7th Solar Integration Workshop
International Workshop on Integration of Solar Power into Power Systems
with Special Topic STORAGE
24 - 25 October 2017
Berlin, Germany

Comparison of Different Photovoltaic Models in a Capacity Credit Evaluation

P. Tapetado , J. Usaola.
ptapetad@ing.uc3m.es
jusaola@ing.uc3m.es

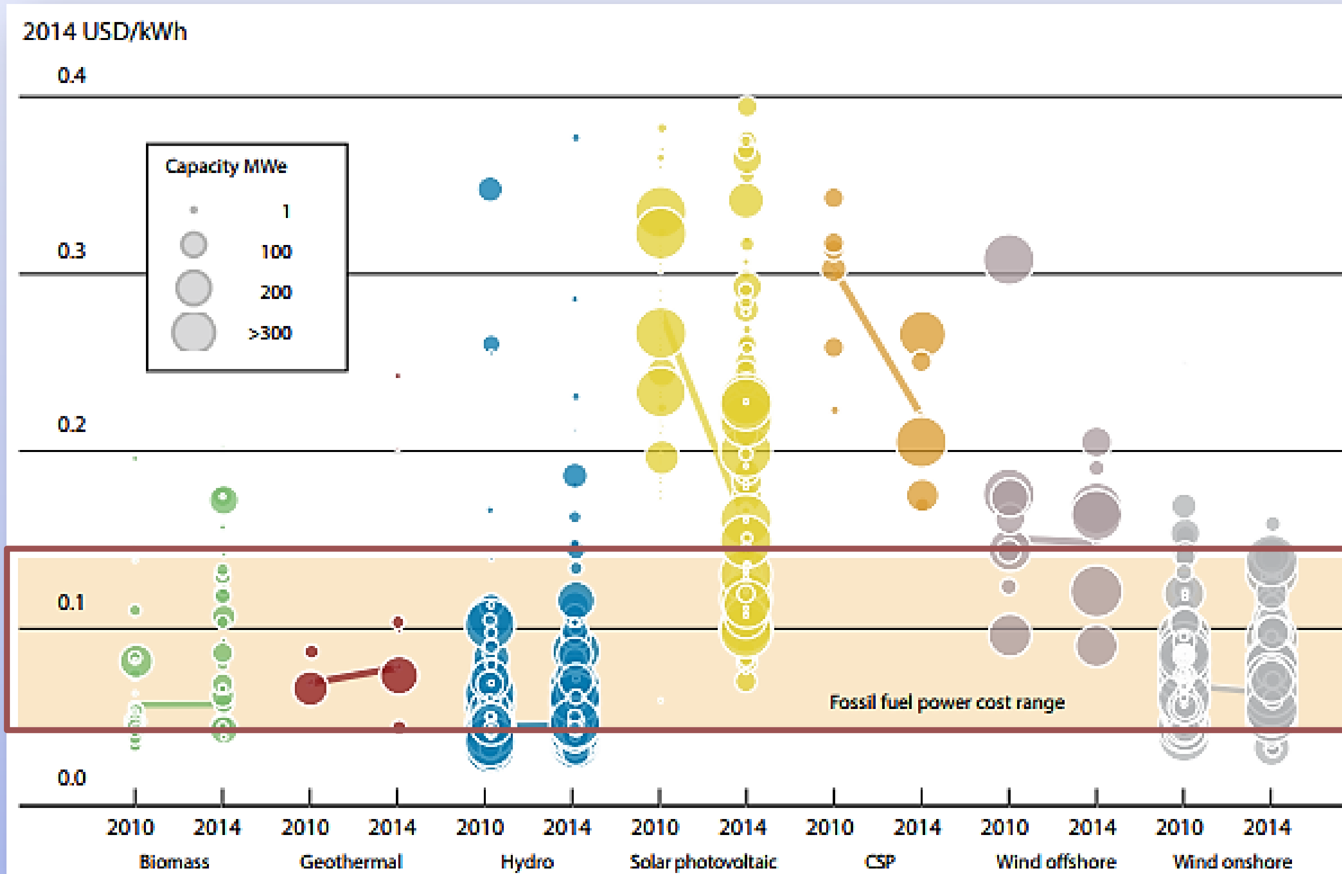
Departamento de Ingeniería Eléctrica, Universidad Carlos III de Madrid, Avenida de la Universidad Nº: 30. C.P: 28911. Leganés. Spain.

Table of contents

1. Introduction
2. Methodology
   - Reliability evaluation
   - Capacity Credit Assessment
3. PV Models Descriptions
   - Measured data differences
   - Irradiance to power conversion differences
4. Results and Conclusions
   - System Description
   - Credit Capacity Results

1. Introduction

Cost of electricity from utility-scale renewable technologies



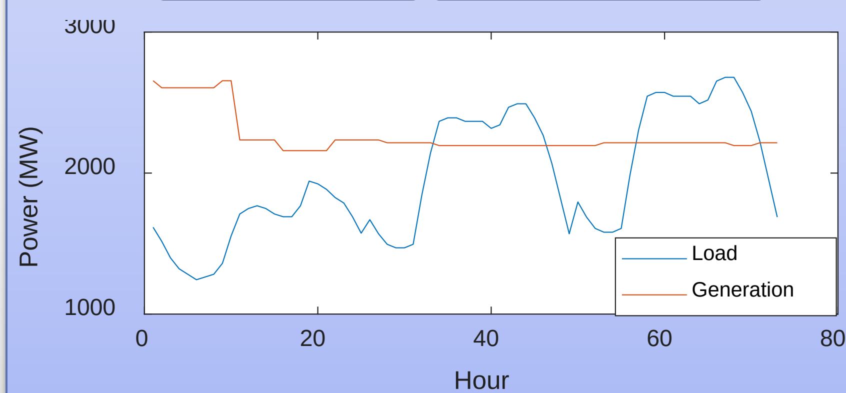
Source: Renewable Power Generation Costs in 2014, IRENA

2. Methodology

Reliability Assessment

- In terms of adequacy
- SMC simulations (tool)
- LOLE and LOEE (reliability index)

Methods to assess reliability
- Deterministic
- Probabilistic
  - Analytics
  - Simulations (MC)
    - Sequential
    - Non-sequential



Credit Capacity Evaluations

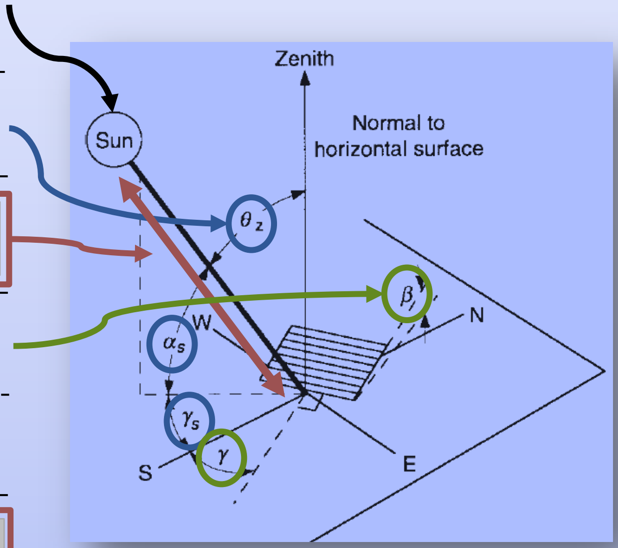
- Equivalent load carrying capability (ELCC)

$$\overbrace{LOLE_{G+PV=D+\Delta D}}^{\text{System Upgrade}} = \overbrace{LOLE_{G=D}}^{\text{Original System}}$$

$$ELCC = \frac{\Delta D}{G_{PV}} \text{(p.u.)}$$

3. PV Models descriptions

STEPS		MODELS: Gafurov	MODELS: Common points	MODELS: Santos-Martin
1	Sun		Extraterrestrial irradiance	
2	Sun-Earth Geometry		Solar angles and time	
3	Measured data	Clearness index		Global horizontal irradiance
4	Array Geometry		Tilt and orientation	
5	Irradiance components		Irradiance Beam reflected difuse	
6	Irradiance to power conversion	5-parameter modified model		Proposed model
7	Net Power output		Power losses	



3. PV Models descriptions

Step 3: Measured data

Santos-Martin Model

Global horizontal irradiance measured (input)

↓

(k_T) Hourly Clearness index

↓

(k_d) Daily Clearness index

↓

Diffuse horizontal irradiance
Beam normal irradiance

Gafurov Model

(k_d) Daily Clearness index (input)

↓ synthetic hourly index generation

(k_T) Hourly Clearness index

↓

Diffuse horizontal irradiance
Beam normal irradiance

Advantage:
Gafurov's involves greater complexity than Santos-Martin (k_T) data

3. PV Models descriptions

Step 6: Irradiance to power conversion

Santos-Martin Model		Gafurov Model
$E_{pu} = E / 800$ $E_{pu,a} = R_{oc} / 1.05 \, E_{pu}$	Energy Normalised at STC conditions	$I_{eff} / I_{eff,stc} = I_T / I_{stc}$
$\Delta T = T_{amb} - 20$	Temperature correction	$T_{pv} = T_{amb} + \left(NOCT - T_{amb,NOCT}\right)\left(1 - \eta_{pv,src} / 0.9\right)\frac{I_T}{I_{NOCT}}$
$P_g = S_{stc} \cdot \left[0.846 E_{pu,a} - 0.106 E_{pu,a}^2 - 0.00368 E_{pu,a} \Delta T\right]$	Gross power output from PV array	$P_{pv} = P_{pv,src} \frac{I_T}{I_{src}}\left[1 + \beta_{Voc}\left(T_{pv} - T_{pv,src}\right)\right]$
$\eta_1 = \eta_{lo} - 0.005 t_{age}$ $P_n = P_g \cdot \eta_m \eta_w \eta_c \eta_1 \eta_{np}$	Net power delivered	$P_{pv,net} = P_{pv} - PL_{pv}$

Advantage:
Gafurov's power conversion needs physical PV array characteristics in contrast to Santos-Martin

4. Results and Conclusions

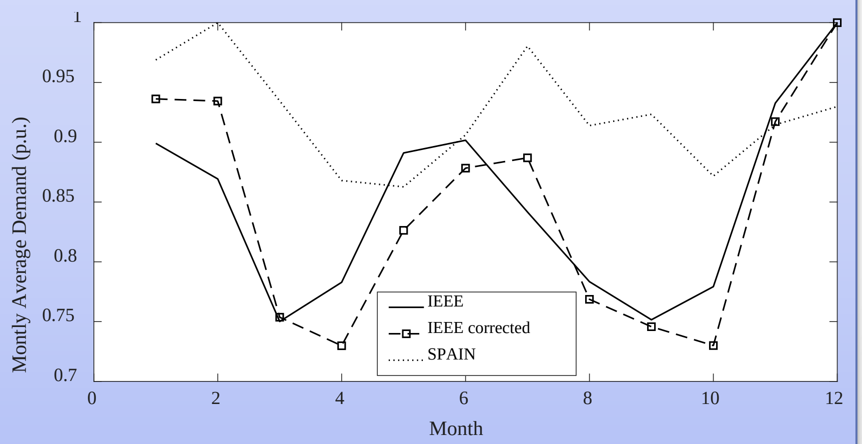
System Characteristics

- IEEE-RTS System

Generation

Unit size (MW)	Number of Units	Mean Time To Failure (MTTF) (h)	Mean Time To Repair (MTTR) (h)
12	5	2940	60
20	4	450	50
50	6	1980	20
76	4	1960	40
100	3	1200	50
155	4	960	40
197	3	950	50
350	1	1150	100
400	2	1100	150
Installed power: 3405 MW. Nº units: 32			

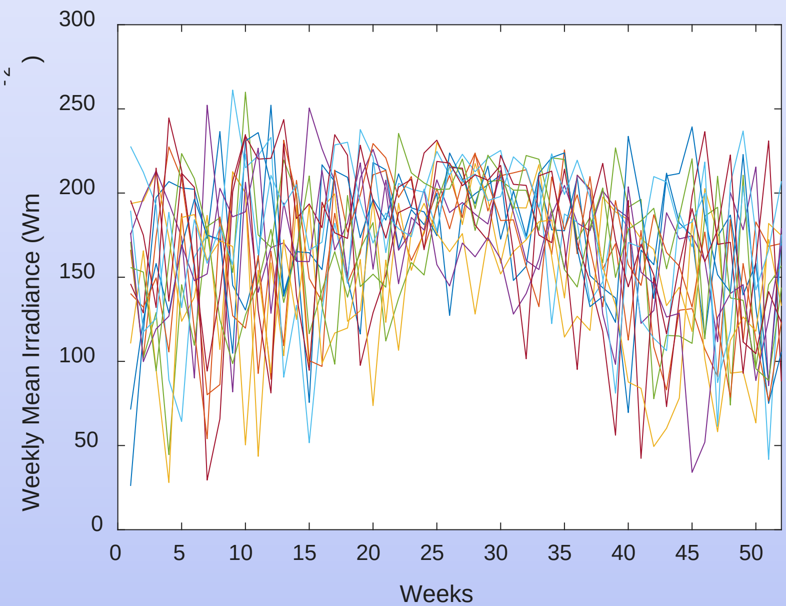
Load



4. Results and Conclusions

System Characteristics

Solar irradiance data



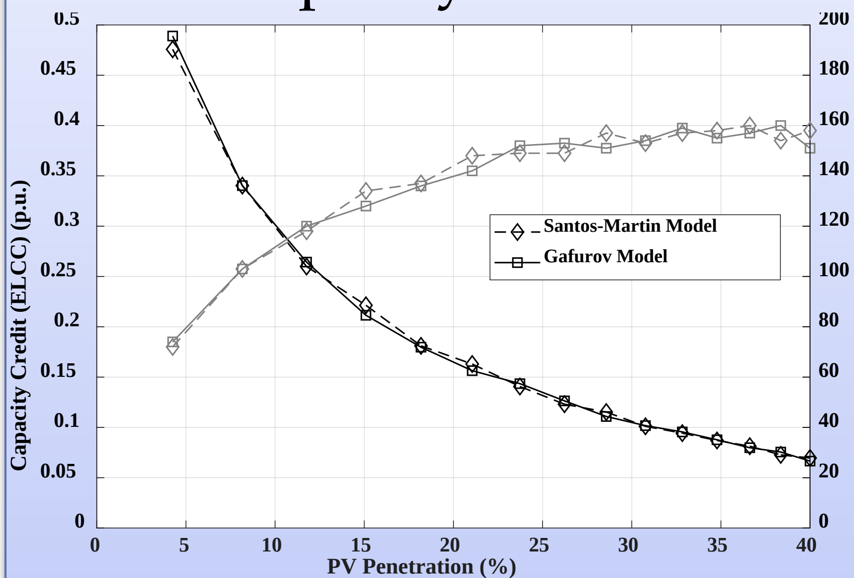
- Solar irradiance data from southern Spain
- 14 years of Solar data
- 18 different photovoltaics power plant localization

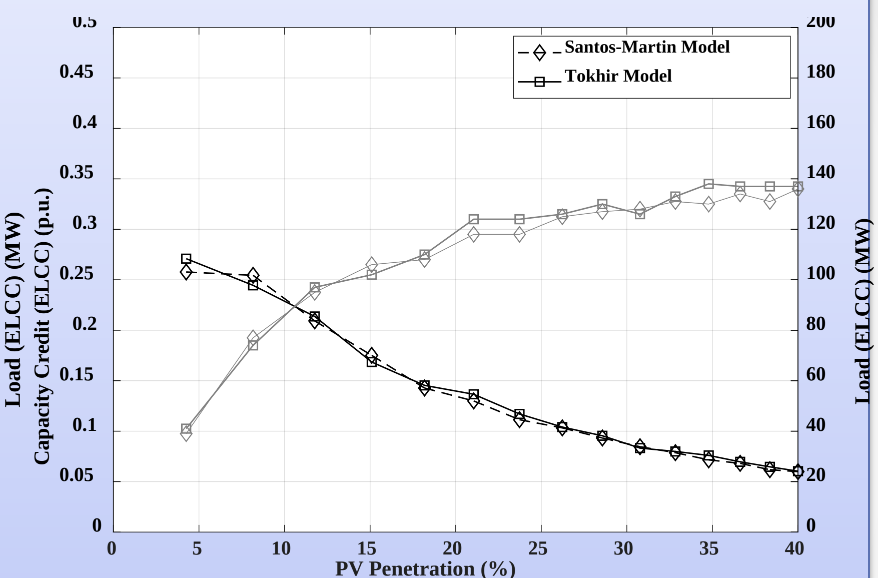
PV Penetration →

$$\frac{\sum PV_{generation}}{\text{Total capacity}} \times 100 = \frac{\sum PV_{generation}}{\sum (PV_{generation} + Thermal_{generation})} \times 100(\%)$$

4. Results and Conclusions

Credit Capacity Results





IEEE Load correction

Original IEEE Load

Conclusion:
Same credit capacity results are obtain with Santos-Martin Model and Gafurov Model.

Thank you for your attention

P. Tapetado , J. Usaola.
ptapetad@ing.uc3m.es
jusaola@ing.uc3m.es

Departamento de Ingeniería Eléctrica, Universidad Carlos III de Madrid, Avenida de la Universidad Nº: 30. C.P: 28911. Leganés. Spain.