1], pointing out and commenting on the most significant differences between the actual PV market (presented in Section 2) and the forecasts made two and half years ago, at the end of 2009, as well as those between the past and present forecasts for the next several years (analyzed in Sections 3 and 4). The focus is mainly on Europe and Italy, but also the Germany, the US and global data are reported. Finally, making reference to the current Italian situation, Section 5 points out some of the most significant consequences of a massive PV penetration in electric power systems.

2 THE CURRENT PV MARKET

The global PV growth has been continuing at a very high pace in the last years. After 6.3 GW of new PV systems were connected to the grid[1] in 2008 (Spain, driven by the regulation adopted, weighted for about 40% of this global jump), the new connections reached 7.4 GW in 2009, 16.8 GW (13.4 GW in Europe) in 2010 and 29.7 GW (21.9 GW in Europe) in 2011 (Fig. 1) [2].

[1]While many market reports present installation figures, this paper reports on new grid-connected capacities. This is because there is no reliable methodology for counting installations and most official bodies report on systems connected to the grid. As installation figures describe the demand for PV systems, they are interesting in the PV industry, but grid connection data are more relevant when considering the increasing share of PV in the electricity mix.

Received July 31, 2012
Accepted October 17, 2012

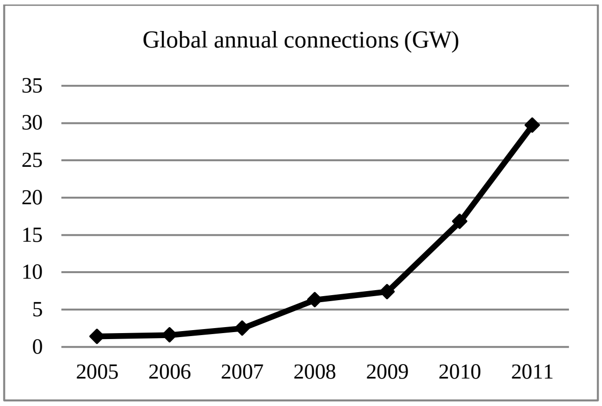

Figure 1. Evolution of global annual new PV connections.

For the first time in history, in 2011 PV was the number one electricity source in Europe in terms of added generation capacity: with 21.9 GW connected to the grid, PV outscored gas and wind, both slightly below 10 GW, whereas all other production sources, renewable and conventional, are far behind. Nuclear lost the most in 2011, after the German decision to shut down immediately eight nuclear power plants as a consequence of the Japanese Fukushima accidents.

The PV global cumulative power connected to the grid totalled to more than 15 GW in 2008, about 23 GW in 2009, about 40 GW in 2010 and almost 70 GW in 2011, with the Compound Annual Growth Rate (CAGR) close to 65% (Fig. 2).

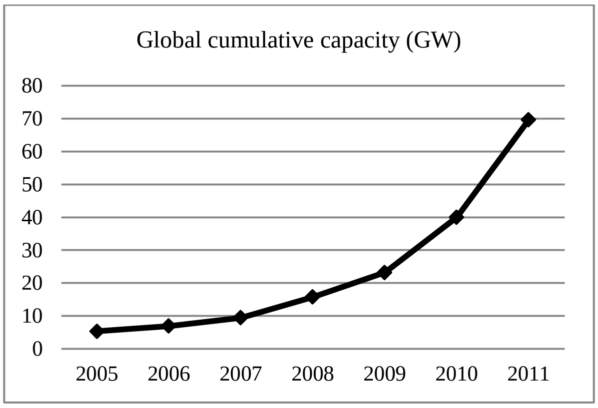

Figure 2. Evolution of the global cumulative PV connected capacity.

Europe accounts for the predominant share of the global PV market with 75% of the global new capacity in 2011. Italy was the top market country in 2011, with a boom of 9.3 GW connected, followed by Germany with 7.5 GW: the two countries together accounted for nearly 60% of the global market growth. About 45 MW (almost a doubling of the market compared to 2010) were connected in Slovenia, a quite significant figure given the size of the country. China was the top non-European PV market in 2011, with 2.2 GW connected, followed by the USA with 1.9 GW.

The Europe PV market development is the result of a few countries that have been taking the lead year after year. Germany in particular shows a constant commitment of policymakers to support the PV growth.

Italy, with 12.8 GW connected to the grid at the end of 2011, takes the second place after Germany (24.7 GW) in the world ranking, but with the highest growth. This is the impressive result of the Feed-in Tariff (FiT)[2] adopted, called “Conto Energia” (CE), that rewards the electricity produced by PV plants. CE has been modified several times since it first came in force in 2005 [3]. PV incentives are going to be modified again by the end of summer 2012 with the new 5° CE, in order to align them with the European levels and with the decline of the PV systems price. The new 5° CE will be much less favorable than the previous one. In particular, it will have a lower money limit available for incentives (700 M€/year, against the 6 G€ totalled by the CE until July 2012).

The share of PV electricity in Italy is no more negligible. 14.5 TWh is the energy generated in one year from May 2011 to May 2012 (almost 5% of the total demand – about 332 TWh in 2011 –, and more than 10% of the peak demand). Only in the first six months of 2012 the PV production was 9.25 TWh. It is noteworthy that the targets for PV by 2020, contained in the National Renewable Energy Action Plan (NREAP) made in 2007 by the Italian government and revised in 2010 [4, 5], which set an 8.5 GW maximum theoretical PV potential with an annual generation of 10.2 TWh, have been already largely exceeded.

More generally, the renewable mix PV + wind + geothermal contributed to cover the June 2012 Italian peak-load (on Thursday 21, at 12 a.m.) by 18.2%, whereas hydro contributed by 16,6% [6]. This is a meaningful datum, as it demonstrates the new green energy sources (with the exception of geothermal) overtaking over the "old" hydro.

Switching back to Europe, PV is now producing about 2% of the demand and roughly 4% of the peak demand. However, the grid parity has not been reached yet (see Section 3) and the PV market deployment is

[2] The Feed-in Tariff is an incentive structure to encourage the adoption of renewable energy through government legislation. The regional or national electricity utilities are obliged to buy electricity generated from renewable sources, such as solar PV, at the above-market rates set by the government over a period of 20 to 25 years (20 years in Italy) since the system connection to the grid. The utilities are authorized to pass on this extra cost, spread equally, to all electricity consumers through their regular electricity bill. This way the feed-in program works independently from the state economy, and the extra cost which each electricity consumer has to pay, in order to increase the share of renewable energy in the national electricity portfolio, is very small.

still dependent on the support programs defined in national laws of any given country. Introduction, modification or fading out of such support schemes can have heavy consequences on PV industries. In order to maintain the market development trends we were witnessing until 2011, the PV industry will need to diversify markets across several countries, to relieve the pressure on Germany and allow markets that have gone bust to revive in a sustainable way. It is interesting to note that, until today, the PV development has corresponded with economic development: after OECD countries (Europe, North America, Japan, Australia), it started to reach emerging countries. Brazil, Russia, India and China have not all started to develop PV, but China and India are expected to pave the way for Brazil and possibly for Russia. Africa scores the last.

As to the typology of the PV systems, a very large share of the market in Europe is concentrated in the commercial rooftop segment. This trend will continue, given that the foreseen evolution of the legal framework is matched.

European markets where PV has grown vigorously in recent years have reached a level that will be difficult to maintain in the two coming years (see the relevant forecasts in Section 4). The market slowdown in Europe will not immediately be offset by the market growth elsewhere in the world, but a rebalancing has already begun. New markets around the world will have to be opened up to drive the PV development in the coming decade just as Europe has been doing until now.

The very fast decline of the PV costs (the average cost of PV plants was about 7.2 $/W in 2007, and 3.5 $/W in 2011) is causing serious difficulties to many traditional companies of the PV sector and has already led some of them to declare bankruptcy. On the other hand, PV cost decline is a powerful driver for the market which is shifting the PV boom from Europe towards the developing countries. In this regard, already by the end of 2012 the share of Europe is expected to reduce drastically from 75% to about 50%.

Over the last 20 years, PV has already shown impressive price reductions, with the price of modules decreasing by over 20% every time the cumulative sold volume has doubled (the so-called learning factor, or "PV Moore's law" [1]). System prices have declined accordingly; during the last five years a price decrease of 50% has been achieved in Europe. EPIA (European Photovoltaic Industry Association) predicts that system prices will decrease in the ten coming years by 36-51% depending on the segment [7].

In this regard, the following forecast was reported in [1]: "in 2015 PV systems will be sold at about 2 k€/kW." Since the average cost of PV plants in 2011 was about 2.7 k€/kW, and it is expected to be close to 2.2 k€/kW already by 2012, the previous statement, that was in line with an expected PV growth lower than real, appears today too prudential.

The solar PV market (including modules, system components, and installation) increased from 71.2 G$ in 2010 to a record of 91.6 G$ in 2011 and Clean Edge, a leading US clean-tech research and consulting firm, projects it to continue to expand to 130.5 G$ by 2021. Note that these figures, while impressive, do not fully capture the extent of the actual PV industry expansion: installations increase at a much higher rate than market revenues, because of the module prices decline. Between now and 2021, Clean Edge estimates that the installed costs for PV will continue to decline, falling to nearly one-third of their current levels [8].

3 GRID PARITY

According to most forecasts, PV will achieve the grid parity – that is competitiveness with the electricity grid retail prices, i.e. the prices at the customer side of the electric meter – by 2020 in many regions. As already reported in [1], the grid parity achievement will mainly depend on reduction of the PV costs but also on the conventional energy cost, linked to the oil price: clearly, the increasing oil price will favor PV competitiveness. Once the grid parity will be achieved, the policy framework should evolve towards fostering self-sustained markets, with the progressive phase-out of economic incentives, but maintaining grid access guarantees and sustained R&D support.

Different projections on the grid parity were reported in [1]. According to DOE (the US Department Of Energy), McKinsey&Co. 2008 study and Italian PV summit held in May 2009, the grid parity could be achieved by 2015 in the most accredited countries (including California, Italy and some others). These projections were matched by the following real developments and with current projections. Indeed, at present the DOE's Solar Energy Technologies Program still works to develop cost-competitive solar energy systems, with the aim to accelerate research and to develop technology to reach cost competitiveness by 2015. In Italy, the FiT programs are projected to last (with proper changes in time) until the end of 2016 when, according to the government expectations, the grid parity should be already reached.

More optimistically, but not in contrast with these more general forecasts, in September 2011 EPIA predicted that a certain level of competitiveness could be achieved as early as in 2013 in Italy in the commercial segment and then spread all across Europe in the different market segments by the end of the decade [7]. Also, in the residential and commercial segments in Germany and Italy, some installations could already be competitive by the end of 2012.

In the US, the Clean Edge study updated in March 2012 shows that the steep price decline is bringing solar PV into the cost parity at the retail level for residential, commercial and industrial applications far sooner than many had projected. At the retail level, the US shows a dynamic and rapidly changing scenario, so that Clean Edge projects that, in less than a decade, in 13 US States solar PV will be cost-competitive at the residential level without any subsidy requirements [8].

Anyway, most studies lead to the conclusion that by 2020 PV electricity will be fully competitive in many countries: according to [7], the cost of PV electricity generation in Europe could decrease from the range 0.16-0.35 €/kWh in 2010 to a range of 0.08-0.18 €/kWh in 2020 depending on the system size and irradiance level. The Clean Edge projections are even more optimistic: in 2020 the PV energy cost in the US could decrease to 0.06-0.10 $/kWh [8].

4 PV GROWTH FORECASTS

The fast PV growth rate cannot be expected to last forever, and the industry is now facing a period of uncertainty in the short term. But, according to EPIA projections, over the medium and long terms there are good prospects for the robust growth to continue. The results of 2011 – presented in Section 2 – and indeed the outlook for the next several years show that under the right policy conditions PV can continue its progress towards competitiveness in key electricity markets and become a mainstream energy source.

The dynamic growth observed at the beginning of 2012 in terms of the newly installed capacity suggests that the PV market could perform as well this year as the past one. But the future is uncertain because of the potential early phase-out or drastic decrease of some FiT programs, and it is not yet clear how the market is going to react to these new conditions. As the PV market still depends on national support schemes, forecasts on the PV growth depend on a deep understanding of the political framework.

In March 2009 EPIA derived two scenarios for the development of the PV industry until 2013 [1]. The Moderate scenario was based on the assumption of a ‘business as usual’ situation which did not assume any major enforcement of the then existing support programs. The Policy-Driven scenario was based on the assumption of the follow-up and introduction of support mechanisms in a large number of countries. Under the Moderate scenario EPIA projected the global annual market to reach 6.0 GW in 2010, 7.5 GW in 2011, 9.6 GW in 2012 and 12.3 GW in 2013. Under the Policy-Driven scenario 10.8 GW in 2010, 13.8 GW in 2011, 17.4 GW in 2012 and 22.3 GW in 2013. But, as shown in Fig. 1, the real figures were much higher: 16.8 GW in 2010 and 29.7 GW in 2011. Clearly, EPIA had much underestimated the PV growth, at least for 2010 and 2011, in its March 2009 forecasts.

Only few months later, in June 2009, the study “SET For 2020” by EPIA [9] analyzed three scenarios for Europe in 2020, characterized by 4%, 6% and 12% PV production on the total electricity demand[3]. The Baseline scenario (4%) envisaged a business as usual case, forecasting about 130 GW of PV cumulative capacity in 2020. The Advanced scenario (6%) was based on the maximum PV growth in Europe that was believed possible without major changes to the electricity infrastructure, and forecasts about 200 GW of cumulative capacity. The Paradigm Shift scenario (12%) forecasts about 390 GW of cumulative capacity in 2020. It was defined “a demanding, but achievable and desirable objective” and assumed that all barriers were lifted and specific boundary conditions were met.

One year before, in June 2008, McKinsey&Co., the advisor and counselor of many of the world's most influential businesses and institutions, estimated that in 2020 the global installed PV capacity could be 20 to 40 times its level at that time (about 12 GW), that means 240-480 GW, representing from 3% to 6% of the installed electricity generation capacity in 2020, or 1.5-3% of the output [1]. This forecast can be compared with the SET For 2020 scenarios, as both studies refer to 2020. Assuming that in 2020 Europe will represent roughly 40% of the global PV market, the SET For 2020 most conservative (Baseline) scenario corresponds to about 325 GW of global cumulated capacity and, thus, is in line with the McKinsey&Co. forecast. The Advanced scenario corresponds to about 500 GW and is very close to the upper, more optimistic McKinsey&Co. forecast. Conversely, the Paradigm Shift scenario envisages an extreme PV growth that is completely out of the McKinsey&Co. forecasts.

In May 2012 EPIA released its most recent forecast for the PV development in Europe until 2016 [2]. As usual, a Moderate and a Policy-Driven scenario were outlined. As Fig. 3 clearly points out, both scenarios reflect the uncertainties on the development of the European PV market in the next years. In 2016, the Moderate scenario foresees about 96 GW of cumulated PV power (Fig. 4), which appears aligned with the 4% target of the SET For 2020 Baseline scenario.

[3] The SET For 2020 report came at a crucial moment in the energy debate, characterized in Europe by the “20/20/20” goals, and was intended to provide the needed input for the definition of National Renewable Energy Action Plans in EU Member States. Its objective was not to forecast the future PV growth, but to outline “the vision of and preconditions for the contribution that Photovoltaic power generation can make to the benefit of Europe.”

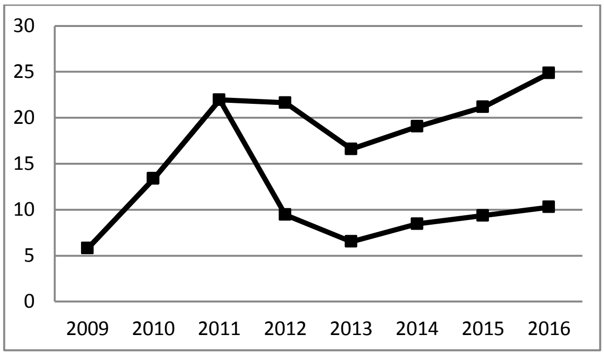

Figure 3. EPIA European annual market scenarios until 2016 (GW) – Moderate (lower) and Policy-Driven (upper).

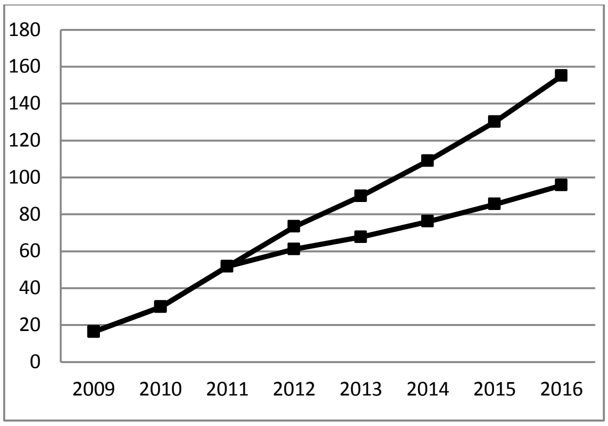

Figure 4. EPIA forecast: European cumulative scenarios until 2016 (GW) - Moderate (lower) and Policy-Driven (upper).

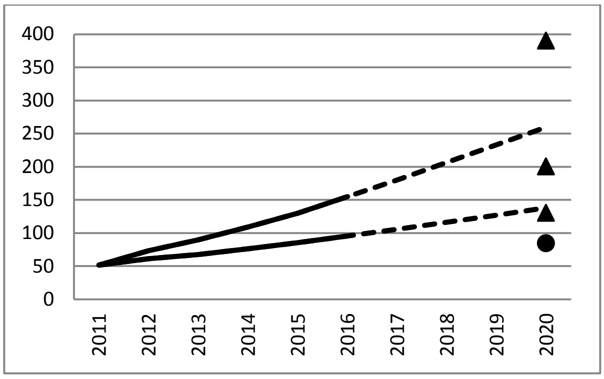

Figure 5. EPIA Moderate and Policy-Driven scenarios (GW) prolonged until 2020 and compared with the SET For 2020 scenarios (▲) and NREAPs targets (●).

This agreement is evidenced in Fig. 5, where the two forecasts are prolonged until 2020 and compared with the above reported 2020 cumulative capacities foreseen by the three SET For 2020 scenarios and by the NREAPs targets. It should be noted that this represents a significant increase compared to the previous EPIA forecasts, which estimated that the growth under the Moderate scenario would not reach the 4% target by 2020. Thus, today EPIA looks reasonable to expect that 4% penetration for PV in 2020 could be reached even in the low-growth case.

The Policy-Driven scenario foresees about 155 GW of PV power connected in 2016 and lies halfway between the Advanced and the Paradigm Shift scenarios of the SET For 2020 study (Fig. 5), covering about 8% of the European electricity demand by 2020. According to these forecasts, the Advanced scenario of reaching 6% by 2020 looks coherent and easily achievable from the Policy-Driven scenario until 2016 point of view. On the contrary, to reach 12% would require a real paradigm shift in the way PV is supported, even after competitiveness is reached in many countries and market segments.

As to Italy, in the September 2007 NREAP, the Italian government estimated 8.5 GW as the maximum theoretical PV potential for 2020, with an annual generation of 10,2 TWh, corresponding to ~3% of the current electricity demand [4]. This figure was substantially confirmed in the subsequent June 2010 NREAP (8.6 GW of maximum theoretical overall solar potential (PV + concentrated solar power), with an annual production of 11,35 TWh [5]).

More optimistically, in 2009 a study of the Italian PV Firms Group believed possible a cumulated PV power in 2020 up to 16 GW, with a rounded annual production of 20 TWh (~6% of the current electricity demand) [1]. This figure, that only 3 years ago could be considered optimistic, today is handy (the PV power connected totals 14.6 GW in July 2012) and could be reached already by the end of 2012!

Anyway, the actual market figures show that the Italian government has significantly underestimated the national PV potential. This holds also for many other countries: with few exceptions, NREAPs in Europe are far from the reality of the PV market, and the PV potential is at least twice as high as the levels foreseen in the NREAPs, pushing towards 200 GW cumulated capacity or more in Europe by 2020.

In the SET For 2020 Paradigm Shift scenario, detail studies for individual countries projected 55 GW for Italy, with a production of 78 TWh corresponding to 18% of the expected 2020 demand, and 80 GW for Germany. In [1], these figures were considered too much optimistic and out of a realistic range: "the 55 GW considered (…) do not appear realistically sustainable, unless the overall conversion efficiency of PV devices rises to a today fantastic level higher than 50%. But a similar exceptional increase is not reasonably imaginable, at least in the next decade." Today, these figures still look quite optimistic, but not fully out of range as they did then. Indeed, by 2016 the new EPIA forecasts developed by country, project for Italy a cumulated PV power between 23 and 30.8 GW, and between 39.7 and 52.7 GW for Germany, despite in both countries the new annual connections are expected to reduce compared to the 2011 level [2].

As to the global PV market, Fig. 6 (that can be compared with Fig. 3) shows the EPIA forecast until 2016 [2]. The fastest growth is expected to continue in China and India, followed by Southeast Asia, Latin America and the Middle East and North African countries. The projected global cumulated PV power in 2016 is 208 GW under the Moderate scenario and 343 GW in the Policy-Driven scenario (with a Europe share around 45% in both cases). The PV potential of the sunbelt countries could range from 60 to 250 GW by 2020.

Finally, in the US, the DOE's SunShot Vision Study released in February 2012 provides an in-depth assessment of the potential of the solar technologies in the US until 2050, exploring a future in which the cost of solar technologies is expected to decrease by about 75% between 2010 and 2020 [10]. In the SunShot scenario, the cumulative PV power in the US is expected to reach roughly 50 GW in 2020, and 300 GW in 2030 with an annual production of about 500 TWh, corresponding to 10.8% of the electric demand.

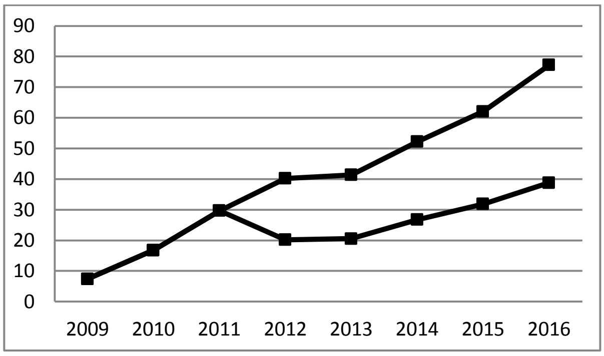

Figure 6. EPIA forecast: global annual market scenarios until 2016 (GW) – Moderate (lower) and Policy-Driven (upper).

5 PV IMPACT ON POWER SYSTEMS

Today PV can be considered as peak-power generation in most European countries. Indeed, it produces during the day, at the time of the mid-day peak, competing directly with other peak generators. The peak-power generation represents roughly 50% of the electricity demand in Europe. Considering the PV power connected to the grid at the end of 2011, as already mentioned PV can provide today roughly 2% of the electricity demand in Europe, that means ~ 4% of the peak electricity demand – more than 10% in Italy, more than 8% in Germany. This achievement has come in a few years and shows again how the PV development in Europe has come faster than what many had expected.

The Italian 2011 PV boom is having heavy effects on the electric stock exchange: until 2010 there were two price peaks, the first in the morning around 11 a.m., and the other in the evening between 6 and 8 p.m.. Nowadays the morning peak is dramatically reduced (whereas the evening peak tends to raise). This is due to the zero marginal production costs of PV plants during the sunny hours – no fuel required to produce 1 more kWh –, so that PV plants enter into competition with traditional power plants limiting the electricity price. GSE, the Italian Energy-Services Managing Office, estimates that this effect allowed a 400 M€ saving in the 2011 Italian energy bill.

As already discussed in [1], the worldwide increasing penetration in the electric power systems of the renewable not programmable distributed generation plants has a growing impact on power systems and requires a significant innovation in the management of both transmission and especially distribution networks, integrating more and more intelligence and flexibility. If (or when) the PV power will approach the levels of the Set For 2020 Paradigm Shift scenario, big changes in power systems, such as transmission-system expansion, availability of energy-storage systems, application of smart-grid concepts, load management, would be unavoidable. In particular, a growing consensus is gathering the idea that the electricity storage technologies could and should play a fundamental role in this process, bringing economical, technical and environmental benefits to the power systems operation nowadays and in the next future.

Addressing specifically the PV source, electricity storage technologies can favor the integration of PV generation in power systems by increasing the system hosting capacity. In particular, electricity storage technologies would allow a certain compensation of the sudden fluctuations of the PV-generated power, thus making the overall PV generation both more regular and more predictable.

More regular PV generation diagrams would allow to reduce modulation of the traditional power plants committed to compensate for the PV generation changes. As these are normally thermal plants, this way both higher efficiency and lower plant ageing rate would be assured.

More predictable PV generation diagrams would allow TSO/DSOs to reduce the supply power reserve, thus reducing the relevant system costs as well. In addition, at a local scale, more predictable PV generation diagrams would allow the owners of PV plants provided with electricity storage systems to reduce unbalance charges, as they would be able to follow with higher precision the generation programs they present at the electricity stock exchange.

Finally, electricity storage systems could reduce the thermal power plants generation increase required at sunset, when PV generation quickly decreases and lighting demand quickly increases.

Several studies on electricity storage technologies are at present in progress in many European countries, including very different candidate solutions such as pumped hydro, CAES (Compressed Air Energy Storage), supercapacitors, batteries (Li, Redox flow, N-Cd, Lead-acid), SMES (Superconductive Magnetic Energy Storage), fly-wheels.

A technical problem concerning grid connection rules has recently risen in Italy as an effect of the massive PV growth. According to the existing connection rules, dispersed generation plants (and, thus, PV plants) must be disconnected from the grid when the frequency error exceeds ±0.3 Hz. The lower limit in particular is becoming a problem, as the lack of PV generation increases power unbalance worsening the situation. However, it is expected that the national connection rules will be modified in a short time to overcome this problem.

More generally, specific studies focused on the effects on the Italian power system of the quickly growing PV penetration are being conducted by RSE, a public research company financed by the Italian Ministry for Economic Development.

6 Conclusion

In the last years PV has been growing much faster than what many had predicted, leading to a very fast decline of the PV systems price, according to the PV learning factor. The PV energy is still too costly, but in some countries (Italy and some others) competitiveness with the electricity price at the retail level should be achieved soon. The forecasts made in 2009 on the grid parity achievement are in good agreement with the current ones and can be regarded as still valid.

On the contrary, most forecasts made in 2009 on PV penetration in 2020 must be revised. Nowadays, the PV share in the 2020 European generation mix in the range of 2-3%, as indicated in the conclusion of the paper [1], is close to be already reached and looks by far underestimated. Today, an updated forecast can be in the range of 6-9%, i.e. tripled!

The fast PV growth will bring to face sooner than expected the constraints set by power systems for reliable and safe operation. These constraints will require introduction of deep changes in the structure of power systems, and are going to become the main practical limit for future PV penetration, whereas other aspects like the costs involved (although very high) and the active surfaces requested, do not seem to be really crucial factors for the PV growth in the next decade.

References

[1] S. Quaia, “Present and future limits for PV generation growth”, Electrotechnical Review, Vol. 77 (2-3), 2010, pp. 95-100.

[2] EPIA (European Photovoltaic Industry Association), “Global market outlook for photovoltaics until 2016”, May 2012, http://www.epia.org

[3] GSE (the Italian Energy-Services Managing Office): Conto Energia, Results of incentivation (in Italian), http://www.gse.it

[4] Energia: temi e sfide per l’Europa e per l’Italia. Position Paper of the Italian Government, Roma, Sept. 2007 (in Italian), http://www.federpern.it/documenti/2008/ppe.pdf

[5] Italian Ministry for Economic Development, “Italian National Renewable Energy Action Plan”, 30 June 2010, http://ec.europa.eu/atoz_en.htm

[6] TERNA: “Rapporto mensile sul sistema elettrico, consuntivo giugno 2012” (in Italian), July 2012, http://www.terna.it

[7] EPIA: “Solar Photovoltaics Competing in the Energy Sector”, September 2011, http://www.epia.org/publications

[8] CLEAN EDGE: “Clean Energy Trends 2012”, March 2012, http://www.cleanedge.com

[9] EPIA (European Photovoltaic Industry Association), “Set For 2020”, June 2009, http://www.setfor2020.eu/

[10] DOE, “SunShot Vision Study”, February 2012, http://www1.eere.energy.gov/solar/sunshot/vision_study.html

Stefano Quaia graduated in Electrotechnical Engineering from the Faculty of Engineering of the University of Trieste in 1988. In 1990 he joined the Electrotechnics, Electronics and Computer Science Department (DEEI) of the University of Trieste. He is currently working as Associate Professor lecturing on Power Systems at the Department of Engineering and Architecture at the University of Trieste. His scientific interests include power quality, power transmission, power system restoration, dispersed generation, renewable energy sources and cathodic protection.