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Decision and Control in Hybrid Wind Farms

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I dedicate this book to almighty for giving me enough patience and strength throughout my journey. I thank my parents Renu & Sanjay, brother Hardik and the love of my life Shiwangi for motivating me to the ends of the world.
—Harsh S. Dhiman

I dedicate this book on Decision and Control to the Supreme Controller for providing whatever decision making ability I have in me. I thank my wife Indulekha and my son Rishabh for providing me unending love and support.
—Dipankar Deb

Preface

Depleting coal resources have raised alarming signals for installation of renewable energy systems (RES). The popularity of renewable sources is in cohesion with power ecosystem with benefits like cleaner production and lower tariff rates, making it reliable and secure candidate for electricity demands globally. Research and development in wind and solar technologies has seen a tremendous rise in the past two decades which, has attracted investors to put their money into these projects. European countries like Denmark, Germany, Sweden, and England have installed large offshore wind farms to cater their country's load demands. China, on the other hand, has been actively involved in manufacturing services, and India is on the developing side of wind energy portfolio.

The book focuses on the two most important aspects of the wind farm operation, that is, decision and control. The first part of the book deals with decision-making processes in wind farms. Modern-day decision-making is a volatile process that is sensitive to the internal and external factors which can directly influence decision-makers' decision. The introductory chapter on decision-making covers prime methods to evaluate a set of alternatives for given criteria. A part of the chapter is also dedicated to sensitivity analysis and how it influences decision-making. We also introduce the concept of hybrid wind farms and enlist the different strategies a operator can face to achieve optimal farm operation. Hybrid wind farm operation is governed by a set of alternatives that the wind farm operator must choose to ascertain optimal dispatch of wind power to the utility grid. The decision-making is accompanied by accurate forecasts of wind speed that must be known beforehand. Errors in wind forecasting are to be compensated fairly by pumping power from reserve capacity to the grid in terms of battery energy storage system (BESS). Alternatives, based on penalty cost, are assessed based on certain criteria, and MCDM methods are used to evaluate the best choice. Further, considering the randomness in the dynamic phenomenon in wind farms, a fuzzy MCDM approach is applied to the decision-making process to evaluate the best alternative for the hybrid wind farm operation. Case studies from the wind farms of the USA are presented with numerical solutions to the problem.

The second part deals with the control aspect, in particular with yaw angle control, that aids in power maximization in wind farms. A novel transfer function-based methodology is presented that controls the wake center of the upstream turbine(s). LIDAR-based numerical simulations are carried out for wind farm layouts. An adaptive control strategy is implemented to achieve the desired yaw angle for upstream turbines. The proposed methodology is tested for two wind farm layouts. Wake management is also implemented for hybrid wind farms, where BESS life enhancement is studied. The effect of yaw angle on the operational cost of BESS is assessed, and the case studies for wind farm datasets from the USA and Denmark are carried out. Overall, this book provides a comprehensive decision and control aspect for hybrid wind farms which may be useful from an industrial point of view.

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Acronyms

AEP	Annual energy production
AHP	Analytic hierarchy process
BESS	Battery energy storage system
CFD	Computational fluid dynamics
COPRAS	Complex proportional assessment
CPS	Cumulative priority score
EKF	Extended Kalman filter
ELECTRE	Elimination and choice translating reality
ERM	Energy reservoir model
FLORIS	FLOw Redirection and Induction in Steady State
HAWT	Horizontal axis wind turbine
IPC	Individual pitch control
KF	Kalman filter
KKT	Karush–Kuhn–Tucker
LIDAR	Light detection and ranging
LSSVR	Least square support vector regression
MAPE	Mean absolute percentage error
MCDM	Multi-criteria decision-making
MPAC	Model predictive active control
NIS	Negative ideal solution
OCV	Open-circuit voltage
PC	Penalty cost
PI	Proportional–integral control
PIS	Positive ideal solution
PROMETHEE	Preference ranking organization method for enrichment evaluation
PS	Priority score
RMSE	Root mean squared error
SAW	Simple additive weighting
SoC	State of charge

SOWFA	Simulation for On/Offshore Wind Farm Applications
SVR	Support vector regression
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
UKF	Unscented Kalman filter
WFLOP	Wind farm layout optimization
WRA	Wind resource assessment

List of Figures