IMPACTS OF PHOTOVOLTAIC PLANTS ON REACTIVE POWER AND POWER FACTOR CORRECTION: THE CAT HEAD CURVE

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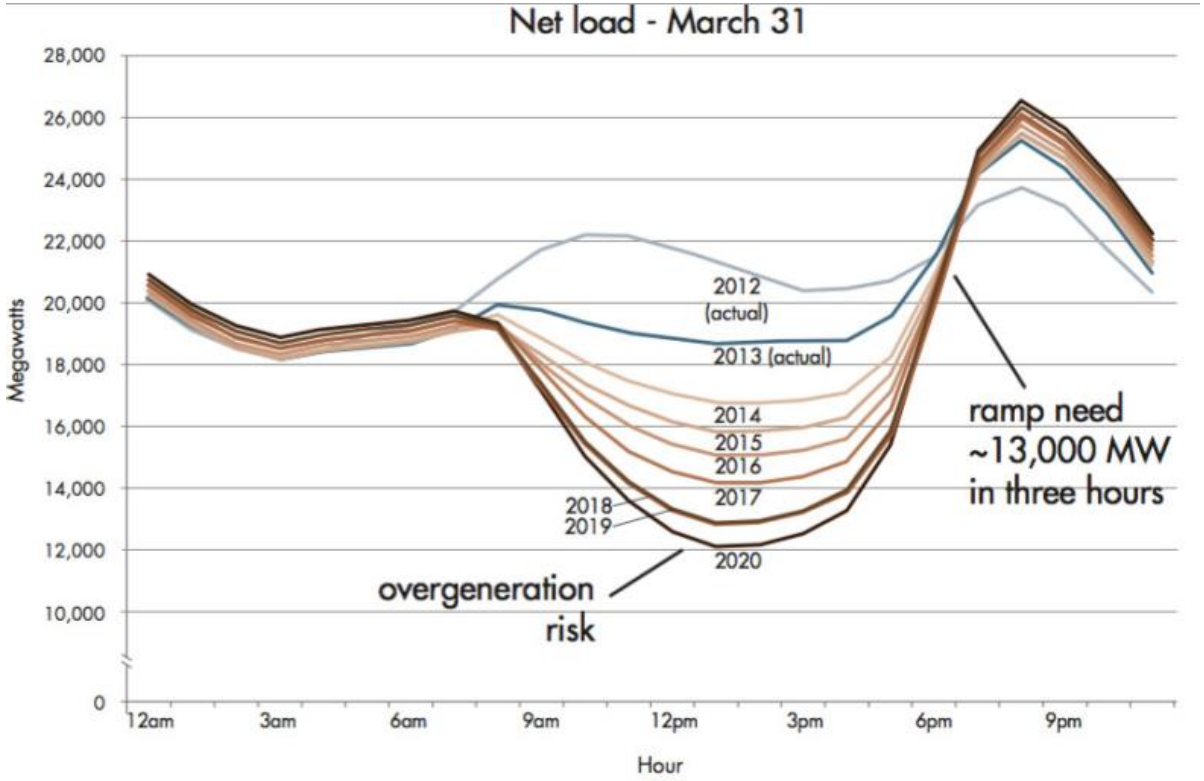
Introduction

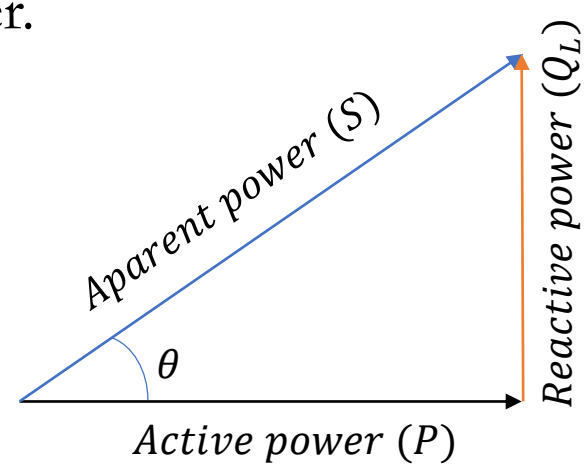
- Distributed generation is economical attractive.
- Photovoltaics cells with efficiency higher than 20%.
- Increase of distributed generations is causing problems.



Introduction

- The duck chart shows a problem in a large electrical power systems.
- This work investigates a problem that occurs in local industries.
- Consumers with low power factor after the installation of a PV plant.
- The power factor depends on active and reactive power
- A drop in the active power also cause the power factor to fall as well by making the power angle higher.

- $pf = \cos\left[\tan^{-1}\left(\frac{Q_L}{P}\right)\right]$

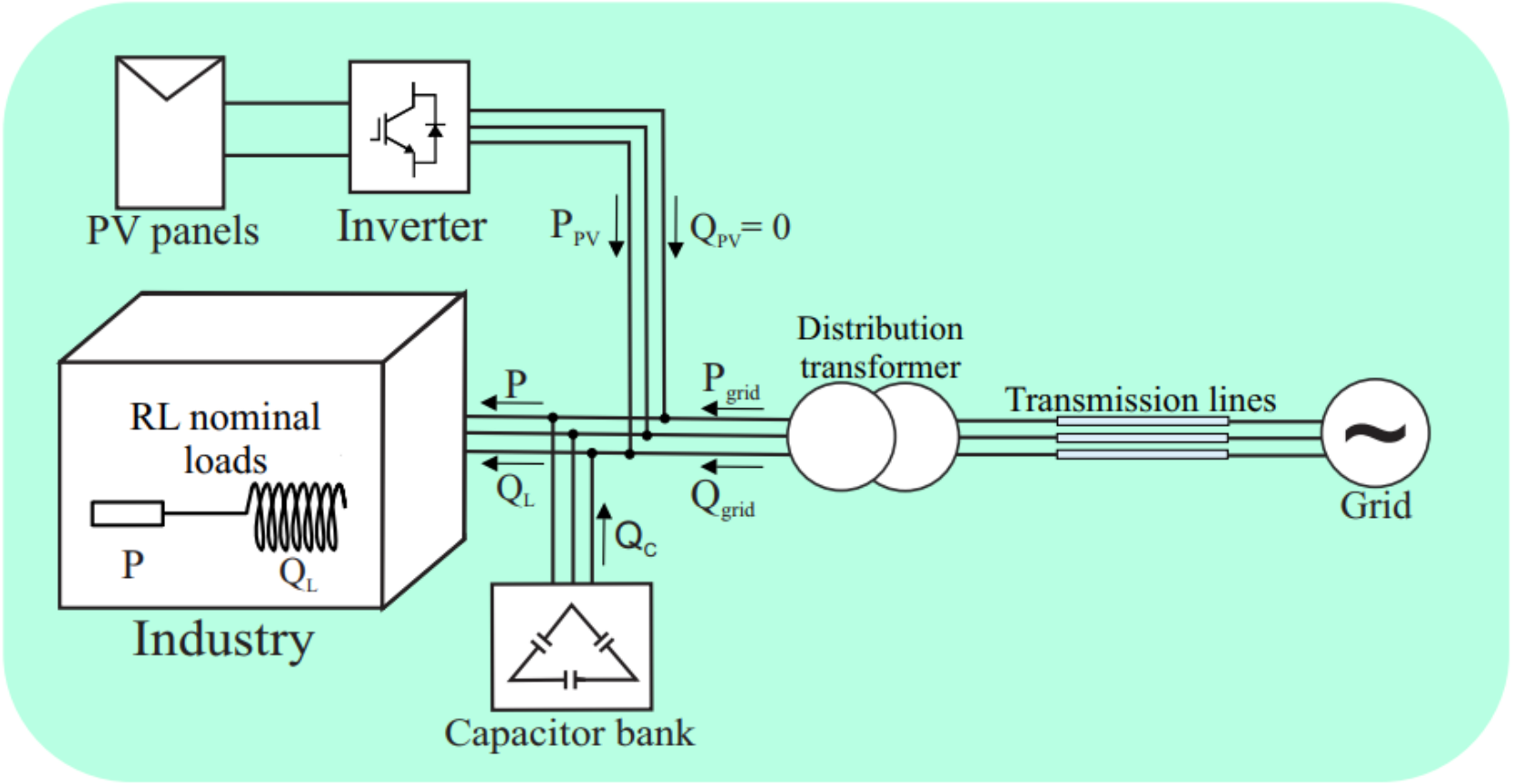


Contributions of this work

- Analysis about the effects of the installation of a PV plant on an industry power factor;
- Show the dynamic variations of the additional capacitive reactive power;
- Propose a solution to this problem using tapped capacitor banks.

Methodology

An overview of the system:



Methodology

Industrial capacitor banks and power factor correction:

- The power factor must be corrected to over 0.92.
- This correction is often used with capacitor banks.

$$pf = \cos\left[\tan^{-1}\left(\frac{Q_L - Q_C}{P}\right)\right]$$

- The necessary reactive capacitive power for any desired power factor is :

$$Q_C = Q_L - P\tan[\cos^{-1}(pf)]$$

Methodology

Industrial capacitor banks and power factor correction:

- The capacitance value can be expressed as:

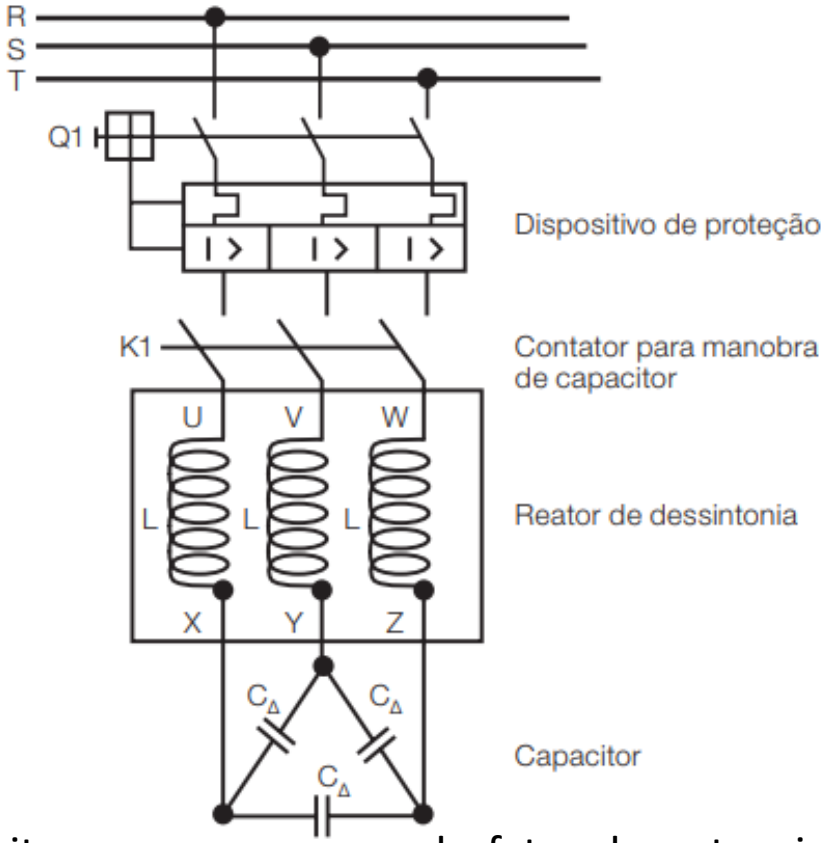
$$C = \frac{Q_C}{2\pi f V_g^2}$$

- Delta connection is more interesting than star connection.

- Commercial capacitor banks for industries are normally delta-connected

Methodology

Industrial capacitor banks and power factor correction:



http://ecatalog.weg.net/files/wegnet/WEG-capacitores-para-correcao-do-fator-de-potencia-50009818-catalogo-portugues-br.pdf

Methodology

Effects of a PV plant on the power factor correction

- The liquid active power drawn from the grid is now:

$$P_{grid} = P - P_{pv}$$

- Then the correction must be made now by:

$$Q_{C,new} = Q_L - |P_{grid}|\tan[\cos^{-1}(pf)]$$

- The extra capacitive power demanded is:

$$\Delta Q_C = \left(P - \left|P_{grid}\right|\right)\tan[\cos^{-1}(pf)]$$

Methodology

Effects of a PV plant on the power factor correction

- The last expression can be expanded as a piecewise function:

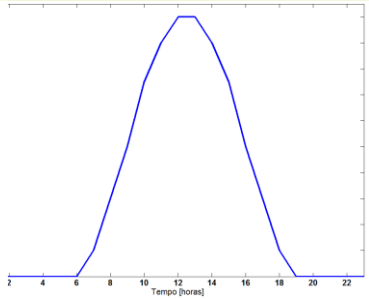
$$\Delta Q_C = \begin{cases} P_{pv} \tan[\cos^{-1}(pf)], & if\ P > P_{pv} \\ (2P - P_{pv})\tan[\cos^{-1}(pf)], & if\ P < P_{pv} \end{cases}$$

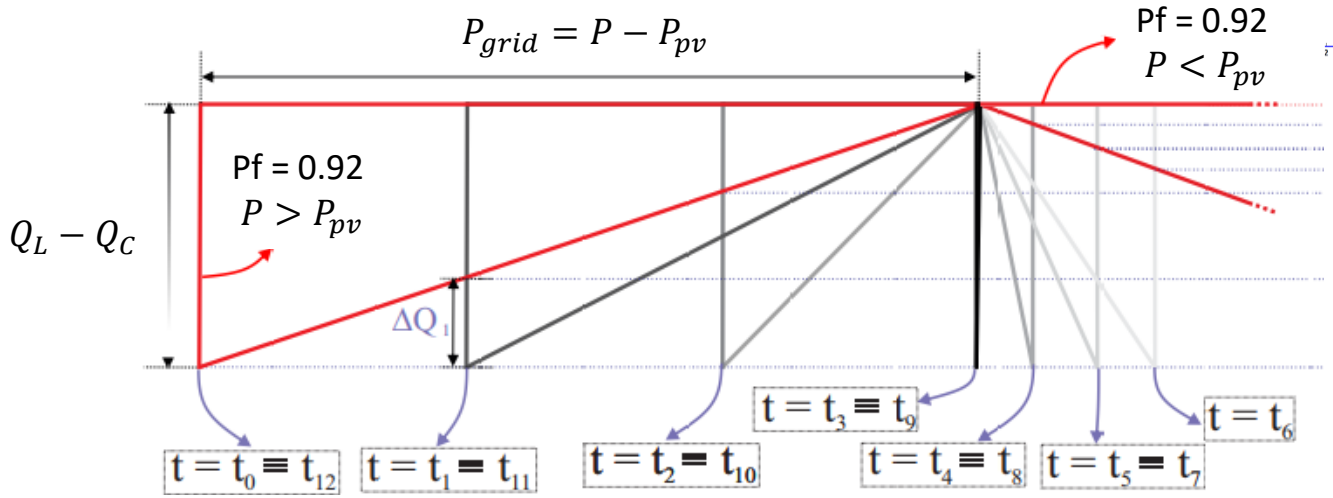
- When there is a production by the PV plant, an extra capacitive power is demanded.

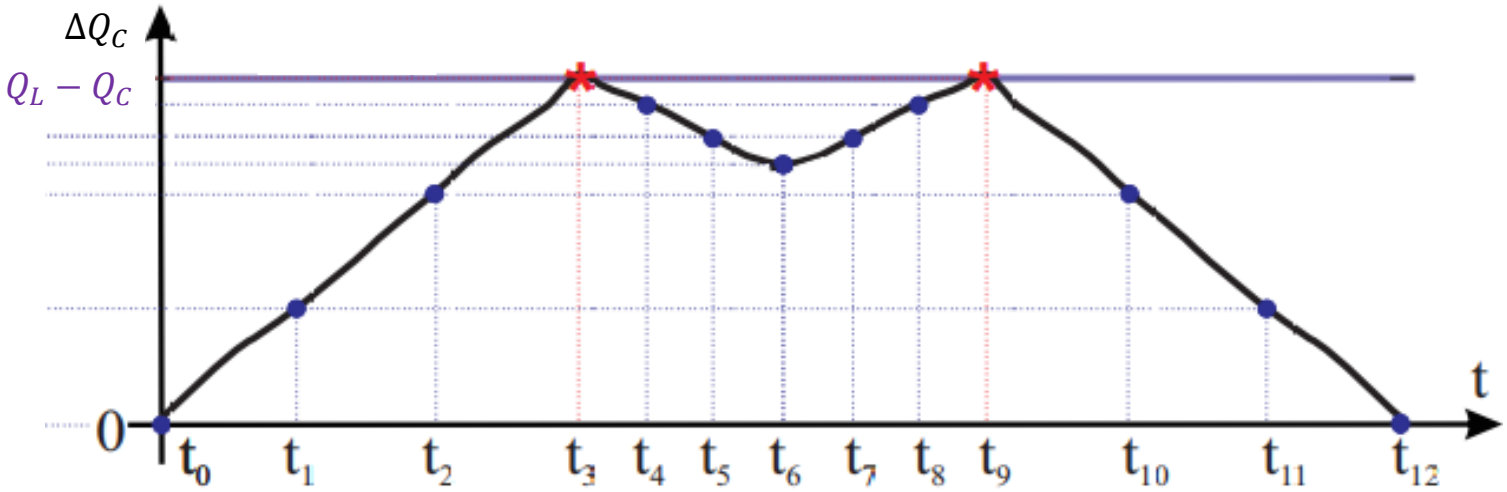
- This curve is defined here as the cat head curve for its shape along the day.

Methodology

Effects of a PV plant on the power factor correction







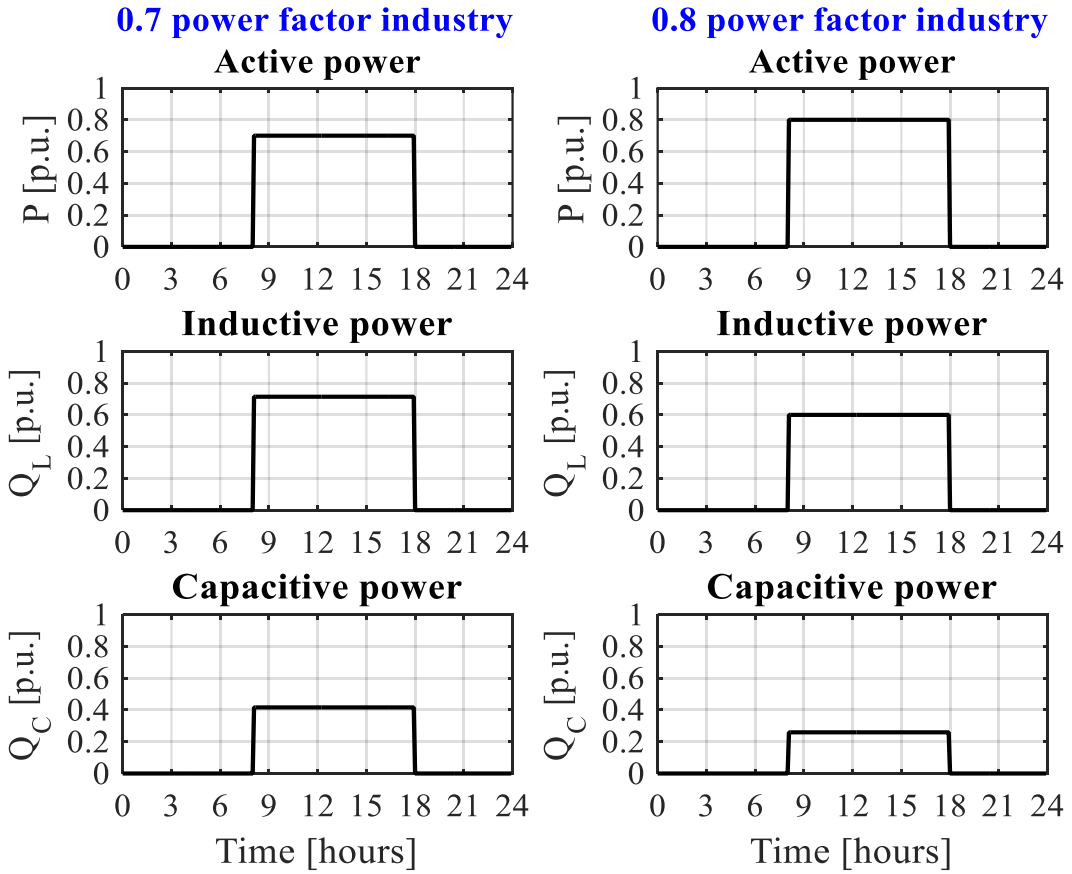
Methodology

Case study:

Methodology

Case study:

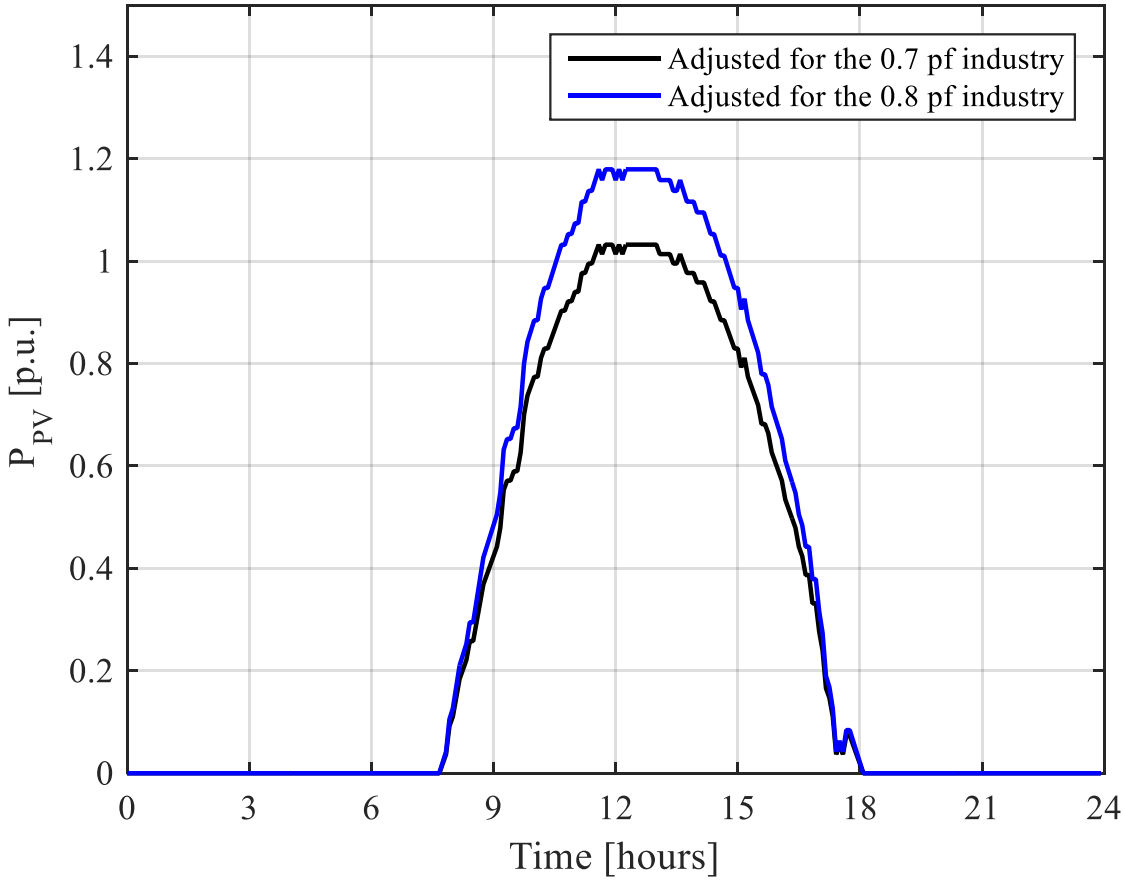
The profiles studied on this work are defined having an apparent power of 1 p.u. and nominal power factors of 0.7 and 0.8.



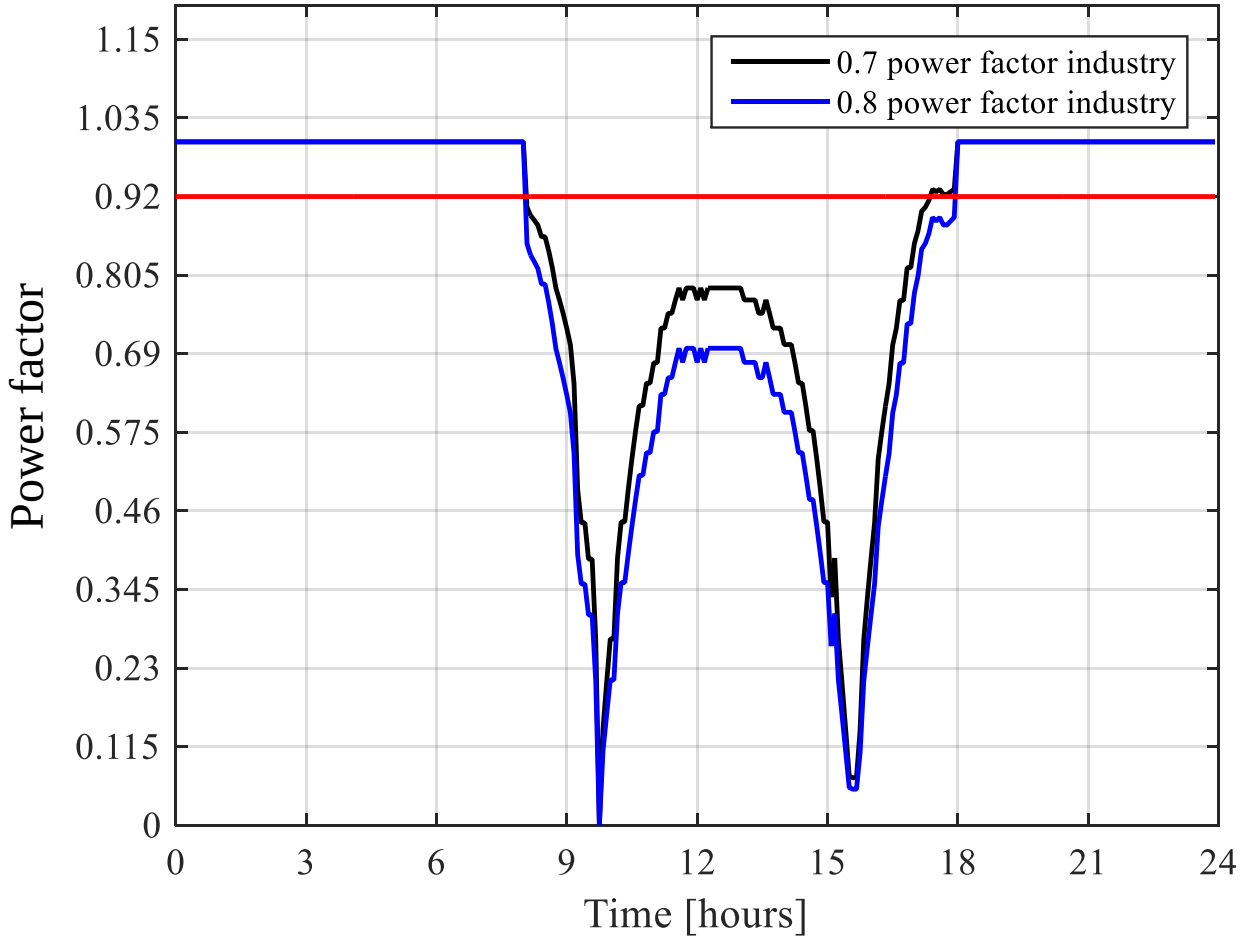
Methodology

Case study:

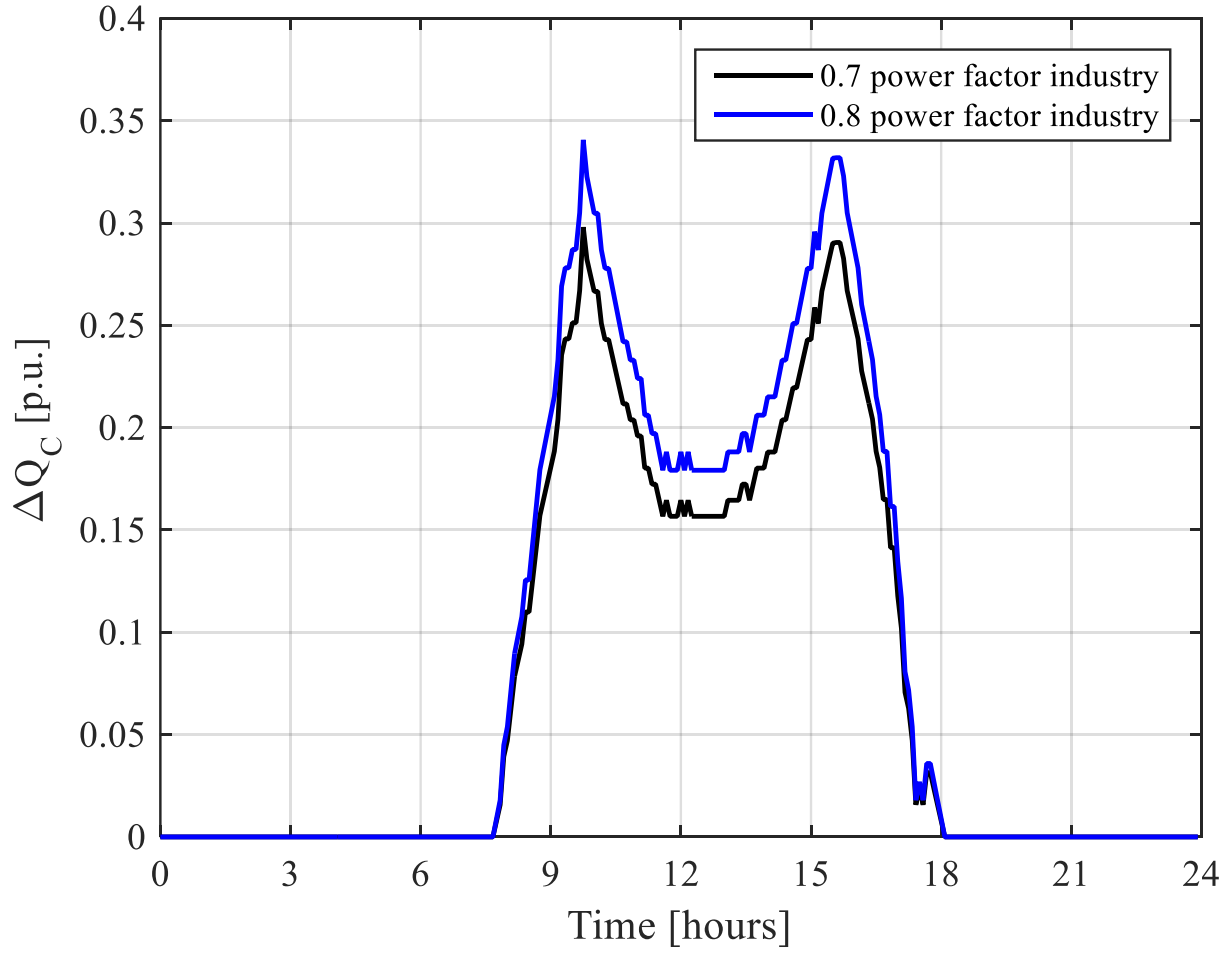
The active PV power was defined to have equal area to the nominal load active power.



Results

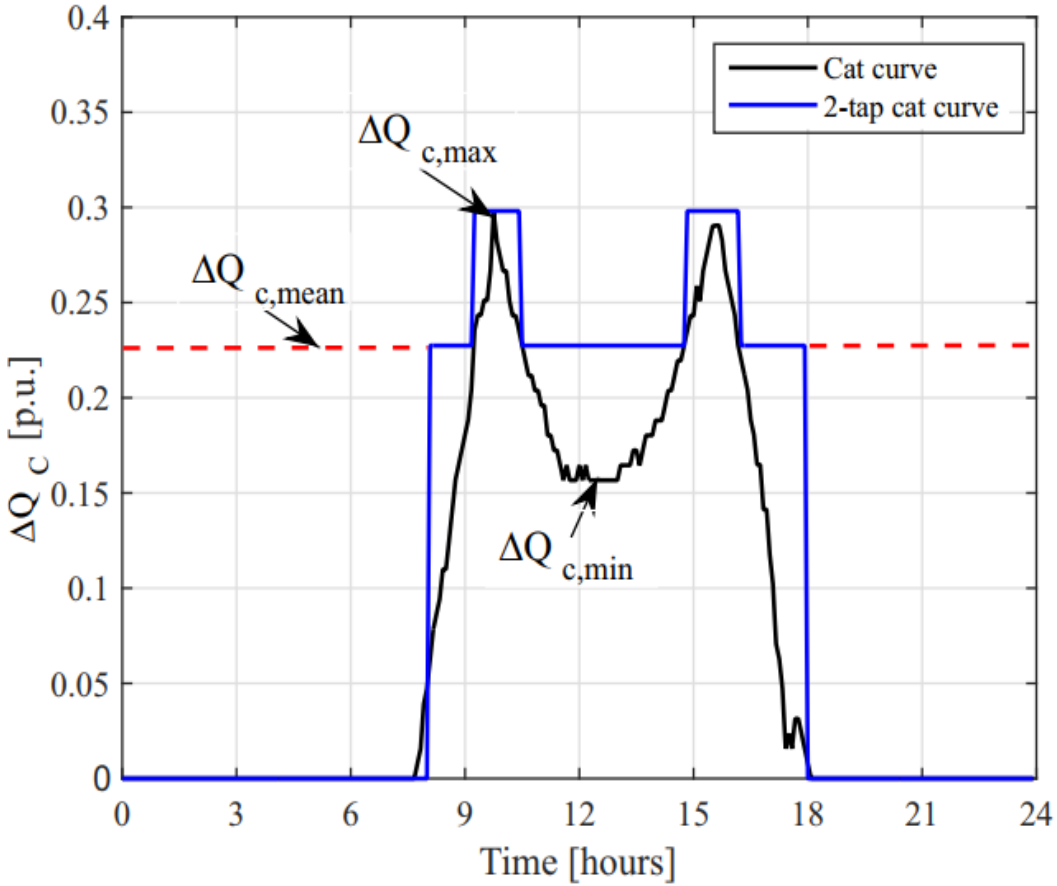

0.7 power factor industry
0.8 power factor industry
Power factor
1.15
1.035
0.92
0.805
0.69
0.575
0.46
0.345
0.23
0.115
0
0
3
6
9
12
15
18
21
24
Time [hours]

Results


0.7 power factor industry
0.8 power factor industry
ΔQ_C [p.u.]
Time [hours]
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
3
6
9
12
15
18
21
24

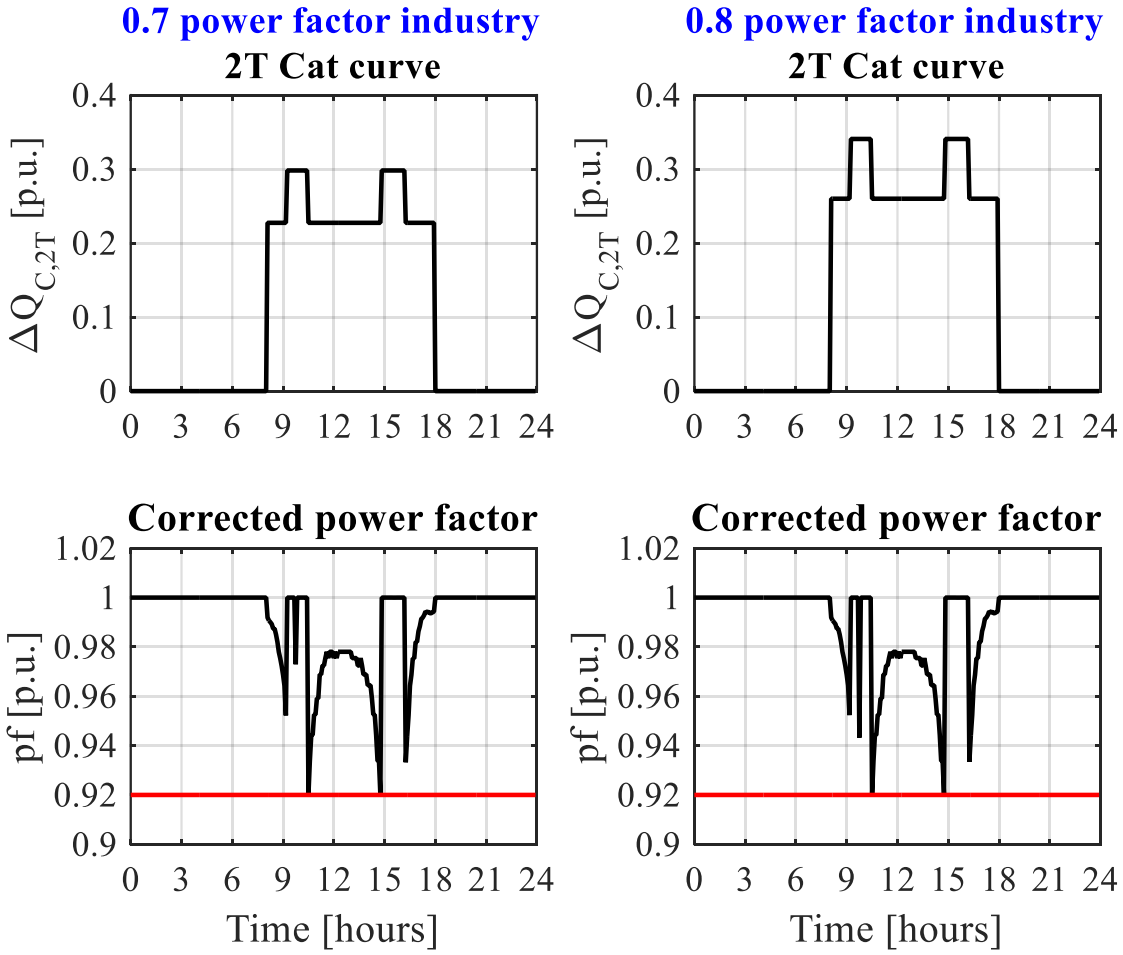
Results

Additional capacitive power ΔQ_C for the 0.7 pf industry



$$\Delta Q_{C,2T} = \begin{cases} \Delta Q_{C,max}, & if\ \Delta Q_c > \Delta Q_{c,mean} \\ \Delta Q_{C,mean}, & if\ 0 < \Delta Q_C \leq \Delta Q_{c,mean} \\ 0, & if\ \Delta Q_c \leq 0 \end{cases}$$

Results


0.7 power factor industry
2T Cat curve
$\Delta Q_{C,2T}$ [p.u.]
0.4
0.3
0.2
0.1
0
0 3 6 9 12 15 18 21 24
0.8 power factor industry
2T Cat curve
$\Delta Q_{C,2T}$ [p.u.]
0.4
0.3
0.2
0.1
0
0 3 6 9 12 15 18 21 24
Corrected power factor
pf [p.u.]
1.02
1
0.98
0.96
0.94
0.92
0.9
0 3 6 9 12 15 18 21 24
Time [hours]
Corrected power factor
pf [p.u.]
1.02
1
0.98
0.96
0.94
0.92
0.9
0 3 6 9 12 15 18 21 24
Time [hours]

Conclusion

- The work showed the effects of a PV plant on reactive power;
- The power factor correction must be considered in the project;
- This work focus on showing the problem, opening space for many solutions in future studies
- A comparative study on the cost of corrections made by capacitor banks and multifunctional inverters.
- Realize a comparison of the lifetime of the inverter with and without the help of an extra capacitor bank.
- A paper made in this area was published in CBENS in 2017 and a journal paper is on development.

Questions?!

Thank you!

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