Aerial pollution detected on 128 panels has no measurable influence on the panel behaviour at present time (or the influence could not be identified because another malfunction is present at the panel).

All other malfunctions (hotspot, microcrack, metalisation defect etc.) have more significant impact on the VA characteristic. This set personate 126 cases (29,2 %). Fig. 13 shows samples of this behaviour. Reference VA characteristic of healthy panel shows measurement 7. Cases 8 and 9 demonstrate influence of the hotspot on one sole cell, while measurements 10 and 11 illustrate the same malfunction but on 2 cells connected into independent strings. Examples 12 and 13 show particular microcracks of the star shape while number 14 presents linear microcrack. Curves 15 and 16 demonstrate defective bus connections in particular strings.
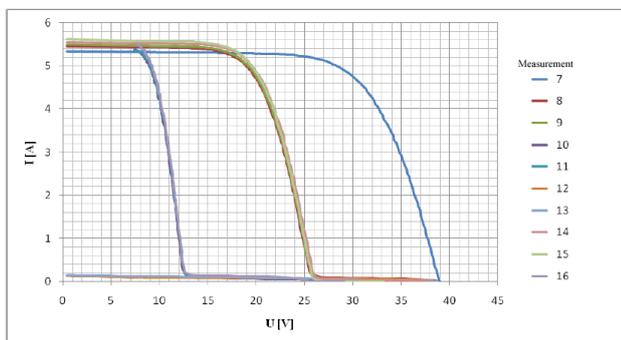

Fig. 13. Sample VA characteristics (measurements 7 – 16)

Direct impact of presented malfunctions on generated energy is demonstrated on Fig. 14 where power characteristics of affected panels are compared. Serious change of generated power and MPP position is evident.
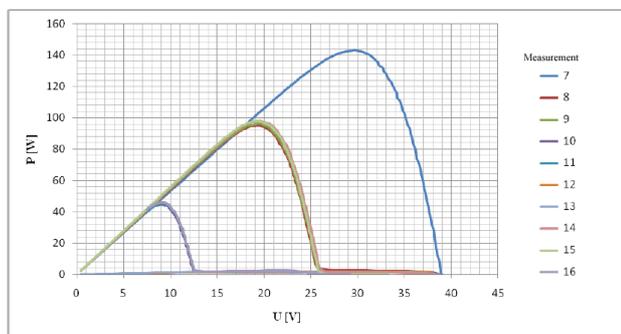

Fig. 14. Sample power characteristics (measurements 7 – 16)

6. Conclusion

Annual measurements performed on the oldest grid-on photovoltaic system operated in CR show interesting evolution of degradation process. Although this process is often simulated, this paper presents real results.

While measurements between 2004 and 2012 did not prove any significant changes, tests in 2013 identified first issues (2 defective panels). These conditions sustained constant until 2018. In general, only 2 panels from 192 showed some malfunctions during 14 years of continual operation. Not until 2019 any other malfunction was detected. At whole 431 particular malfunctions affecting 116 panels were detected during 2019 measurements. This represents 60,4 % of installed panels.

Interesting fact is not the large number of affected panels but the rapid change between measurements 2018 and 2019, which initiated this study.

2 particular scenarios of the degradation are possible. The first one predicts 2019 as the starting point of final degradation. The degradation will grow with constant speed. Another scenario expects staircase degradation. It means that the state detected in 2019 will stay almost constant for some period after which another strong degradation will be identified. Measurements in next years will prove, which scenario is correct.

References

[1] Nelson, J., The physics of solar cells, London Imperial College Press, 2003.
[2] Kladiva, R., Dlouhodobe sledovani parametru fotovoltaickych panelu, Brno. 2013.
[3] Fahrenbruch, A. L., Bube, R. H.,Fundamentals of Solar Cells. Academic Press Inc., New York. 2016.
[4] Libra, M., Poulek, V., Solarni energie. CZU Praha, 2005.
[5] Belik, M., Weather dependent mathematical model of photovoltaic panels. ICREPQ, 2017.
[6] Cerna, L., A Simple Method of Evaluating Thermograms of Photovoltaic Modules. Proceedings 31st European Photovoltaic Solar Energy Conference and Exhibition. Hamburg, 2015.