

Positive effects of the migration from Ka-band satellite to 4G solution for the communication needs of a scattered set of 1 MW solar farms in Poland: a user's experience

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Abstract. This paper contains a concise overview of the deployment of scattered solar power plants in Poland, mainly from the perspective of their communication networks, and how the recent development of the Polish 4G networks has a very positive impact for the performance of the whole monitoring system (production control and video-surveillance), with a special emphasis on video-analytics, due to its higher bandwidth demand. All the information will be shown from the point of view of the solar photovoltaics developer I+D Energías, and therefore it constitutes a real user's experience.

Keywords. Solar photovoltaics in Poland; scattered generation; video-analytics; 4G migration; CCTV monitoring; Ka-band; lag time.

I. INTRODUCTION – GENERAL VISION OF THE CONTEXT

Nowadays, the demand for solar photovoltaic energy in Poland is growing very fast year-by-year, passing from less than 20 MW installed in 2014 up to 500 MW in 2018. [1]

Several reasons explain this scenario, from which we can detach the reduction of the equipment costs (according to Irena's Dashboard, the cost of solar modules has been reduced by a factor of 5 between 2010 and 2018 [2]) and the subsidies from the European Union to make Poland, as well as some other UE new coming countries, reduce the volume of CO₂ emissions to the atmosphere. In fact, in order to reduce electricity prices and look for safer and alternative solutions for the environment, the government in Poland enacts a number of laws and their amendments to facilitate the construction of solar farms. [3][4]

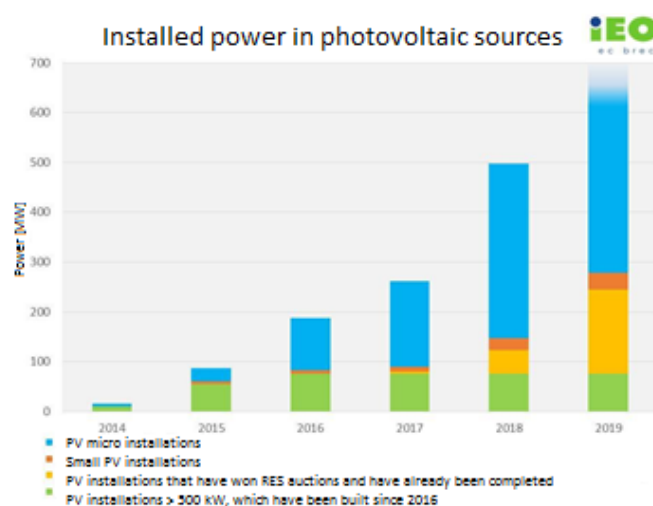


Fig.1: Photovoltaic power installed in Poland 2014-19. [1]

State-owned companies, foreign investors with huge capital and private owners opt for solar energy as a very reliable option. Solar photovoltaics is the most predictable renewable source, since its statistical variance is much lower than for wind or hydro; in fact, we count with powerful software tools as PVGIS [5] to forecast the expected solar irradiation at a specific point inside the European continent based on the characteristics of the climate of a specific region, and therefore we are able to estimate the expected energy gains per year. In the case of Poland, as shown in Figure 2, the average annual PV insolation is around 1000 kWh/m². Another advantage for solar from wind power plants is the minor visual impact and its better landscape integration.

II. EVOLUTION OF 4G NETWORK IN POLAND

In parallel with the evolution of solar photovoltaics, is also a fact that the 4G network in Poland has experienced a spectacular growth for what concerns to rural areas (where the solar farms are installed), making possible a global solution for the vast majority of Polish territory [10]. 4G networks are also known as LTE (*Long Term Evolution*), since it is the name for the standard for the 4th Generation of Mobile Wireless Communications.

Figure 4 shows the 4G coverage map for the operator Play, the one with a more complete one, in September 2019.



Fig. 4: Map of 4G network coverage for Play operator in Poland. Source: [11]

4G network, in case of a proper coverage, can be a good option for the communication needs of the solar farms, because they need a good, fast and reliable network connectivity to control and monitor CCTV images, production control, atmospheric changes (through the weather station that is also installed to monitor weather parameters), security systems and in general all the data needed for the operation of a solar farm.

The problem is that, during the construction of the first solar farms of Energija portfolio, at the second quarter of 2018, 4G network quality on these sites was still poor, and in some cases even non-existent, so 4G option was dismissed for this portfolio and I+D Energías had to choose a Ka-satellite communication system, as described at the next point.

III. ENERGIJA DOSSIER: GLOBAL SATELLITE SOLUTION

This Ka-satellite communication system, is composed of Satellite Antenna + LNB, Satellite Modem, Uninterruptible Power Supply and Router, as shown in Figures 5 and 6. Its provider is Skylogic, a company belonging to the European carrier Eutelsat.

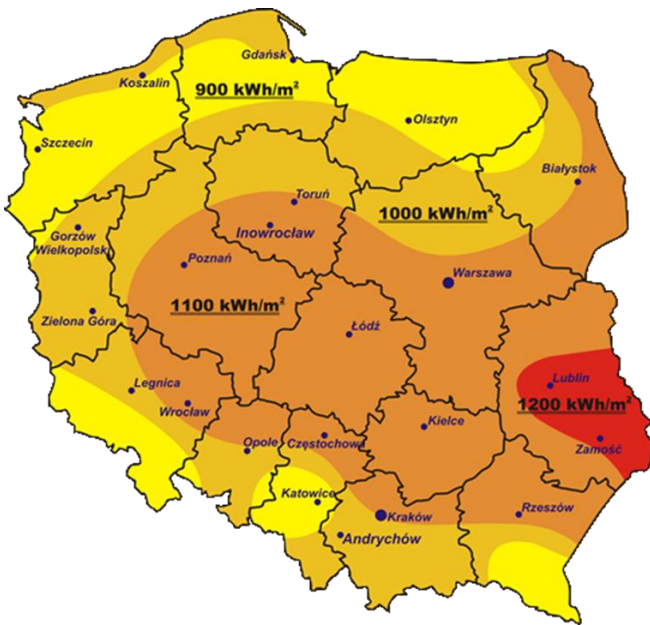


Fig.2: Map of average annual PV insolation in Poland in kWh/m². Source: Enis Photovoltaics, www.enis-pv.com

One of the largest and rapidly operating companies in Solar Photovoltaics in Poland is the Spanish company I+D Energías, [6] which in cooperation with its Polish partner company Sun Investment Group (SIG) [7] is building a huge portfolio of 109 solar power plants, divided into 2 portfolios of 43 and 66 MW respectively, for 2 different clients. The first one for E Energija Group (locations marked in yellow at Figure 3), was finished in June 2019 [8] and the second one for Lords LB Asset Management (locations marked in red), still under construction at September 2019. [9]



Fig.3: Map of Poland with solar farms built by I+D Energías for Energija (in yellow) and Lords (in red).



Fig.5: Satellite Modem and Router already connected to the monitoring cabinet, inside transformer station.



Fig. 6: Satellite Antenna mounted on the top of the transformer station

Satellite solutions are universal, but unfortunately quite expensive and they have a high latency time that comes to be around 800 ms and even above. The transmission speed is very asymmetrical depending on the direction: 30 Mb/s for the downlink (reduced to 0.5 Mb/s when the 25 GB monthly quota is consumed) and 3 Mb/s for the uplink.

Concerning lag time, for a continuous data flow in one direction, mainly the uplink because the information is sent from the solar farm to the remote controlling user and not reverse, this is not a problem (the information just reaches the destination 800 ms later), but if we need to remotely interact with the communication systems, as explained in next chapter, the lag times make the procedure very ineffective and tiresome. This effect is even worse when we need to control a lot of scattered installations, as it happens at these project portfolios developed in Poland. In fact, every 1 MW solar farm must count with its own communication system, making the remote control more difficult than for a non-scattered PV generator, as it can be a single solar farm, on the order of several tens of megawatts, but with a single communications system to control it entirely.

Another advantage of satellite systems with respect of 4G option is that satellite is in fact a dedicated link (point-to-point solution), with no usual competence with more users that can be suddenly present in the area of the corresponding base station, competing for the available channels and their bandwidth.

IV. VIDEO ANALYTICS AND FLIR SYSTEM

When the technology was not as developed as at present time, the CCTV systems in general used to work under the simple observation of the screen monitoring. Nowadays, as described in [12], Video analytics is now the Big Focus in CCTV Surveillance, even more if we must control so many installations at once in real time.

The advantages are clear: Time and money savings because less video information is sent over the network, reducing network load and storage needs, and higher efficiency because we can count with different scenario patterns depending on weather conditions, height of vegetation, existing local fauna, etc.

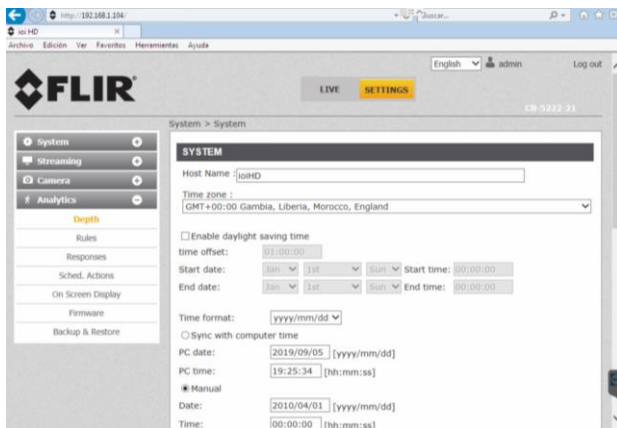


Fig. 7: Flir's Video analytics System with the changing parameters: Depth, Rules, Responses and Scheduled Actions

I+D Energías works, for the CCTV Video analytics, by using a software developed by the manufacturer Flir [13], that can be used for own Flir devices and also compatible ones from other manufacturers, as Uniview (Figure 8), the one used for these projects in Poland.



Fig.8: Uniview camera and lamp mounted over a pole for CCTV surveillance, I+D Energías, Poland

As shown in Figure 7, Flir's Video analytics System works under a web browser, given that the cameras are IP-based

technology. At left-hand menu, we can select the different parameters for the video analytics: Depth, Rules, Responses and Scheduled Actions.

As described in [13], these patterns establish the usual scenarios for potential intruders: height (an animal should not be detected as a human), trajectory run by the potential intruder (a person would cross the fence and walk in a straight way), and behaviour (probably trying to be hidden from the cameras by the structures, whilst an animal would not behave this way), etc.

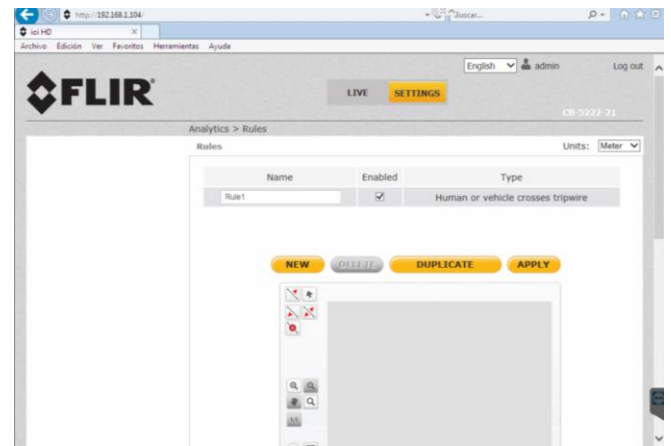


Fig. 9: Screenshot of Analytics Configuring: "Human or vehicle crosses tripwire".

It is not the objective of this article to deepen the different configurable rules of video analytics, but to show the reader that a large number of configurable parameters are available. We can highlight the following ones:

- *Depth* tab enables CCTV system administrator define the perspective of the scene being monitored (3D view). Depth can be calibrated automatically or manually. Figure 10 (a) shows the definition of a multi-segment fence.
- *Detection rules* are a combination of one or more conditions that must be met in order to register an intruder detection (and therefore, an alarm is generated), whilst a friendly or non-intruder detection would not generate any kind of alarm. Detection rules in a defined region include: Region entrance, Loitering, Tripwire Crossover, Fence Trespassing, Stopped Vehicle and Object Removal. Figure 10 (c) to (g) shows different situations of intruder and non-intruder's detection.
- *Responses* and *Sched. Actions* screens are similar, and they include the following elements: *Triggering Events* (Definition of the type of event which will start the automatic response), *Actions* (Definition of the actions to be performed on the occurrence of a triggering event), and *Schedule* (When configuring automatic responses, this option enables CCTV system administrator to

define when to monitor for the triggering event occurrence).

The authors want to show not only the complexity of the video analytics system (with a very extensive number of rules to be defined for each scenario), but also the need to make an effective and dynamics re-configuring of these rules, not only to fine-tune the system effectiveness, but also to make it adaptive to the numerous context variations.

In this way, a high vegetation or tree crowns, linked to a

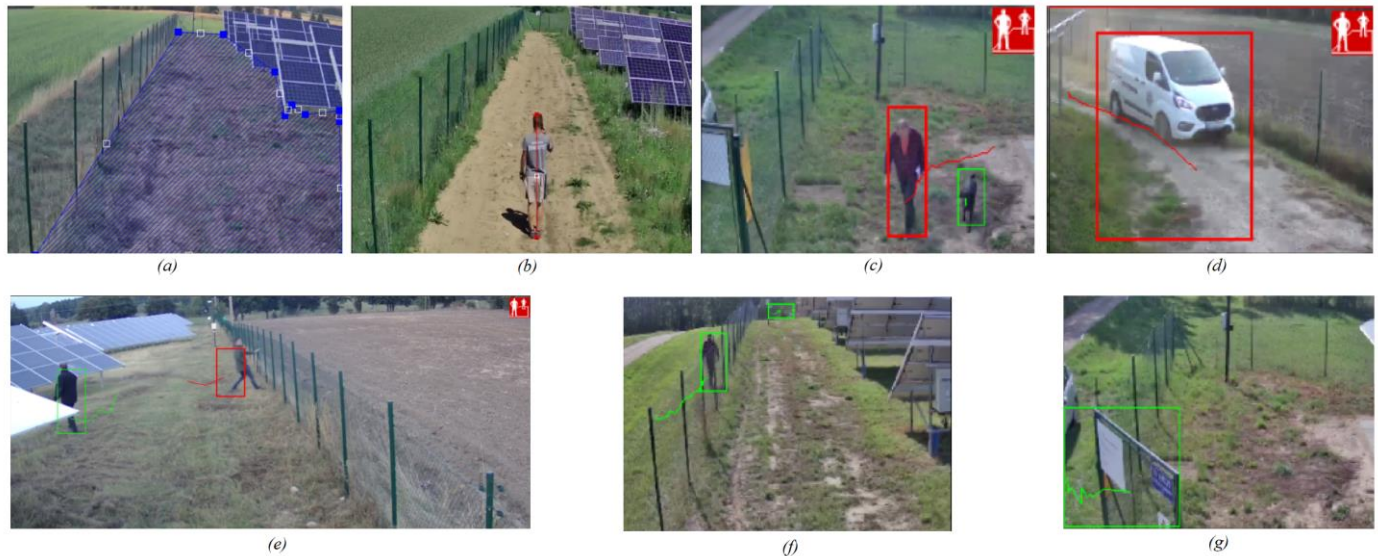


Fig.10: Definition of intrusion area (a) and intruder's height (b) in Flir's Video analytics System. Human (red) and Animal detection (green) (c). Vehicle detection (d). Non-intruder (left, green) and Intruder detection (right, red) (e). Non-intruder, walking outside the fence (green) (f). Object movement (gate being swung by the wind) (green) (g).

Source: I+D Energías's proprietary production.

homogeneous wind speed, may be understood by Video analytics as a straight trajectory run by an intruder (equivalent height), creating a fake alarm. Besides, if the terrain is wet or snowed, the cameras may receive reflections since the terrain can act as a mirror, creating also fake alarms. And at night, for a more efficient operation of the system at night we use special lamps with infrared light and ordinary lamps with white light, whose operating times can only be set according to our preferences. But the appearance of night insects flying around the lamp may also create fake alarms into the camera because they act as light scatterers.

In conclusion, thanks to Video analytics and Flir's software we can dynamically control the parameters of cameras and sensors from every corner of the world. As described, we can adapt them to the different patterns, to reduce the number fake alarms. But these patterns and parameters must be set manually by a CCTV operator or administrator because, with the existing technology, the human criteria is the only way to have a clear idea of what must be changed.

In this sense, it is very important to emphasize the fact that changing one camera parameter requires mouse moving, clicking many buttons, opening or the closing of the different screens and takes a lot of time, even more for a scattered PV generator composed of 43 or 66 solar farms. So, what happens if a lot of parameters must be changed, after the observation and decision made by the operator, with a lag of about 800 ms? Flir's software management can be eternal for the operator with such a high latency time. So, at the end, these patterns are very rarely remotely changed if we run under Satellite Systems, and therefore the power and effectiveness of Video analytics is

reduced because of lag time of Satellite option. Once again, it is important to emphasize that we must control quite a lot of solar farms at once in real time.

V. LORDS DOSSIER: MIGRATION TO 4G

To increase the efficiency of the Video analytics, and to enable the system operator to change its patterns and parameters, we must quit satellite option for communications. We must therefore try 4G system.

When Lords dossier started in July 2019, several field tests were made in order to verify if 4G option was suitable. The results were quite satisfactory and the solar farms belonging to this dossier are running on a highly directive 4G Mikrotik antenna, model SXT-2 10dbi, 60 degree, integrated AP/Backbone/CPE, dual chain, Gigabit Ethernet (Figure 11) [14], with a SIM card, instead of a satellite system.

From the economic and technical points of view, 4G is a cheaper solution with a tiny lag time. However, if there are many network users in the coverage area, the range may drop to 3G or even 2G, and even the signal can be completely lost.

This phenomenon can have a negative impact on the functioning of all systems on the farm, responsible for its proper functioning.



Fig.11: 10-dbi directive Mikrotik antenna to increase the 4G signal level. I+D Energías, Poland

It is important to highlight that a few Lords projects are running on satellite, because we cannot find a correct 4G network coverage alternative with any Polish 4G operator. But this can be considered the least bad option, since it can never be as tiresome as running all the projects under satellite link.

VI. COMPARISON OF COSTS AND SPEED RATES

Comparing satellite and 4G systems costs we can check at Table 1 that in the case of satellite, the initial cost is 500 € per device, and the monthly fee for a 25 GB quota is 60 €. 4G-based technology costs are really much smaller. The cost of one antenna is 75 €, and monthly fee for an unlimited quota is 25 € per month.

| Comparison of costs and speed rates (average of several tests) for 4G and Ka-satellite technologies | | |
|---|------------------------|--------------|
| Communications type | 4G | Ka-satellite |
| <i>Initial cost for device</i> | 75 € | 500 € |
| <i>Monthly fee</i> | 25 € | 60 € |
| <i>Monthly high-speed quota</i> | Unlimited | 25 GB |
| <i>Download rate</i> | 25 Mbps ⁽¹⁾ | 30 Mbps |
| <i>Upload rate</i> | 5 Mbps ⁽¹⁾ | 3 Mbps |
| <i>Lag time (Typical value)</i> | 20 ms | 800 ms |

(1) Values obtained in our described work scenario. However, a 4G LTE network can provide much higher download and upload bitrates, what depends on the sharing of resources, in turn based on the concurrency given by the number of subscribers.

Table 1

The transmission speed rates for Ka-satellite system are 30 Mbps for downlink and 3 Mbps for uplink (the direction in which the majority of the information is sent, because the solar farm is sending much more information than the one received). For 4G system, the results obtained after running speed tests at the different locations are better for our main purpose (around 5 Mbps for uplink).

In both cases, rates are certainly sufficient to monitor and control solar farms with the sole and important exception of lag time and its negative effects for the real-time remote video analytics controlling, as explained in previous chapters.

VII. CONCLUSIONS

The 4G LTE networks are exponentially becoming more and more efficient, for which relying on them for monitoring communication systems in rural area locations (as it happens in our case with solar farms) at the expense of Ka satellite systems will be much more usual progressively, also depending on local conditions and the speed and coverage growth of 4G operators, as well as the working frequency bands¹. In the case of Poland, the signal has become stronger and more stable, and the connectivity has a larger range, which covers almost the entire country.

In addition, as checked on site from our user's experience, 4G networks are cheaper to install and maintain than satellite systems and their exponential growth is very positive for the effective monitoring of scattered PV generators, a key factor for the distributed production. This is an advantageous option, not

¹ Lower frequencies (Around 800 MHz) are more suitable for rural environments (our case), where the density of Base Stations decreases in comparison to urban settings (2600 MHz), given that the lower the frequency, the higher the wave propagation and therefore the bigger the area covered.

only from the cost-saving because of the lower transport losses but also in terms of usual redundancy and reliability, since distributed systems have the potential to supply electricity during grid outages resulting from extreme weather or other emergency situations, reducing blackouts or the adverse effects of terrorism. [15]

However, satellite systems can also work synchronised with 4G LTE networks, where we can divide the transmitted information for a specific system. E.g. the 4G network can be responsible for the data collected from video surveillance (much higher bitrate needs), and the satellite system can be responsible for other data with no need of interaction, as production control or values given by weather station. Another variant of the solution is to use satellite systems only as backup data, whilst 4G can be mainly used to collect data.

| Set of parameters for the different existing technologies of Mobile Wireless Communications | | | |
|---|-------------------------|-----------------------|---|
| Kind of technology | Value max. Downlink (1) | Value max. Uplink (1) | Latency (Typical value) |
| Real needs of PV farm system | 128 kbps | 10 Mbps | As low as possible for interaction purposes |
| Satellite | 20 Mbps | 6 Mbps | 600 ms |
| 5G | 10-20 Gbps | 1-10 Gbps | 1 ms |
| 4G+ (LTE-A CAT 16) | 700-1000 Mbps | 50+ Mbps | 20 ms |
| 4G (LTE CAT 4) | 150 Mbps | 50 Mbps | 40 ms |
| 3G (DC-HSPA+) | 42.2 Mbps | 8 Mbps | 100-500 ms |
| 2G (EDGE) | 300 kbps | 100 kbps | 300-1000 ms |

(1) Lab conditions: Maximum available resources, optimal environment.

Table 2

Table 2 [16,17] does not include information about the future 6th Generation of Mobile Wireless Communications, given that the joint of telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC), to produce the Reports and Specifications from 3G and beyond, also known as 3GPP (3rd Generation Partnership Project) [18] has not defined yet the 6G standard, as well as its specifications, capabilities and timelines.

Comparing the two systems in terms of security, we can conclude that the satellite system is much more secure than 4G networks, because its point-to-point beam makes difficult that other indirect relays could hack or steal private information. Moreover, satellite systems do not introduce a sporadic

presence of users with mobile devices that may appear and suddenly consume 4G resources in a certain area.

And of course, a very important advantage from 4G networks is their reduced lag time, enabling an easy remote interaction from a system supervisor, mainly to control video analytics in a dynamic way. In fact, I+D Energías will be also migrating existing Energija installations from Ka-satellite to 4G during the following months, precisely because of this reason.

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