Bayesian Structural Time Series for Behind-the-Meter Photovoltaic Disaggregation

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Introduction

Rapid Growth of BTM PV

Total Installed Capacity of Small-Scale PV in the U.S.

<table>
<thead>
<tr>
<th>Year</th>
<th>Capacity (GW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>7.3</td>
</tr>
<tr>
<td>2015</td>
<td>16.1</td>
</tr>
<tr>
<td>2016</td>
<td>23.3</td>
</tr>
<tr>
<td>2017</td>
<td>27.9</td>
</tr>
</tbody>
</table>

Lack of BTM PV Visibility

Data

• Advanced metering infrastructure (AMI) data from 7 days in January and August 2017
• Solar irradiance and temperature from the National Solar Radiation Database (NSRDB)
• Feeder-head measurements of active power consumption

Data

• Four models (A-D) proposed in [2]

Bayesian Structural Time Series

BSTS model:

\[ S_t = \beta_0 \phi_t + \epsilon_t^{(s)} \]
\[ \beta_t = \beta_{t-1} + \epsilon_t^{(\beta)} \]
\[ L_t = X_t \gamma + L_{t-1} + \epsilon_t^{(L)} \]
\[ P_t = S_t + L_t \]

Random noise terms \( \epsilon_t^{(s)} \sim N(0, \sigma_s^2) \) represent evolution in gross load and PV generation not explained by their covariates.

State space model:

\[ y_t = Z_t \gamma \phi_{t-1} + \omega_t \]
\[ P_t = A_t y_t \]

Fitting is performed by combining Kalman Filtering and Markov Chain Monte Carlo

Model Comparisons

• Comparison with five state-of-the-art disaggregation methods
• Contextually supervised generation estimation (CSGE) [1]
• Four models (A-D) proposed in [2]
• Error metric

\[ rRMSE = \sqrt{\frac{1}{N} \sum_{t=1}^{N} (\hat{x}_t - x_t)^2 \max(\xi_t)} \]

Load Model

• A lagged temperature model
• Temperature lags determined by randomly designating 1 day as training data
• Lags determined using the cross-correlation function

\[ CCC(k) = \frac{1}{k} \sum_{t=1}^{k} [x_t | T_{t-k+1}^{\omega}] [x_t | T_{t-k+1}^{\omega}] \]

Times \( k_1, \ldots, k_m \) corresponding to local maxima of \( |CCC(k)| \) were selected as lags.

Gross load covariate vector

\[ X_t = [T_{t-k_1}, \ldots, T_{t-k_m}] \]

References


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