Preface

There needs to be more clarity regarding optimization and related words. Ideally, in simple terms, optimization should mean finding the very best; however, this meaning has become diluted, and optimization among practicing engineers has become synonymous with finding some improvements, any improvement, not necessarily finding the best.

Mathematics, which is supposed to be an exact science, has unwittingly added to this confusion. Mathematically, optimization could be local or global. However, this distinction is often not made so that the same word could mean either a local or the global optimum. And the difference between the two could be huge, depending on the situation.

Another contributing factor to this confusion is using equipment efficiencies to describe equipment performance in utility systems, such as boilers. Such efficiency curves are almost always upside-down parabolic-shaped, which is a nonlinear function. So, it seems like we are dealing with a nonlinear problem. But are we? Not necessarily, why? Let us take a closer look at what efficiency is. It is a derived quantity; generally, it is a ratio of “energy usefully absorbed” to “total energy consumed,” which for a boiler would be proportional to the ratio of steam produced to the fuel consumed. So, how about looking at the relationship in terms of the fundamental variables: steam production and fuel consumption? Whoa! Now, that relationship looks linear for the most part, except for a little upward slant at higher production rates, so a line with two or more segments would be a very close approximation. Consider an optimization technique called Mixed Integer Linear Programming (MILP), a variant of Linear Programming (LP). It can handle segmented linear functions using integer variables and still give guaranteed global optimum. In summary, if you rely on the efficiency curve to model a boiler, the problem is nonlinear. Still, if we revert to more fundamental quantities, the relationship suddenly becomes segmented linear, amenable to global optimization using MILP.

An implied criticism of using integers in modeling is that the problem computation time could grow exponentially with integers, i.e., if you introduce a single binary (0/1) variable, the computation time could double. That sounds bad, but what if we had 38 binary variables? The compute time now could be 2^{38} or over 200 billion times, and even if the base problem without integers was solved very fast, say in 1/100 of a second, that could take well over 87 years. It’s a scary thought experiment; *let us think of an alternative method* that would be a reasonable reaction. But wait, that doubling of time with each additional binary integer is not the expected or the average but the absolute worst-case scenario . . . the reality is much different.

In this book, we will develop an MILP optimization model of a sample utility system; it has 38 integers, actually 37 binaries and one integer that could take an integer value between 0 and 4; it takes less than a second to solve it on a three-year-old laptop. The worst case is just a possibility. Yes, it does happen, but more for contrived

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problems. However, operations optimization problems of utility systems are not those kinds; I can confidently say so, having done many such optimization projects.

And so on, there are many myths, and we will address some of those in the book.

Yes, granted, most problems, especially those in the process operations optimization arena, are nonlinear, and local optimization is all that can be achieved. Still, this idea that only local optimization is possible for any process plant operations optimization has become the norm. This attitude has become so pervasive that it applies even to problems where global optimization is a definite possibility.

One such problem is the operations optimization of utility systems embedded within a process plant, which is the subject matter of this book. Global optimization of utility systems is possible but seldom sought because of the prevailing attitude. This is sad as this general attitude is losing many opportunities to conserve significant energy and help lessen global warming.

This book aims to make this knowledge of global optimization of process plant utility systems widely available and help you model plant utility systems by giving a complete example from start to finish, modeling through implementation. The book does not assume prior knowledge of modeling or optimization; it starts with concepts and slowly builds the first model of the boiler, gradually refines the model, and then tackles other unit operations models, subsystems, and, ultimately, the entire utility system. The book develops deployment strategies for the optimization model for offline and online closed-loop usage. The pace increases steadily so as not to repeat things ad nauseam and to keep the book manageable in size.

The book is suitable for self-study, as an optimization project resource, or an upper-level one-semester course. The software used to develop these models is affordable and readily available. All model files mentioned in the book are available from the publisher's website.

I would be remiss not to take this opportunity to thank so many who have led me in my professional life journey. First and foremost, my gratitude to many professors in general and in particular to the late Prof. Rudy Motard for kindling the spirit of research; late Prof. Angelo Miele, the best teacher I ever had for demystifying optimization; the person from the University of Chicago at Union Carbide in Y. P. Tang's group, whose name I cannot recall, who introduced me to LINDO, a modeling system in which you could write model equations in algebraic form, a far cry from the dreaded MPSX format popular at that time. John Holiday for introducing me to the problem of utility system optimization; utility system engineers and utility system managers at various Union Carbide plants for supporting utility optimization projects at their plant sites; my colleagues and friends who encouraged me in all professional endeavors, in particular, Sanjay Sharma; my supervisors at Union Carbide (now Dow), Linnhoff March (now KBC Yokogawa), Setpoint (now Aspen Tech), and Honeywell, who gave me ample opportunities to work in the area of operations optimization of processes and utility systems. Prof. Linus Schrage and Kevin Cunnigham, the creators of LINDO, for taking an interest in my early modeling efforts; folks at LINDO systems, particularly Mark Wiley, for supporting any LINDO/LINGO software issues. Dane Takemoto, at Frontline Systems, for providing a complimentary license for the Premium Solver for the duration of this book project. Bob Esposito for introducing me to the world of publishing; Karin Sora and Stella Muller at De Gruyter for guiding me in preparing this manuscript. And last but not least, my family for bearing with me and supporting me all these years through thick and thin. Thank you all from the bottom of my heart.

Although I have been careful in developing the manuscript, I wouldn't be surprised if you find errors in the book. I am solely responsible for those; please do not hesitate to bring them to my attention via the publisher.

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