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Forecasting and Assessing Risk of Individual Electricity Peaks

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Preface

At the height of climate crisis, the UK strives to maintain its position at the forefront of the most rapidly decarbonising countries, harnessing efforts to end domestic coal power generation by 2025. The Net-zero initiative is the recent UK contribution to stop global warming. Technology has become ubiquitous and this has prompted a fundamental shift from large-scale centrally controlled energy market to distribution system operators (DSO) taking part in the single-flow energy market. As business and homes shift to less energy- and emissions-intensive activities, sustained by the emergence of affordable renewable energy, opportunities arise for new businesses and new market entries in the energy sector, which has hastened a lot of interest into the prediction of individual electric energy demand. With extreme weather events, inter-connectivity of modern society and information collection and speed with which it propagates, the sector faces mass digital disruption. There will be many challenges going forward, but also opportunities, for coming-together scientific disciplines to devise new solutions to old and new problems.

In this book, that grew out of a co-supervision of a Master dissertation in the forecasting of individual electric demand, we present central concepts of extreme value theory, an area of statistics devoted to studying extreme events. We also list currently the most popular prediction algorithms for short-term forecasting that are normally dispersed across different research literature coming from mathematics, statistics and machine learning. Our main goal is to collect the different concepts needed for peak forecasting of individual electric demand, so they require minimal background knowledge and to present those concepts with a clear view of the assumptions required for their application and their benefits and limitations.

The structure of the book The introductory chapter provides a description of the problem, namely, short-term prediction of electric demand on individual level, and motivation behind it. Our focus on peaks is also explained. The two data-sets that are used in Chap. 5 to illustrate the concepts presented in Chaps. 2–4 are described and basic exploratory analysis of two data-sets is presented.

Chapter 2 starts with linear regression that is a basic ingredient of many different forecasting algorithms. Several methods from time-series data analysis are presented including hugely popular ARIMA models. Recently developed permutation-based methods are included, based on their focus on peaks, and this is up to our knowledge for the first time that those methods have a place of their own in a review of popular methods. We hope that the time will show their usefulness. Support vector machines and artificial neural networks, with examples from both forward feed and recurrent networks, are representing machine learning based methods.

Chapter 3 concerns the probabilistic theory underpinning extreme values of independent and identically distributed observations. In the way it is presented here, this theory relies strongly on the analytic theory of regular variation, following closely the work developed by Laurens de Haan. The content of this chapter will lay the foundations to the stochastic properties and corresponding statistical methodology presented in Chap. 4.

The methodology for inference on extreme values addressed in Chap. 4 has its focus narrowed down, as we go along, to the case of short tails with a finite upper bound to suit the specific application to the Irish smart meter data described in Chap. 1. This class of short-tailed distributions being tackled includes, but is not limited to Beta distributions and alike. We will be working on the max-domain of attraction rather than pretending that the limiting distribution provides an exact fit to the sampled data. This will enable a stretch to those distributions attaining finite boundary despite being attached to the Gumbel domain of attraction, thus endowed with more realistic characteristics than the typified exponential fit. Chapter 4 is drawn to a close with a brief literature review on recent theory for extremes of non-identically distributed random variables.

Finally, in Chap. 5 short-term prediction with the focus on peaks is illustrated comparing methods described in Chap. 2 using a subset of publicly available data from Thames Valley Vision project.

Chapter 1 was written by all three authors. Chapter 2 has Maria Jacob and DVG as authors, and Chap. 3 is authored by CN and Maria Jacob. Chapters 4 and 5 are authored by CN and DVG.

The book is designed for any student or professional who wants to study these topics at a deeper level and assumes a wide range of different technical backgrounds. We hope that the book will be also useful for teaching. While we have attempted to balance mathematical rigour with accessibility to people with different technical backgrounds, the presented techniques are illustrated using the real-life data, and the corresponding code can be found on GitHub.

Reading, UK — Maria Jacob
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CN and DVG deepest gratitude go to their dear families, who have witnessed our preoccupation and endured our torments over the course of this project.

Contents

Acronyms

a.s.	Almost sure(ly)
AA	Adjusted Average
ANN	Artificial Neural Networks
ApE	Adjusted *p*-norm Error
AR	Autoregressive
ARIMA	Autoregressive Integrated Moving Average
ARMA	Autoregressive Moving Average
BM	Block Maxima
BRR	Bayesian Ridge Regression
d.f.	Distribution function
DSO	Distribution System Operator(s)
DTW	Dynamic Time Warping
EVI	Extreme value index
EVS	Extreme value statistics
EVT	Extreme value theory
GEV	Generalised Extreme Value
HWT	Holt-Winters-Taylor
i.i.d.	Independent and identically distributed
KDE	Kernel Density Estimation
LCT	Low carbon technologies
LSTM	Long Short-Term Memory
LW	Last Week
MAD	Median Absolute Deviation
MAE	Mean Absolute Error
MAPE	Mean absolute percentage error
MLP	Multi-layer Perceptrons
MLR	Multiple Linear Regression
OLS	Ordinary Least Squares
OSH	Overnight Storage Heating
PDF	Probability density function

PLF	Probabilistic load forecasts
POT	Peaks Over Threshold
QQ	Quantile-Quantile
r.v.	Random variable
RNN	Recurrent Neural Network
SD	Similar Day
SME	Small-to-medium enterprises
STLF	Short-term load forecasts
SVM	Support Vector Machine
SVR	Support Vector Regression
TVV	Thames Valley Vision