Intérêt de la prévision photovoltaïque pour minimiser les impacts sur les réseaux : activités en cours au SIRTA

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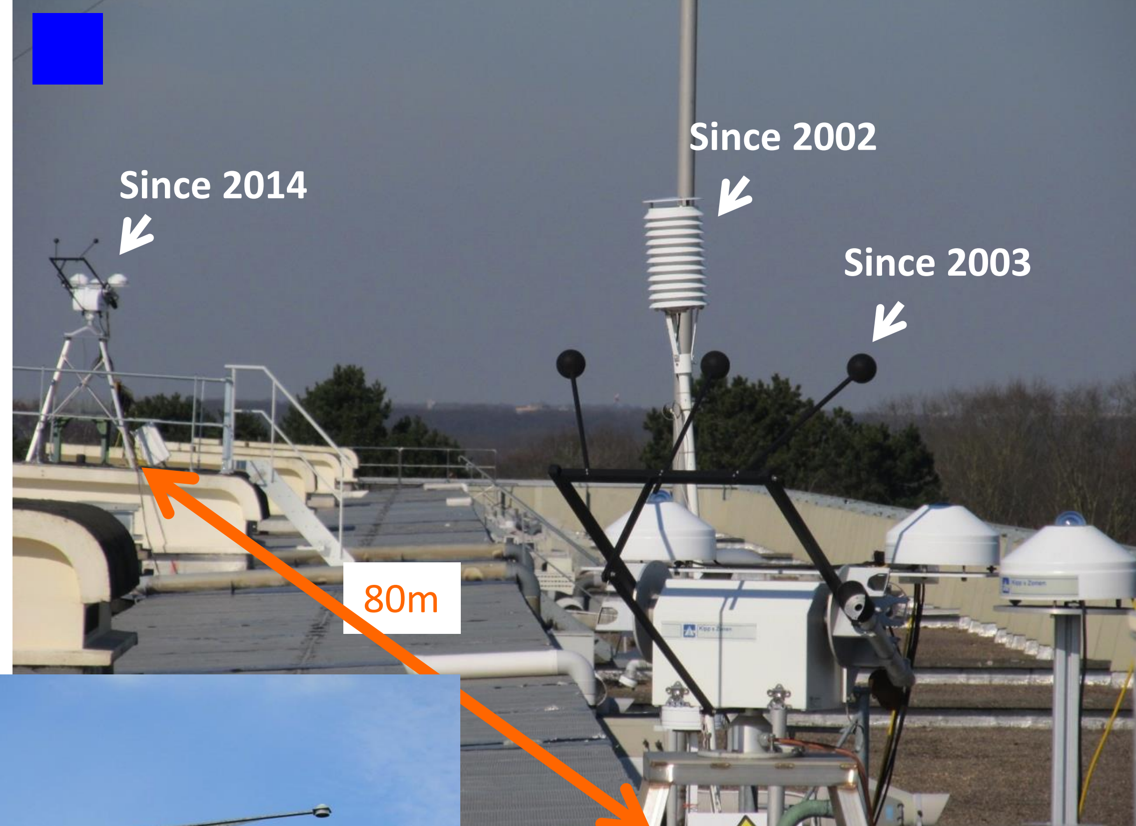
École Polytechnique Université Paris-Saclay · LMD · GeePS Génie électrique et électronique de Paris · Limsi · LPICM · TREND-X · MISTIGrid · SIRTA Site Instrumental de Recherche par Télédétection Atmosphérique

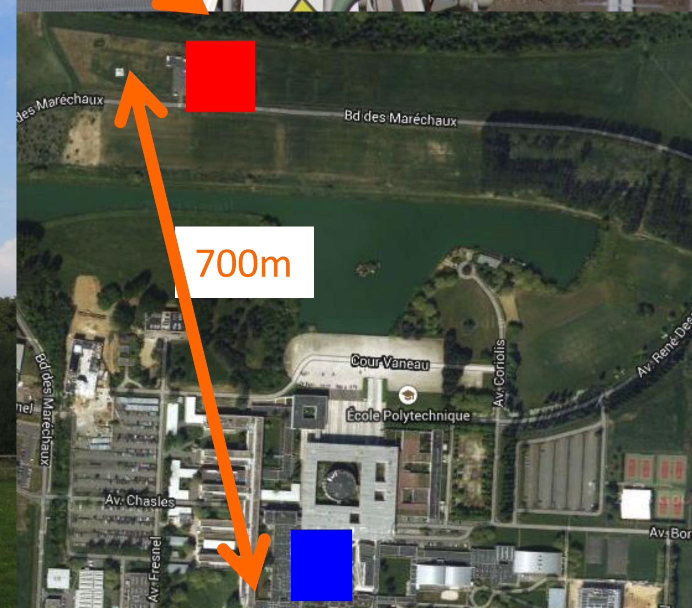
Station PAL, Paris region, France

Contribution to BSRN since 2003.
Current available parameters in BSRN archive :

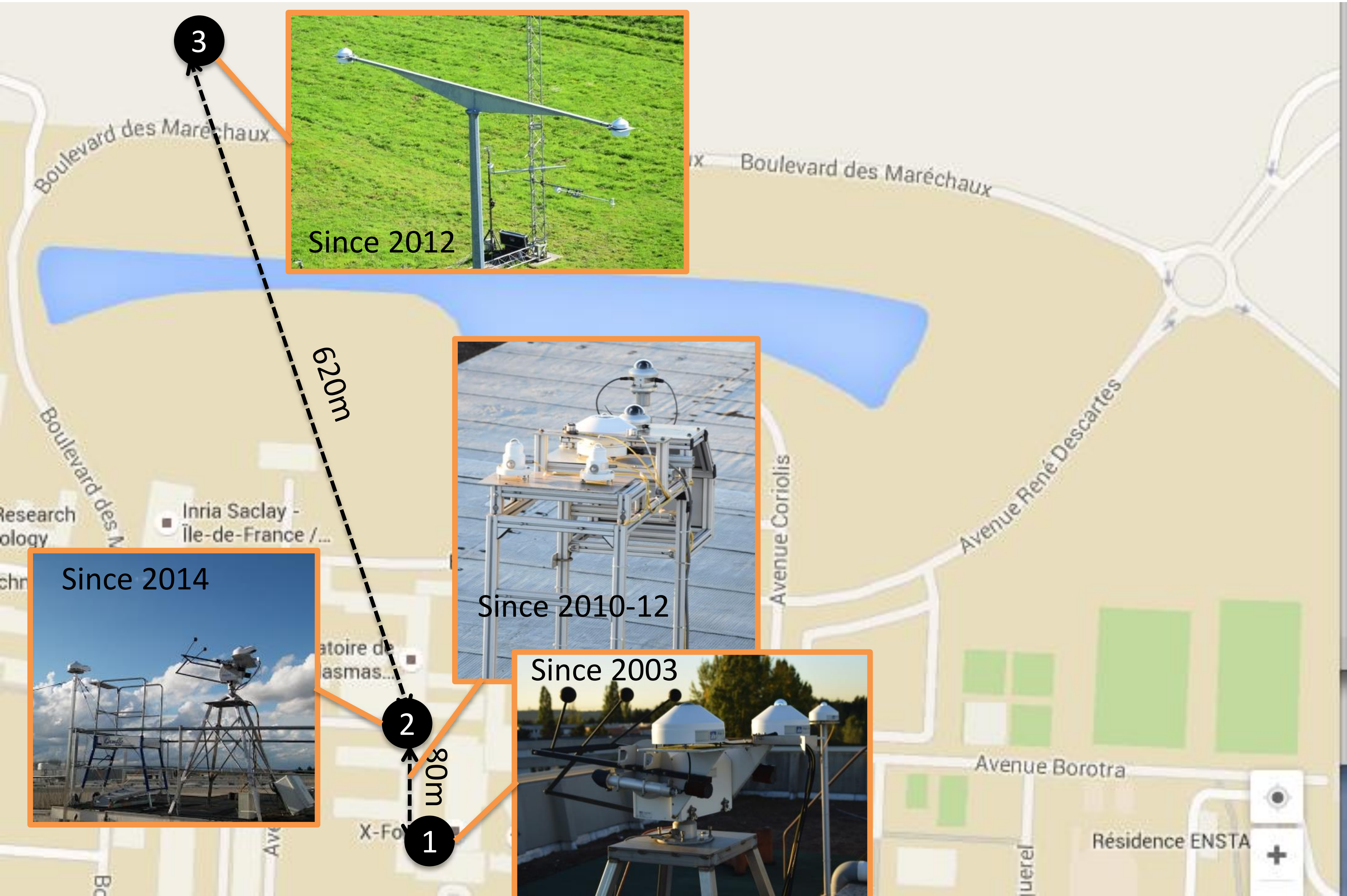
- SWDn (DIF, DIR, GLO), LWDn
- Air temperature, RH, pressure

The new installation in 2014 will become reference for the site.

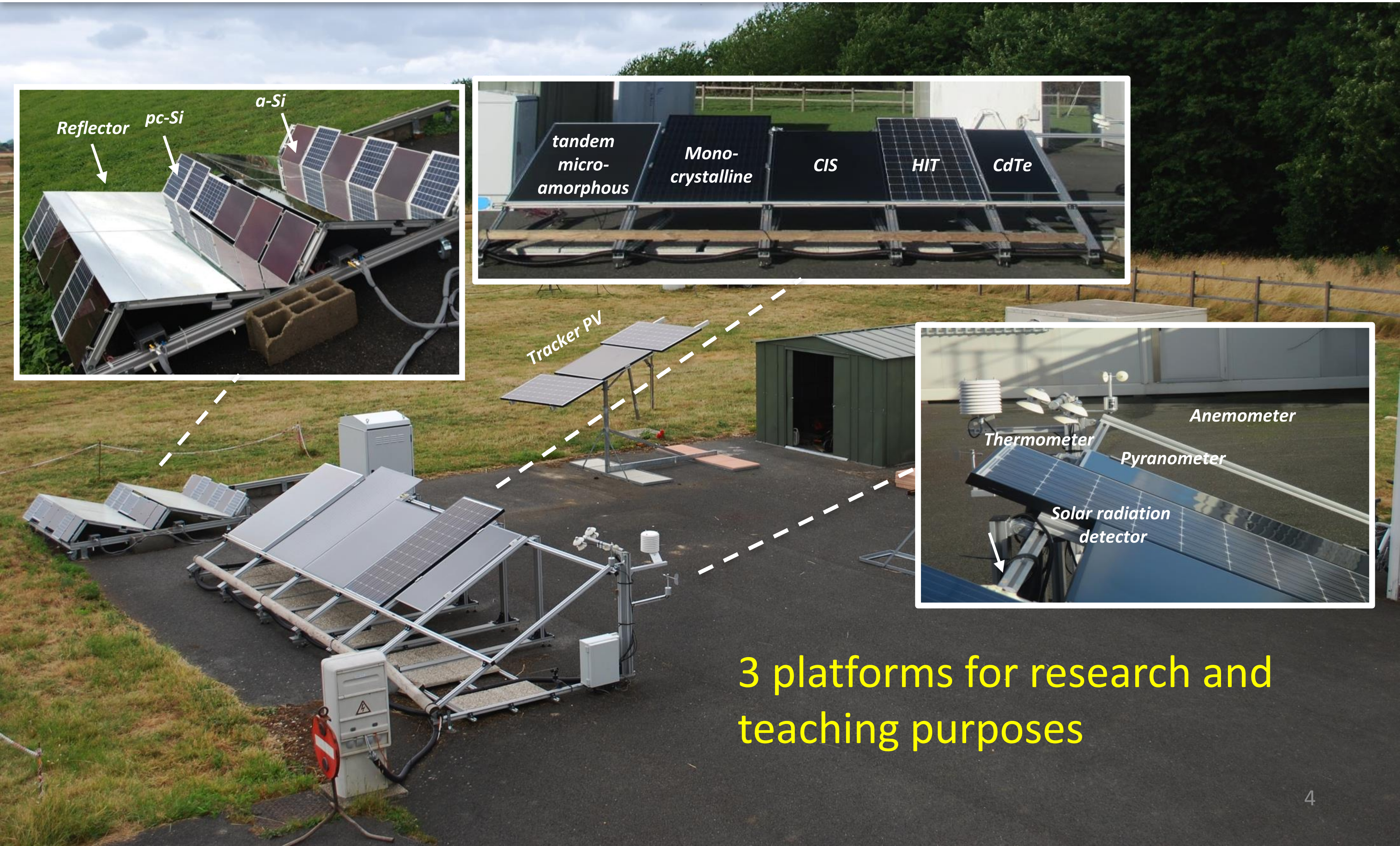




Radiative measurement locations at SIRTA



Photovoltaic characterization under real life conditions



3 platforms for research and teaching purposes

PHOTOVOLTAIC CHARACTERIZATION

Outdoor PV characterisation test bench

µc-Si/a-Si tandem
P_{mpp} = 128 W
η= 9,5%
Thin film technology

CIS
P_{mpp} = 150 W
η= 12,2%
Thin film technology

CdTe
P_{mpp} = 82,5 W
η= 11,4%
Thin film technology

C-Si
P_{mpp} = 250 W
η= 15%
1st generation

a-Si triple junction
P_{mpp} = 144 W
η= 6,7%
Thin film technology

HIT
P_{max} = 240 W
η= 19%
Best PV efficiency

Intérêt de la prévision de la production et de la demande

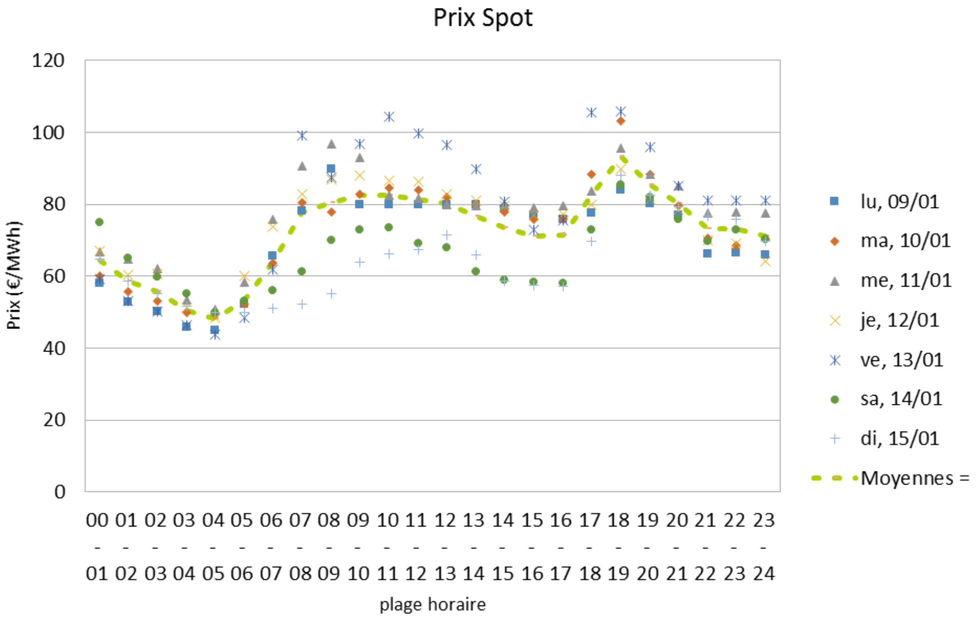
Opérateurs Réseau & Grandes centrales

Equilibrage réseau :

- Production
- Effacement

Trading :

- Injection
- effacement



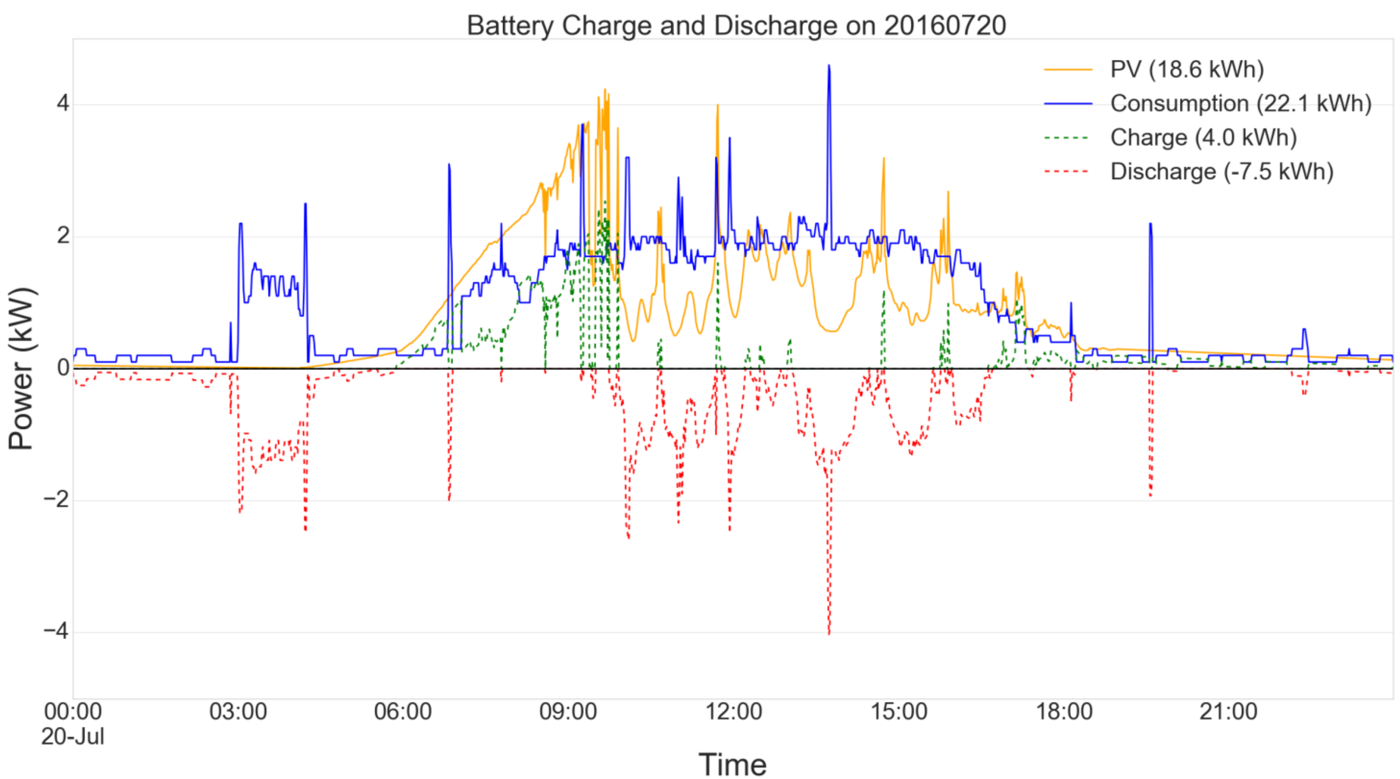
Intérêt de la prévision de la production et de la demande

Micro réseaux ilotés ou raccordés

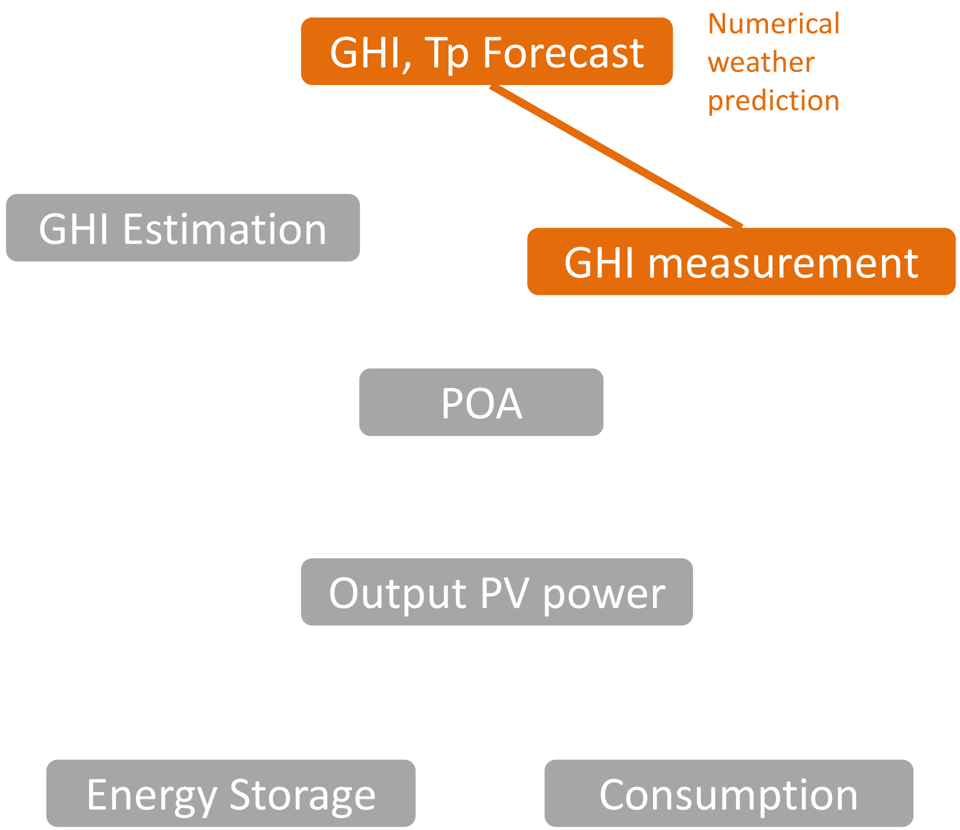
Zone éloignée du réseau 100% autoconsommation et autoproduction
Equilibrage réseau :

- Minimiser l'impact pour une injection massive d'ENR
- Contribuer à la stabilisation

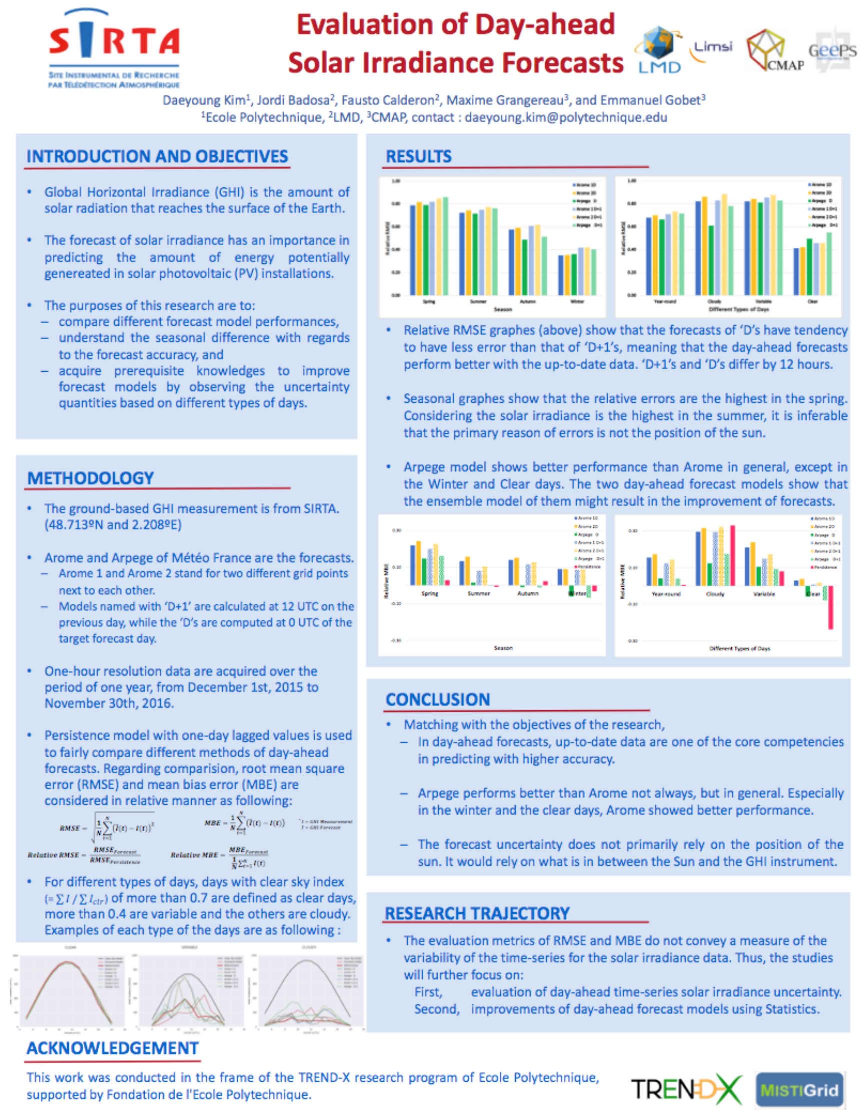
Trading ?



Etudes en cours



GHI: Global horizontal irradiance
POA: Plane of array irradiance
Tp : Panel temperature



SIRTA
Site Instrumental de Recherche par Télédétection Atmosphérique

Evaluation of Day-ahead Solar Irradiance Forecasts

LMD Limsi CMAP GeePs

Daeyoung Kim[1], Jordi Badosa[2], Fausto Calderon[2], Maxime Grangereau[3], and Emmanuel Gobet[3]
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INTRODUCTION AND OBJECTIVES

- Global Horizontal Irradiance (GHI) is the amount of solar radiation that reaches the surface of the Earth.
- The forecast of solar irradiance has an importance in predicting the amount of energy potentially generated in solar photovoltaic (PV) installations.
- The purposes of this research are to:
  - compare different forecast model performances,
  - understand the seasonal difference with regards to the forecast accuracy, and
  - acquire prerequisite knowledges to improve forecast models by observing the uncertainty quantities based on different types of days.

METHODOLOGY

- The ground-based GHI measurement is from SIRTA. (48.713ºN and 2.208ºE)
- Arome and Arpege of Météo France are the forecasts.
  - Arome 1 and Arome 2 stand for two different grid points next to each other.
  - Models named with 'D+1' are calculated at 12 UTC on the previous day, while the 'D's are computed at 0 UTC of the target forecast day.
- One-hour resolution data are acquired over the period of one year, from December 1st, 2015 to November 30th, 2016.
- Persistence model with one-day lagged values is used to fairly compare different methods of day-ahead forecasts. Regarding comparision, root mean square error (RMSE) and mean bias error (MBE) are considered in relative manner as following:

$$RMSE = \sqrt{\frac{1}{N}\sum_{t=1}^{N}(\hat{I}(t) - I(t))^2} \qquad MBE = \frac{1}{N}\sum_{t=1}^{N}(\hat{I}(t) - I(t))$$

$$Relative\ RMSE = \frac{RMSE_{Forecast}}{RMSE_{Persistence}} \qquad Relative\ MBE = \frac{MBE_{Forecast}}{\frac{1}{N}\sum_{t=1}^{N} I(t)}$$

- For different types of days, days with clear sky index ($=\sum I / \sum I_{clr}$) of more than 0.7 are defined as clear days, more than 0.4 are variable and the others are cloudy. Examples of each type of the days are as following :

RESULTS

- Relative RMSE graphes (above) show that the forecasts of 'D's have tendency to have less error than that of 'D+1's, meaning that the day-ahead forecasts perform better with the up-to-date data. 'D+1's and 'D's differ by 12 hours.
- Seasonal graphes show that the relative errors are the highest in the spring. Considering the solar irradiance is the highest in the summer, it is inferable that the primary reason of errors is not the position of the sun.
- Arpege model shows better performance than Arome in general, except in the Winter and Clear days. The two day-ahead forecast models show that the ensemble model of them might result in the improvement of forecasts.

CONCLUSION

- Matching with the objectives of the research,
  - In day-ahead forecasts, up-to-date data are one of the core competencies in predicting with higher accuracy.
  - Arpege performs better than Arome not always, but in general. Especially in the winter and the clear days, Arome showed better performance.
  - The forecast uncertainty does not primarily rely on the position of the sun. It would rely on what is in between the Sun and the GHI instrument.

RESEARCH TRAJECTORY

- The evaluation metrics of RMSE and MBE do not convey a measure of the variability of the time-series for the solar irradiance data. Thus, the studies will further focus on:
  First, evaluation of day-ahead time-series solar irradiance uncertainty.
  Second, improvements of day-ahead forecast models using Statistics.

ACKNOWLEDGEMENT

This work was conducted in the frame of the TREND-X research program of Ecole Polytechnique, supported by Fondation de l'Ecole Polytechnique.

TREND-X MISTIGrid

Etudes en cours

GHI, Tp Forecast

GHI Estimation

GHI measurement

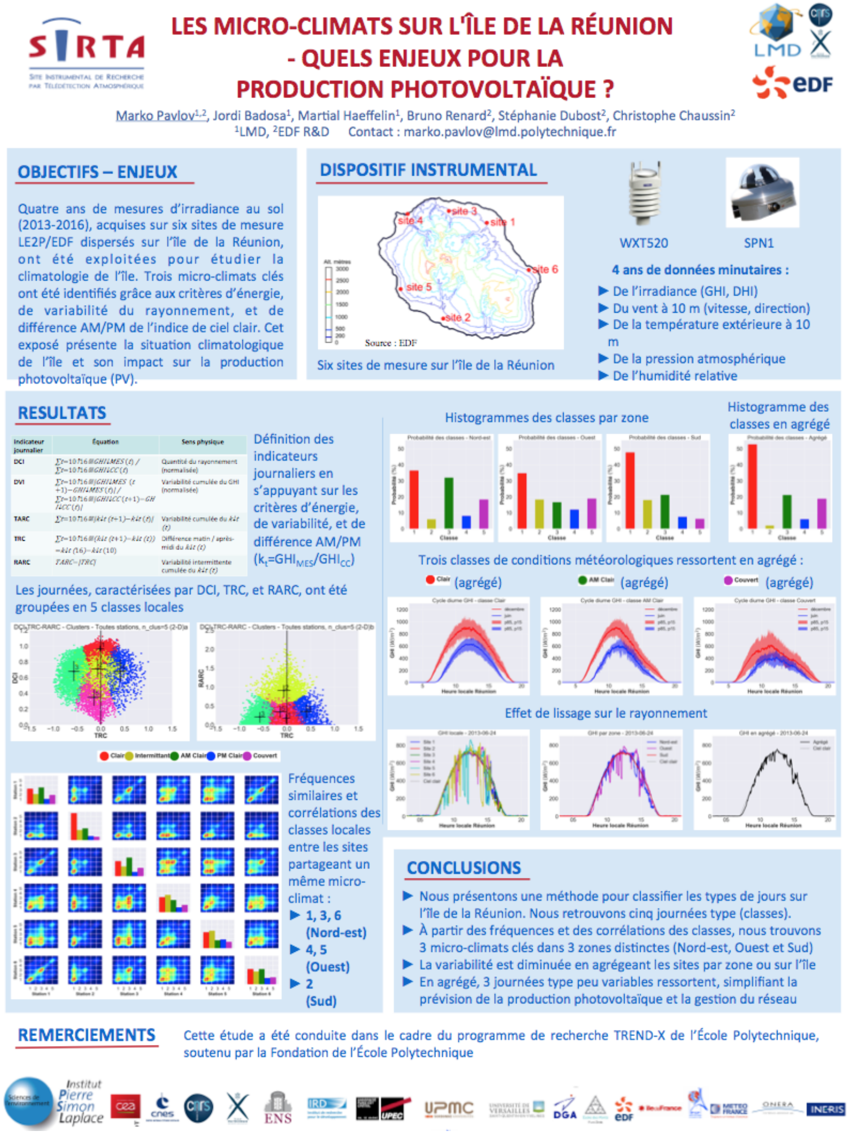
Variability study
Day types

POA

Output PV power

Energy Storage

Consumption



GHI: Global horizontal irradiance
POA: Plane of array irradiance
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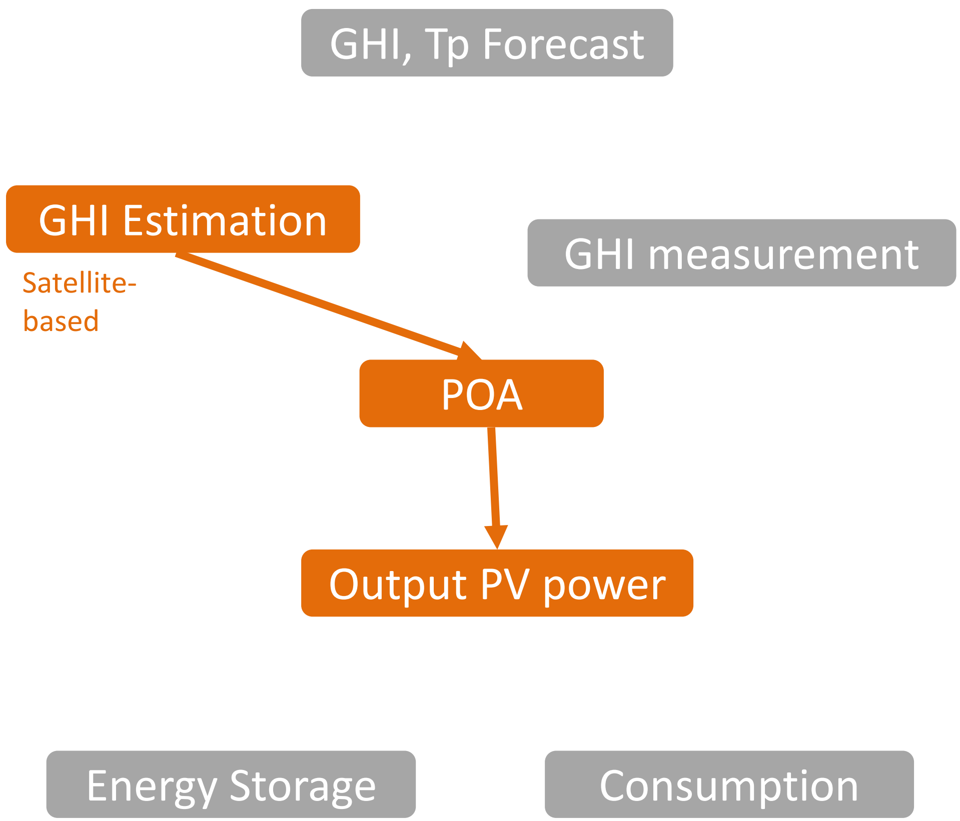
Etudes en cours



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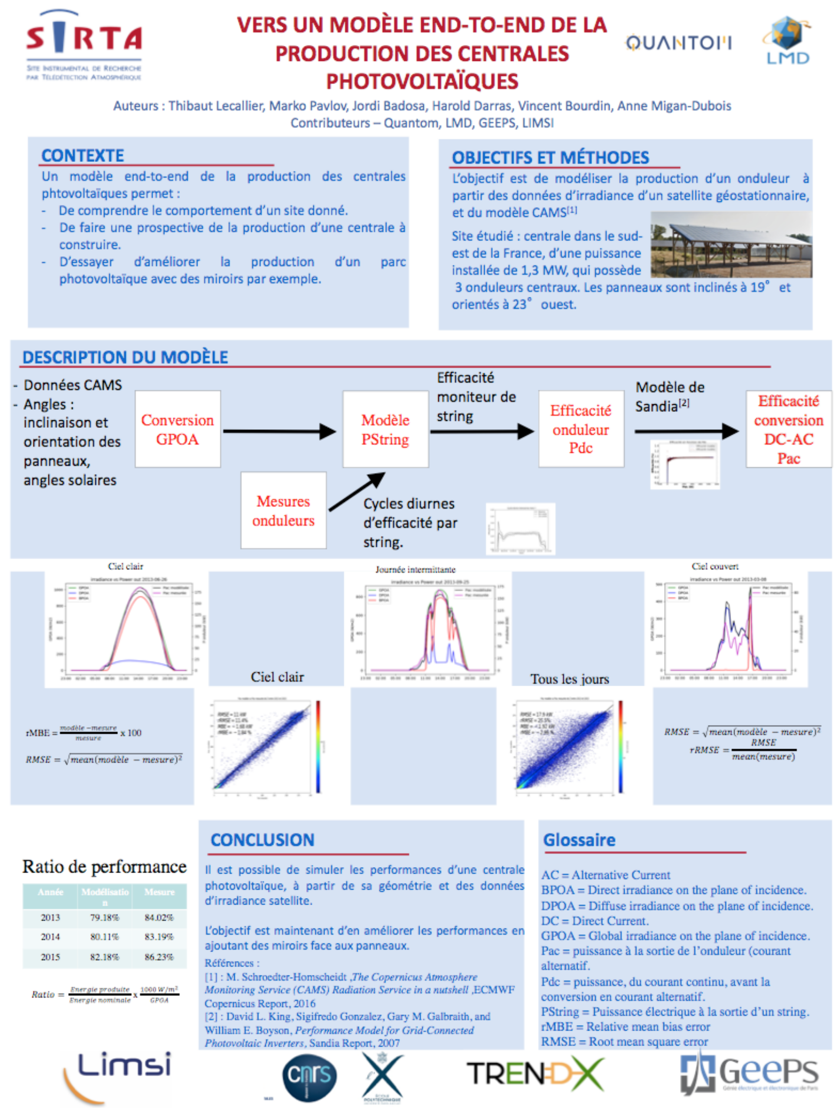


VERS UN MODÈLE END-TO-END DE LA PRODUCTION DES CENTRALES PHOTOVOLTAÏQUES

Auteurs : Thibaut Lecallier, Marko Pavlov, Jordi Badosa, Harold Darras, Vincent Bourdin, Anne Migan-Dubois
Contributeurs – Quantom, LMD, GEEPS, LIMSI

CONTEXTE

Un modèle end-to-end de la production des centrales phtovoltaïques permet :

- De comprendre le comportement d'un site donné.
- De faire une prospective de la production d'une centrale à construire.
- D'essayer d'améliorer la production d'un parc photovoltaïque avec des miroirs par exemple.

OBJECTIFS ET MÉTHODES

L'objectif est de modéliser la production d'un onduleur à partir des données d'irradiance d'un satellite géostationnaire, et du modèle CAMS[1]

Site étudié : centrale dans le sud-est de la France, d'une puissance installée de 1,3 MW, qui possède 3 onduleurs centraux. Les panneaux sont inclinés à 19° et orientés à 23° ouest.

DESCRIPTION DU MODÈLE

- Données CAMS
- Angles : inclinaison et orientation des panneaux, angles solaires

Conversion GPOA → Modèle PString → (Efficacité moniteur de string) → Efficacité onduleur Pdc → (Modèle de Sandia[2]) → Efficacité conversion DC-AC Pac

Mesures onduleurs → (Cycles diurnes d'efficacité par string.) → Modèle PString

Ciel clair — Journée intermittante — Ciel couvert

Ciel clair — Tous les jours

$$rMBE = \frac{modèle - mesure}{mesure} \times 100$$

$$RMSE = \sqrt{mean(modèle - mesure)^2}$$

$$rRMSE = \frac{RMSE}{mean(mesure)}$$

Ratio de performance

Année	Modélisation	Mesure
2013	79.18%	84.02%
2014	80.11%	83.19%
2015	82.18%	86.23%

$$Ratio = \frac{Energie\ produite}{Energie\ nominale} \times \frac{1000\ W/m^2}{GPOA}$$

CONCLUSION

Il est possible de simuler les performances d'une centrale photovoltaïque, à partir de sa géométrie et des données d'irradiance satellite.

L'objectif est maintenant d'en améliorer les performances en ajoutant des miroirs face aux panneaux.

Références :
[1] : M. Schroedter-Homscheidt ,*The Copernicus Atmosphere Monitoring Service (CAMS) Radiation Service in a nutshell* ,ECMWF Copernicus Report, 2016
[2] : David L. King, Sigifredo Gonzalez, Gary M. Galbraith, and William E. Boyson, *Performance Model for Grid-Connected Photovoltaic Inverters*, Sandia Report, 2007

Glossaire

AC = Alternative Current
BPOA = Direct irradiance on the plane of incidence.
DPOA = Diffuse irradiance on the plane of incidence.
DC = Direct Current.
GPOA = Global irradiance on the plane of incidence.
Pac = puissance à la sortie de l'onduleur (courant alternatif.
Pdc = puissance, du courant continu, avant la conversion en courant alternatif.
PString = Puissance électrique à la sortie d'un string.
rMBE = Relative mean bias error
RMSE = Root mean square error

Etudes en cours

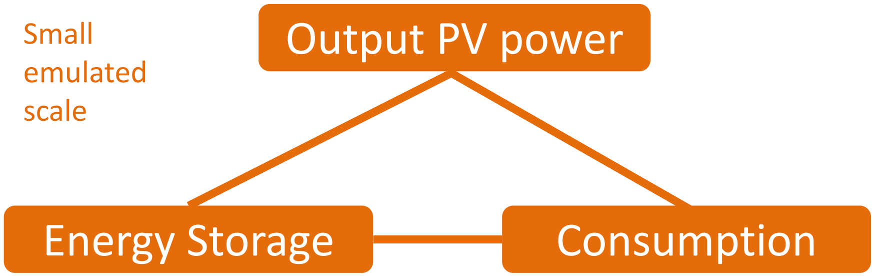
GHI, Tp Forecast

GHI Estimation

GHI measurement

POA

Small
emulated
scale



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PV-powered Nanogrid hardware & software development for academic experimentation

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Victorien Hamon – IUT Cachan (victohamon@yahoo.fr)

OBJECTIVES

- To study small-scale low-voltage DC power systems
- Develop a hardware that allows to test basic energy management algorithms in a PV powered nanogrid
- To have a system for teaching experimentation in smart grids, small scale DC power systems and renewable energies
- To record real time data of the electrical behavior of this type of systems that can serve for further research

The system is intended to be a starting point for further developments of the hardware & software to include other renewable sources, alternative storage means as well as meteorological information to support the energy management of the system

INSTRUMENTAL SETUP

- 240 W HIT Solar panel
- 50 W Solar simulator
- 2kW electronic variable load
- 100 Ah lead-acid deep-cycle Battery
- RaspberryPi + Arduino microcontrollers

SYSTEM OUTCOMES

Measurements

- Current, voltage, power and cumulated energy of each element
- Joule losses of the system
- Irradiance & panel temperature in PV simulator mode
- Date & time and recorded data counter

Functionalities

- Real-time power & cumulated energy graphs for all the elements
- Visual indications regarding the sense of the power flow for each element
- Remote voltage and current limit control of the power source
- Manual connection/deconection of each element of the system
- Automatic deconnection of the elements if voltage/power limits are surpassed. The system warns the user before deconnection (limit values can be user defined).
- Manual and Remote selection between external PV panel or PV simulator
- Two modes for irradiance input in simulation mode: manual and pre-loaded daily irradiance profile. Four diffferent 'type of days' can be chosen, which can be defined by the user
- Creation of excel file in simulation mode with the recorded data (V,I,P,E), power & energy graphs and performance parameters. The file is send by mail automatically to the user at the end of the simulation cycle
- User-defined simulated battery size and initial state of charge. View of the current state of charge.
- Possibility of user-defined power scale factor to simulate bigger PV arrays in simulation mode

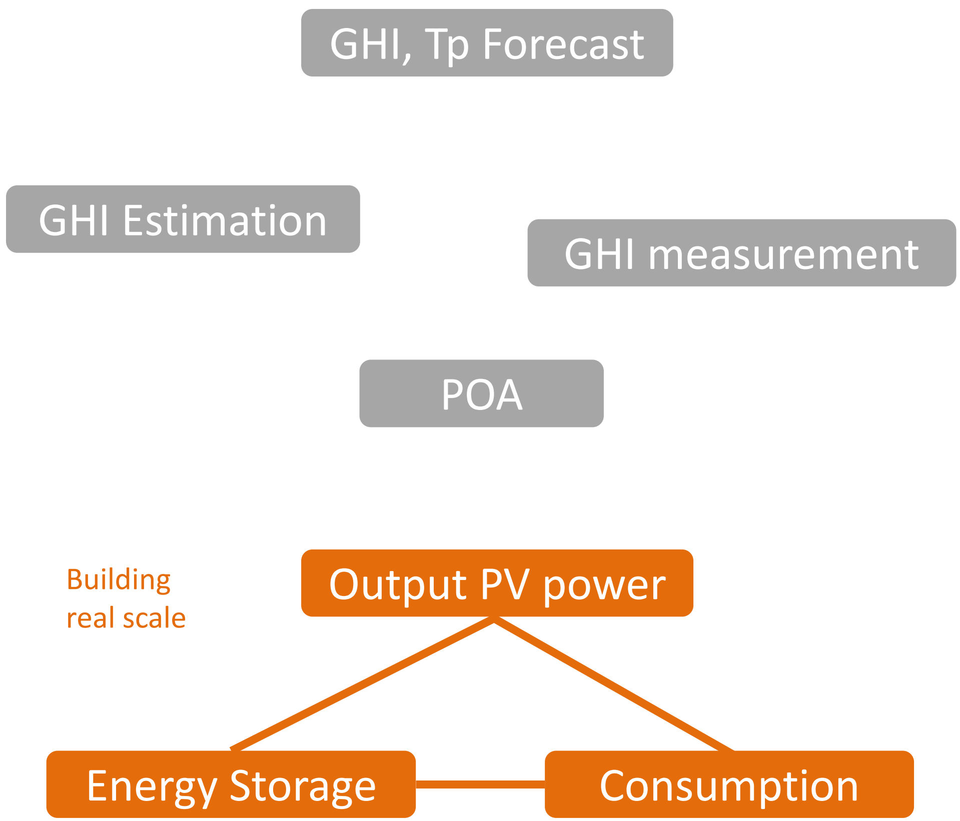
Small scale DC power systems

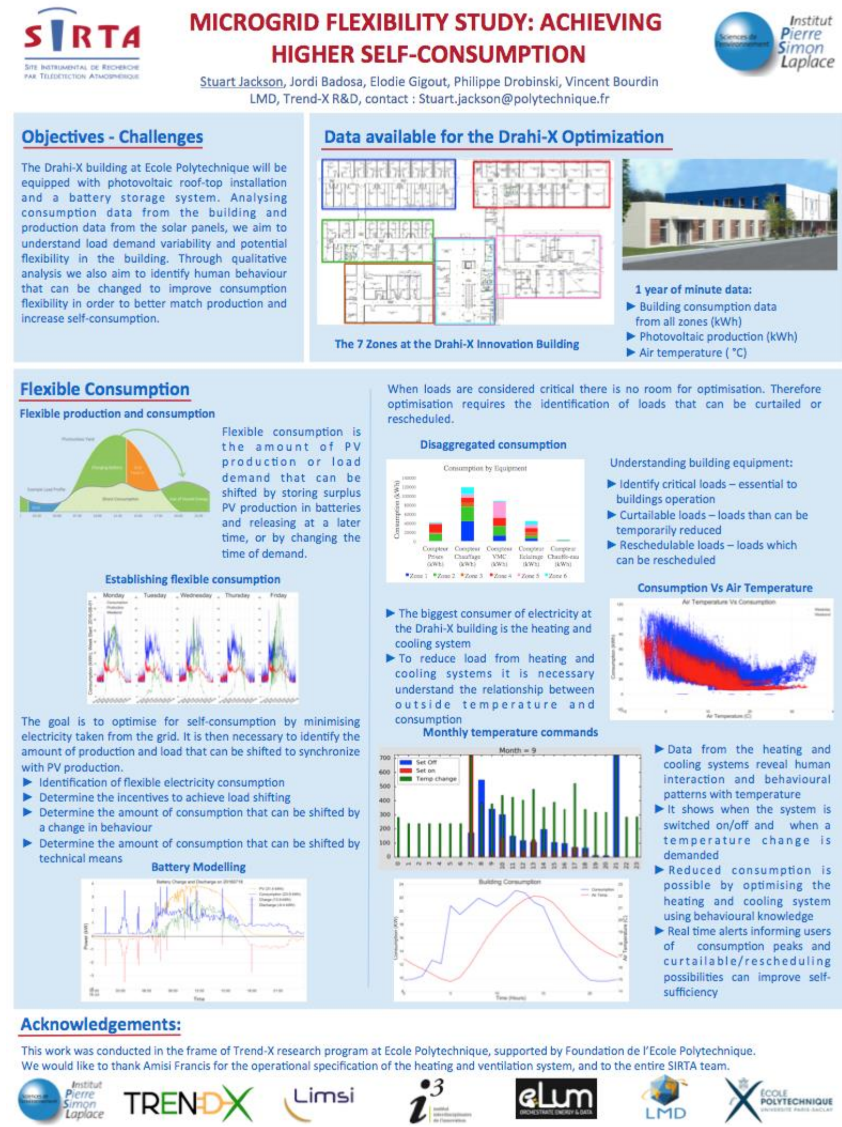
- The equilibrium point between demand and consumption is always passively assured by the system as long as there is enough production to satisfy the demand
- If the system cannot supply the demand required, the voltage of the system drops until finding the balance point. If this point is not found, the system will 'collapse'
- Voltage is the agent that controls the flow of power between the elements. Voltage control of the elements is mandatory if manipulation of the flow of power in the system is required

REMERCIEMENTS

Universidad de Costa Rica, Siebel Energy Institute and TREND-X program of École Polytechnique for the partial funding of this project, with the support of Fondation de l'École Polytechnique

Etudes en cours





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Thanks for your attention

l'X École Polytechnique Université Paris-Saclay | LMD | GeePS Génie électrique et électronique de Paris | Limsi | LPICM | TREND-X | SIRTA Site Instrumental de Recherche par Télédétection Atmosphérique